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Exploring Potential of Public Land Based Revenues to Finance City Infrastructure: An assessment using linear programming for Guntur Municipal Corporation

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ABSTRACT

Municipalities are in search of exploring alternative own revenues to finance urban infrastructure investments in India. As compared to others, monetization of public land is within the functional domain of local governments subject to certain constraints. This study employs a linear programming model incorporating the constraints enforced by state government to assess the potentials of public lands for urban infrastructure capital investments. This approach is largely different from the existing literature, which does not determine the capacity of municipal public lands based on realized revenues. This investigation finds that certain proposed leasing strategies for Guntur Municipality under different simulations as done in this research have potentials to realize 240% more revenues compared to 'business as usual' scenario and hence, provide new policy insights for leasing public lands in a revenue optimization perspective. The framework adopted by this helps local governments to estimate the potentials of public lands and establish revenue targets.

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1. Introduction

Public land assets' fiscal capacities and a framework for determining the revenue potentials of existing public land assets in local self-governments have not been clearly defined in India. In recent years, the role of urban local governments in financing proposed urban infrastructure and services by exploiting their own alternative sources of revenues has been amplified by the thirteenth and fourteenth finance commissions, Government of India.and augmenting own resources to an extent of 200 percent is sought after as per the High-Power Expert Committee estimates on Indian urban infrastructure and services till 2030 (HPEC, 2011). The same committee and other studies focusing on financial sustainability of urban local governments indicate that *'Indian municipalities as weakest globally in terms of access to resources, revenue-raising capacity and fiscal autonomy'* (Mohanty, 2016) and '*improving municipal finance is central to achievement of India's economic growth objectives'* (Mathur, 2011). Realizing the challenges in bridging resource gap for infrastructure investments by local self-governments, a few studies have recommended the following options to be explored to determine the revenue potentials (Thirteenth Finance Commission, 2009; Peterson, 2009; Phatak, 2009; Mckinsey, 2010; HPEC, 2011; Mohanty, 2016; MOUD, 2017)

1. Reforms in property taxation and user/development charges
2. Value capture mechanisms
3. Debt based financing

4. Public private partnerships
5. Land based financing instruments & monetization of assets

Subsequently, the number of research initiatives, policies and documentation undertaken in view of the above recommendations are very few in India and limited to higher order cities with population of more than 1 million. However, the proposed urbanization trends in India by 2031 indicate that urban areas with less than 1 million population will account for higher share in terms of absolute increase in population and urban areas (HPEC, 2011). This shift of demographics is likely to create more pressure on provision of urban infrastructure for both economic and domestic purposes in small and medium municipalities and requires a special attention on fiscal stability. Further, the experiences on monetization of lands assets and its revenue generation capacity has drawn scholarly attention nationally and internationally in the recent past (Peterson, 2006; Sridhar & Reddy, 2009; Peterson & Kaganova, 2009; Phatak, 2013; Ballaney et al., 2013; Lin & Zhang, 2014; Patricia & Gangopadhyav, 2017, MOUD, 2017) but limited to metropolitan cities and no attempt is being made in assessing the potential of public land assets with small and medium municipalities in India. The existing revenues from public land assets, as reflected in balance sheets by local governments were considered for estimating revenue potentials of public lands (Peterson, 2006; Sridhar & Reddy, 2009). Whether these reported figures convey the revenue potentials of public lands or not, is yet to be ascertained along with various other considerations such as ownership status of public lands, regulatory constraints, and availability of marketable lands for revenue purposes, especially in small and medium municipalities of Andhra Pradesh.

More than 80% of the notified urban area is with Small and Medium municipalities in Andhra Pradesh (as on 2016), which are characterized by low to moderate population densities estimated to accommodate more than 60% of the absolute increase in population between 2011 and 2031 (arrived based on UN growth rates adopted by HPEC 2011). It is pertinent to note that the revenues realized from public lands in a financial year may be less than the demanded revenues or more (CDMA, 2014). Further, there can be difference between the demanded revenues and the potential revenues. Here, potential revenue is referred as the fair rental value of the property in case of lease, i.e., the rent that leased property can lawfully fetch if leased out to a hypothetical tenant, which can be referred from the Supreme Court decision of India in GMC vs Guntur town rate payer's association on fixation of a fair rent of any premises, reported in AIR 1971 SC 353 and AIR 353, 1971 SCR (2) 423. Internationally it was observed that municipalities have adopted to differential leasing strategies while leasing public lands with huge variations between potential value to offered/realized value, for example in China, one-on-one negotiations (*xieyi*) and auction (*paimai*) were the two main leasing approaches where the later one was recognized as the most competitive and transparent approach (Lin & Ho, 2005). However, the share of one-on-one negotiations was 86% of the total leases granted by Chinese municipalities between 1995 and 2005 (Tao et al., 2010) and authors opinion that due to the long-term tax benefits i.e., personal and business income tax, business tax and VAT, municipalities have offered land at much lower prices for industrial uses and for commercial and residential leases, the competitive approach based on market value was preferred (Lin & Ho 2005). Here potential value is determined based on the market value and with industrial uses, the indirect revenues, i.e., the long term tax revenues are considered as potential revenues. Unlike China, the central government taxes, i.e., income tax, wealth tax are not shared directly with municipalities. Transfers in the form of grants are realized but municipalities have been expected to play a key role in mobilizing financial resources for investments on their own(HPEC, 2011). Thus, it becomes essential to understand and determine the potentials of urban public land assets through a scientific approach, which helps municipalities in estimating realistic revenues (Peterson & Kaganova 2009; Sridhar & Reddy 2009) before leasing the public lands. At this juncture, this research has made a progress in determining the potentials of public land assets for Guntur Municipal Corporation, a small and medium municipality in Andhra Pradesh through revenue optimization method using linear programming model after analyzing the state of municipal finances.

In this investigation, the null hypothesis refers as "Ho: The magnitude of revenues realized from marketable public lands determines the capacity of a municipality in financing the capital investments of urban infrastructure". This investigation assumes (Ha) that leasing strategies under revenue maximization approach through liner programming model subject to constraints have higher potentials to realize revenues and can become the basis of determining the fiscal capacity as compared to standard approach, and is inherently connected to the status of public land ownership in marketable category.

2. Methodology

2.1 Description of Study Area

As per the revised UN classification, Guntur Municipal Corporation (GMC) comes under Class IC category with 7.4 lakhs population and recorded highest growth rate of 44 % as compared between 2001 and 2011. The sudden increase in population is due to the merger of 10 peripheral villages into the GMC notified urban area. It is the third largest and fast growing city in Andhra Pradesh and serves as Administrative Headquarters of the Guntur District, and an important trade and commerce centre in the State, especially for Chillies, tobacco and turmeric commodities. The importance of Guntur as market and administrative center can be observed from the rate at which the floating population is observed, as per the city development plan of Guntur 2041, Guntur currently receives about 15,000 to 20,000 floating population from and it is projected to reach 90,000 by 2041. The average density of the erstwhile city is 142 persons per hectare (pph) and the core city densities range from 300 to 500 pph in 2011. By 2031, the city population is projected to reach 13 lakhs based on the growth rates adopted by HPEC 2011. Workers participation ratio is 37.3% in erstwhile city limits, which is very less as compared to the state and district worker's ratio of 46.6% and 48.7%

respectively in 2011. With this brief introduction, the following sections present the methodology and overview of municipal finances of GMC from 2009 to 2014 based on the data collected from CDMA, coordinating authority between the urban local bodies and the state in Andhra Pradesh, 2014, and the status of public land revenues in relation to proposed investments on urban infrastructure services 2030. All the public lands owned by GMC, leases information from 2009 to 2019, existing market values were collected from GMC and primary surveys. Every year the stamp duty and registration department of the state publishes unit rate for areas in municipalities to arrive at market value based on which the stamp duty and registration charges are fixed. The same unit values were adopted in this study for 2019.

2.1 Approach and Variables

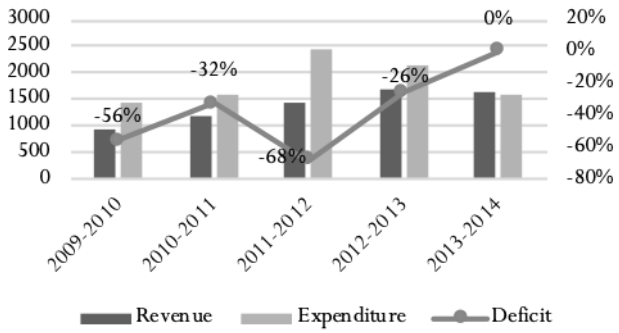
This exploratory research followed systemic approach to arrive at findings on the status of municipal finances, public land revenues, their potentials and sufficiency to finance infrastructure and services. The analytical framework adopted from literature (Roy & Johannes, 1992; Keshishishian, 2006, Mohanty, 2007; HPEC, 2011; Mathur, 2013) to assess the status of municipal finance consists of the indicators, a) fiscal gap, b) level of grants c) ratio of own revenues to expenditures, d) sufficiency of expenditures as compared to normative levels, e) share of grants in expenditures, f) property tax, and efficiency of tax revenues. Further, the potentials of public land is measured through revenue optimization approach using linear programming model along with the supporting variables, a) revenues from public lands, b) land lease revenues as proportion of GMC revenues, c) per capita revenues from land leasing, and d) utilization of proceeds from land lease (Sridhar & Reddy, 2009; Lin & Zhang, 2014). The study has adopted the normative Per-Capita Investment Cost (PCIC) 2030 determined by HPEC (2011), to estimate the proposed investments in urban infrastructure and services till 2030.

3. Results and Analysis

3.1 Municipal Finances

Sufficiency of municipal revenues towards normative expenditures in a municipality is one of the indicators that helps in assessing the status of municipal finances (Mohanty et al., 2007; HPEC, 2011, MOUD, 2017). Figure 1 underlines that the per-capita revenues realised by GMC during the study period (2009-2014) was lower as compared to per-capita expenditures with an average revenue deficit of -36%. However, the average growth rate of own revenues was at 16% as compared to the expenditures at 10%. This indicates that there was a steady increase in the per-capita revenues realised by GMC and a detailed analysis in regard to sources of own revenues, their consistency and expenditures is presented below. The average per-capita revenue and expenditure during the assessment years were INR. 1385 and INR. 1851.

Figure 1 Per-capita Revenue and Expenditures of GMC

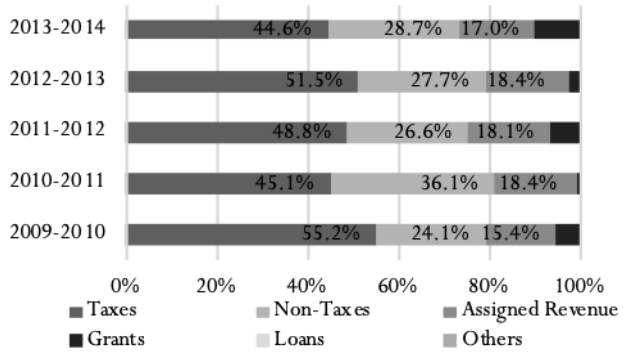


Source: CDMA, 2014

3.2 An Overview of GMC Revenues

The structure of GMC revenues consists of taxes, non-taxes, transfers from higher level governments – assigned revenues, grants, loans and others. Municipal taxes and non-taxes are the two major local revenues. Figure 2 presents that the share of tax revenue was 49% of total revenues with an average growth rate of 11%, and property taxes (local revenues) account for 90% of tax revenues. As property tax being the most reliable, principle and general tax resource of municipality (GoI, 2009; Mckinsey, 2010; HPEC, 2011; Mathur, 2011), the per-capita surplus tax revenues from this source helps in determining the capacities to finance urban infrastructure. However, it was evident that municipal revenues were in deficit, the proceeds of taxes can be understood as not sufficient. The share of non-tax revenue constitutes 28.6% with an average growth rate of 26% and public land based revenues, which is the major focus of this investigation, are part of this revenue source. All the revenues realised from public lands are kept under general revenues as per the regulating rules of Andhra Pradesh and reservation towards a specific expenditure criterion is currently not practised (GMC 2019). However, scholars recommend that public land revenues/proceeds should be diverted for investments in urban infrastructure (Phatak 2013; MOUD 2017; Patricia & Gangopadhyav 2017). As compared to other sources, higher-level governments grants were relatively low at 5% but observed higher growth rates above all. During the year 2013-14, share of grants has increased to an extent of 9.8% of total revenues from 2.4% in the preceding year, which indicates higher dependency on grants. Assigned revenues from the governments account for 17.5% with an average growth rate of 20%, which is higher as compared to the overall growth rate of revenues. The major share of assigned revenues is from the stamp duty surcharges, which constitutes about 90% of the assigned revenues. Stamp duty is a charge levied on property transaction and on registration by the state and part of the revenues are shared with municipalities.

Figure 2 Revenue Sources of GMC from 2009 to 2014

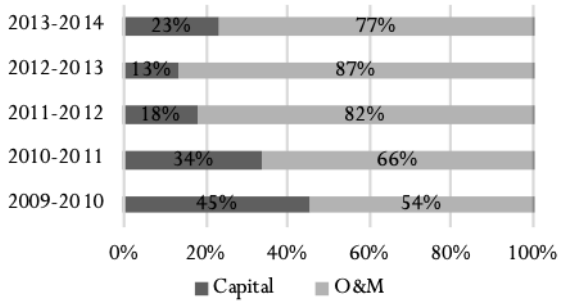


Source: CDMA, 2014

3.2 An Overview of GMC Expenditures

Expenditures are classified in to Capital and Operation and Maintenance (O&M) expenditures. Salary and allowances of staff working for GMC, administrative expenses, maintenance of infrastructure and services, etc., are part of O&M expenditures and others related to creation of assets, construction of roads, water supply installations, etc., are part of capital expenditures. Figure 3, highlights that 78% of the overall expenditure is on O&M with an average growth rate of 24% during 2009-14. It was observed that non-tax revenues growth rate of 26% was relatively better among others revenues and the efficiency of growth rate of non-tax revenues to O&M expenditures during the study period was at 1.08, which indicates a positive scenario. However, a closer investigation on per-capita revenues over expenditure reveal that, non-tax revenues were able to recover only 30% of O&M expenditures and the sufficiency of own revenues (including taxes and non-tax) to the total expenditures was only 59%. Studies on municipal finances have indicated that Indian municipalities spend very less on infrastructure services as compared to normative expenditures levels with poor O&M collection efficiency (HPEC, 2011). The analysis on Guntur reveal that the underspending was high at 70% during the study period and recovery levels were at less than 20% as compared to the existing levels of 30%. Therefore, it can be understood that the revenues realised by GMC were not sufficient to the present expenditure levels and also when compared to normative levels. The fiscal condition of municipality is likely to further deteriorate due to the existing gap between the per-capita expenditures to own revenues.

Figure 3 Expenditures of GMC from 2009 to 2014



Source: CDMA, 2014

3.3 Estimates on Urban Infrastructure Investments

To arrive at estimates for urban infrastructure investments in Guntur Municipal Corporation (GMC), normative Per-Capita Investment Cost (PCIC) 2031 determined by HPEC, 2011 were adopted in this investigation. These capital investments cover eight sectors of physical infrastructure and to assess fiscal capacity of GMC at regular intervals in relation to investments required, the estimates have been arrived for three time periods, i.e., 2020, 2025 and 2030 on the basis of relative share of absolute change in population. As the base year estimates of HPEC is for 2011, Consumer Price Index – India (CPI) from 2009 to 2019 was used to arrive at PCIC for 2019-20 and for the later investment years, an inflation of 4% per annum was assumed. From the estimates arrived, presented in table 1, it's evident that a total of 50.4% of the investment required for urban infrastructure services during the study period (2019 to 2031) is required by 2020. The subsequent investment years demand relatively a minor share of 8.4% in 2025 and 11.2% in 2030 of the total investments. Further, it is assumed that 30% of remaining investments are committed investments till 2019 by GMC, arrived based on the budget accounts of preceding years to 2020. To finance the proposed capital investments of INR.441 crores in 2020, the potentials of public lands have been assessed as a part of this research.

Table 1 Estimates for Urban Infrastructure Investments in GMC

Year	Population	Per Capita Investment Cost (INR.)	Investment Required (in crore)
2019	952547	84092	252.9
2020	994029	87456	441.1
2025	1097382	106404	89.0
2030	1211480	129456	144.9

Source: Authors calculations

3.3 Ownership Status Of Public Land Assets

Public land is a multidimensional resource and commodification of public land to finance urban infrastructure investments is one among the resource options practiced by local governments, and as compared to other revenue sources, this revenue stream has freedom and offers flexibility to local self-governments (Peterson, 2009). Authors argue that urban land in India is yet to be exploited as fiscal resource to finance urban infrastructure developments (Mohanty, 2014) and urban public land is underutilized from fiscal perspectives (Patricia and Gangopadhyav, 2017). Few authors claim that monetization of public lands allow the municipalities to capture future land value increments and become an important source of revenues (Yeh, 1994; Farvacque & McAuslan, 1992; Archer). Further it can be assumed that the magnitude of revenues realized from public lands rely on the status of public land ownership under marketable category (Lin & Zhang 2014; Liu 2018) and the efficiency of municipality in monetizing. In this connection, first an assessment is carried out to understand the current status of public land ownership by category in Guntur along with regulating constraints on leasing.

A total of 184 hectares of public land belong to GMC as on 2019, excluding the area under water works and transportation. This land is distributed in 277 plots of various land uses within the notified area of municipality, and are of freehold ownership. For the purpose of this research, all these lands were classified in to three groups while determining revenue potentials, i.e., marketable properties, marketable restricted properties and non-marketable properties. All the marketable properties are free from any restrictions and can be leased out for such land uses permitted in the regulating master plan, by fulfilling the conditions set by state governments on leases whereas marketable restricted properties have limited possibilities of using them for revenue maximization. The non-marketable properties cater the social needs of society, i.e., parks, playgrounds, schools, primary health care center, burial grounds and others where change of use or revenue maximization strategies cannot be imposed.

Table 2 presents the existing status and distribution of public lands by category in GMC. It is evident that very limited amount of land is under marketable category with an extent of 13% of total public land and there has been no increase in ownership status of marketable land in the last 30 years. This signifies that the regulating statutory plans, land management approaches and development projects in GMC have not been able to generate or build additional marketable land bank during the last 30 years. Further, 56% of the public land is under non-marketable followed by 31 % in marketable restricted category. Under marketable restricted category, a few of the vacant lands obtained by GMC through planning instruments as layout open spaces are to be utilized only for creation of open spaces. Close to 90% of vacant land are part of layout open spaces and the remaining vacant lands can be leased out while complying the regulating rules enforced by higher Governments. The conditions, referred as rules in this investigation are related to lease of public lands, reservations of properties, fixation of user charges in markets and etc., are discussed below.

Table 2 Public Land Assets of Guntur Municipal Corporation

	Type		No of Plots	Area (sq.m)
A	Marketable			
1	Lands Leased	(L)	8	16963
2	Markets	(M)	6	19029
3	Shopping Complexes	(SC)	20	16659
4	Others	(O)	1	5760
B	Marketable Restricted			
5	Municipal Buildings	(Q)	9	16797
6	Community Halls	(C)	4	4385
7	Urban Health Centre	(U)	10	5000
8	Vacant Lands	(VC)	67	267478
C	Non-Marketable			
9	Burial Grounds	(B)	12	112639
10	Parks & Play Grounds	(P)	9	196091
11	Reservoir	(R)	17	559790
12	Sanitary Offices	(S)	9	3055.45
13	School Buildings	(SB)	94	160596
14	Dumping Yards	(D)	6	457735
15	Libraries & Others	(LB)	4	2129

Source: GMC, 2019

3.3 Reservation of public land leases

When municipal governments in the State of Andhra Pradesh intent to award a lease, or enter into a lease agreement on public lands, fix the lease value of the property, etc., the following set of rules and regulations enacted by State Government have to be confirmed by municipality.

a. Fees from lands, the right to collect fees in respect of public land used for markets within the municipal jurisdiction is entrusted to municipality. The competent authority shall approve the conditions and terms, and enter into a contract with the lessee as per the section 43 of AP municipality Act. *"All the leases are to be executed through public auction".*

b. Fixation of Rent, as per the G.O.Ms.No.56 dated 05-02-2011, the amendment to AP Municipalities (regulation of receipts and expenditures) states that the commissioner through preliminary notice will set the terms and conditions subject to which the lease of immovable properties is granted. The following are advised for fixing the upset price of the lease.

- *Rent at 10% of the current market value of the property per annum (both building and land) market value of land and construction rates of the structures and buildings fixed by registration department*
- *Prevailing rent of such properties situated in the vicinity whichever is higher in case of lease of immovable properties for the first time*
- *Renewal of lease, either by 1 or 2 or rent at 33. 1/3 percent rent above the earlier rent (higher)*

c. Reservation of Shops for SC and ST community members and 50 percent concession, as per the G.O.Ms.No. 253 dated 02-04-1993 and G.O.Ms.No. 178 dated 23.04.2010 of Government of Andhra Pradesh, the government by order stated that 15% of the shops and stalls constructed by municipality to be leased out to members of the Scheduled Caste (SC) community on payment of market rate or rent paid by the neighboring shops without the public auction. Subsequent orders states that the rent of such shops to be fixed at INR. 2.5 per square feet or 50 percent of the rent paid by neighboring shops whichever is less. In same respect, Government orders have reserved 6% of shops for Scheduled Tribe (ST) community members on payment basis of INR. 2.5 per square foot or 50 percent of the fare paid by neighboring shop rooms whichever is less without public auction.

d. Reservation of Shops for AP Nayee Brahmana Seva Sangham, G.O.Ms.No. 116 MA dated 01-02-2008 by order stated to reserve 5 % of shops and stalls constructed by the municipalities under various schemes including good will auction to be leased out by conducting public auction among the Nayee Brahmin and washer men co-operative

societies without public auction under the provisions of AP Municipalities.

e. **Lease Duration,** it is observed that as per the regulation of receipts and expenditure rules, 1968 and G.O.Ms.No.120, dated 31-03-2011, GMC has the powers *"to renew the lease for a period of not exceeding three years at a time and with the approval of state government exceeding three years".* However, the municipality can renew the lease not exceeding twenty-five years of a particular property without conducting public auction subject to *"willingness of the lessee for 33 1/3 percent increases in lease value to the earlier rent or the prevailing market value of such shops satiated in the vicinity, whichever is higher".*

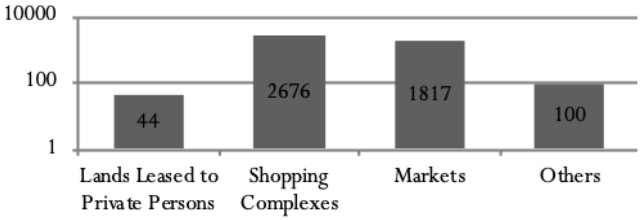
Based on the above set of rules, it is inferred that "rent", which is a key determinant of revenue potential of public lands is fixed based on the prevailing market rental value or 10% of the current market value of the property per annum or 33 1/3 rent above the earlier rent of such plots, whichever is higher. Further, it was observed from the data and discussions held with officials that the process of revising rental values by municipality doesn't happen periodically and due to which, there are variations observed between the actual market rental values to demanded amount. Therefore, the demanded amounts from leases don't determine the actual capacity of the public lands. All public leases in GMC, except the reservations are leased through public auction with less than 5 years of lease term, which is inferred as an effective mode of lease mechanism (Pan et al., 2016). The following section discusses the trends of public land based revenues realized by GMC based on the data sets collected from CDMA for the years 2009 to 2014. There are more than 800 leases granted by GMC annually and data is compiled plot and category wise to arrive at inferences.

4 Per-capita Public Land Revenues (2009-14)

Among all the public land leases, revenues realized from shopping complexes and markets stands highest with an annual growth rate of 22% and 85%. The occupancy of these leases reported was 100% as GMC being a trade center for agriculture and allied activities, demand for markets and commercial land uses is higher (CDP 2014). It was observed that the tenants deposit rents in three possible options, i.e., a) regular installments on monthly basis, b) advance payment for the complete lease duration, i.e., for 3 years and c) late payment with penalty charges at the time of renewal and this has resulted variations in realized revenues and reason for higher growth rates. The revenues realized during the study period 2009-14 had capacity to finance 8% of the capital investments of GMC, which is relative low as compared to cities in China (Lin & Zhang, 2014). The revenues presented here was based on net payments received by GMC but not on the demanded amounts. Studies carried out in this field have referred to revenues realized as the fiscal capacities (Peterson, 2009; Peterson, 2006; Sridhar & Reddy, 2009) but not on the basis of demanded revenues or potential value. Authors opinion that demanded revenues based on the potential value may indicate the actual capacity (Patricia & Gangopadhyay, 2017 and an assessment in this regard is presented below.

4.1 Per-capita Land Revenues Demanded

Figure 4 Annual average revenues from marketable public land in GMC per sq.m (2009 – 2019)



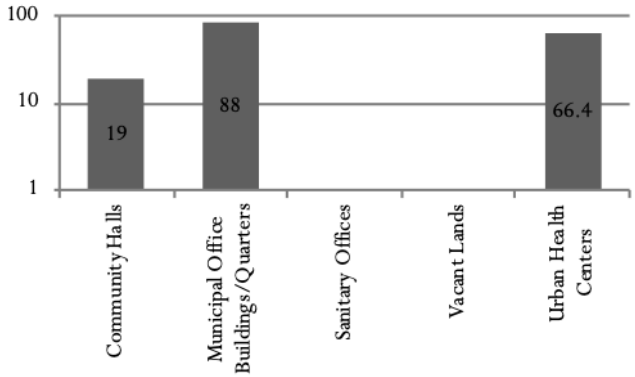
Source: GMC, 2019

Among all the marketable lands, the average lease amount demanded in shopping complex was INR. 2676 per sq.m followed by markets, others and lands leased categories (figure 4). There were 27 properties of different sizes under shopping complex category located in various parts of the city and the variation within this category on revenues demanded vary from INR. 18 per sq.m to 4859 per sq.m per year. It was observed that plots of same use located in close proximity have varied rental values demanded. Similarly, there were 6 markets located having more than 500 shops leased out had the average demanded amount of ranging from INR. 427 per sq.m to INR.3368 per sq.m. The other leases also recorded variations with in the category and over other categories (Figure 5). Further, the analysis on plot area utilization ratio, assessed by comparing the potential rental area (including built up area) of the plot to existing leased area highlights that close to 30% of the properties have additional permissible area, which can fetch more revenues, if leased but involves development costs to GMC.

Based on the discussions held with municipal officials and from the data analyzed, it is inferred that public lands located within close proximity to each other with same land market value have varied demanded rental values due to the extent of reservations offered, and the net revenue area leased. Here net revenue area refers to the built up area made available for lease in a given plot. Besides, there is no regulatory compulsion or requirement on reserving lands for commercial, markets or shopping complexes, and municipalities are free to decide upon the land use to which the marketable lands can be leased with or without development. Therefore, it can be assumed that existing public lands of GMC under marketable category may fetch higher revenues, if the plots are fully developed and leased to its optimum use from the revenue maximization perspective. This approach might require GMC to obtain loans from market and compare the revenues over project life cycle to arrive at Net Present Value (NPV) and determine the overall financial feasibility and compare the results to existing revenues. There has been no assessment carried by GMC in this regard while leasing the public land and leaves an opportunity for this research to examine the potentials through linear programming. Overall, it is clear to note from the above that demanded revenues or realized revenues, existing use of public land and current lease area of the plot may not indicate the actual fiscal capacity of public lands, and there is a need to develop a

comprehensive framework to ascertain the potentials of public lands, which can become the base for GMC to establish revenue targets from public lands and also to ascertain the fiscal capacities. Further, to identify the other control variables that influence the rental values, a correlation and regression analysis is carried and the results are discussed below.

Figure 5 Annual average revenues from marketable restricted public land in GMC per sq.m (2009 – 2019)



Source: GMC, 2019

4.2 Correlation and Regression Analysis

Based on the variables identified through expert's opinion survey, a correlation and regression analysis was carried out to understand statistical relationship and significance of rental value demanded for all the leases awarded between 2008 and 2019. The rental value demanded per sq.m of public lands was considered as the dependent variable and the independent variables were plot size, distance from CBD, plot shape & use, abutting road width, permissible FSI, no. of shops, in case of markets and shopping complex, market value and net revenue area of each plot. Through analysis, it is understood that none of these variables have statistical significance and the coefficient of determination was very low with higher variance. Outliers within the data sets were then identified using SPSS software and carried out multiple linear regression using step wise approach method. Among all the variables, net revenue area of each plot has 0.759** and market value has 0.739** correlation significant at 0.01 level (2-talied). Other variables have shown very low significance with higher variations. From the above, it is significant to note that higher the market value and availability of rental area, including the built-up area of a plot determine the potential rental value of the public land, and confirms to the inference presented earlier.

Therefore, this research presumes herein that it is essential to consider the following aspects while estimating the potential of public lands: *a) existing rental and potential value, b) permissible developable area c) reservations on leases d) time period of lease e) revision of rental values f) development costs and net present value of future revenues from leases*. Considering all the above, an attempt has been made to assess the revenue potentials of public lands for GMC through revenue maximization approach using linear programming model, which is presented below in detail.

5. Application of Linear Programming

Linear Programming, an optimization technique (Taha, 1999; Srinivasan, 2010) is employed to arrive at the potentials of the existing public land assets in GMC subject to constraints. Here constraints refer to all the government reservations on leases, rental values, revision of rental values and reservation of lands for other purposes. By satisfying the conditions set by governments on reservation of lands, this research has formulated four scenarios to ascertain the potentials of public lands. In all scenarios, the revenue strength of public lands is assessed based on the net rental value of future cash flows for different time periods, i.e., 10 years, 15 years, 20 years, 25 years, 30 years, 35 years, 40 years and 50 years. Net rental value was arrived after subtracting the administrative expenditures of municipality and the reservations, which account for 26% of the total leases in markets and shopping complexes at 50% actual rental value. This has been arrived to check the revenue capacities of GMC at regular intervals and to determine the time period, number of years for which public land revenues need to be reserved towards estimated capital investments. As per the regulating government orders, the rate of increase in rental values of 33 and 1/3 % once in three years is considered as the rental inflation value in discounting cash flow analysis. Development costs of plots were arrived through Central Public Works Department costs determined on per sq.m basis and inflation of costs during the time period (2020 – 2060) was assumed as 4.5%. The formulation of linear program problem in scenarios developed followed the standard approach, i.e., identification of decision variables, ascertain the objective function, incorporating the constraints, defining the non-negative variables. Through GRC non-linear method by incorporating all the constraints, the optimum results are arrived and the details of each scenario are presented below.

5.1 Scenario 1, Business-As-Usual-Scenario

The basic objective of this scenario was to construct the existing model of public land leases (without any change) and determine the revenue capacities of public lands in financing the estimated infrastructure investments of GMC using discounted cash flow analysis. Once the optimal solution was arrived for the base year, i.e., 2019, the revision of rental values and development costs during the assessment years were incorporated based on the historical trend analysis for determining the revenue strengths of public lands. In business as-usual scenario, the objective function is to maximize the revenues from public lands subject to constraints. As this scenario being the base model, the existing revenue area of public lands (in 2019) in marketable category was considered as the maximum area available for lease till the property reaches its obsolescence year, and no additional development costs were considered in the base year. When the buildings reach to its obsolescence year, re-development of the plots to its permissible capacity was permitted in the model and subsequently the development costs were included in the discounted cash flow analysis to arrive at NPV of future revenues. As discussed earlier, the development costs were arrived through CPWD rates (2019), and an inflation of 4.5 % annually on costs was assumed during the assessment years, i.e.,

from 2020 to 2060. Based on the historical trend observation method, preferred option by GMC for mobilising capital resources through bank loans with 12% Rate of Interest (RoI) and 10 years payback period post construction activity were considered in the analysis. Though there was more potential revenue area available within the plot for further leasing, the existing revenue area of each plot was considered as the maximum revenue area in the base model. The details of the decision variables, objective functions, constraints, non-negative variables.

Decision Variable – Revenues from public land leases (Z)
Objective Function –

$$Z = x_B + x_C + x_D + x_L + x_{LB} + x_M + x_Q + x_O + x_P + x_R + x_S + x_{SB} + x_{SC} + x_U + x_{VC}$$

$$Z = \sum_{rb=1}^{12} x_{rb} + \sum_{rc=1}^{4} x_{rc} + \sum_{rd=1}^{6} x_{rd} + \sum_{rl=1}^{8} xr_l + \sum_{rlb=1}^{4} x_{rlb} + \sum_{rm=1}^{6} x_{rm} + \sum_{rq=1}^{9} x_{rq} + \sum_{ro=1}^{1} x_{ro} + \sum_{rp=1}^{9} x_{rp} + \sum_{rr=1}^{17} x_{rr} + \sum_{rsb=1}^{94} x_{rsb} + \sum_{rsc=1}^{20} x_{rsc} + \sum_{ru=1}^{1} x_{ru} + \sum_{rvc=1}^{4} x_{rvc}$$

r = Net existing rental value of the plot per sq.m;
xrb…rn= net revenue from each category of plots,
refer table 2 for categories

a. Shopping Complex

$$x_{SC} = \sum_{rsc=1}^{20} x_{rsc}$$

x_{SC} = 10671 (Area under revenue category in base year) ……1

$Dx_{SC} = 0$ (Base Year) ……2

D=Development cost per sq.m

$x_{rSC} = r_1 \times sc_1 + r_2 \times sc_2 + \ldots\ldots\ldots\ldots + r_{20} \times sc_{20}$

sc = existing revenue area of the plot in sq.m

b. Markets

$$x_M = \sum_{rm=1}^{6} x_{rm}$$

$x_M = 11036$ *(Area under revenue category in base year)* ……3

$Dx_M = 0$ *(Base Year)* ……4

$x_{rm} = r_1 \times m_1 + r_2 \times m_2 + \ldots\ldots\ldots\ldots + r_6 \times m_6$

m = Net revenue area of the plot in sq.m

c. Municipal Office Buildings/Quarters

$$x_Q = \sum_{rq=1}^{9} x_{rq}$$

$X_Q = 7836$ *(Area under revenue category in base year)* ……5

$Dx_Q = 0$ *(Base Year)* ……6

$x_{rq} = r_1 \times q_1 + r_2 \times q_2 + \ldots\ldots\ldots\ldots + r_9 \times q_9$

q = Net revenue area of the plot in sq.m;

d. Land Lease

$$x_L = \sum_{rl=1}^{8} x_{rl}$$

$x_L = 16484$ *(Area under revenue category in base year)* ……7

$Dx_M = 0$ *(Base Year)* ……8

$x_{rl} = r_1 \times l_1 + r_2 \times l_2 + \ldots\ldots\ldots\ldots + r_9 \times l_9$

l = Net revenue area of the plot in sq.m

e. Vacant Land

$$x_{VC} = \sum_{rvc=1}^{4} x_{vc}$$

$x_L = 4114$ *(Area under Revenue Category in base year)* ……9

$Dx_M = 0$ *(Base Year)* ……10

$x_{rvc} = r_1 \times vc_1 + r_2 \times vc_2 + \ldots\ldots\ldots\ldots + r_9 \times vc_9$

vc = Net revenue area of the plot in sq.m;

f. Others

$$x_O = \sum_{ro=1}^{1} x_{ro}$$

$x_L = 4320$ *(Area under revenue category in base year)* ……11

$Dx_M = 0$ *(Base Year)* ……12

$x_{ro} = r_1 \times o_1$

o = Net revenue area of the plot in sq.m;

$x_n > 0$……13

$\sum_{rb=1}^{n} x_{rb} = 0.001 \times r_n$	(Revenue)	…14	Burial Grounds
$\sum_{b=1}^{n} x_b = 112639$	(Area)	…15	
$\sum_{rc=1}^{n} x_{rc} = 4385 \times r_n$	(Revenue)	…16	Community Halls
$\sum_{c=1}^{n} x_{]c} = 4385$	(Area)	…17	
$\sum_{rd=1}^{n} x_{rd} = 0.001 \times r_n$	(Revenue)	…18	Dumping Yards
$\sum_{d=1}^{n} x_d = 457735$	(Area)	…19	
$\sum_{rd=1}^{n} x_{rlb} = 0.001 \times r_n$	(Revenue)	…20	Libraries & Reading Rooms
$\sum_{lb=1}^{n} x_{lb} = 2129$	(Area)	…21	
$\sum_{rp=1}^{n} x_{rp} = 0.001 \times r_n$	(Revenue)	…22	Parks & Play Grounds
$\sum_{p=1}^{n} x_{lb} = 196091$	(Area)	…23	
$\sum_{rr=1}^{n} x_{rr} = 0.001 \times r_n$	(Revenue)	…24	Reservoir
$\sum_{r=1}^{n} x_r = 559789$	(Area)	…25	
$\sum_{rs=1}^{n} x_{rs} = 0.001 \times r_n$	(Revenue)	…26	Sanitary Offices
$\sum_{s=1}^{n} x_s = 3055$	(Area)	…27	
$\sum_{rsb=1}^{n} x_{rsb} = 0.001 \times r_n$	(Revenue)	…28	
$\sum_{sb=1}^{n} x_{sb} = 160596$	(Area)	…29	
$\sum_{ru=1}^{n} x_{ru} = 5000 \times r_n$	(Revenue)	…30	Urban Health Center

Equations from 14 to 30 refer to all the reservation of lands of restricted category, where the change of use, area and revenue was not permitted.

Results of Business As Usual Scenario

Time Period	Years	NPV 2019 (Crores)
2020-2029	10	₹53
2020-2034	15	₹81
2020-2039	20	₹105
2020-2044	25	₹125
2020-2049	30	₹142
2020-2054	35	₹156
2020-2059	40	₹166
2020-2069	50	₹186

The total investments required by 2020, as per the estimates was INR.441 crores and from the above results, it is evident that GMC has the capacity to finance 42.15% of the capital investments required for urban infrastructure in GMC 2020, if the revenues from public land leases are reserved for 50 years towards capital investments for urban infrastructure. The fiscal capacity of GMC can further improve in business as usual scenario, if the debt is made available by governments at reduce rate of interest.

5.2 Scenario 2, Revenue Optimization By Utilizing The Maximum Developable Area Within The Plot And Change Of Land Use In Few Categories

The overall objective of this scenario was to maximize the revenues from public lands by allowing the model to change the land use of plots in marketable category based on potential rental values and to maximize the revenue area within the plots. Unlike the business as usual scenario, the existing land use of each plot under marketable category was permitted to change for revenue maximization in this model with least development costs as a criterion, except markets and shopping complexes. Besides, the potential revenue area with in the plot was compared to the existing revenue area, and the difference in area was assumed for development and lease in this scenario. For each category of land use, the revenue optimization through linear programming by utilizing the maximum developable area within the plot and conversion of land use plot wise was carried out while reserving the non-marketable and marketable restricted category land uses in this scenario. The major objectives of revenue optimization of each category of public lands employed in this approach are as follows.

1. *Shopping Complex (Maximization of revenue area)*
2. *Markets (Maximization of revenue area)*
3. *Vacant Lands (Conversion of land use from vacant land to land lease)*
4. *Land Lease (Revision of rental value based on the market value 2019)*
5. *Municipal Buildings & Quarters (Maximization of revenue area)*
6. *Others (Conversion of Land use from others to land lease)*

Among all the categories, conversion of use from vacant lands, others to land lease was least development cost approach to municipality, where the costs of development are very less.

Objective Function Overall – Revenue Optimization by utilizing the developable area

$$Z = x_B + x_C + x_D + x_L + x_{LB} + x_M + x_Q + x_O + x_P + x_R + x_S + x_{SB} + x_{SC} + x_U + x_{VC}$$

a. Shopping Complex

$$X_{SC} = \sum_{sc=1}^{20} rx_{sc}$$

Objective Function & constraints

$$X_{SC} = 2526(SC_{r1}) + 4001(SC_{r2}) + 4096(SC_{r3}) + 1354(SC_{r4}) + 1589(SC_{r5}) + 2702(SC_{r6}) + 23(SC_{r7}) + 3945(SC_{r8}) + 1657(SC_{r9}) + 1911(SC_{r10}) + 1155(SC_{r11}) + 3438(SC_{r12}) + 3243(SC_{r13}) + 1150(SC_{r14}) + 414(SC_{r15}) + 1664(SC_{r16}) + 2514(SC_{r17}) + 547(SC_{r18}) + 2728(SC_{r19}) + 3103(SC_{r20}) \quad \ldots\ldots\ldots\ldots\ldots 1$$

$$\sum_{sc=1}^{20} x_{sc} \leq 22455 \text{ (Maxmium Area under revenue category)} \quad \ldots\ldots\ldots\ldots\ldots 2$$

$$sc_n = sc_{rn};\ rn = \text{maximum net revenue area of each plot}$$

$$x_{sc1} + x_{sc2} + x_{sc3} + x_{sc4} + x_{sc5} + \ldots\ldots\ldots + x_{scn}\ 0\ (DevelopmentCost) \quad \ldots\ldots\ldots\ldots\ldots 3$$

b. Markets

$$x_M = \sum_{rm=1}^{6} x_{rm}$$

$$X_M = 14658 \text{ (Maximum Area under Revenue Category)} \quad \ldots\ldots\ldots\ldots\ldots 4$$

$$x_{rm} = 585(m_{r1}) + 2194(m_{r2}) + 1911(m_{r3}) + 12066(m_{r4}) + 1405(m_{r5}) + 5330(m_{r6}) \quad \ldots\ldots\ldots\ldots\ldots 5$$

$$m_n = m_{rn};\ rn = \text{maximum net revenue area of each plot}$$

c. Vacant Land

$$x_{VL} = \sum_{vml=1}^{n} rx_{vml} + \sum_{vmm=1}^{n} rx_{vmm} + \sum_{vmsc=1}^{n} rx_{vmsc} + \sum_{vmq=1}^{n} rx_{vmq} + \sum_{vmo=1}^{n} rx_{vmo}$$

$$x_{VL} \leq 6171 \text{ (Maximum Area under Revenue Category)} \quad \ldots\ldots\ldots 6$$

$$vl_n = vl_{rn}$$

rn= maximum net revenue area of each plot

vml =plots converted from vacant land category to land lease category; vmm = plots converted to markets category; vmsc = plots converted to shopping complex; vmq = plots converted to quarters; vmq= plots converted to other.

d. Municipal Office Buildings/Quarters

$$X_Q = \sum_{rq=1}^{8} x_{rq}$$

$$x_{rq} = -12(q_{r1}) + 1200(q_{r2}) - 12(q_{r3}) + 1500(q_{r4}) - 12(q_{r5}) + 44(q_{r6}) + 500(q_{r7}) + 33(q_{r8}) \quad \ldots\ldots\ldots\ldots\ldots 7$$

$$X_Q = 14679 \text{(Maximum Area under Revenue Category)} \quad \ldots\ldots\ldots\ldots\ldots 8$$

$$q_n = q_{rn}$$

rn= maximum net revenue area of each plot

Some of the plots under municipal buildings and Quarters have no revenues realised and regular expenditures towards the O&M and administrative expenses result in deficits.

e. Land Lease

$$X_L = \sum_{rl=1}^{7} x_{rl}$$

$$x_{rl} = 588(l_{r1}) + 588(l_{r2}) + 1578(l_{r3}) + 1188(l_{r4}) + 2088(l_{r5}) + 588(l_{r6}) + 588(l_{r7}) \quad \ldots\ldots\ldots\ldots\ldots 9$$

$$X_L = 16484.2 \text{(Maximum Area under Revenue Category)} \quad \ldots\ldots\ldots\ldots\ldots 10$$

$$x_{rl} = r_1 \times l_1 + r_2 \times l_2 + \ldots\ldots\ldots\ldots + r_9 \times l_9$$

l = Net revenue area of the plot in sq.m;

f. Others

$$X_O = \sum_{ro=1}^{1} x_{r0}$$

$$x_{ro} = 2088(X_o) \quad \ldots\ldots\ldots\ldots\ldots 11$$

$$X_o = 5760 \text{ (Maximum Area under Revenue Category)} \quad \ldots\ldots\ldots\ldots\ldots 12$$

Other constraints and Assumptions, Equations from 14 to 30, of Scenario 1 refer to all the reservation of lands of restricted category, remains same in Scenario 2.

Results of Scenario 2

Time Period	Years	NPV 2019 (Crores)
2020-2029	10	₹41
2020-2034	15	₹78
2020-2039	20	₹113
2020-2044	25	₹145
2020-2049	30	₹173
2020-2054	35	₹198
2020-2059	40	₹223
2020-2069	50	₹264

With few changes to scenario 1, the fiscal capacity of GMC in revenue optimization approach of scenario 2 has increased to INR. 264 crores and able to finance near about 60% of total investments required by 2020 based on the NPV of future cash flows in base year. Form the above results, it is evident that by undertaking the developments from base year onwards in those plots where more buildable area was permissible in conjunction with building bylaws and by revising the rental values based on the proposed land use, the revenue strengths of GMC has increased by 44% as compared to scenario 1. This has been achieved while reserving public lands for non-marketable land uses and marketable restricted as observed in base year 2019. As the development costs were more during the initial years, the revenue potentials of this scenario in long term fetch better revenues when compared with scenario 1.

5.3 Scenario 3, Revenue Optimization through Revision Of Rental Values

In this scenario, the revision of rental values based on market values arrived through unit cost method or prevailing rental values of neighbouring plots or 33.1/3% of the existing rental values, whichever is higher was considered and assessed the revenue potentials. Conversion of use other land uses with moderate development costs based on the revenue potentials along with revision of rental values was allowed in this scenario and the details are as given below:

1. Shopping Complex (Revision of rental values on Scenario 2)
2. Markets (Revision of rental values on Scenario 2)
3. Vacant Lands (Conversion of land use to land lease and revision of rental value)
4. Land Lease (Conversion of use to shopping complex and revision of rental value)
5. Municipal Buildings & Quarters (Conversion of land use to other land uses)
6. Others (Conversion of Land use from Others to shopping complex)
7. Objective Function Overall – Revenue Optimization by utilizing the developable area

$$Z = x_B + x_C + x_D + x_L + x_{LB} + x_M + x_Q + x_O + x_P + x_R + x_S + x_{SB} + x_{SC} + x_U + x_{VC}$$

a. Shopping Complex

$$X_{SC} = \sum_{sc=1}^{20} rx_{sc}$$

Objective Function and constraints

$$X_{SC} = 2526(SC_{r1}) + 4001(SC_{r2}) + 4096(SC_{r3}) + 1354(SC_{r4}) + 1589(SC_{r5}) + 4620(SC_{r6}) + 1588(SC_{r7}) + 3945(SC_{r8}) + 2088(SC_{r9}) + 1911(SC_{r10}) + 1788(SC_{r11}) + 3438(SC_{r12}) + 3330(SC_{r13}) + 2238(SC_{r14}) + 4389(SC_{r15}) + 2430(SC_{r16}) + 5620(SC_{r17}) + 1709(SC_{r18}) + 2891(SC_{r19}) + 3246(SC_{r20})$$

$\sum_{sc=1}^{20} x_{sc} \leq 22455$ (Maxmium Area under revenue category).....1

$sc_n = sc_{rn}$

rn= maximum net revenue area of each plot, 10% of the total market value of the plot or the prevailing rental value of the plot, whichever is higher.

$x_{sc1} + x_{sc2} + x_{sc3} + x_{sc4} + x_{sc5} + \ldots\ldots\ldots + x_{scn} \geq 0$ $(DevelopmentCost)$.....2

b. Markets

$$x_M = \sum_{rm=1}^{6} x_{rm}$$

$X_M = 14658$ *(Maximum Area under Revenue Category)* 3

$x_{rm} = 1938(m_{r1}) + 2194(m_{r2}) + 1911(m_{r3}) + 12066(m_{r4}) + 1938(m_{r5}) + 5330(m_{r6})$

$m_n = m_{rn}$

rn= maximum net revenue area of each plot, 10% of the total market value of the plot or the prevailing rental value of the plot, whichever is higher.

c. Vacant Land

Conversion of Land use from Vacant Land to Land Lease

$$x_{VL} = \sum_{vml=1}^{n} rx_{vml}$$

$X_{VL} = 2288(vl_{r1}) + 2088(vl_{r2}) + 1788(vl_{r3}) + 1588(vl_{r4})$

$x_{VL} = 4114$ *(Maximum Area under Revenue Category)* 4

$vl_n = vl_{rn}$

rn= maximum net revenue area of each plot

d. Municipal Office Buildings/Quarters

$$X_Q = \sum_{rq=1}^{8} x_{rq}$$

$x_{rq} = -12(q_{r1}) + 1200(q_{r2}) - 12(q_{r3}) + 1500(q_{r4} - 12(q_{r5}) + 44(q_{r6}) + 500(q_{r7}) + 33(q_{r8})$

$X_Q = 14679(Maximum\ Area\ under\ Revenue\ Category)$ 5

$q_n = q_{rn}$

rn= maximum net revenue area of each plot

e. Land Lease

$$X_L = \sum_{rl=1}^{7} x_{rl}$$

$x_{rl} = 588(l_{r1}) + 588(l_{r2}) + 1578(l_{r3}) + 1188(l_{r4}) + 2088(l_{r5}) + 588(l_{r6}) + 588(l_{r7})$

$X_L = 16484.2(Maximum\ Area\ under\ Revenue\ Category)$ 6

$x_{rl} = r_1 \times l_1 + r_2 \times l_2 + \ldots\ldots\ldots\ldots + r_9 \times l_9$

f. Others

$$X_O = \sum_{ro=1}^{1} x_{r0}$$

Leasing of the land based on the market value of the plot

$x_{ro} = 2088(X_o)$.....7

$X_o = 5760\ (Maximum\ Area\ under\ Revenue\ Category)$ 8

Other constraints and Assumptions, Equations from 14 to 30, of Scenario 1 refer to all the reservation of lands of restricted category, remains same in Scenario 3.

Results of Scenario 3

Time Period	Years	NPV 2019 (Crores)
2020-2029	10	₹41
2020-2034	15	₹99
2020-2039	20	₹152
2020-2044	25	₹202
2020-2049	30	₹247
2020-2054	35	₹287
2020-2059	40	₹326
2020-2069	50	₹389

As compared to Scenario1 and Scenario 2, the revenue capacities of this scenario able to finance 88 % of the capital investments required in urban infrastructure by 2020. It was evident that, if the revision of rental values takes place as per the provisions of regulating acts, the revenue strength of the plots would increase significantly.

5.4 Scenario 4, Revenue Optimization Through Change Of Land Use And Revision Of Rental Values

In this scenario, conversion of land use based on potential rental value and maximization of revenue area in all possible categories was permitted in the linear programming model. It was observed that by allowing the change of land use from markets to shopping complex, both the revenue area and returns were increasing as compared to scenario 2 and 3. However, the existing public lands for vegetable and flower markets have been the major economic source for significant employment in an around GMC and were reserved for same use in this model. Whereas few other public lands in markets category have mix of commercial shops, which can be accommodated even in shopping complexes and by allowing the conversion of land use of these plots fetch more potential area and revenue for GMC. This scenario has permitted the change of land use of few plots in markets to other land uses and aimed at maximizing the revenue area for GMC. Besides, the change of land use with higher development costs was not a constraint in this scenario, while allowing the revision of rental values of all categories. The objectives of each category considered in the model are as follows:

1. Shopping Complex (Revision of rental values based on market value; Scenario 3)
2. Markets (Conversion of land use, revision of rental values based on market value)
3. Vacant Lands (Conversion of land use to markets and revision of rental value)
4. Land Lease (Conversion of land use to shopping complex and revision of rental value)
5. Municipal Buildings& Quarters (Conversion of land use to other land uses)
6. Others (Conversion of land use from others to markets and Revision of rental value based on market value)

Objective Function Overall – Revenue Optimization by utilizing the developable area

$$Z = x_B + x_C + x_D + x_L + x_{LB} + x_M + x_Q + x_O + x_P + x_R + x_S + x_{SB} + x_{SC} + x_U + x_{VC}$$

a. Shopping Complex

$$X_{SC} = \sum_{sc=1}^{20} r x_{sc}$$

Objective function and constraints

$$X_{SC} = 2526(SC_{r1}) + 4001(SC_{r2}) + 4096(SC_{r3}) + 1354(SC_{r4}) + 1589(SC_{r5}) + 4620(SC_{r6}) + 1588(SC_{r7}) + 3945(SC_{r8}) + 2088(SC_{r9}) + 1911(SC_{r10}) + 1788(SC_{r11}) + 3438(SC_{r12}) + 3330(SC_{r13}) + 2238(SC_{r14}) + 4389(SC_{r15}) + 2430(SC_{r16}) + 5620(SC_{r17}) + 1709(SC_{r18}) + 2891(SC_{r19}) + 3246(SC_{r20})$$

$$\sum_{sc=1}^{20} x_{sc} \leq 22455 \text{ (Maxmium Area under revenue category)} \ldots\ldots\ldots 1$$

$SC_n = SC_{rn}$; rn= maximum net revenue area of each plot, 10% of the total market value of the plot or the prevailing rental value of the plot, whichever is higher.

$$x_{sc1} + x_{sc2} + x_{sc3} + x_{sc4} + x_{sc5} + \ldots\ldots\ldots + x_{scn} \geq 0 \ (DevelopmentCost) \ldots 2$$

b. Markets

$$x_M = \sum_{rmn=1}^{6} x_{rmn}$$

$$x_M = \sum_{rm=1}^{n} x_{rm} + \sum_{rsm=1}^{n} x_{rsm} + \sum_{rqm=1}^{n} x_{rqm} + \sum_{rvm=1}^{n} x_{rvm} + \sum_{rom=1}^{n} x_{rom} + \sum_{rlm=1}^{n} x_{rlm}$$

$$\sum_{m=1}^{n} x_m \geq 1920 \ (minimumMarketAreareserved) \ldots\ldots\ldots 3$$

$$\sum_{rmn=1}^{6} x_{rmn} \leq 27104 \ (Maximum\ Area\ under\ revenue\ Category) \ldots\ldots\ldots 4$$

$$x_{rm} = 12066(m_{r1}) + 5330(m_{r2}) \ldots\ldots\ldots 5$$

$m_n = m_{rn}$; rn= maximum net revenue area of each plot, 10% of the total market value of the plot or the prevailing rental value of the plot, whichever is higher.

c. Vacant Land

$$x_{VL} = \sum_{vlm=1}^{n} r x_{vlm}$$

$$X_{VL} = 2292(vm_{r1}) + 2092(vm_{r2}) + 1792(vm_{r3}) + 1592(vm_{r4})$$

$$x_{VL} = 3291 \text{ (Maximum Area under Revenue Category)} \ldots\ldots\ldots 6$$

$vl_n = vl_{rn}$; rn= maximum net revenue area of each plot

d. Municipal Office Buildings/Quarters

$$X_Q = \sum_{rq=1}^{8} x_{rq}$$

$$x_{rq} = -12(q_{r1}) + 1200(q_{r2}) - 12(q_{r3}) + 1500(q_{r4} - 12(q_{r5}) + 44(q_{r6}) + 500(q_{r7}) + 33(q_{r8})$$

$$X_Q = 14679 \text{(Maximum Area under Revenue Category)} \ldots\ldots 7$$

$q_n = q_{rn}$; rn= maximum net revenue area of each plot

e. Land Lease

$$X_L = \sum_{rl=1}^{7} x_r$$

$$x_{rl} = 588(l_{r1}) + 588(l_{r2}) + 1578(l_{r3}) + 1188(l_{r4}) + 2088(l_{r5}) + 588(l_{r6}) + 588(l_{r7})$$

$$X_L = 16484.2 \text{(Maximum Area under Revenue Category)} \ldots\ldots 08$$

$$x_{rl} = r_1 \times l_1 + r_2 \times l_2 + \ldots\ldots\ldots + r_9 \times l_9$$

l = Net revenue area of the plot in sq.m;

f. Others

$$x_O = \sum_{rn=1}^{1} x_{rm}$$

Change of land use to markets

$$x_{ro} = 2288(X_o) \ldots\ldots 9$$

$$X_o = 4032 \text{ (Maximum Area under Revenue Category)} \ldots\ldots 10$$

Other constraints and Assumptions, Equations from 14 to 30, of Scenario 1 refer to all the reservation of lands of restricted category, remains same in Scenario 4.

Results of Scenario 4

Time Period	Years	NPV 2019 (Crores)
2020-2029	10	₹41
2020-2034	15	₹99
2020-2039	20	₹152
2020-2044	25	₹202
2020-2049	30	₹247
2020-2054	35	₹287
2020-2059	40	₹326
2020-2069	50	₹389

By allowing the change of land use form markets to other category based on the revenues and by allowing the revision of rental values in other categories, GMC shows to achieve the revenue potential of INR.447 crores from public land lease by 2020 and can finance 100% of the capital investments required in urban infrastructure. Thus, it can be assumed that without

any additional land acquisition or debts, the municipality can finance the urban infrastructure investments by reserving the lands of public leases for 50 years from the year 2020.

5.4 Hypothesis Test

The Wilcoxon signed rank test, a non-parametric test was used to compare the results, financial strengths of public lands of business as usual scenario and other scenarios formulated. The critical value of Z for 8 variables is 10 at 5% of alfa, and it is observed that the results of others simulations are less than 10. Therefore, the null hypothesis is rejected.

6. Conclusion And Way Forward

The assessment on municipal finances of GMC clearly indicates that the municipal revenues realized were not sufficient and the share of own revenues was very low towards total expenditures. When the expenditures were compared to normative levels, the capacity of own revenues reported much below 20% with 70% underspending levels on urban infrastructure and services in GMC, and the need for revision of user charges, property taxes and exploring other potential revenue sources to improve the municipal finances was established. Unlike China, municipal governments in India don't have access to personnel income tax and business income taxes and required to raise municipal revenues through alternative sources where monetization of public lands become a trust area for assessing their revenue potentials, and leasing strategies for public lands have to be based on the market potentials. Thus, revenue optimization techniques using linear programming model finds its application for this case area. The results indicate that existing public lands of GMC has fiscal capacity of financing 40% of the investments required for urban infrastructure by 2020 while reserving land revenues for 50 years. The optimization scenarios proposed under different simulations as done in this research have potentials to realize 240% more revenues compared to 'business as usual' scenario and hence, provide new policy insights for leasing public lands in a revenue optimization perspective. Further, the scenarios developed had recognized and considered the reservation of lands for social purposes and didn't exploit them for monetary benefits. The study also indicates how local governments can estimate potentials of their own revenues and establish revenue targets.

Overall, it is concluded that the revenue potentials of public lands can't be determined based on the realized revenues alone and it is essential to consider the following aspects while estimating the potential of public lands: *a) existing rental and potential value by category, b) permissible developable area within the plot c) reservations on leases d) time period of lease e) revision of rental values f) development costs and net present value of future revenues from leases g)marketable public land for revenue maximization.* The outcomes of this study convey that reservation of public land lease revenues towards capital investments on urban infrastructure services is an important policy recommendation that municipalities have to undertake and approaches on building more marketable public land through planning instruments will further increase the fiscal capacity of municipality.

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Providing a Model For Assessing Risk Management Of Construction Projects With A Sustainable Development Approach: Case Studies Of Small-Scale Power Plants

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ABSTRACT

Economic growth in developing countries requires the implementation of infrastructural projects such as power plants, the sustainability of which plays an important role in the social, economic, and environmental development. Despite, these projects are always associated with uncertainties and risks due to features such as uniqueness, unspecified time, the need for specific equipment, correlation between different phases and so on. Therefore, in the present study, a small-scale power plants in Mazandaran was subjected to a case study by which the project risks were properly studied. By interviewing the experts associated with the construction of the power plant, 34 risks were identified and subsequently categorized into four categories of environmental, economic, social, and technical. Then, using the failure factor analysis method, their effects were evaluated, and critical risks were identified. In the next step, Fuzzy TOPSIS hierarchical analysis method was used to prioritize critical risks according to the project objectives in accordance with the PMBOK project management standard. After prioritizing the critical risks, in accordance with the real conditions of these projects, suggestions were made to respond and face the critical risks.

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1. Introduction

Construction projects have been executed over a long period and involve many stakeholders such as government agencies, designers, contractors, investors, and end-users, and have a great effect on society (Marrewijk, Clegg, Pitsis, & Veenswijk,2008; Chang, Soebarto, Zhao & Zillante, 2016). Therefore, the collaboration between stakeholders should be improved so that the product can provide the desired features and have a high level of sustainability (Kivilä, Martinsuo & Vuorinen, 2017; SILvIuS, Schipper, Van Den Brink & Planko, 2012). Therefore, the integration of sustainability into construction projects is one of the challenges of project management.

Sustainable construction satisfies the needs of sustainable development and can ensure economic development, social health and the reduction of the negative effects of construction on the environment (Czarnecki, Kaproń & Van Gemert, 2013; Li, Zhang, Ng & Skitmore, 2018) By focusing on environmental principles and resource efficiency, sustainable construction not only considers the environmental issue, but also tries to create a balance among the environmental, economic and social goals (Shi,Ye, Lu & Hu, 2014). Sustainable project management is a process whereby projects are controlled to ensure the achievement of sustainability goals based on environmental, economic and social principles (Silvius & Schipper, 2014). Although sustainable project management has been proposed for integration of sustainability into project management, it is not free from shortcomings. The studies having been conducted on the role of project management and planning show that its main objective is to reduce the uncertainty of projects (Laufer, Kusek, & Cohenca-Zall, 1997). Therefore, planning efforts can be considered a risk management tool in a hazardous environment (Zwikael & Sadeh, 2007).

Large-scale projects such as power plant projects are carried out in a dynamic and complex environment in such a way that uncertainty and risk are among their inherent characteristics. According to the 5th Edition of the *PMBOK. Guide*, project risk is "an uncertain event or condition that, if it occurs, has a positive or negative effect on one or more project objectives such as scope schedule cost (PMI. 2008). According to the project risk management researchers, risk management covers all project management activities (Grey, 1995; Turner, 1995). Risk management is an important part of project management. The more accurately the uncertainties of a precise are analyzed, the more efficient and, of course, more practical its risk management will be (Patrick, Guomin & Jiayuan, 2007). The goal of risk management is to increase the probability of a project's success by providing systematic detection and evaluation of risk, and providing methods for avoiding or reducing risks and maximizing opportunities (Chapman & Ward, 2003).

So far, several standards have been proposed for risk management, including the Shape, Harness And Management Project Uncertainty (SHAMPU), Project Uncertainty Management (PUMA) (Del Cano & De la Cruz, 2002), and Active Threat & Opportunity Management (ATOM) (Hillson & Simon, 2007), but the most prominent and widely used standard of all is the PMBOK (Patrick, Guomin & Jiayuan, 2007).

This uncertainty has led to the failure of most of the country's projects to achieve their predetermined goals (time, cost, quality, etc.), which, in turn, has led to problems such as lack of economic justification of exploitation of projects, reduced efficiency and increased dissatisfaction among key stakeholders. There are a lot of problems in this industry and many studies have dealt with different ways to get out of these issues. Identifying the priority of risk factors through risk assessment is an important decision-making problem for the project construction management team. Le Wang proposed a model for assessing the risk of a construction project using the VIKOR and PFNP multi-criteria decision making framework (Wang, Zhang, Wang & Li, 2018). Kim and Kang presented a model for the analysis of the risk of construction costs (Kim & Kang, 2017). Han et al. predicted the integrated cash flow risk for construction projects (Han, Park, Yeom,. & Chae, 2014). Considering the dynamic nature of risks and constant changes in the projects, Nasirzadeh et al., provided a dynamic system-based approach that can simulate the impact of different risks on time, cost, and quality (Nasirzadeh, AFSHAR& KHAN, 2008). Ardeshir investigated the risks of projects for the construction of water transfer tunnels, specifically the risks associated with time, cost, quality and safety criteria using the fuzzy AHP approach (Ardeshir, Amiri, Ghasemi, & Errington, 2014). Using the fuzzy Bayesian model, Islam examined risk assessment in power plants projects (Islam & Nepal, 2016). Yelin et al. studied the critical risk factors affecting the implementation of public-private partnerships for waste-to-energy projects in China in a case study on 14 incineration plants (Xu, Chan, Xia, Qian, Liu, & Peng, 2015). Wang also used the neural network model to assess the risk management of power plant construction projects to create a risk assessment model and classify the risks that affects project goals during construction and even during operation (Wang, Niu, & Xing, 2010).
Doskocil & Lacko analyzed the key aspects of sustainable projects, namely, advanced risk management and project knowledge (Doskočil, & Lacko, 2018). Weiyao et al. evaluated the sustainability risks of large-scale hydropower projects and classified sustainability risks into three environmental, social and economic categories (Tang & Tu, 2018). Dongxiao et al. evaluated the sustainability of power grid construction projects. This project first identified 17 sustainability criteria and then classified them into four main technical, environmental, economic and social criteria and evaluated them using the improved TOPSIS method (Niu, Dai, Kang, Xue, Jin, & Song, 2018). Kim & Lee an investment decision-making process for sustainable development based on the profitability impact factors for overseas projects based on the value-at-risk (Kim & Lee, 2018). Despite the publication of numerous articles on risk management, there is little information available about its use in the real world (Lyons, 2002). According to various researchers, there is no comprehensive model for evaluating project risk reduction measures (Ben-David, Rabinowitz, & Raz, 2002). The purpose of this research is to evaluate risk with the sustainability approach. Sustainability in the environmental dimension means protecting and improving the capacity of production and renewal of environmental systems. In the economic dimension, sustainability means maximizing

the current net benefits and future economic development, while not reducing the quality of natural resources and related services. From the social point of view, sustainability means improving the people's quality of life and health status and ensuring access to the necessary resources in order to create an environment in which the freedom and equality of people's rights are protected. Given the definition of risk and the multidimensional nature of sustainability, sustainability risk involves considering the risks of the environment, economy and society (Tang & Tu, 2018). Since sustainable development is becoming more and more important for policymakers and decision-makers around the world, achieving the goals of sustainable development requires considering and integrating the sustainability and technical aspects, which have gradually been recognized by decision makers and policymakers (Ness, Urbel-Piirsalu, Anderberg & Olsson, 2007; Jeswani, Azapagic, Schepelmann & Ritthoff, 2010). Therefore, risks have been identified and categorized in the present paper into four environmental, economic, social, and technical sections.

2. Methodology

The relationship between the criteria affecting the risk of construction projects is very complex and usually one criterion affects other criteria. The evaluation and analysis of alternatives in different complex conditions, especially in the construction industry area which is affected by multiple criteria and varied alternatives, requires the use of quantitative techniques and mathematical models of decision-making. Although different mathematical decision techniques are available to contribute to the decision making process, these techniques are hardly used due to the limited time and their inherent complexity. In addition, various studies show that decision-making techniques related to risk management mainly focus on optimizing and improving a criterion. Therefore, it is necessary to study the methods in which several criteria, which are sometimes even contradictory, in planning simultaneously. This is why the present study has sought to present a different model for risk management in the construction of power plants projects using the Failure Modes and Effects Analysis (FMEA) and the Multiple Criteria Decision Making (MCDM) techniques in fuzzy environment.

2.1 Fuzzy Numbers And Fuzzy Sets

The fuzzy set theory was introduced by Professor Lotfizadeh. This theory is used in conditions of ambiguity and uncertainty. This theory is able to express many of the inaccurate concepts and terms with mathematical language and provide grounds for reasoning, inference, control, and decision making in conditions of uncertainty. According to this theory, $\tilde{A} = \{(x, \mu_{\tilde{A}}(x)) | x \in X\}$ is a fuzzy set in which x accepts the real values of the member of the R set and its membership function is as $\mu_{\tilde{A}}(x) :\rightarrow [0,1]$.

The most commonly used fuzzy numbers are triangular and trapezoidal fuzzy numbers. Triangular fuzzy numbers are most often used due to their simpler calculations. Triangular fuzzy numbers are also used in this study. A triangular fuzzy number A with linear membership function μA is defined as Equation (1), which is represented as a triangular fuzzy number (l, m, u). Figure 1 shows this membership function(Masoudnejad,Rayati & Gholampour, 2018).

$$\mu_A(x) = \begin{cases} (x-l)/(m-l), & l \le x \le m \\ (u-x)/(u-m), & m \le x \le u \\ 0, & otherwise \end{cases} \quad (1)$$

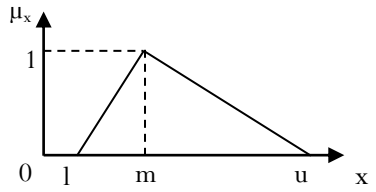


Figure 1. Triangular fuzzy number

If $\tilde{A} = (l_1, m_1, u_1)$ and $\tilde{B} = (l_2, m_2, u_2)$ are two triangular fuzzy numbers, the distance function d ($\tilde{A}$, $\tilde{B}$) is defined as Equation (2) (Masoudnejad,Rayati & Gholampour, 2018):

$$d(\tilde{A}, \tilde{B}) = \sqrt{\frac{1}{3}[(l_1 - l_2)^2 + (m_1 - m_2)^2 + (u_1 - u_2)^2]} \quad (2)$$

2.2 Failure Modes and Effects Analysis (FMEA)

The FMEA is an analytical technique based on the integration of two factors of technology and the experience of individuals to prevent the receiving an unwanted product by customers and prevent the risk of validity and reputation of the company (Besterfield, Besterfield-M Besterfield & Besterfield-S, 2003) which is widely used in construction and production industries in the various phases of the product life cycle and has increasingly been accepted in service industries (Kumru & Kumru, 2013).

Since the FMEA is about the failure modes and its effects, we need to define the term "failure". In terms of production, failure can be defined as "the inability of a design or a process to perform the desired task" (Kumru & Kumru, 2013). Most often, traditional FMEA uses a risk priority number (RPN) to assess the risk level. RPN is obtained by multiplying three factors of occurrence (O), severity (S) and detection (D) (Equation 10) (Kumru & Kumru, 2013). This method uses a score of 1 to 10 (1 for the best and 10 for the worst) to measure these three parameters.

$$RPN = O \times S \times D \quad (3)$$

Although the traditional FMEA method is widely used in research, this method has fundamental weaknesses.

To overcome the weaknesses in risk assessment and prioritization in relation to the traditional prioritization of the FMEA method, we have used the fuzzy logic in this method.

The term "fuzzy logic" gas come from the Lotfizade's fuzzy set theory. In 1965, Lotfizade proposed the fuzzy set theory and later proposed fuzzy logic based on the fuzzy set.

Tables 1, Table 2 and Table 3 show the ranks for severity, occurrence and detection, as well as linguistic terms and their corresponding triangular fuzzy numbers (Kumru & Kumru,2013).

Table 1 Definition of linguistic terms for occurrence(Tang & Tu, 2018)

Triangular fuzzy numbers	occurrence	linguistic terms
(0,1,3)	Above 66%	Very low
(1,3,5)	Between 33% and 66%	low
(3,5,7)	Between 10% and 33%	moderate
(5,7,9)	Between 1% and 10%	high
(7,9,10)	Below 1%	Very high

Table 2 Severity classification assessment criterion(Tang & Tu, 2018)

Triangular fuzzy numbers	Severe effect	linguistic terms
(0,1,3)	Without effect	Very low
(1,3,5)	With a low effect on the construction trend	low
(3,5,7)	Moderate effect on the construction trend	moderate
(5,7,9)	With high effect on the construction trend	high
(7,9,10)	With very high effect on the construction trend	Very high

Table 3 Definition of linguistic terms for detection / control(Tang & Tu, 2018)

Triangular fuzzy numbers	Detection/control	linguistic terms
(0,1,3)	The project team is able to identify a risk response strategy with a proven high impact on identifying risk events, controlling the underlying causes and outcome of the risk event.	Very low
(1,3,5)	The project team is able to identify a risk response strategy with a high probability of identifying risk events, controlling the underlying causes and outcome of the risk event.	low
(3,5,7)	The project team is able to identify a risk response strategy with a moderate probability of identifying risk events, controlling the underlying causes and outcome of the risk event.	moderate
(5,7,9)	The project team is able to identify a risk response strategy with a low probability of identifying risk events, controlling the underlying causes and outcome of the risk event.	high
(7,9,10)	The project team is unable to identify a risk response strategy with a capability of identifying risk events, controlling the underlying causes and outcome of the risk event.	Very high

The FRPN is not very efficient when the dimensions of failure (risk) affect several dimensions of an issue, because the FRPN is obtained based on the three criteria of occurrence, severity and control, and each one of these criteria by itself does not reflect the effects of all aspects of risk. In addition, there is dependency among different criteria in the real world. Therefore, we will use the Fuzzy TOPSIS Analytic Hierarchy Process to consider the impact of the risks on the different dimensions and objectives of the project and to consider the dependency among them.

2.3 The Fuzzy TOPSIS Method

The reason for using the TOPSIS method in the present study is that the TOPSIS (Technique for Order Preference by Similarity to Ideal Solution Solution) method has appropriate mathematical foundations. This method deals with distances. TOPSIS chooses the option that has the most distance from the worst option and the least distance from the best option as the optimal option, and for this reason, and its mathematical basis, it is superior to other methods. Another advantage of this method is that it is a compensatory method. That is, the weight of all options and criteria is involved in the decision and no weight is ignored in this method.

The TOPSIS technique is one of the multi-criteria decision-making methods proposed by Hwang and Yoon in 1981 (Hwang & Yoon, 1981) developed by Yoon in 1987 (Yoon, 1987) and Huang et al. in 1993 (Hwang, Lai, & Liu, 1993.).
The fuzzy TOPSIS technique was first proposed by Chen to solve multi-criteria decision-making problems under uncertainty conditions (Chen, 2000). This technique has been used in many studies, and Fuzzy TOPSIS decision making methods have been developed in the electric power industry (Ervural, Zaim, Demirel, Aydin, & Delen, 2017) and finance (Tavana, Keramatpour, Santos-Arteaga, & Ghorbaniane, 2015) since the 1990s. Linguistic terms are used in this method to rank the alternatives and weights of the criteria, because the use of linguistic terms rather than numerical evaluation is more realistic and more tangible when dealing with unclassified and uncertain data, especially in modeling human judgments (Walczak, Rutkowska, 2017). We have

used linguistic variables and direct weighing methods in this study to evaluate the weights of the criteria and rank the alternatives. The linguistic variables and fuzzy triangular numbers corresponding to them, which have been used by decision makers (D = 1, 2 …, K) for the weighing, were based the triangular fuzzy numbers introduced by Chen, as shown in Table 4 & 5 (Chen, 2000).

Table 4 Linguistic variables for the importance weight of each criterion

Linguistic variables	Triangular fuzzy numbers
Very low (VL)	(0.0, 0.0, 0.1)
Low (L)	(0.0, 0.1, 0.3)
Medium low (ML)	(0.1, 0.3, 0.5)
Medium (M)	(0.3, 0.5, 0.7)
Medium high (MH)	(0.5, 0.7, 0.9)
High (H)	(0.7, 0.9, 1.0)
Very high (VH)	(0.9, 1.0, 1.0)

Table 5 Linguistic variables for the ratings

Linguistic variables	Triangular fuzzy numbers
Very poor (VP)	(0, 0, 1)
Poor (P)	(0, 1, 3)
Medium poor (MP)	(1, 3, 5)
Fair (F)	(3, 5, 7)
Medium good (MG)	(5, 7, 9)
Good (G)	(7, 9, 10)
Very good (VG)	(9, 10, 10)

The Fuzzy TOPSIS method consists of the following steps (Chen, 2000):

Suppose that the decision group consists of K members. We can obtain the weights of the criteria and the ranking of the alternatives using equations 11 and 12. $\tilde{W}_j$ represents the weight of the jth criterion.

$$\tilde{W}_j = \frac{1}{K}\left[\tilde{W}_J^1 + \tilde{W}_J^2, \ldots\ldots, \tilde{W}_j^k\right] \quad (4)$$

$$\tilde{x}_{ij} = \frac{1}{k}\left[\tilde{x}_{ij}^1 + \tilde{x}_{ij}^2 + \ldots. + \tilde{x}_{ij}^k\right] \quad (5)$$

In this matrix (D), $\tilde{x}_{ij}$ represents the rank of the ith alternative (i = 1, 2 ..,., m) based on the mth criterion (j = 1, 2 ..,., n), which is based on linguistic variables (Equation 13).

$$\tilde{x}_{ij} = (a_{ij}, b_{ij}, c_{ij}) \quad (6)$$

Step I: Equation 14 shows the decision matrix of the criteria and alternatives:

$$\tilde{W} = \left[\tilde{W}_1, \tilde{W}_2, \ldots\ldots, \tilde{W}_n\right] \quad (7)$$

Step II. Then, the fuzzy decision matrix must be converted to a comparable scale and be normalized. There are several methods for normalization, but Chen has proposed a linear normalization method. Thus, we can use equations 16 and 17 to normalize the profit and cost criteria.

$$\tilde{R} = \left[\tilde{r}_{ij}\right]_{m\times n} \quad (8)$$

$$\tilde{r}ij = \begin{cases} \left(\frac{a_{ij}}{c_j^*}, \frac{b_{ij}}{c_j^*}, \frac{c_{ij}}{c_j^*}\right), & j \in B \ , c_j^* = \max c_{ij} \ if \ j \in B \\ \left(\frac{a_j^-}{c_{ij}}, \frac{a_j^-}{b_{ij}}, \frac{a_j^-}{a_{ij}}\right), & j \in C \ , a_j^- = \min a_{ij} \ if \ i \in c \end{cases} \quad (9)$$

Step III: Now, we can obtain the fuzzy weighted normal matrix using Equation 16.

$$\tilde{V} = \left[\tilde{v}_{ij}\right]_{m\times n}, \quad i = 1,2,\ldots,m, \quad j = 1,2,\ldots,n \quad (10)$$

If $\tilde{v}_{ij} = \tilde{r}_{ij} . \tilde{w}_j$

Step IV: The positive ideal (FPIS, A +) and the negative ideal solution (FNIS, A-) is obtained using equations 21 and 22.

$$A^* = \left(\tilde{v}_1^*, \tilde{v}_2^*, \ldots\ldots, \tilde{v}_n^*\right) \quad (11)$$

$$A^- = \left(\tilde{v}_1^-, \tilde{v}_2^-, \ldots\ldots, \tilde{v}_n^-\right) \quad (12)$$

Here, $\tilde{v}_j^- = (0,0,0)$, and $\tilde{v}_j^* = (1,1,1,)$.

Step V: The distance between the ith alternative, or the positive ideal (A +) and negative ideal (A-) can be obtained using equations 23 and 24, and the distance between the two triangular fuzzy numbers is calculated from Equation (2).

$$d_i^* = \left\{\sum_{j=1}^{n} d\left(\tilde{v}_{ij}, \tilde{v}_j^*\right)\right\} \quad i = 1,2,\ldots,m, \ j = 1,2,\ldots,n \quad (13)$$

$$d_i^- = \left\{\sum_{j=1}^{n} d\left(\tilde{v}_{ij}, \tilde{v}_j^-\right)\right\} \quad i = 1,2,\ldots,m, \ j = 1,2,\ldots,n \quad (14)$$

Step VI: Now using Equation 25, we can calculate the relative closeness coefficient of the ith alternative (CCi).

$$CC_i = \frac{d_i^-}{\left(d_i^* + d_i^-\right)}, \quad i = 1,2,\ldots,m, \ 0 \le cl_{i+} < 1 \quad (15)$$

The ranking of alternatives is arranged in a descending order based on the closeness coefficient of CCi. The best alternatives include the closest alternative to the FPIS and the farthest alternative from it. In other words, the greater the relative closeness coefficient, the more ideal its corresponding alternative will be.In the proposed model of the present study, to manage risk in power plant projects, first using the failure technique and impact analysis and considering the criteria of probability of occurrence, impact intensity and control, risks in four sectors: environmental, economic, social and Technical, identified and classified, and critical risks identified. Then, the critical risks were evaluated according to the studied criteria using TOPSIS method in a fuzzy environment and during that the weight of the criteria was determined. In the next step, the risk ranking was determined according to the studied criteria in a fuzzy environment. The framework of the proposed model is presented in Figure 3.

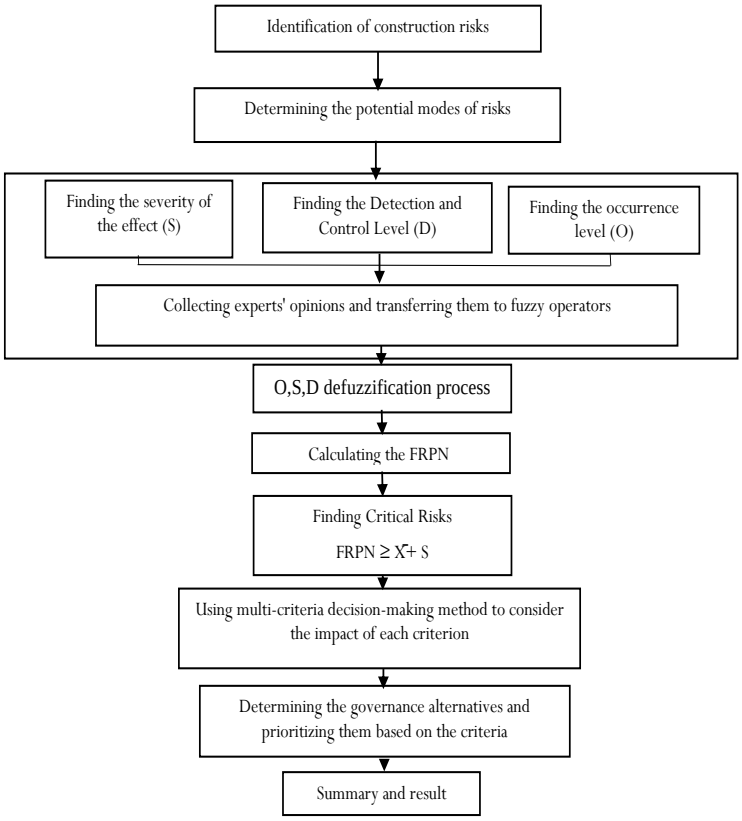


Figure 3 The conceptual model of risk assessment and management

3. Case Study

Today, the power industry is considered the engine of growth and development of other sectors. This industry is a dynamic and influential industry due to its underlying role and its close relationship with the factors affecting economic growth, and an increase in its productivity and efficiency is, therefore, of great importance. The power generation sector, which is the power plant, is one of the most important and cost-effective sectors of the power industry.

The purpose of this study is to provide a model for risk management of construction projects, with a sustainable development approach. To this aim, we first detected the risks existing in the project and then, using the FMEA Fuzzy method, we prioritized the risks and determined the critical ones. Having identified the critical risks, we used the multi-dimensional decision-making technique to assess their impact on the project's goals, because, as stated earlier, the RPN is not very effective when the risks affect several dimensions of the project's objectives. Besides, there is a dependency among different goals. Multi-criteria decision-making is a set of methods and procedures that try to make an analysis on several - most often inconsistent- indices or criteria to select an ideal alternative or prioritize the alternatives. We used the TOPSIS FUZZY technique in the present study so as to solve the decision-making problem. This method, like other decision-making methods, has three levels of goal, criteria, and alternatives. The purpose of the research is to " Provide a model for risk management of construction projects, with a sustainable development approach ". In the proposed model, the critical risks derived from the FMEA were considered the "alternatives", as shown in Table 8. The effective criteria for project goals were also selected based on the PMBOK project management standard and experts' views.

The book "Project Management Body of Knowledge (PMBOK)" was prepared by the Project Management Institute (PMI) Institute, which is the most well-known global reference for project management. PMBOK is the most popular standard in project management and is the most commonly used criterion for the design and evaluation of project management systems. Many of the most common definitions, terms and classifications that are used today in project management are taken from this standard. In other words, it is a common global language in project management. This standard is classified in the sixth edition in ten areas including project integration management, project scope management, project schedule management, project cost management, project quality management, project resource management, project communications management, project risk management, project procurement management and project stakeholder management, which have been regarded as the basis for this research. According to the studies and interviews conducted with the industry experts, the most important and effective goals of the project under study include project schedule management, project cost management, project quality management and project

procurement management. Table 6 summarizes each of these areas in accordance with the PMBOK standard.

Table 6 Description of the most effective goals of the project

The most effective goals of the project	Definition	Code
Project schedule management	This includes the processes needed for the full project schedule management.	C_1
Project cost management	This includes the processes of budget planning, financing, cost management and control until the project is completed in the approved budget.	C_2
Project quality management	This includes processes to ensure fulfillment of the project stakeholders' needs based on the quality that has been committed.	C3
Project procurement management	Processes needed to access goods and services outside the project team.	C4

4. Finding and Discussion

Risk detection is a major step in the risk management process without which it is impossible to carry out other steps. There are various techniques for identifying project risks. There is not only one solution as the best way to identify project risks, but a combination of different techniques should be used (Kasap & Kaymak, 2007).

We have used a hybrid approach in this research for identifying risks in the project under study. Some of the tools used include an extensive review of the studies related to risk detection, backgrounds of previous projects, various interviews with experts, and holding brainstorm sessions. Considering the large number of risks in power plants projects on the one hand and the limited resources of the organization for risk management on the other, these risks must be prioritized and critical ones must be identified. For this purpose, the researchers performed risk assessment was based on the brainstorm method after the formation of the decision-making team. Based on this method, the group of contractors, who played the most important role in the implementation of the project and the group of employers and consultants reached a single conclusion during a joint meeting and determined a value for each risk.

For risk assessment using Fuzzy FMEA, we have used FuzzyTech software 5.54 to calculate the fuzzy risk priority number (FRPN). The generated model has 3 inputs and one variable output, as shown in Figure 4.

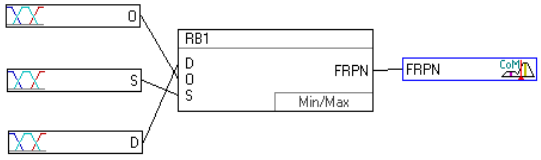
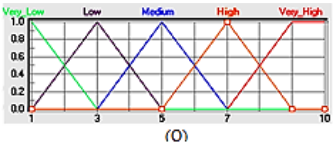


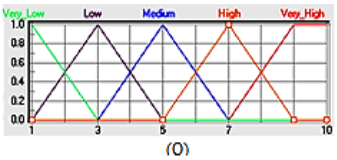
Figure 4 The Fuzzy Expert System for analyzing the critical mode of risk

The input variables include the occurrence, severity, and detection, each of which is presented in five levels with triangular membership functions (Figure 5).

A: Membership functions for the probability of occurrence



B: Membership functions for severity



C: Membership functions for detection/ control

Figure 5 The membership function of the O, S, D input variables

Identified risks and their prioritization using the Fuzzy FMEA method are shown in Table 7.

Table 7 Prioritization of identified risks based on the FRPN

category	Specified risk	O	S	D	FRPN
Technological	1.Inaccurate data transfer from basic design to detail design	5	9	5	520.2
	2.Changes in budget, schedule, and executive procedures	5	5	4	230.2
	3.Inaccuracy in controlling and matching the plan and execution	4	5	3	140.2
	4.Inaccurate insertion of technical and executive documents	3	4	2	50.50
	5.Lack of project planning and control processes and project delays' resulting from this factor	3	6	3	100
	6.The inappropriate selection of the execution method and the lack of up-to-date and appropriate standards for execution	3	4	3	50.50
	7.Lack of full mastery of the consultant on project conditions	6	8	6	622.54
	8.Lack of quality and delay in equipment supply	6	4	4	186.8
	9.Inadequate specifications of the project	5	4	4	186.8
	10.Changes in the design and scope of tasks	5	4	4	186.8
	11.Employer's low experience	5	7	5	590.1
	12.Management weakness of the project executive	8	8	4	520.27
	13.Rise of a commissioning problem due to unqualified execution of construction and installation	6	7	5	527.56
	14.Accidents for manpower and equipment	3	5	4	140.2
social	15.Popular strikes and protests	3	7	5	180.42
	16.Changes in laws and regulations	3	5	3	100
	17.Employer's interventions	4	7	5	350.32
	18.Inappropriate way of bidding and selecting contractors	5	7	5	520.2
	19.Administrative bureaucracy existing in the administrative agencies associated with the project	8	7	8	715.1
	20.Lack of specialized and skilful human resources	5	7	5	520.2
	21.Problems with the neighbors and residents of the region regarding construction	4	3	7	138.28
	22.Problems caused by robbery from the workshop	3	5	5	180.42
Economic	23.Failure to review the project contract specifications	3	5	3	100
	24.Shortage or lack of materials, machinery and equipment	4	6	2	186.8
	25.Inadequate estimation of the project implementation cost	6	5	3	180.42
	26.Low financial strength of the employer	7	8	7	715.1
	27.Failure to supply equipment due to political and economic sanctions	5	6	7	529.98
	28.Inappropriate way of contracting with executive agents	3	5	4	140.2
	29.Lack of human resource productivity	3	5	2	100
environmental	30.Power location and access roads	3	5	3	180.42
	31.Creation of noise pollution	5	6	3	230.2
	32.Creation of soil and climate pollution	2	4	3	50.50
	33.Inappropriate atmospheric conditions	5	5	5	280
	34. Supply of water and power to the workshop	3	5	9	180

It's important to note that in the Fuzzy FMEA, there is no base for the FRPN with which to compare the data and determine the critical levels. We used statistical methods in this research to determine the critical level.

Using the SPSS software and based on the distribution results, the FRPN values were obtained as 283.27 for 34 risks, and the standard deviation was obtained as 206.48. The critical limit for detected risks was considered the sum of the mean value with the standard deviation of FRPNs, which was equal to 489.75. Given the critical level obtained, we detected 10 risks as the critical risks using the Fuzzy FMEA method, as shown in Table 11 in an order of priority.

Table 8 Critical risks resulting from Fuzzy FMEA

Code	Critical risks	RPN
A_1	Low financial strength of the employer	715.1
A_2	Administrative bureaucracy existing in the administrative agencies associated with the project	715.1
A_3	Lack of full mastery of the consultant on project conditions	622.54
A_4	Employer's low experience	590.10
A_5	Failure to supply equipment due to political and economic sanctions	529.98
A_6	Rise of a commissioning problem due to unqualified execution of construction and installation	527.56
A_7	Management weakness of the project executive	520.27
A_8	Lack of specialized and skilful human resources	520.20
A_9	Inappropriate way of bidding and selecting contractors	520.20
A_{10}	Inaccurate data transfer from basic design to detail design	520.20

To analyze the impact of critical risks on the most effective project objectives (project schedule management, project cost management, project quality management and project procurement management), we used the Fuzzy TOPSIS Hierarchy Analysis Method.

The hierarchical analysis chart has been presented at three levels, as shown in Figure 6.

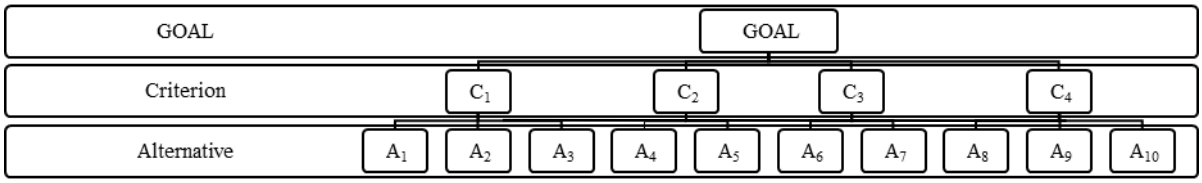


Figure 6 Analytical Hierarchy Chart

The formation of the hierarchy of the proposed model was followed by the assessment of the weights of the criteria and the ranking of alternatives by decision makers (including the contractor's representative, consultant, and employer) by use of the linguistic terms presented in tables 4 and 5, the results of which are shown in Tables 9 and Table 10.

Table 9 The importance weight of the criteria

Code	D1	D2	D3
C1	ML	M	ML
C2	ML	ML	ML
C3	VH	H	H
C4	H	VH	H

Table 10 The ratings of the three candidates by decision makers under all criteria

Alternative	Criteria	D_1	D_2	D_3		D_1	D_2	D_3		D_1	D_2	D_3		D_1	D_2	D_3
A1		VG	G	VG		VG	VG	VG		VG	VG	VG		VG	VG	VG
A2		VG	VG	VG		MG	F	MG		F	G	F		VG	G	VG
A3		G	G	VG		G	MG	G		VG	VG	VG		F	MG	MG
A4		G	MG	G		VG	VG	G		VG	VG	VG		VG	G	VG
A5	C_1	G	VG	VG	C_2	G	G	VG	C_3	VG	VG	VG	C_4	VG	VG	VG
A6		MG	F	F		MG	MG	G		VG	VG	VG		VG	VG	VG
A7		MG	MG	F		VG	G	G		MG	G	G		VG	G	G
A8		F	G	G		G	G	VG		VG	VG	VG		VG	VG	VG
A9		MG	MG	F		VG	MG	G		MG	G	F		VG	VG	VG
A10		MG	F	G		MG	MG	MG		VG	G	VG		F	F	F

Now the linguistic variables in Tables 9 and 10 are converted to triangular fuzzy numbers. After normalization based on Equation 9, the weighted normal matrix, which is the result of the fuzzy multiplication of the normal matrix by the weight of the criteria, is calculated (Table 11). Then the weighted fuzzy decision matrix was calculated by using 13 and 14 relationships of ideal positive and negative ideal numerical values. Finally, the relative proximity of each of the options to the ideal solution (relation 15) was determined and descended (Table 12).

Table 11 The fuzzy weighted normalized decision matrix

Code	C_1	C2	C_3	C_4
A_1	(0.14, 0.35, 0.57)	(0.09, 0.30, 0.50)	(0.69, 0.93, 1.00)	(0.69, 0.93, 1.00)
A_2	(0.15, 0.37, 0.57)	(0.04, 0.19, 0.42)	(0.33, 0.59, 0.80)	(0.64, 0.90, 1.00)
A_3	(0.13, 0.34, 0.57)	(0.06, 0.25, 0.48)	(0.69, 0.93, 1.00)	(0.43, 0.72, 0.90)
A_4	(0.11, 0.31, 0.55)	(0.08, 0.29, 0.50)	(0.69, 0.93, 1.00)	(0.64, 0.90, 1.00)
A_5	(0.14, 0.35, 0.57)	(0.08, 0.28, 0.50)	(0.69, 0.93, 1.00)	(0.69, 0.93, 1.00)
A_6	(0.06, 0.21, 0.43)	(0.06, 0.23, 0.47)	(0.69, 0.93, 1.00)	(0.69, 0.93, 1.00)
A_7	(0.07, 0.23, 0.47)	(0.08, 0.28, 0.50)	(0.49, 0.78, 0.97)	(0.59, 0.87, 1.00)
A_8	(0.09, 0.28, 0.51)	(0.08, 0.28, 0.50)	(0.69, 0.93, 1.00)	(0.69, 0.93, 1.00)
A_9	(0.07, 0.23, 0.47)	(0.07, 0.26, 0.48)	(0.38, 0.65, 0.87)	(0.69, 0.93, 1.00)
A_{10}	(0.08, 0.26, 0.49)	(0.05, 0.21, 0.45)	(0.64, 0.90, 1.00)	(0.23, 0.47, 0.70)

Table 12 The distance measurement,closeness coefficient and rank order of alternatives

Code	d^+	d^-	CC_i	Rank
A_1	0/90521	1/86049	0/67270	2
A_2	1/27170	1/52074	0/54459	9
A_3	1/12836	1/66751	0/59642	6
A_4	0/97459	1/80997	0/62425	4
A_5	0/91728	1/96579	0/68184	1
A_6	1/03245	1/71522	0/48907	5
A_7	1/19784	1/62527	0/65000	7
A_8	0/96187	1/80326	0/57570	3
A_9	1/2320	1/56000	0/65214	8
A_{10}	1/4286	1/36754	0/55872	10

The results of analysis of the experts' opinions using the proposed model for risk management in the construction of power plant projects showed that lack of equipment supply due to political and economic sanctions (0.681) is the most important risk based on the four examined criteria. The employer's low financial strength (0.672) and the shortage of specialized and skilful human resources (0.652) were ranked second and third respectively, and employer's low experience (0.650), the occurrence of a problem in commissioning due to unqualified implementation of construction and installation (0.624), the consultant's lack of full mastery on project conditions (0.596), weakness in workshop management (0.575), inappropriate method of bidding and contractor selection (0.558), the administrative bureaucracy available in administrative agencies related to the project (0.544) and the inaccurate data transfer from basic design to detail design (0.489) were ranked fourth to tenth respectively.

These results are consistent with the objective conditions and evidence of these projects. Political and economic sanctions have always had an impact on the economy and infrastructure, and their impact depend on the severity level of sanctions. Banking sanctions in general and the sanctions imposed on the Central Bank in particular disturbed the monetary exchanges in Iran and caused a lot of disruptions in its trade activities. The sanctions led to a significant reduction in the country's foreign exchange earnings, and led to a sharp and severe decline in the supply of foreign exchange in the market, resulting in a sharp increase in the exchange rate. The supply of foreign exchange needs of the country faced a plethora of problems due to the shortage of foreign exchange reserves. Therefore, the allocation of foreign currency to imports was prioritized, and even some commodities were subject to non-allocation of the government's currency, which was followed by a sudden increase in the price of many commodities. Many domestic products, especially in the private sector, faced reduced production due to their dependence on imports of intermediate goods and raw materials, and some firms were closed in some cases. Like other economic and infrastructure activities, power plant projects also faced problems due to their being technology-based and the need to import technology to the country, and also due to the employer's reduced power to supply the required resources and the existence of technological sanctions in this sector.

It should be noted that in the knowledge-based economy of the current era, intellectual property, especially human capital, is the most important asset of the organization, and the latent success of organizations is rooted in the ability and expertise of their workforce. Many of the tasks in projects are performed by the human resources of the employer, the contractor and the consultant. These forces play a key role in achievement of the predetermined goals of organizations. In addition, due to the complicated process of power plant construction and the lack of sufficient experience, there is a significant deviation in some stages of the project between the predicted volumes of work and the actual values, which in turn leads to repeated delays, increased project costs and reduced quality, thereby influencing other predetermined goals for the project. Therefore, we can increase the rate of success and achievement of project sustainable goals by implementing effective risk management in such projects. This is because it leads to greater mastery on the risks of projects and the adoption of appropriate decisions under different conditions of the project.

As mentioned, one of the most important steps in risk management is risk response. In the following, according to the case studies conducted in Mazandaran small-scale power plants, the following suggestions are presented in order to respond and face critical risks:

- Planning financing such as foreign financing, long-term loans, sale of participation bonds, etc.
- Preparing the cash flow of the project at the beginning of the construction phase and installing and obtaining the commitment of the shareholders and the board in committing to the payments
- Selection of intermediaries and the third factor to meet the required needs
- Supply from another source or change in part of the project due to lack of access to the required specific materials or technology
- Obligation to establish a knowledge management system, documentation and project events by the power plant project management to use the planning and management of future projects
- Planning the required resources based on the priorities of the project schedule for the optimal use of existing containers
- .Using experienced experts and specialized software for project management and planning

5. Conclusion

Today, the ambiguous and complex atmosphere of large projects has forced project managers to use modern management tools and modern knowledge of the world. The dynamism and complexity of the manufacturing industry is such that uncertainty and risk are their inherent characteristics. Conducting this research in order to achieve sustainable risk management in large power plant projects that can play a significant role in achieving these projects to predetermined goals (time, cost, etc.). One of the features of the present study was to present a hybrid model for identifying and evaluating sustainable risk in a fuzzy environment. Critical risks were first identified using the Fuzzy FMEA method. This technique is a traditional method of risk assessment and evaluates only three parameters of probability of occurrence, severity of effect and the amount of control. In order to investigate the effect of other criteria on the prioritization of critical project risks, the Fuzzy TOPSIS hierarchical analysis method has been used. The results observed in the proposed model for sustainable risk management of construction projects showed the use of verbal and linguistic expressions with the help of fuzzy theory to answer questionnaires and complete the pairwise comparison matrix to collect information from experts and decision makers, better results and It contains more real. Also, the results of the study showed that the impossibility of providing equipment due to political and economic sanctions is recognized as the most important risk of power plant construction according to the four criteria. After that, the risk of low financial capacity of the employer and lack of specialized and skilled human resources were also in the second and third ranks, which indicates the suitability of the proposed model with the conditions of ambiguity and uncertainty of the studied projects.

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Spreadsheet Iteration of Reversionary Leasehold Rental Growth Rate Within The Framework of Explicit DCF Appraisals

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ABSTRACT

Income growth rates are required to justify decisions and strategies for property investments. Although existing studies addressed this phenomenon in freehold investments, a relative question regarding the determination of rental growth rates of leasehold investment properties valued part-way through rent review periods has not been addressed before now. This study examined the spreadsheet-assisted scenario analysis tools and techniques that are required for the determination of rental growth rates of leasehold investment properties valued part-way through rent review periods. A precursor to the scenario analysis was the development of a hybrid leasehold DCF valuation model arising from the equation of the formula for reversionary leasehold equivalent yield valuation to the formula for reversionary leasehold growth explicit DCF valuation model; thereby culminating into the identification of four unknown variables comprising the all risks yield and the implied growth rates of leasehold cash inflows and cash outflows which were subsequently derived using the solver tool of Excel®. From a total of eleven scenarios generated, the 9th successive scenario produced optimal results indicating zero slack between iterated and calculated values for the growth rates of leasehold cash inflows and cash outflows respectively. With recourse to the hybrid leasehold DCF valuation model, the spreadsheet-assisted scenario was found to produce mathematically valid growth rates that justify the valuation of leasehold investment properties part-way through rent review periods. The value of this research is the analytical tools and rigour it avails investors seeking income returns and growth from reversionary leasehold property as an instance of terminable investments.

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1. Introduction

Notwithstanding that the limited time horizon of leasehold investments may not be attractive compared to freeholds, there are investors who still make leasehold investment decisions on the basis of specific factors such as short-term profits, outperformance of a competing investment, asset-liability matching, stability and security of returns, and expectations of future rental growth (Sayce *et al.*, 2006). Furthermore, it is possible that some investors might be attracted to leasehold investments as a result of personal or corporate considerations and macroeconomic factors beyond their control. Notwithstanding that leaseholds are terminable investments and ideally prone to capital value depreciation over time (Fraser, 1993), it is not impossible to rule out the chance of cyclical movements in the economy that might warrant capital value

appreciation in the leasehold market in favour of speculators and arbitrageurs. In most cases however, there might be an appeal for cash flow growth potential of a leasehold investment to warrant "purchase-" or "hold" decision throughout the unexpired term of the grant.

When expected rental growth rate is implied in a transaction, it is appropriately called the implied rental growth rate (Brown & Matysiak, 2000). Geltner and de Neufville (2018) define rental growth as the forecast rate required to project the periodic cash flows of an investment property. Alternatively, it is the constant annual rate of increase in rack rent required to retain the real value of an investmen property and produce an overall rate of return (equated yield) that justifies the exit yield (Baum & Crosby, 2008; Parsons, 2003). Associated with the phenomenon of income growth in property investment is the notion of a standard interval for upward rent review. This rent revision interval is the stipulated period for which rents are expected to be reviewed upward as contained in the lease agreement. According to RICS (1997), rental growth rate may imply an increase or decrease in rent required to forecast rent at a specific date in the future. But in the case of upward rent reviews, it is only rational to have a positive growth rate.

In any typical explicit DCF valuation of leasehold interest or it real value variant, it is rare for the growth rate of cash inflow and cash inflow to be equal otherwise both cash flows would have the same all risks yield which is not possible in practice. Sayce *et al.* (2006) presented a case of complex leasehold interest with non-coinciding reviews for rent received and rent paid. In other words, this phenomenon exerts influence on growth rates of rent received and rent paid respectively. Therefore, if the sales price of a leasehold interest is known, it would be appropriate to use existing scenario analysis techniques to find the optimal growth rates and all risks yield required by the cash flows to produce the market price of a leasehold interest.

Besides the nominal amount quoted as leasehold cash inflow, its associated growth rate relative to that from the cash outflow contributes significantly to leave a surplus of discounted cash flow representing the capital value of the interest. Where the likely purchase price of a leasehold interest has been discerned part-way through rent review epoch, the fundamental questions which this study has put forward to address are:

(a) How can the growth rates of leasehold cash inflow and cash outflow be determined?
(b) what growth rate of leasehold cash inflow relative to cash outflow would be required to achieve this likely purchase price?

Answers to these questions might only be feasible using a blend of leasehold investment valuation models designed to produce identical results. The Implied rental growth rates for cash inflows and cash outflows does not feature at all in the leasehold equivalent yield valuation model so that the only crucial information that can be derived from that model is the price of the leasehold interest. On the other hand, the growth rates being sought after can only be found in the explicit DCF leasehold valuation model. In other words, the equation of the leasehold equivalent yield valuation model (containing the price information) to the explicit DCF leasehold valuation model might likely metamorphose into a hybrid leasehold DCF model from where the all risks yield and growth rates of cash inflows and cash outflows could be iterated and calculated.

Key among the factors driving Investors' sentiments is their rental growth expectation (Clayton *et al.*, 2009), which justifies the need to have a complete hands-on-tools for the assessment of implied rental growth rates for both freehold- and leasehold interests. Previous seminal works by Brown and Matysiak (2000) and Wyatt (2013) specifically used the equivalent yield- and growth explicit DCF valuation models with the aid of the Microsoft® Excel® Solver tool to determine the "single" implied rental growth rate of freehold investment properties valued part-way through a rent review period; but there is a dearth of scholarly efforts addressing the question of how rental growth rates of leasehold investment properties valued part-way through rent review periods could be determined.

This study aims to examine the spreadsheet-assisted scenario analysis tools and techniques that are required for the determination of rental growth rates of leasehold investment properties valued part-way through rent review periods. Objectives put forward to address this aim include setting out an appropriate model for the identification of input parameters for leasehold rental growth determination; setting up a hypothetical case study of reversionary leasehold appraisal; examining the tools and procedure for scenario analysis leading to the determination of appropriate growth rates for leasehold cash inflows and cash outflows; and identifying the required variables to be iterated and calculated within the leasehold DCF valuation scenario.

2. Literature Review And Analytical Framework

The three themes examined in this section comprise leasehold equivalent yield valuation, leasehold growth explicit DCF appraisals, and insights into model-assisted induction of valuation parameters, particularly the iteration of implied rental growth rates of investment properties valued part-way through rent review periods. Shown in Figure 1 is the historical antecedents of models for the valuation of property investments. For the purpose of this study, the review and construction of valuation models were anchored on the assumption that income is received- and payable annually in arrears.

2.1 Equivalent Yield Valuation Technique

Arguably, there are more valuation textbooks and scholarly journals detailing the application of equivalent yield valuation techniques to freehold interests compared to leasehold interests. However, Jones (1983) among other authors at that time availed scholars with the early appearance of an article dealing with equivalent yield valuation technique for leasehold interests using the sinking fund approach which retains a single remunerative rate.

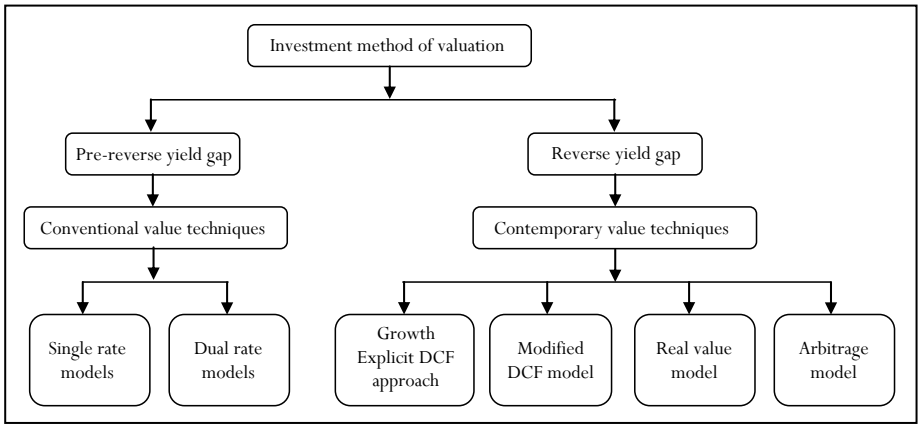


Figure 1 Taxonomy of property investment valuation techniques and associated models

Although Jones (1983) observed nearly four decades ago that the use of equivalent yield in property investment analysis was evolving, the valuation discipline has since evolved academically and professionally by the end of the 20th century and up to the 21st century to warrant awareness of the how this conventional valuation technique can be used to appraise investment properties as noted in seminal works of Brown and Matysiak (2000); Isaac (1998); Sayce *et al.* (2006); Udo (1989), just to mention a few authors. While, Brown and Matysiak (2000); Isaac (2002) and Sayce *et al.* (2006) among others have sustainted the application of equivalent yield valuation techniques to freeholds, Udo (1989) provided insight into how leasehold equivalent yield can be derived upon the completion of explicit DCF valuation of a leasehold interest.

The equivalent yield valuation model for leasehold investments comprises two parts. The first entails calculating the capital value of the contract profit rent in the period to the next rent review, while the second part deals with the capital value of the reversionary profit rent [See Figure 2, and Equations 1 and 2 respectively]. Parameters for the valuation include the equivalent yield, y, the market profit rent, R_1', the contract profit rent, R_0', the number of years to the next rent review, n, and the the unexpired period of reversion to the head lessor, N.

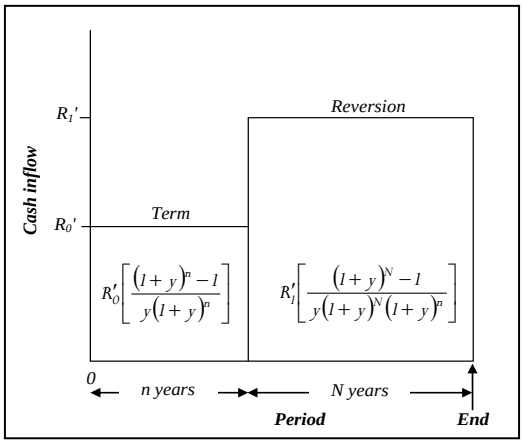


Figure 2: Term and reversion approach to the equivalent yield valuation of leaseholds

Contrary to the layer approach, the term and reversion approach in Figure 2 is deemed logical For leasehold equivalent yield valuation given its terminable characteristic. In other words, leasehold income cannot continue to be earned in perpetuity as construed by the layer approach.

The equation detailing the equivalent yield model of leasehold investment property valuation can be written as:

$$PV = \frac{1}{y(1+y)^n}\left[\left(R_0'\left((1+y)^n-1\right)\right)+\left(\frac{R_1'\left((1+y)^N-1\right)}{(1+y)^N}\right)\right] \quad \ldots\ldots\ldots\ldots (1)$$

Equation 1 can be expressed in the format understood by valuers:

$$PV = \left[\left(\frac{R_0'\left((1+y)^n-1\right)}{y(1+y)^n}\right)+\left(\frac{R_1'\left((1+y)^N-1\right)}{y(1+y)^N(1+y)^n}\right)\right] \quad \ldots\ldots\ldots\ldots\ldots (2)$$

Among the advantages of the equivalent yield valuation technique is that it avails valuers with objective analysis of transactions (Baum & Crosby, 2008; Sayce *et al.*, 2006) thereby making it the only conventional technique that can bridge the gap between growth implicit- and growth explicit DCF valuation of reversionary property investments (Brown & Matysiak, 2000). Although there is a dearth of existing literature pertaining to the application of equivalent yield valuation techniques to reversionary leaseholds, surrogates can be found in capital budgeting exercises for terminable investments; see Ajayi (1998); Brown and Matysiak (2000); Dayananda *et al.* (2002); and Luenberger (1998).

2.2 Growth Explicit Investment Valuation Models

With reference to Figure 1, the first of the contemporary value models is the growth explicit DCF approach, which has been demonstrated as the tabulation and discounting of the future values of cash inflows and cash outflows using the Years' Purchase [YP] and Present value [PV] formula at the appropriate nominal rate of interest (equated yield) to arrive at the present values of the cash inflows and cash outflows respectively (Ajayi, 1998; Baum & Crosby, 2008; Baum *et al.*, 2011; Blackledge,

2009; Brown & Matysiak, 2000; Isaac, 2002; Marshall, 1976; Mba, 2020; Sayce *et al.*, 2006; Wyatt, 2013). With respect to this technique, the capital value of the leasehold interest represents the difference between the discounted cash inflow (capital value of rent received) and the discounted cash outflow (capital value of rent paid) (Baum & Crosby, 2008; Butler & Richmond, 1990). The future value of each tranche of cash inflow or cash outflow is determined with recourse to the implied growth rates for rents received and rents paid respectively.

The second category of the contemporary value model is the rational model otherwise called the modified DCF model. When applied strictly to freehold investments, it can be termed the short-cut DCF. In their seminal work, McIntosh and Sykes (1983), Sykes (1984) and McIntosh and Sykes (1985) demonstrated the application of this model to leasehold valuations without recourse to dual rate years purchase. Subsequently, Baum and Yu (1985) provided an improved alternative to the originally developed rational model credited to McIntosh and Sykes (1983) with the intent of handling the valuation of leaseholds with gearing potentials.

For the valuation of rent received (cash inflow), the nominal term rent is discounted at the equated yield over the period to the next rent review and the amount is added to the present value of the growth-adjusted leasehold market rent. In a similar vein, the capital value of rent paid equals the sum of the present value of the nominal head rent passing discounted at the equated yield and the present value of the growth-adjusted market rent payable to the headlessor, so that the capital value of leasehold interest equals the difference between capital value of rent received and the capital value of rent paid.

Equations 3 - 8 in this article provide insights into the structure of the mathematical relationship among the parameters in the rational model that could be used to value a leasehold interest. Although, the rational model was criticised as a re-invented DCF approach (Baum & Crosby, 2008; Crosby, 1986b), it has been demonstrated as an equated yield model, which could be utilized in deriving implied rental growth rates of properties valued part-way through rent review periods (Brown & Matysiak, 2000; Wyatt, 2013).

The third category of the contemporary model is generally called the real value model. Laying the foundation for the evolution of this contemporary value model include Marshall (1976) who developed the "Equated yield model"; Wood (1986a) who developed the "real value model"; and the seminal works of Baum and Crosby (2008), Crosby (1983), Crosby (1984), Crosby (1986c), and Crosby (1986a) which synthesized the equated yield model of Marshall (1976) with the real value model by Wood (1986a) in what was tagged - "the real value/equated yield hybrid model". For the valuation of term income, this technique entails capitalizing the term rent at the equated yield and then adding it to the capital value of the reversion, which is a product of the market rent, a unique variant of income multiplier, and present value of the reversion at the real return (inflation risk free yield) over the period to the next rent review. This unique variant of net income multiplier otherwise called the 3-in-1 Years' Purchase (YP) formula is an incorporation of the nominal rate of interest (equated yield), real return (inflation risk free yield), period to the next rent review, and unexpired term of the investment. Irrespective of the variant of real value model deployed, the capital value of leasehold investment properties remains the difference between the capital value of rent received and that of rent paid.

On the condition that the equated yield, e is greater than the implied rental growth rate, g, the real rate of return (inflation risk free yield), *IRFY* was found to be mathematical related to the equated yield and implied rental growth rate via the formula:

$$IRFY = \{(1+e)/(1+g)-1\} \quad \text{.....(3)}$$

It can be infered from Equation 3 that real value models are basically equated yield models characterized by analytical footprints of alternative data inputs that are implicit about rental growth rates and rent review periods of an investment property.

The fourth contemporary model in Figure 2 is the arbitrage model, which still adopts the convention of term and reversion. The variants of the arbitrage technique include the implicit growth arbitrage technique and the explicit growth arbitrage technique (Crosby, 1996; French & Ward, 1995; French & Ward, 1996). Just as in the equated yield models, the arbitrage growth rate is a function of the low risk yield, R_f; all risk yield, k_0; the full rent review period, t; and the deferred capital yield, *DCY* becomes:

$$g_{arb} = \frac{1+R_f}{1+\left(\left(\sqrt[t]{\frac{1}{1-\left(k_0 \times Y.P \ for\ t\ years@R_f\right)}}\right)-1\right)} - 1 \quad \text{.....(4)}$$

$$g_{arb} = \{(1+R_f)/(1+DCY)-1\} \quad \text{.....(5)}$$

With respect to the explicit arbitrage model, the term rent is valued using the low risk yield, and added to the valuation of the market rent at reversion. The reversionary rent is projected using a different growth rate derived from the low risk yield and deferred capital yield [equation 4] after which it is valued in perpetuity at the all risks yield deferred over the period to the next rent review at the low risk yield (Crosby *et al.*, 1997; French & Ward, 1995; French & Ward, 1996). The explicit arbitrage model could serve as an alternative to the rational model in the iteration and determination of implied rental growth rates of leasehold investment properties valued part-way through rent reviews except that there is dearth of studies regarding an appropriate arbitrage model for reversionary leasehold valuations.

2.3 Techniques of Rental Growth Iteration

The incorporation of rental growth in explicit DCF valuations is informed by the legacy of income growth rate which accrues to

recipients of cash inflow and cash outflows respectively. Drawing insights from the seminal works of Adams *et al.* (1999), Doppeigieter and Rode (2002), Fraser (1988), and McGough and Tsolacos (2001), the expression of an asset pricing model is in the form:

$$p_o = \sum_{m=1}^{t} \frac{r_o}{(1+e)^m} + \sum_{m=1}^{t} \frac{r_o(1+g)^t}{(1+e)^{t+m}} + \sum_{m=1}^{t} \frac{r_o(1+g)^{2t}}{(1+e)^{2t+m}} + ... \quad .....(6)$$

where g is the constant rental growth rate per annum; e is the discount rate (equated yield), and t is the period between each rent review, and $e > g$, would imply that the asset price equals the sum of the discounted growth incomes, r_0 over the life of the asset. The simplification of equation 6 becomes:

$$p_o = \frac{r_o}{e - e\left(\frac{(1+g)^t - 1}{(1+e)^t - 1}\right)} \quad ..... (7)$$

If all risks yield (capitalization rate), k_0 equals the ratio of cash inflow to the price of an asset then a model of all risks yield similar to that deployed by Fraser (1993) for the pricing of property investments can be expressed as:

$$k_o = e - e\left(\frac{(1+g)^t - 1}{(1+e)^t - 1}\right) ..... (8)$$

So that the implied rental growth rate is derived from Equation 8 as:

$$g = \left(\frac{(e-k)(1+e)^t + k}{e}\right)^{1/t} - 1 ..... (9)$$

It can be further expressed in the format understood by valuers:

$$(1+g)^t = \frac{YP\ in\ Perp.@\ k - YP\ \ for\ t\ years@\ e}{YP\ in\ Perp.@\ k \times PV\ in\ t\ years@\ e} \quad ..... (10)$$

With recourse to Equation 3, the implied rental growth rate, g, could be made the subject of the formula as:

$$g = \{(1+e)/(1+IRFY) - 1\} ..... (11)$$

While the theory examined above appears simplistic, the determination of the same rental growth rates for property investments valued part-way through rent review may not really be straightforward.

2.4 Underlying Theory Of "What-If" Scenario Analysis In The Spreadsheet Environment

A spreadsheet software is an application software organized in the form of ledger sheets comprising rows and columns which can be used to perform calculations and alphanumeric operations (Morley & Parker, 2011). Within the context of this article, Microsoft® Excel® 2007 was deployed. Facilitating the deployment of this spreadsheet is the "What-If Analysis" function. Within the context of investment appraisals, "What-if" or scenario analysis has been defined as an experiment designed to unravel the effect of a change in the deterministic value of more than one variable on a single or multiple output variables (Ajayi, 1998; Dayananda *et al.*, 2002). It is an advancement over sensitivity analysis which addresses the impact of a change in one input variable on a single output variable while holding all the other input variables constant. While the outcomes of scenario analysis are commonly expressed in three-folds of base case-, worst case-, and best case scenarios, a different approach involving the concept of slack in linear programming was adopted.

Scenario analysis problems involving constraints are likened to linear programming problems with likely solutions indicating binding or non binding solutions. Cornell (2006) defines slack as a figure representing the difference in the value between the left side (iterated input) constraint and the right side (output) constraint. So that a zero slack implies that the iterated input and the calculated output variables are binding and optimal. In other words, non-binding solutions have values above zero.

The two prominent methods of deploying What-if or scenario analysis in spreadsheets include Goal Seeking and the Solver functions. Cornell (2006) defines goal seeking as the process of finding a single value for a variable in a given cell within the worksheet by changing the value of another associated variable within the worksheet. In other words, goal seeking can only be possible when the existing and unknown variable are related through a system of equations or formula. In MS Excel®, Goal Seek can be instantiated using the command: Data Toolbar > Data tools > What-If Analysis > Goal seek.

An advanced alternative to Goal Seek is the Solver tool. Within the context of Excel®, Cornell (2006) defines the Solver tool as a command that obtains either an exact-, a maximum-, or a minimum value of a worksheet cell by changing other related cells in the same worksheet. Just as in Goal Seeking, the Solver tool can only be instantiated for one or more unknown variables that are related through a system of equations or formula. The Excel® Solver Add-in can be instantiated using the commands: Data Toolbar > Analysis > Solver. Whether the Solver tool or Goal Seek was deployed, the target cell for capital value in the short-cut DCF valuation should be equated with the capital value derived from the "conventional" equivalent yield valuation technique by altering the input cell expected to contain the implied rental growth rate.

Solver- and Goal Seek tools are subsets of What-if analysis in Excel®. Although Goal Seek tool can reference a changing cell and a cell containing a formula across distinct worksheets contrary to the Solver tool, the advantages of the Solver tool over Goal Seek include ability to handle multiple inputs and outputs; ability to determine the minimum, maximum, and exact values of target cell(s); affording user liberty in the specification of constraints and restrictions in cell values; retention of last user settings (Cornell, 2006). The next section examines the previous studies where What-if scenario analysis tool in Excel® among other iteration techniques were deployed

in property investment appraisals to determine implied rental growth rates.

2.5 Previous Studies On Complex Rental Growth Iteration

It is recalled from the preceding section that the incorporation of rental growth in explicit DCF valuations was informed by the notion that income growth rate which accrues to recipients of cash inflow and cash outflows respectively. These logical notion appeared in the seminal works of McIntosh and Sykes (1983), McIntosh and Sykes (1985), and Sykes (1984) pertaining the explicit treatment of income growth in both freehold and leasehold appraisals. Besides, other scholarly works featured the simple and complex treatment of rental growth calculation pertaining to investment properties valued part-way through a lease.

In the simplified approach, Fraser (1993) applied equation 8 above to calculate rental growth rate. Similarly, Isaac (2002) applied equation 8 and further suggested equation 10 as surrogate. A variant of equation 9 was deployed by Baum *et al.* (2011) and French (2006) to calculate implied rental growth rate. The undelying gap in the studies of rental growth calculations was the illustrative application to freehold investment property while ignoring the treatment of leasehold investment properties.

Since implied rental growth rate is primarly featured in explicit DCF appraisal models, it may be recalled from Sayce *et al.* (2006) that the investment value of leaseholds equals the difference between discounted cash inflow (rent received) and discounted cash outflow (rent paid) so that a complicated problem of having to iterate and determine growth rates for both cash flows is created. Hence, the simple deterministic models in equations 9 - 11 is deemed inappropriate to handle such complex situations.

Although Wyatt (2013) acknowledged the existence of the problem of determining rental growth rate across rent review period, he only provided brief notes on the solution to such a challenge without specifically mentioning spreadsheet or iteration tool that can be used to address the problem.

Within the context of freehold investment property, Brown and Matysiak (2000) demonstrated three techniques for the calculation of implied rental growth rate part-way through rent review epochs using available data comprising price, rent passing, market rent, number of years to the next rent review, equivalent yield, and the nominal yield. These techniques include graphical solutions, What-if scenario analysis tool - Excel® Solver, and the development and use of an Excel® Add-in called "RVGrowth" using Visual BASIC Programming.

According to Brown and Matysiak (2000), the graphical solution to implied rental growth rate calculation entails finding the point of intersection at the abscissa where the simultaneous algebraic equations relating to the equivalent yield and periodic growth intersects.

The second is a software iteration technique involving the What-if scenario analysis tool comprising Excel® Solver Add-in and the Excel® Goal Seek commands. Although the Excel® Goal Seek approach appears to be simpler than the Excel® Solver and Graphical solutions, Brown and Matysiak (2000) did not demonstrate its use at that time. Nevertheless, a limitation of the Goal Seek to the appraisal of income growth rates in leasehold investments is that it can only address growth rate of cash inflow or cash outflow at a time whereas, Excel® Solver can address iteration of multiple variables (Cornell, 2006); hence its adaptability to simultaenous rental growth rate iterations for cash inflow and cash outflows respectively.

The third technique demonstrated by Brown and Matysiak (2000) to calculate freehold rental growth rate was the deployment of Visual BASIC Programming to write and compile a program that computes rental value growth across rent review epochs and then deploy same program as Excel® Add-in. While applauding this approach as an unprecedented feet in the interface between spreadsheet iteration and property appraisal, its application to leasehold investment property is beyond the scope of this study and has been reserved for further studies. This is because the use of this technique to determine optimal growth rate of leasehold cash flows is not really straightforward since input parameters in leasehold equivalent yield valuation- and the growth explicit leasehold DCF valuation models would have to be iterated to determine two growth rates namely - the growth rate for rent received and the growth rate for rent payable. In this view, it is important to point out that this study should not be construed to be synonymous to the seminal work of Nanthakumaran (1988) who examined the application of the two growth rate model to the appraisal of leaseholds. The focus is on determining the simultaneous values of rental growth rates for cash inflows and cash outflows required to produce an indicated price of an interest in leasehold investment property.

2.6 Impact Of Embedded Options In Leases

In financial parlance, an option is defined as "*the right without obligation to obtain something of value upon the payment or giving up of something else of value*" (Geltner *et al.*, 2010). There are real options that coul be associated with real estate investing. Pezeshkian *et al.* (2014) outlined some of them to include option to purchase land for development, option to renew a lease and the option to terminate a lease. Others include option to invest (Lucius, 2001); option to sescure debt or equity finance (Shen & Pretorius, 2013); option of upward-only rent reviews and option of upward- and downward rent reviews (Ward & French, 1997); option to purchase or lease (Hargitay & Yu, 1993); break clauses, option for change of use (Booth *et al.*, 2001); and option of pre-emption rights (Buetow & Albert, 1998). An investor instantiates an option when (s)he exercises a right to invest in landed property at a future date of his or her choice. An option is a right and not an obligation to invest (Lucius, 2001). The determination of capital value of an interest in real property in anchored on the process of ascertaining the present value of the right to receive a stream of annuity subject at a discount rate over a definite or indeterminate period of time; so that in the investment valuation context, an option is

exercised by an investor who is entitled to a right to receive the sum of discounted income streams over a given period of time.
Among the array of seminal works on option pricing of real estate decisions, an attempt shall be made to examine five related studies. First, Ward and French (1997) deployed a combination of arbitrage valuation and the Black and Scholes model and concluded that the loss of option to restrain upward-only rent reviews can significantly improve the attractiveness of property investment.

With respect the pricing of embedded options in a lease, Buetow and Albert (1998) developed a partial differential equation that describes option granted to a lessee to either purchase a leased property or to renew the lease at a price at par with the consumer price index (CPI). By implication, it is possible for a lease contract to avail a lessee the alternatives of either exercising pre-emption right of purchasing her landlord's property or lease renewal upon the payment of an upward-reviewed rent if the termination of the contractual agreement may not be favourable to both parties.

Lucius (2001) provided a critique of the application of option pricing theory to investment valuation and concluded that the pricing of options in real estate decision-making is characterized by academically abstract results which have limited practical applications to real estate projects. Lucius (2001) at that time however suggested the conduct of further research aimed at fostering a transition of that body of knowledge into the practice of property investment valuation.

With respect to property development, Booth *et al.* (2001) underscored the possibility of risk arising from changes in occupier market condition, delays in project completion and cost overruns which are injurious to project viability. In the first instance, adverse changes in occupier market condition and delayed completion might exercebate rental loss. Secondly, whether or not there is rental loss, these risks are embedded in the rents payable by the leasehold investor and the sub-lessee in occupation of a leasehold property so that adequate measures for maintenance of optimal profit rent margin may arise.

Adams *et al.* (2003) acknowledged the deficiency of DCF valuation techniques to handle array of options contained in lease contracts and made a compelling case for the development of techniques from the field of finance to handle complex lease contracts and options. While applauding the strength of the option pricing technique over DCF valuation technique, Adams *et al.* (2003) observed that the valuation of lease options was yet to be accorded any significant attention in practice, which aligns with a similar observation by Lucius (2001).

With respect to the use of binomial option pricing technique to assess the portfolio value of real estate developments, Shen and Pretorius (2013) found that timely completion of projects would curtail cost overrun and avail the developer with excess capital for further projects. According to Shen and Pretorius (2013), the application of real option valuation in property development practice is determined by the structure and available resources of the developer.

Pezeshkian *et al.* (2014) demonstrated the deployment of tools from the field of finance and decision trees to address the pricing of real estate options comprising land purchase option, lease renewal option, and lease termination option using industry-related case studies. They however did not mention the extent to which the option pricing technique is applicable to real estate market particularly in Florida and the United States in general.

Turning attention to the synergy between rental growth analysis and option pricing associated with loss of rent, it could be recalled that the valuation of reversionary leasehold interest is made up of the valuation of term and reversionary cash inflows and cash outflows respectively. The actual rents received and payable are laid out in the term, while the anticipated or market rents receivable and payable are laid out in the reversion.

First, actual rental loss in property development could arise from period of voids that precedes letting. So that a longer period of void will exercebate a higher risk of loss in the actual rent. Secondly, the risk of tenant or sub-tenant default also contributes to the phenomenon of actual rental loss in the sense that the present value of a rent payable after some periods of default is diminshed unless specific clauses have been introduced in the tenancy agreement to demand a percentage of the owed rent as penalty to shield the rent payable against inflation and real value dimunition.

On the other hand, the loss of market rent might arise from two phenomena. The first is a situation where an income producing property is let at a rent below the market rental value. The second is attributed to abnormal timing of contract rent revision beyond the market rent of comparable properties. The explicit DCF valuation technique has been demonstrated to handle similar situation of rental loss especially in the case of over rented properties where contract rent exceeds the market rent (Adams & Booth, 1996; Crosby, 1996; Crosby & Goodchild, 1993; Crosby & Henneberry, 2016); however Adams and Booth (1996) suggested the deployment of sophisticated appraisal techniques to surmount the existing deficiencies of the existing DCF techniques.

With these practical realities, what should real estate investors or developers generally do when confronted with the problem of rental loss? In consonance with the seminal work of Ward and French (1997), it is possible to envisage that the attractiveness of property investment is enhanced significantly when investors exercise measures aimed at ameliorating rental loss. For the developer, this may be achieved through income gains associated with timely completion of a project (Shen & Pretorius, 2013). Notwithstanding this measure, the developer is bound to face rental value loss during the construction phase and would have to "wait for more time to compensate for this loss" (Shen & Pretorius, 2013).

It is pertinent at this juncture to mention that the possibility of rental loss in leasehold interest is acknowledged in this study from an option pricing perspective. However, it does not form part of the scope of this research which has the aim of using spreadsheet-embedded scenario analysis tools to determine

growth rates of cash inflows and cash outflows of reversionary leaseholds valued part-way through rent review epochs.

2.7 Analytical Framework For Leasehold Rental Growth Iteration

A typical diagram of stepped leasehold rent in Figure 3 analyzes the treatment of growth-induced cash inflow and outflow arising from upward rent revision at stipulated epochs. At the start of the lease in year 0, the leaseholder earns a contract rent, R_0 from the sublease. The total holding period available to the leaseholder at first grant from the freeholder is "*3t*" years. It is further observed that cash inflow is revised upward on a *t*-yearly basis. On the valuation date, V_d; the number of years to the next revision of rent receivable is (t - V_d) years, which would eventually be used in conjunction with a nominal rate of interest (equated yield) to determine the value of the term. Again at the valuation date, V_d; the leasehold market rent remains static at R_1 until the next upward review. The future value of R_1 at the first revision is $R_1'(1+g)^t$, which is equivalent to $R_1(1+g)^{t-Vd}$. This rent increases to $R_1'(1+g)^{2t}$ and $R_1'(1+g)^{3t}$ during the second and third periods of upward reviews to align with the numerators of each tranche of discounted cash flow in equation 6. The phenomenon in Figure 3 equally applies to the determination of the present value of rent payable.

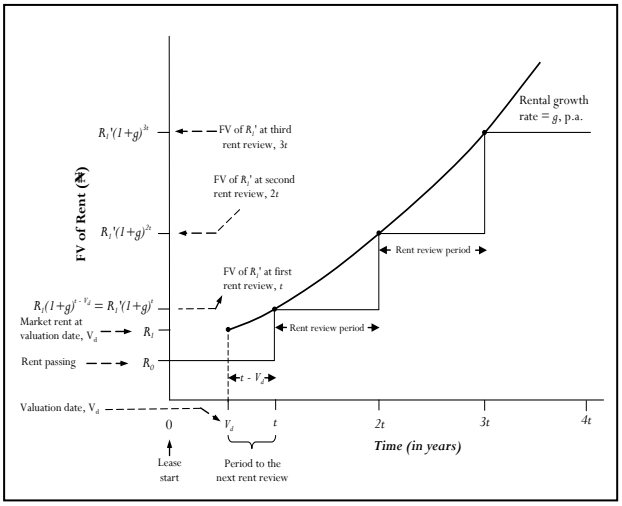


Figure 3 Term- and future rent review profile of leaseholds

The stepped rents in Figure 3 is only a simplification of the reality. Figure 4 depicts the actual nature of the stepped rents at each rent review epoch.

In actual sense, the transition of future rent across each review date is not regular as shown in Figure 4 so that the fitted exponential trend line of the form $FV = ae^{b(time)}$ would help explain the rising profile of rent paid or rent received throughout the life of a leasehold investment. If Figures 3 and 4 would apply to the cases of rent received and rent payable by the leaseholder, then the growth rates of rent received and rent payable can be tagged as g_0 and g_1 respectively.

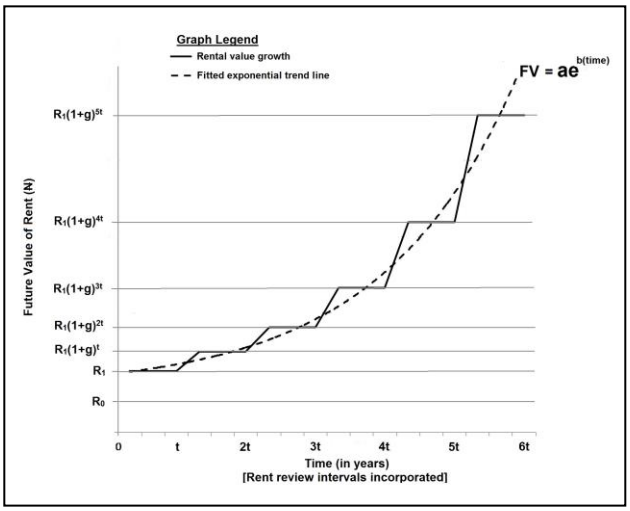


Figure 4 Actual nature of term- and future rent review profile

In order to determine rental growth rate of a freehold, Brown and Matysiak (2000) and Wyatt (2013) set up a system of equation that placed the freehold equivalent yield valuation model on the left hand side, and the freehold DCF valuation model with rent review period and growth on the right hand side as shown in equation 12 without using the Y.P. notation:

$$\left[\frac{R_0}{y_0}+\frac{R_1-R_0}{y_0(1+y_0)^n}\right]=\frac{R_0\{(1+e)^n-1\}}{e(1+e)^n}+\frac{R_1(1+g)^n}{e(1+e)^n}\left[\frac{(1+e)^t-1}{(1+e)^t-(1+g)^t}\right] \quad \ldots\ldots (12)$$

Whether or not the all risks yield of an investment property is known, a surrogate for the Years purchase in Perpetuity is derived from equation 12 as:

$$\frac{1}{k_0}=\left[\frac{(1+e)^t-1}{e\left((1+e)^t-(1+g)^t\right)}\right] \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (13)$$

Therefore, equation 12 can be reduced to the format in equaton 14 as:

$$\left[\frac{R_0}{y_0}+\frac{R_1-R_0}{y_0(1+y_0)^n}\right]=\left[\frac{R_0\{(1+e)^n-1\}}{e(1+e)^n}+\frac{R_1(1+g)^n}{k_0(1+e)^n}\right] \quad \ldots\ldots\ldots\ldots\ldots (14)$$

Equated yield however becomes the capitalization rate for stationary incomes in the valuation of the term cash inflows; that is $k_0 = e$, (Ifediora, 2005).

This study examines a case of Reversionary leasehold where rent paid grows throughout the term coupled with a reversion of rent payable; in which case, two growth rates comprising the growth rate for rent received, g_0 and that for rent payable $g_1$would have to be calculated. The appropriate growth explicit DCF model for the valuation of this instance of leasehold interest is captured in Equation 15 where, e = equated yield, R_0 = rent received by the leaseholder, R_1 = leasehold market rent, g_0 = implied rental growth rate of leasehold income, k_0 = All risks yield of leasehold income, $n = (t - V_d)$ = number of years to the next leasehold rent review, N = unexpired term of leasehold investment, r_0 = rent paid to the freeholder, r_1 = freehold rack (revised) rent g_1 = implied growth rate of rent paid, k_1 = All

risks yield of freehold income, and m = number of years to the next freehold rent review.

In the event where the full reversion of a leasehold interest coincides with a full reversion of rent payable, equations 15 and 16 could be trimmed to equations 17 and 18. Equation 15 was used to perform the spreadsheet iteration, while the presentation of valuation scenarios was carried using equations 15 and 17 where applicable. The spreadsheet iteration was supported by equating the models captured in equations 2 and 15 respectively.

$$\text{PV of interest} = \left[\left(R_0\left(\frac{1-(1+e)^{-n}}{e}\right)\right)+\left(\frac{R_1}{k_0}\left(\left(\frac{(1+g_0)^n}{(1+e)^n}\right)-\left(\frac{(1+g_0)^N}{(1+e)^N}\right)\right)\right)\right]-\left[\left(r_0\left(\frac{1-(1+e)^{-m}}{e}\right)\right)+\left(\frac{r_1}{k_1}\left(\left(\frac{(1+g_1)^m}{(1+e)^m}\right)-\left(\frac{(1+g_1)^N}{(1+e)^N}\right)\right)\right)\right] \quad \ldots\ldots (15)$$

Equation 14 can be written conventionally as:

$$PV = [R_0(\text{Y.P. for } n \text{ years @ } e) + R_1(\text{Y.P. for } N \text{ years @ } k_0 \text{ deferred for } n \text{ years @ } e] - [r_0(\text{Y.P. for } m \text{ years @ } e) + r_1(\text{Y.P. for } N \text{ years @ } k_1 \text{ deferred for } m \text{ years @ } e] \quad \ldots\ldots (16)$$

On the other hand, leasehold valuation model where full reversion of a leasehold interest coincides with a full reversion of rent payable:

$$\text{PV of interest} = \left(\frac{R_1}{k_0}\left(\left(\frac{(1+g_0)^n}{(1+e)^n}\right)-\left(\frac{(1+g_0)^N}{(1+e)^N}\right)\right)\right) - \left(\frac{r_1}{k_1}\left(\left(\frac{(1+g_1)^m}{(1+e)^m}\right)-\left(\frac{(1+g_1)^N}{(1+e)^N}\right)\right)\right) \quad \ldots\ldots .(17)$$

Or conventionally expressed as:

$$PV = [R_1(\text{Y.P. for } N \text{ years @ } k_0 \text{ deferred for } n \text{ years @ } e] - [r_1(\text{Y.P. for } N \text{ years @ } k_1 \text{ deferred for } m \text{ years @ } e] \quad \ldots\ldots (18)$$

where all the parameters in equations 17 and 18 maintain the same meaning as described in equations 15 and 16.

Placing the leasehold growth explicit DCF valuation model [Equation 15] on the left hand side and the leasehold equivalent yield valuation model [Equation 2] on right hand side informed the deployment of an appropriate layout [Figure 6] of the data inputs for the appraisal and rental growth iterations.

$$\left[\left(R_0\left(\frac{(1-(1+e))^{-n}}{e}\right)\right)+\frac{R_1}{k_0}\left(\left(\frac{(1+g_0)^n}{(1+e)^n}\right)-\left(\frac{(1+g_0)^N}{(1+e)^N}\right)\right)\right]-\left[\left(r_0\left(\frac{(1-(1+e))^{-m}}{e}\right)\right)+\frac{r_1}{k_1}\left(\left(\frac{(1+g_1)^m}{(1+e)^m}\right)-\left(\frac{(1+g_1)^N}{(1+e)^N}\right)\right)\right]=\left[\left(R_0'\left(\frac{(1-(1+y))^{-n}}{y}\right)\right)+R_1'\left(\frac{(1-(1+y))^{-N}}{y(1+y)^n}\right)\right] \quad \ldots\ldots\ldots (19)$$

Contrary to the procedure for the determination of a "single" implied rental growth rate for freehold investment, Equation 19 was used to help address the question of what growth rates in cash inflow and cash outflow would be required for a leasehold interest to achieve a desired purchase price.

3. Methodology

3.1 Data Requirements

For the purpose of this experimental research design, data required for the modelling of growth rate of leasehold cash inflow and cash outflow were drawn from the valuation case study involving a reversionary leasehold investment property. Details are shown in Table 1.

3.2 Valuation Case Study

The contemporary valuation problem used to illustrate Spreadsheet iteration of Leasehold rental growth rate is a case where the holder of the leasehold interest obtained consent from the freeholder 2 years ago to sublet a commercial property for a term of 20 years at a contract rent of ₦1,200,000 per annum subject to 5-yearly upward review. The market rent accruing to the leaseholder was determined to be ₦1,500,000 per annum and subject to 5-yearly upward review. The leasehold interest in question was secured from the freeholder at a head rent of ₦180,000 per annum reviewed at 3-yearly interval. While this head rent paid shall be revised upward in 2 years' time, the market head rent payable is put at ₦250,0000 per annum reviewable at 3-yearly interval. Given an equated yield of 25%, the leasehold interest may likely be purchased today at a price of ₦8,704,728.55. The valuation layout leading to the determination of the leasehold and freehold rental growth rates necessary to achieve the purchase price of ₦8,704,728.55 was prepared in Excel® as indicated in Figure 5.

3.3 Software Specification And Application Tools

While any reasonable computer hardware (desktop or notebook) could be used to perform the operations leading to valuation scenario analysis, this section emphasizes on the preparation and use of MS Excel in the performance of spreadsheet iterations required to address the research problem.

A1 fx Valuation data

	A	B	C	D	E	F	G	H	I	J
1	**Valuation data**									
2	Equated yield	25%								
3	Leasehold Equivalent yield, ke	11.63717960%								
4	Leasehold rent received	1,200,000								
5	Leasehold market rent	1,500,000								
6	Leasehold rent review	5	yearly							
7	Leasehold rental growth, g0	0.00000000%								
8	All risks yield of leasehold income, k0	25.00000000%								
9	Rent paid to the freeholder	180,000								
10	Revised head rent	250,000								
11	Freehold rent review	3	yearly							
12	freehold rental growth, g1	0.00000000%								
13	All risks yield of freehold income, k1	25.00000%								
14	Number of years to the next leasehold rent review	3	years							
15	Number of years to the next freehold rent review	2	years							
16	Unexpired term of leasehold interest	18	years							
17										
18										
19	**Equivalent yield Valuation**									
20	Term									
21	Rent received						1,200,000			
22	Rent paid						180,000			
23	Profit rent						1,020,000			
24	Y.P. for 3 years @ ke						2.416885653		2,465,223.37	
25										
26	Reversion									
27	Leasehold market rent						1,500,000			
28	Revised rent payable						250,000			
29	Revised profit rent						1,250,000			
30	Y.P. for 15 years @ ke				6.9449					
31	Less P.V. of ₦1 in 3 years @ ke				0.7187		4.991604147		6,239,505.18	
32	**Valuation**								8,704,728.55	
33										
34										
35										
36	**Growth Explicit DCF Valuation**									
37	Term									
38	Rent received				1,200,000					
39	Y.P. for 3 years @ 25%				1.9520		2,342,400.00			
40										
41	Reversion									
42	Leasehold market rent				1,500,000					
43	Amount of ₦1 in 3 years @ g0	1.0000								
44	Y.P. in Perp @ k0	4.0000								
45	P.V of ₦1 in 3 years @ 25%	0.5120	2.0480							
46										
47	Less Amount of ₦1 in 18 years @ g0	1.0000								
48	Y.P. in Perp @ k0	4.0000								
49	P.V of ₦1 in 18 years @ 25%	0.0180	0.0721		1.9759		2,963,913.61		5,306,313.61	
50										
51	Rent paid				180,000					
52	Y.P. for 2 years @ 25%				1.4400		259,200.00			
53										
54	Reversion									
55	Leasehold market rent				250,000					
56	Amount of ₦1 in 2 years @ g1	1.0000								
57	Y.P. in Perp @ k1	4.0000								
58	P.V of ₦1 in 2 years @ 25%	0.6400	2.5600							
59										
60	Less Amount of ₦1 in 18 years @ g1	1.0000								
61	Y.P. in Perp @ k1	4.0000								
62	P.V of ₦1 in 18 years @ 25%	0.0180	0.0721		2.4879		621,985.60		881,185.60	
63	**Present Value of Leasehold interest**								4,425,128.01	
64										

Figure 5 Valuation framework for the iteration of all risks yield and implied rental growth rates

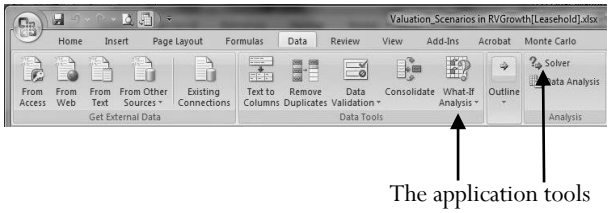


Figure 6 Tools deployed for the scenario analysis

From the Menu Bar tagged "Data", the two tool bars specified for this study are the What-If Analysis data tool and the analysis tool tagged "Solver" (See Figure 6).

Cells "B8" and "B13" in Figure 5 where initially edited with equation 20 for the purpose of computing all risks yield of cash inflow and cash outflow respectively. These yields represent the implicit return on capital value of cash inflow and cash outflow respectively. By virtue of the spreadsheet design in Figure 6, the optimal all risks yield for cash inflow and cash outflow were automatically calculated when the optimal implied rental growth rates for cash inflow and cash outflow were returned in cells "B7" and "B12" following the conclusion of the iteration process using Excel Solver tool.

With recourse to Figure 1 above, the What-If tool was deployed to run the Goal Seek function for the determination of equivalent yield (See Table 2), while the Solver tool under the Analysis tool bar was used to perform the iteration and determination of rental growth rates of the leasehold investment property featured in the case study (See Figure 7).

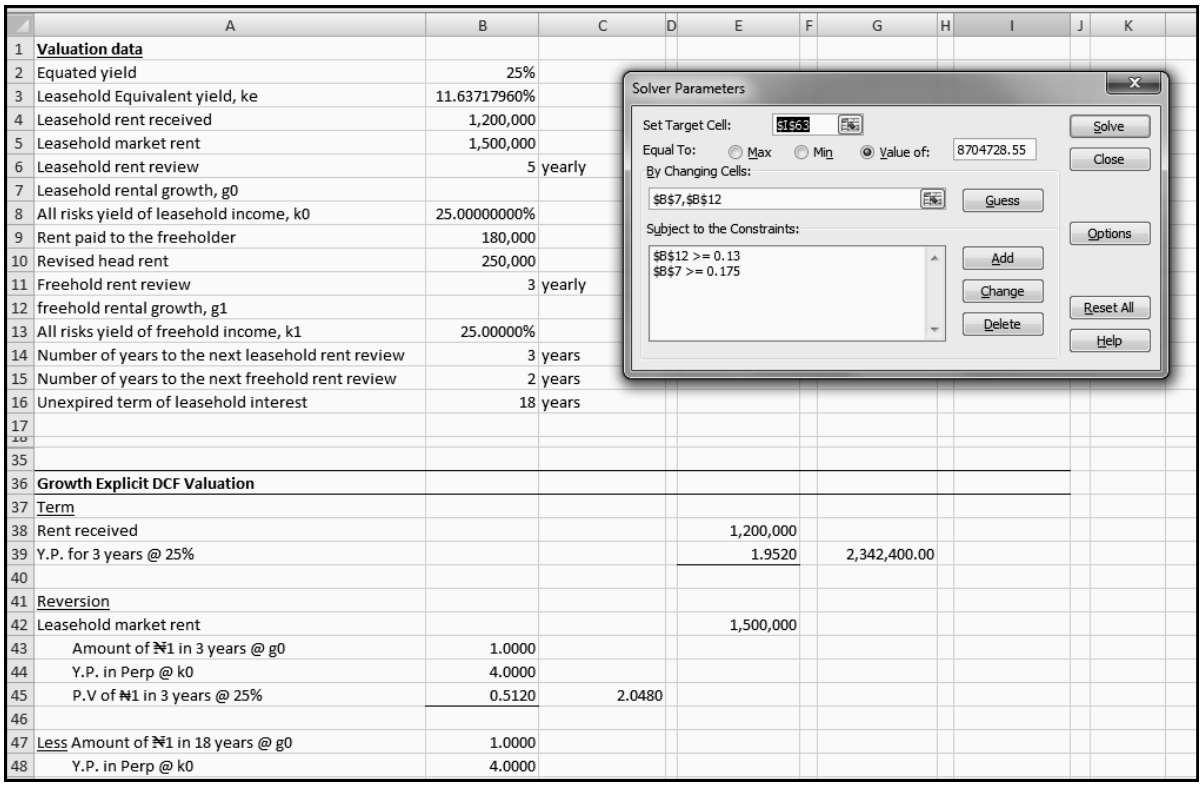
The abridged format of the DCF table used to determine the leasehold equivalent yield was presented in Table 2. Equation 9 was used to calculate the implied rental growth rate. Furthermore, on the condition that g < e, the formula deployed in MS Excel® to calculate the all risks yield of leasehold and freehold incomes is generally expressed as the reciprocal of Equation 13:

$$k_0 = \frac{e\left((1+e)^t - (1+g)^t\right)}{(1+e)^t - 1} \quad \text{..... (20)}$$

Both parameters of g and k were computed simultaneously using the Solver function. The contents of the Equivalent yield valuation and the growth explicit DCF valuation were numerically linked to the valuation data in Cells "B1" to "B16".

Prior to the commencement of the scenario analysis, the iterated values for the leasehold rental growth rate were accorded a range of 14.0% to 19.0% and at an interval of 0.5%; while the iterated growth rates of rent payable were accorded a range of 9.5% to 14.0% and at the same interval of 0.5%. This proposition was anchored on the possibility that the true growth rates would fall within these range of values.

As mentioned in section 2.4, the appropriate scenario analysis tool was instantiated with the operation of Data menu button as follows: Data > Analysis > Solver.



	A	B	C	D	E	F	G	H	I	J	K
1	**Valuation data**										
2	Equated yield	25%									
3	Leasehold Equivalent yield, ke	11.63717960%									
4	Leasehold rent received	1,200,000									
5	Leasehold market rent	1,500,000									
6	Leasehold rent review	5	yearly								
7	Leasehold rental growth, g0										
8	All risks yield of leasehold income, k0	25.00000000%									
9	Rent paid to the freeholder	180,000									
10	Revised head rent	250,000									
11	Freehold rent review	3	yearly								
12	freehold rental growth, g1										
13	All risks yield of freehold income, k1	25.00000%									
14	Number of years to the next leasehold rent review	3	years								
15	Number of years to the next freehold rent review	2	years								
16	Unexpired term of leasehold interest	18	years								
17											
35											
36	**Growth Explicit DCF Valuation**										
37	Term										
38	Rent received				1,200,000						
39	Y.P. for 3 years @ 25%				1.9520		2,342,400.00				
40											
41	Reversion										
42	Leasehold market rent				1,500,000						
43	Amount of ₦1 in 3 years @ g0	1.0000									
44	Y.P. in Perp @ k0	4.0000									
45	P.V of ₦1 in 3 years @ 25%	0.5120	2.0480								
46											
47	Less Amount of ₦1 in 18 years @ g0	1.0000									
48	Y.P. in Perp @ k0	4.0000									

Figure 7 Scenario Analysis of leasehold and freehold rental growth rates using What-If Solver function in MS Excel

A dialogue box appeared as shown in Figure 7. The Solver tool was instantiated to carryout scenario analysis of leasehold capital values vis-á-vis the implied growth rates for rent received and rent payable. Cell "I63" is the target cell for the calculation of the leasehold capital value in the growth explicit model. Within the solver dialogue box, the cell "I63" was set to an instant value of 8704728.55 by changing the cells B7 and B12 representing the leasehold and freehold rental growth rates respectively. The best approach was to set these iterations as constraints using the "greater than or equal to" sign. The solver engine was prompted through the dialogue box in Figure 7 to conduct 100 iterations by default and return results with 0.000001 precision in a maximum of 100 seconds. Other selected meta analysis for the scenario analysis include Quadratic estimates, Central Derivatives, and the embedded use of Newton's method for solving numerical equations derived from the explicit discounted cash flow technique. The central derivative box was selected to help control rapid divergence between iterated and calculated growth rates.

3.4 Decision Rule For The Scenario Analyses

Associated with each scenario of cash inflow and cash outflow is the **tabulation** of growth rate constraint, calculated growth rates, slack in the calculated growth rates, and present values leading to the capital value of the leasehold interest (See Figure 8). Within this context, a slack is defined as the numerical difference between iterated and calculated values of a given parameter; so that the **decision rule** for the scenario analysis is to accept the iterated and calculated growth rates of cash inflows and cash outflows that simultaneously exhibit zero slacks.

Therefore, **inference** could be drawn regarding the true growth rates as those that simultaneously return zero slacks for iterated and calculated growth rates of leasehold discounted cash inflows and cash outflows respectively.

4. Scenario Analysis And Data Presentation

4.1 Preliminary Data

Table 1 indicates the preliminary valuation data associated with the valuation case study in section 3.2. It is observed from Table 1 that the valuation problem is silent on the growth rates of rent received and rent paid respectively. In order to deploy these data for the spreadsheet iteration and determine these growth rates, the all risks yields of leasehold and freehold incomes, and the leasehold equivalent yield shall be computed. Computation of these parameters is anchored on the fact that they are embedded in the valuation problem and could be extracted using the techniques described in the preceding section.

4.2 Goal Seek Calculation Of Equivalent Yield

With recourse to the equivalent yield valuation model, the profit rents for the leasehold interest under consideration are put at ₦1,020,000 for the term and ₦1,250,000 at reversion. With the likely leasehold purchase price of ₦8,704,728.55, the Goal seek function of MS Excel's What-If Analysis tool was deployed to determine the leasehold equivalent yield as 11.63717960%. The abridged DCF for the determination of this equivalent yield is indicated in Table 2.The result of the What-If Analysis indicates that it would take a leasehold equivalent yield of 11.63717960% to achieve a likely purchase price of ₦8,704,728.55 in the market.

The question now would be - At what rental growth rates would the leaseholder realize a capital value of ₦8,704,728.55 for the commercial property in question? Full data specification and base case valuation shown in Figure 5 was set up to help provide a feasible answer.

Table 1 Valuation data for rental growth determination

Equated yield, e	25%
Leasehold Equivalent yield, k_e	?
Leasehold rent received	₦1,200,000
Leasehold market rent	₦1,500,000
Leasehold rent review	5 yearly
Leasehold rental growth, g_0	?
All risks yield of leasehold income, k_0	?
Rent paid to the freeholder	₦180,000
Revised head rent	₦250,000
Freehold rent review	3 yearly
freehold rental growth, g_1	?
All risks yield of freehold income, k_1	?
Number of years to the next leasehold rent review	3 years
Number of years to the next freehold rent review	2 years
Unexpired term of leasehold interest	18 years
Likely purchase price of Leasehold interest (today)	₦8,704,728.55

Table 2 Abridged Discounted Cash Flow technique of equivalent yield determination

Purchase price of property:		₦8,704,728.55		
Target rate of return, R_x:		11.63717960%		
Term:		3 years		
Reversion:		15 years		
Year	**Cash inflow**	**Y.P for 15 years @ R_x%**	**P.V. of ₦1 @ R_x%**	**Present Value**
1	1,020,000		0.895758925	913,674.10
2	1,020,000		0.802384052	818,431.73
3	1,020,000		0.718742676	733,117.53
4 - 18	1,250,000	6.944911323	0.718742676	6,239,505.19
	Present value of cash inflow @ R_x%			8,704,728.55
Less	Purchase price of property			8,704,728.55
	Net Present Value			**0.00**

	A	B	C	D	E	F	G	H	I	J	K	L
1	Parameters	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9	Scenario 10	Scenario 11
2	Leasehold rental growth constraint	≥ 14.0%	≥ 14.5%	≥ 15.0%	≥ 15.5%	≥ 16.0%	≥ 16.5%	≥ 17.0%	≥ 17.5%	≥ 18.0%	≥ 18.5%	≥ 19.0%
3	Freehold rental growth constraint	≥ 9.5%	≥ 10.0%	≥ 10.5%	≥ 11.0%	≥ 11.5%	≥ 12.0%	≥ 12.5%	≥ 13.0%	≥ 13.0%	≥ 13.5%	≥ 14.0%
4	Calculated Leasehold rental growth	17.5277%	17.5890%	17.6522%	17.7175%	17.7849%	17.8543%	17.9260%	18.0000%	18.0000%	18.5000%	19.0000%
5	Calculated Freehold rental growth	9.5000%	10.0000%	10.5000%	11.0000%	11.5000%	12.0000%	12.5000%	13.0000%	13.0000%	16.0218%	18.5630%
6	Slack in calculated Leasehold rental growth	3.5277%	3.0890%	2.6522%	2.2175%	1.7849%	1.3543%	0.9260%	0.5000%	0.0000%	0.0000%	0.0000%
7	Slack in calculated Freehold rental growth	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	2.5218%	4.5630%
8	PV of Leasehold rent received	9,969,028.69	9,996,898.40	10,025,776.26	10,055,704.67	10,086,727.86	10,118,891.99	10,152,245.22	10,186,837.83	10,186,837.83	10,425,444.79	10,672,639.24
9	PV of rent paid	1,264,300.14	1,292,169.85	1,321,047.71	1,350,976.12	1,381,999.31	1,414,163.44	1,447,516.67	1,482,109.28	1,482,109.28	1,720,716.24	1,967,910.69
10	Capital value of Leasehold interest	8,704,728.55	8,704,728.55	8,704,728.55	8,704,728.55	8,704,728.55	8,704,728.55	8,704,728.55	8,704,728.55	8,704,728.55	8,704,728.55	8,704,728.55

Figure 8 Scenarios of leasehold and freehold rental growth rates leading to ₦8,704,728.55 leasehold capital value

4.3 Scenario Analysis Using The Solver Tool

Eleven valuation scenarios were generated [Figure 8]. It can be observed that all the scenarios of varying leasehold and freehold rental growth rates returned leasehold capital value of ₦8,704,728.55 after holding the values of all other input parameters in Table 1 constant. This capital value represents the difference between the present value of leasehold rent received and the present value of rent paid.

For scenarios 1 to 7, slacks in the neighbourhood of 3.5277% and 0.9260% were returned for calculated leasehold rental growth rates following the deployment of iterated growth rates in the range of 14.0% to 17.0%. There was no corresponding slack in the calculated freehold rental growth rates for each scenario of iterated growth rates in the range of 9.5% to 12.5%. The implication of these simultaneous results of slack in leasehold rental growth rate and zero slack in freehold rental growth rates is that the results violated the decision rule for the appropriate income growth rates for leasehold investment properties valued part-way through a rent review period.

Drawing attention to the eighth scenario, the iterated leasehold rental growth rate of 17.5% returned a calculated growth rate of 18.0%, representing 0.5% slack. On the other hand, the iterated freehold rental growth rate of 13.0% returned a calculated growth rate of 13.0%, representing zero slack. Consequently, the real-time DCF valuation of the leasehold interest deployed the calculated leasehold income growth rate of 18.0% to return ₦10,186,837.83 as present value of cash inflow, while the freehold income growth rate of 13.0% returned ₦1,482,109.28 as the present value of cash outflow. In other words, the eighth scenario analysis provided insight into the true growth rates for cash inflow and cash outflow as 18% and 13% respectively.

Consequently, the ninth scenario which is a deviation from the 0.5% interval earlier specified returned calculated growth rates of 18.0% and 13.0% for leasehold cash inflow and cash outflow for the 18.0% and 13.0% iterated growth rates; implying a zero slack and a validation of the decision rule for the appropriate income growth rates for leasehold investment properties valued part-way through a rent review period.

Scenario results from the tenth and eleventh iteration indicated slacks which diminished the reliability of the calculated rental growth rates and violated the decision rule for the appropriate income growth rates for leasehold investment properties valued part-way through a rent review period.

Inference can be drawn that the ninth scenario presents the optimal growth rates for cash inflow and cash outflow required by the investor to realize the likely purchase price of ₦8,704,728.55.

4.4 Validation of Rental Growth Rates

Attempts were made in this section to carryout array of appraisals aimed at validating the growth rates obtained from the 9th scenario. In Table 3, the summary of the results from the ninth scenario analysis indicates that the leasehold investor might require 18% and 13% growth rates in cash inflow and cash outflow to realize a likely purchase price of ₦8,704,728.55.

Where k_0 = 9.30909159% and k_1 = 13.38303% and the leasehold- and freehold implied rental growth rates are fixed at

18% and 13% respectively, results of the remaining three scenario-generated valuations in Table 4, Table 5 and Table 6 indicated an increase (decrease) in the leasehold equivalent yield (capital value) from 11.63717960% (₦8,704,728.55) in the 3rd year to 13.51423732% (₦7,867,964.66) at full reversion of the sublease to the leaseholder.

Results from the conduct of scenario tests across the appraisals in Table 4, table 5 and table 6 indicated zero slack between the iterated and calculated leasehold- and freehold rental growth rates of 18% and 13% respectively.

Table 3: Value parameters at 3 years to the next rent review

Parameter	Value
Equivalent yield valuation	₦8,704,728.55
Explicit DCF valuation	₦8,704,728.55
Leasehold Equivalent yield, k_e	11.63717960%
All risks yield of leasehold income, k_0	9.30909159%
Leasehold rental growth, g_0	18.0%
freehold rental growth, g_1	13.0%
All risks yield of freehold income, k_1	13.38303%

Table 4: Value parameters at 2 year to the next rent review

Parameter	Value
Equivalent yield valuation	₦8,541,010.09
Explicit DCF valuation	₦8,541,010.09
Leasehold Equivalent yield, k_e	11.94054523%
All risks yield of leasehold income, k_0	9.30909159%
Leasehold rental growth, g_0	18.0%
freehold rental growth, g_1	13.0%
All risks yield of freehold income, k_1	13.38303%

Table 5: Value parameters at 1 year to the next rent review

Parameter	Value
Equivalent yield valuation	₦8,266,305.88
Explicit DCF valuation	₦8,266,305.88
Leasehold Equivalent yield, k_e	12.52225966%
All risks yield of leasehold income, k_0	9.30909159%
Leasehold rental growth, g_0	18.0%
freehold rental growth, g_1	13.0%
All risks yield of freehold income, k_1	13.38303%

Table 6: Value parameters at full reversion to leaseholder

Parameter	Value
Equivalent yield valuation	₦7,867,964.66
Explicit DCF valuation	₦7,867,964.66
Leasehold Equivalent yield, k_e	13.51423732%
All risks yield of leasehold income, k_0	9.30909159%
Leasehold rental growth, g_0	18.0%
freehold rental growth, g_1	13.0%
All risks yield of freehold income, k_1	13.38303%

For reversionary leaseholds, there is a negative relationship between number of years to the next rent revision and the leasehold equivalent yield. Similarly is the observation of a drastic decline in the capital value of leasehold interest as it approaches reversion.

4.5 Discussion of Results

The application of equivalent yield valuation technique to leasehold investment properties appears to be loathed by valuation scholars over the years on the condition that it belongs to the family of the conventional techniques that have come under serious criticism (Baum & Crosby, 2008; Baum *et al.*, 2011; Wood, 1986b). This may have informed its neglect in the construction of a synergized model aimed at determining implied rental growth rate of leaseholds valued part-way through rent review periods. However, insight into the existence of leasehold equivalent yield was provided in the seminal work of Udo (1989). Equivalent yield technique was recommended by Brown and Matysiak (2000) as the only conventional technique that can bridge the gap between growth implicit- and growth explicit DCF valuation of reversionary property investments. It is on the basis of these feats that this study attempted to set out an appropriate model for the determination of input parameters of explicit leasehold DCF appraisal. Just as in the case of reversionary freeholds exemplified by Brown and Matysiak (2000) and Wyatt (2013), the reversionary leasehold equivalent yield valuation model was equated with the reversionary leasehold growth explicit DCF valuation model, to form hybrid DCF model from where four unknown variables comprising the all risks yield and the implied growth rates of leasehold cash inflows and cash outflows were calculated. The tools used to perform the scenario analysis that lead to the determination of appropriate growth rates for leasehold cash inflows and cash outflows comprise Goal Seek- and Solver, which are specialized What-If analysis functions in Excel®.

The appropriate test of an optimal valuation in this case is the one that exhibits zero slack in the iterated and calculated implied growth rates for cash inflows and cash outflows respectively. From the hypothetical reversionary leasehold valuation case study, the sale of the leasehold interest for ₦8,704,728.55 might have been driven by a market implied growth rates of 18% and 13% for rent received and rent payable respectively. On the other hand, the purchase of the same leasehold interest for ₦8,704,728.55 might have been influenced by an expectation of market implied growth rates of 18% and 13% for cash inflows and cash outflows respectively. Although existing seminal works of Brown and Matysiak (2000) and Wyatt (2013) provided the framework and technique for the determination of a "single" implied rental growth rate of freehold investment properties valued part-way through a rent review period, this study is an extension of the same framework and technique to the determination of implied growth rates of leasehold cash inflows and cash outflows respectively.

5. Conclusion

This study examined the use of spreadsheet-assisted scenario analysis tools and techniques to determine rental growth rates of leasehold investment properties valued part-way through rent review periods. In consonance with the first objective of study, it was found that a combination of the leasehold equivalent yield valuation model and the leasehold DCF valuation model to form what is tagged "the hybrid leasehold DCF model" is required for the identification of input parameters for determining growth rates of cash inflow and cash outflow respectively. It was on this basis that a contemporary leasehold valuation problem where the market price, contract rent received and payable, market rent received payable, review period of cash inflow and cash outflow, number of years to the next revision of cash inflow and cash outflow, unexpired term of head lease, and equated yield are known was put forward. Thirdly, the tools and procedure for scenario analysis leading to the determination of appropriate growth rates for leasehold cash inflows and cash outflows were derived from the basic theories of linear optimization and the Solver scenario analysis tool in Excel®. In consonance with the fourth objective of study, the four unknown variables that were calculated within the leasehold DCF valuation scenario include all risks yields and growth rates for cash inflow and cash outflow respectively.

With recourse to the first research question and a valuation case study, growth rates of leasehold cash inflow and cash outflow were determined using Excel Solver which is a What-if scenario analysis tool capable of solving multiple output variables arising from changes in multiple input variables in a valuation. A total of eleven scenarios were generated to help identify the optimal solution for these parameters. In response to the second research question and the valuation case study, the leasehold capital value of ₦8,704,728.55 was likely driven by expectation of market implied growth rates of 18% and 13% for cash inflows and cash outflows respectively.

The use of spreadsheet-assisted scenario analysis with the hybrid DCF appraisal model to determine the rental growth rate of leasehold investment properties valued part-way through a rent review period presents some implications for leasehold investors. For instance, the market for leasehold investments responds to the gradual termination of the interest by compensating the holder of such interest with higher weighted average income yield in lieu of diminishing capital value. Therefore, investors seeking income returns and income growth for a limited time horizon might opt for leasehold investments provided an appraisal of viable cash flow growth rates can be established.

Just as in the case of freehold investments, the use of spreadsheet-assisted scenario analysis and techniques can possibly address the question of rental growth rates that justifies the discounted cash inflows and outflows required to produce a desired outcome for leasehold investment properties valued part-way through rent review periods.

This study was conducted within the framework of spreadsheet and DCF valuation of leaseholds. It would be recalled that Adams *et al.* (2003) underscored the deficiency of DCF valuation technique to handle the complexity of options in lease contracts. Therefore, further research should evolve appropriate techniques for the determination of implied rental growth rate of leasehold cash inflows and cash outflows characterized by embedded options and how these techniques can be deployed in the appraisal of leasehold investment property.

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The Effect of the Relationship between Indoor Architectural Design Studios and Outdoor Landscape on Increasing Students' Satisfaction Level

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ABSTRACT

The environmental factors in the educational spaces along with the other factors affect the teaching and learning process. One of the characteristics of environmental space is the type of relationship of each space with its outdoor space. This factor is more important, especially in the spaces where students spend long hours such as architectural design studios. Nowadays, outdoor spaces in academic environments provide functions like accessing to closed spaces and various buildings and creating their relationship. In this regard, the visual function is considered as another important function, which is often overlooked and less considered and created by the outdoor environments for indoor closed spaces. The main question is related to whether the type of the relationship between the closed space of the architectural design studio and the outdoor natural space is considered as an important factor in achieving students' satisfaction with long hours working in this space based on the attention restoration theory or not. The present study aimed to examine the effect of the relationship between the indoor spaces of architectural design studios and outdoor environment on increasing students' satisfaction. This research was conducted by combining the quantitative and qualitative methods. The population included 65 students majoring in architecture, who experienced designing classes in all three studied studios. This research compared three architectural design studios with different conditions of proximity and outward view. The research data were analyzed with SPSS software. The results indicated that the open and diverse outdoor natural landscape was more effective factor in increasing students' satisfaction rather than among the various factors influencing the type of relationship between the studios and the outdoor space. Accordingly, designing the university landscape from the indoor closed spaces should be considered more, especially in spaces such as studios due to the long hours of attending and working of students.

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1. Introduction

Today, the importance of designing educational spaces to improve the quality of learning and teaching is clear for anyone. The learning environment refers to a socio-cultural and physical context in which learning takes place. Understanding the effective function of learning environment is essential for the architectural environment designing. An effective learning environment plays

an important role in education along with the other components, such as teachers, curricula, educational tools, etc. The physical environment is only one of the influential components in learning, which is considered as the most important component in an active learning environment (DeGregori, 2007). Actually, learning is highly efficient and enjoyable in an appropriate behavioral setting for education. The physical and architectural environmental factors in relation to non-environmental factors strongly influence the learning process. Based on the findings of Weinstein (1979) in the field of designing educational environments, there is no appropriate specific learning setting for all types of learning. The best learning settings have the most congruence with the learning matter. learning is maximized when each physical setting of education is considered as much as the other effective aspects of learning such as educational aid tools, teachers' ability to explain and express, etc.

In designing educational spaces, first of all the physiological needs and then, the safety needs are considered more than other issues. However, limiting the designers' perspective on these two issues makes them unaware of the higher-level needs. However, meeting all his needs is the condition of the relative mental health of man. The type of the relationship of each space with its surrounding spaces is considered as one of the spatial features, influencing the quality of space and the better performance of the activities inside the space. In the past, the design of university campus emphasized the physical development and open spaces such as remaining and vacant lands were considered (Wang & Chen, 2012). Actually, the green space design of the campus is as important as its architectural design. The building design and academic landscape cannot be considered as two separate activities. Designing open space by the relationship with the buildings as a complementary component is regarded one of the principles of designing the open space of the university campus (Peker, 2010). Based on the results, the close relationship of the class with the nature is considered as one of the most important features of a healthy class (Dudek, 2005). Li and Sullivan (2016) indicated that the green space in educational places has aesthetic aspect and designers should create the possibility to move, access, and view the green spaces in the educational spaces, especially in spaces with more teacher-student interaction. Nowadays, outdoor spaces in academic environments provide functions such as access to closed spaces and various buildings and the creation of relationship between them. Further, the visual function is considered as another important function, which is often overlooked and created by the outdoor environments for closed indoor spaces in order to look at outdoor spaces from the indoor spaces. Accordingly, the present study aimed to examine the effect of the type of relationship between the educational indoor closed spaces and outdoor environment of the architectural design studios on students' satisfaction since it is considered as one of the important factors in shaping the plan of the educational spaces, as well as the arrangement of closed and open spaces together based on the attention restoration theory.

2. Research Hypothesis

Among the various factors affecting the type of the relationship between the indoor space of the studio and the outdoor environment such as the level of natural light, lack of outdoor noise, and outdoor natural landscapes, wide and open outdoor natural spaces visible from the indoor spaces is considered as the most important factor in students' satisfaction based on the attention restoration theory due to the long hours of presence and work in the studio and students' mental fatigue.

3. Background Of The Study

The attention restoration theory (ART) of Kaplan has been examined in many experimental studies and the results indicated that the natural environments significantly increase the cognitive function and attention of individuals. A large number of studies considered the attention restoration theory on adults. In the same vein, Bratman et al. (2015) indicated that adults' walking in the natural environments influences their concentration and attention improvement. Based on the results of early studies, looking at the nature or natural elements from indoor spaces is effective in improving people's concentration and attention (Holden & Mercer, 2014; Kuo, 2001; Lee et al., 2015). Further, looking at the images of nature has a positive effect on improving concentration and attention of people (Berman et al., 2008; Berto, 2005; Chow & Lau, 2015; Gamble et al., 2014; Thompson & Bendall, 2014). A limited number of studies considered the link between the attention restoration theory and educational spaces. Moreno et al. (2018) confirmed the positive effect of attending the natural environments instead of built environments on improving children's cognitive function, which is consistent with findings of some studies conducted on children's educational spaces. Wu et al. (2014) evaluated the relationship between the natural conditions around the classroom and students' performance in math and language and indicated the positive relationship between vegetation and students' academic performance. Matsuoka (2010) examined the effect of the environment around the high school, namely the amount of green space visible from the classroom and cafeteria window, size of windows, and density of green space in each section of the high school campus on the students' performance. The results indicated a positive relationship between the nature around the educational space and students' performance. Further, Li and Sullivan (2016) demonstrated the better performance in attention and concentration activities among high school students attended in classrooms with windows to the green spaces compared to the students attended in the classrooms without windows or with windows facing buildings. Another similar study indicated that the college students, facing more natural landscapes from indoor windows, scored higher on the direct concentration-required tests compared to the students facing the lower natural landscapes (Tennessen & Cimprich, 1995). In this regard, Moreno et al. (2018) restored the children's attention required for their concentration activities using attention restoration theory of Kaplan by providing software, which included natural images with the characteristics of Kaplan's theory.

There is limited studies about the effect of existence of nature in educational spaces in university.

Van Den Bogerd, et al. (2018) examined preference for university indoor and outdoor spaces with and without greenery. They showed that students gave higher preference ratings to the indoor

spaces with a nature poster, a green wall and interior plants than to the standard designs without natural elements.

Gulwadi et al. (2019) examined normalized differential vegetarian index at three spatial levels. Their correlation analysis demonstrated positive association between objective and perceived greenness and quality of life between university students.

The study results of Felsten (2009) indicated that generating indoor natural conditions such as large wall paintings of the nature in indoor spaces of academic environments creates attention restoration for students, suffering from mental fatigue. However, the appropriate views of the outdoor natural green spaces should be created as much as possible. Actually, the large wall paintings of the nature are not a substitute for outdoor natural green spaces. However, they can be used as a suitable tool in places, where it is not possible to create appropriate natural landscapes or in the seasons when the natural landscapes are not attractive.

In none of previous researches were examined the effect of views from inner to outdoor nature on university students according to their majors. Among the various educational spaces of the university environments, the architectural design studios create a lot of physical fatigue due to the long hours of students' attendance and continuous work. Accordingly, the present study selected the architectural design studios as the case study.

The present study aimed to evaluate the effect of the type of relationship between the indoor spaces of architectural design studios and the surrounding outdoor space on the students' satisfaction with an emphasis on the attention restoration theory of Kaplan. For this purpose, the students' satisfaction with the types of relationship between the indoor space and its surrounding outdoor environment and their satisfaction with each of the studios were examined. The relationship between indoor space and outdoor was defined by three factors including: level of the natural light, lack of outdoor noise, and attractiveness of outdoor visual landscapes. Among the various educational spaces of the university environments, the architectural design studios create a lot of physical fatigue due to the long hours of students' attendance and continuous work. Accordingly, the present study selected the architectural design studios as the case study. The present study aimed to evaluate the effect of the type of relationship between the indoor spaces of architectural design studios and the surrounding outdoor space on the students' satisfaction with an emphasis on the attention restoration theory of Kaplan. For this purpose, the students' satisfaction with the types of relationship between the indoor space and its surrounding outdoor environment and their satisfaction with each of the studios were examined.

4. The Attention Restoration Theory

Some functions of the outdoor spaces in the academic environments included providing the access to the closed spaces and various buildings, creating their relationship, and giving the designer the ability to create spaces for sitting, talking, and studying in the natural context in order to create the vitality and variety in the outdoor space. In addition, the visual function is considered as another important function, which is often overlooked and less considered and created by the outdoor environments for indoor closed spaces to look at outdoor spaces from the indoor spaces. The attention restoration theory is considered as one of the theories in the landscape architecture, providing a new method to understand the cognitive mechanism. This theory is formed based on the early studies indicating the separation of attention mechanism into two components including involuntary attention, where a person's attention is captured voluntarily by attractive stimuli, and direct attention, and the individual's attention is captured to a stimulus through a controlled attention process. The distinction between the types of attention was first proposed by James (1892), and subsequent research confirmed the difference in the concentration mechanism for the voluntary and direct attention and involuntary attention (Fan, et al., 2002; Jonides, 1981). There are two processes in ART to focus attention on a stimulus by individual (Kaplan and Kaplan, 1989). These processes are selected based on the structural features of the environment. The first attention process, called direct attention, requires mental concentration since the stimulus does not capture attention or the individual should be able to distinguish the stimulus from the other types of environmental stimuli. Therefore, the constant exposure to these stimuli leads to the mental fatigue and reduced cognitive function (Kaplan, 1995). The second attention process refers to the attracting stimulus, in which the person is paying attention to the inherently intriguing stimulus without any need for mental focus and expending energy due to the inactive nature of this state of attention. Kaplan and Kaplan believed that there are inherently absorbing elements and stimuli in the natural environments, where spending time can restore the energy needed for the mental concentration. (Kaplan&Kaplan,1989)

Based on the attention restoration theory, the constant attention such as studying and working behind a desk exhausts the mind, leads to the fatigue or distraction of the mental focus, increases the mental error, and results in the irritability, distraction, bad temper, impatience, and reduced efficiency (Berman, et al., 2008). The mental fatigue is restored and improved through the natural environments, parks, and gardens. As already mentioned, based on the Kaplan's research, there are two mechanisms of attention including voluntary attention and involuntary attention. In this regard, students should focus their attention voluntarily during the classroom activities and consciously remove the distracting elements. This inhibitory mechanism causes mental fatigue after a while (Kaplan & Berman, 2010). Among these focused voluntary activities, the involuntary attention of individual is activated by a window, which opens to the natural space in the classroom. After a short time, the voluntary inhibitory mechanism is rested and the student's ability to focus attention is restored and improved (Li & Sullivan, 2016). It was once thought that the windowless classrooms are more useful for students' focus and attention. However, the windowless environments had no positive effect on improving student's performance (Holden & Mercer, 2014). The attention restoration theory (ART) of Kaplan and Kaplan is an appropriate practical model for reducing stress and anxiety in urban environments away from the nature. Accordingly, the landscape in the educational

campuses should not only be seen from the green and beauty perspective. However, the importance of the natural landscapes for students' health and attention restoration should be considered (Akpinar, 2016). According to Kaplan, the natural environments have a soft fascination feature, which automatically and simultaneously attracts attention and generates a sense of pleasure in the viewer (Pearson and Craig, 2014).

The mental fatigue related to the constant focus and working behind the desk is higher in educational spaces such as architectural design studios, where students work and spend more time. The research hypothesis, formed based on the ART, is that the mental fatigue is improved to some extent through the surrounding natural environments and the possibility of looking at outdoor spaces with a pause from the indoor closed spaces. The natural environments next to the closed spaces should have specific characteristics in order to create mental liberation and expansion of the mind. The landscape should be wide and open and its end should not be visible as soon as observed. The minimum opening in the landscape should be in such a way that it can create a deliberate pause in the mind to get rid of the preoccupation with the subject and the previous user in the architecture and should not be immediately occupied by the new subject or user. The amount of keeping the mind away from the current situation and relieving its fatigue is directly related to the extent of the opening or the extent of the field of view. The breadth of the landscape to the extent which end is not visible quickly is enough to relieve mental fatigue from before and after preoccupations.

5. Methodology

In the present mixed-method study, the field data were collected by observing and completing the questionnaire. The characteristics of the studio outdoor openings were recorded through the observation and measurements. A questionnaire with open-ended and close-ended questions was used to examine the students' satisfaction level and the relationship between the architectural design studios and their neighboring outdoor space. The qualitative data obtained from the open-ended questions were coded and analyzed by SPSS software along with the data obtained from the closed-ended questions.

Three architectural design studios of the Babol Noshirvani university of technology were selected as the case study that all the practical lessons of bachelors' students were held on these studios (see Figure 1). Given that none of these studios had a direct access to the outdoor environment, the students' satisfaction with the level of the natural light, lack of outdoor noise, and attractiveness of outdoor visual landscapes was questioned. Further, the students were asked to prioritize these three studios based on their satisfaction level with the three factors and express the factors influencing their satisfaction and dissatisfaction in the open-ended question. The openings of the three studios were also examined and analyzed in terms of quantitative dimensions.

Figure 1 Situation of the studios in the university campus

The population was included 65 students majoring in architectural engineering including 19 freshmen, 28 juniors and 18 senior students. These respondents were selected because of their experiences of more than 3 hours' class in all three studios. They were in the range of age 18-21; 24% male and 76% female.

Given that none of these studios had a direct access to the outdoor environment, the students' satisfaction with the level of the natural light, lack of outdoor noise, and attractiveness of outdoor visual landscapes was questioned.

The variables examined were included: independent variable (students' satisfaction level) and dependent variables (level of the natural light, lack of outdoor noise, and attractiveness of outdoor visual landscapes). The students' satisfaction level was examined through these three factors with questionnaire.

Further, the students were asked to prioritize these three studios based on their satisfaction level with the three factors and express the factors influencing their satisfaction and dissatisfaction in the open-ended question. Further, the openings of the three studios were examined and analyzed in terms of quantitative dimensions.

6. Data Analysis

The present study aimed to examine the satisfaction level of students when attending architectural studios with several variables including the level of natural light, lack of outdoor noise, and outdoor natural landscapes, which measured students' satisfaction with the type of light, sound, and visual relationship between the indoor space and outdoor environment in the studio, respectively. The present study examined three architectural design studios of the university on the ground floor as a case study. The studio 1 has wide north and south windows, providing the visual view to the green spaces of the university on both sides. Further, it is located next to the entrance of the building on the south side, where students gather there and make noise during the day. The studio 2 has two windows on the south side, which is open to the entrance of the building, which is a place for students to stop and a green landscape is visible. The studio 3 is located with a distance from the entrance of the building and has a west window with a view to the wall of building and a north window with a view to the back of the building that is not designed and the surrounding buildings are visible. Table 4 represents the characteristics of the windows in all three studios such as the number of window, sides of the placement of the openings, the area of the windows, OKB and height of the windows, the ratio of the opening area to the wall area, and the use of the outdoor space next to the windows. The simulation has been done in parametric CAD environment of the Rhino/Grasshopper software with the ladybug environmental simulation analysis. Ladybug imports standard EnergyPlus Weather files (. EPW) in Grasshopper and allows users to work with validated energy and daylighting engines such as EnergyPlus, RADIANCE and DAYSIM. (Roudsari, M.S et al., 2013) daylighting analyzes results of these three studio has been indicated in table 1.

Using the descriptive statistics of SPSS software frequency and percent of students', satisfaction level of three variables of each studio was evaluated (level of the natural light, lack of outdoor noise, and attractiveness of outdoor visual landscapes).

The results indicated that 84% of students reported their satisfaction with the level of natural light as desirable in the studio 1. In the studio 2, 66% reported the level of natural light as desirable and 34% as low light, and no one considered the light to be high. However, only 22% considered the light of the studio 3 as desirable and 78% as low light.

Further, the students' satisfaction with the lack of outdoor noise during the working hours in architectural studios was considered. Based on the results, 19% of students were satisfied with the lack of outdoor noise in the studio 1, 66% were somewhat satisfied, and 16% were dissatisfied. Regarding the studio 2, 13% were satisfied with the lack of outdoor noise during the working hours, 56% were somewhat satisfied, and 31% were dissatisfied. In addition, 38% were satisfied with the lack of outdoor noise in the studio 3, 44% were somewhat satisfied, and 19% were dissatisfied.

Furthermore, the results of examining the satisfaction level of students with the visual relationship of studios with the outdoor environment indicated that in the studio 1, 75% of the students were satisfied with the outdoor natural landscapes, 22% were somewhat satisfied, and only 3% were dissatisfied. In the studio 2, 9% were satisfied with the outdoor natural landscapes, 75% were somewhat satisfied, and 16% were dissatisfied. Additionally, in the studio 3, 6% were satisfied with the outdoor natural landscapes, 19% were somewhat satisfied, and 75% were dissatisfied.

The students were asked to prioritize the studios based on the sound (lack of outdoor noise), light (the level of natural light), and visual (outdoor natural landscapes) relationship with the outdoor environment. The results were investigated using the descriptive statistics of SPSS software. The results indicated that 91% considered studio 1 as the first priority, 91% considered studio 2 as the second priority, and studio 3 was the third priority among 91% of students (Figure 2)

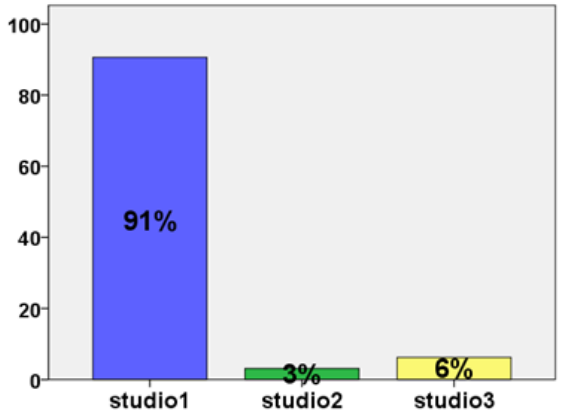
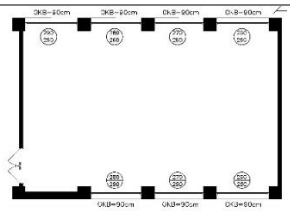
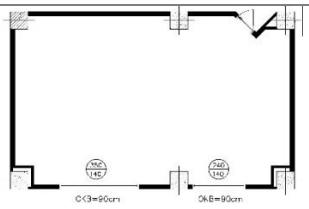
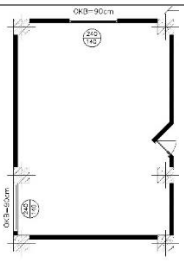
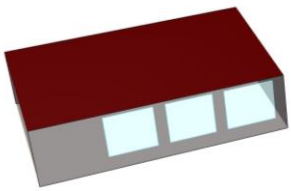
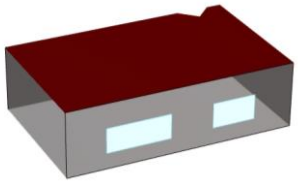
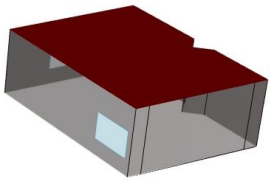
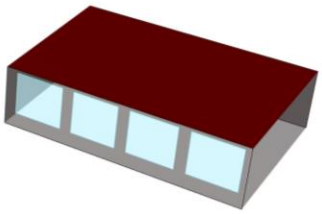
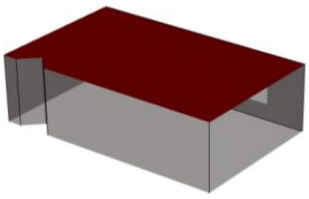
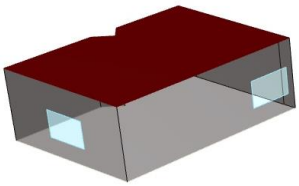


Figure 2 The first priority of three architectural design studios

Table 1 The specifications of the windows in the studio 1, 2, and 3

		Studio 1	Studio 2	Studio 3
picture				
Plan				
Dimensions of space		14 * 8.5 m	12.4 * 7.6 m	10.6 * 7.6 m
Height of space		3.5 m	3.5 m	3.5 m
windows	**Number Of each side**	4 northern 3 southern	2 southern	1 northern 1 western
	area	29.6 m2 northern 22.2 m2 southern	8.4 m2 southern	3.3 m2 northern 3.3 m2 western
	Next function	Side passage space -green space Main passage space - green space	Main passage space - green space	Unplanned landscape from the behind buildings
	OKB	0.9 m	0.9 m	0.9 m
	Height	2.6 m	1.4 m	1.4 m
Modeling picture For daylighting analysis				
				
illuminance values (lux)	**May** (Ordibehest)	2348.278	749.339	383.874
	August (Mordad)	2218.055	665.903	374.379
	November (Aban)	2620.316	1079.76	231.704
	February (Bahman)	1516.424	590.52	166.158

The students were asked to respond the open-ended questions in relation to the factors influencing their satisfaction and dissatisfaction with the outdoor environment from each studio. The results indicated that 73% of students stated the effect of landscape and good green space next to the studio 1 on their satisfaction and only 9% of the students mentioned the natural light. In addition, 18% of the students expressed their dissatisfaction with the outdoor noise in the studio 1.

These results are more varied in studio 2 since the students expressed several factors. In this regard, 26% stated the effect of good landscape of the studio on their satisfaction. However, the rest of the students only mentioned the reasons for their dissatisfaction with the studio 2 including 32% high noise, 16% window shortage and outward view, 11% lack of green space, 11% simultaneous access of facilities and services to the side of the building, and 5% lack of natural light

The results of evaluating the students' satisfaction and dissatisfaction with the architectural design in studio 3 indicated that most of the students only referred to their dissatisfaction factors. In the same vein, 64% of the students stated that the bad class vision to the abandoned and unplanned building spaces influences their dissatisfaction with the studio 3. Further, 23% expressed low windows and 9% considered high noise as the factors influencing their dissatisfaction.

The existence of a linear relationship between the independent variable (students' satisfaction level) and the dependent variables (level of the natural light, lack of outdoor noise, and attractiveness of outdoor visual landscapes) was examined with Beta coefficient. The Spearman correlation test was then used to measure the correlation between the variables. Accordingly, there was no significant linear relationship between light and students' satisfaction with the studio 3 and this variable was not examined in the correlation tests (Table 2)

Table 2 The beta coefficient to measure the existence of a linear relationship between the dependent variables and the level of satisfaction with studios

	Beta coefficient	**Sig.**
Satisfaction with the light in studio 3	-0.042	**0.792**
Satisfaction with the lack of outdoor noise in studio 3	-0.305	**0.008**
Satisfaction with the visual vision in studio 3	0.731	**0.000**
Satisfaction with the light in studio 1	4.467	**0.000**
Satisfaction with the lack of outdoor noise in studio 1	-2.921	**0.007**
Satisfaction with the visual vision in studio 3	-5.408	**0.000**

Given the ranking of independent and dependent variables, the Spearman correlation test was used to significantly measure the correlation between the variables. As indicated in Table 2, the negative correlation coefficient (-0.594) between the satisfaction level with the visual view to outdoor in the studio 1 and the selection of the most satisfactory studio demonstrated that their selection of the most satisfying studios reduced from the studio 1 to studio 3 when the students' opinions changed from the dissatisfaction towards the complete satisfaction with the view to outdoor Therefore, the studio 1 was selected as the most satisfactory studio among three studios in terms of the view to outdoor.

The negative correlation coefficient of (-0.558) between the level of satisfaction with the lack of outdoor noise in studio 1 and selecting the most satisfactory studio indicated that most of students selected the studio 1 as the most satisfactory studio among three studios in terms of the lack of outdoor noise. Accordingly, the appropriate view to outdoor and lack of outdoor noise were considered as the factors influencing the selection of studio 1 as the most satisfactory studio, respectively. Further, despite the students' satisfaction with the level of daylighting in the studio 1, this variable was not considered as an effective factor in their selection of the studio 1 as the most satisfying studio. Therefore, the appropriate view to outside significantly influenced students' choice (Table 3).

Table 3 The Spearman correlation coefficient between the studied variables in the studio 1 and the selection of the most satisfying studio

		Satisfaction with the light of the studio space 1	**Satisfaction with the lack of outdoor annoying noise in the studio space 1**	**Satisfaction with the space visual view to outside in the studio 1**
The most satisfying studio	Spearman correlation coefficient	0.319	-0.558	-0.594
	Sig.	0.076	0.001	0.000

As already mentioned, the light variable in studio 3 was not examined in the correlation test due to the lack of its linear relationship with the satisfaction with the studios. As shown in Table 3, a positive correlation (r=0.633) between the satisfaction with the visual view to outdoor in the studio 3 and the selection of the most satisfactory studio indicated that the high selection of the most satisfying studio increased from studio 1 to studio 3 when the students' opinions changed from dissatisfaction to the full satisfaction with the view to outdoor. Namely, the students chose studio 3 as the most dissatisfying studio in terms of the lack of visual view to the outdoor space.

Further, the negative correlation (r=- 0.488) between the satisfaction with the lack of outdoor noise in the studio 3 and selecting the most satisfactory studio demonstrated that the greatest selection of the most satisfying studio reduced from studio 1 to studio 3 when the students' opinions shifted from dissatisfaction to the satisfaction with the lack of outdoor noise. Accordingly, the studio 3 was highly chosen as the most dissatisfying studio among the three studios. (Table 4).

Based on the results, there is a significant positive relationship between the selection of studio 3 as the most unsatisfactory studio and the dissatisfaction with the appropriate visual view to outdoor in studio 3. In addition, although the students expressed their satisfaction with the lack of outdoor noise in the studio 3, this variable was not considered as an effective factor in their satisfaction with this space.

Table 4 The Spearman correlation coefficient between the studied variables in the studio 3 and the selection of the most satisfying studio

		Satisfaction with the lack of outdoor annoying noise in the studio space 3	**Satisfaction with the space visual view to outside in the studio 3**
The most satisfying studio	Spearman correlation coefficient	-0.488	0.633
	Sig.	0.005	0.000

7. Conclusion

The present study aimed to evaluate and compare the students' satisfaction with the type of relationship between the indoor space of studios and the outdoor environment in three architectural design studios. The studios had relatively similar areas and geometric shapes and the type of their relationship with the outdoor environment including the dimensions, side of the placement of the openings, and their proximity to the outside was different. The type of the relationship of studios with the outdoor environment refers to the factors influencing the students' satisfaction with the level of the natural light, the lack of outdoor noise, and the outdoor natural landscapes in the studios. Based on the results, students had the highest satisfaction level with the natural light in studio 1, which had the highest opening area compared to the wall area. The students' satisfaction with the natural light of studio 2 was much more than that of studio 3 since 66% of students considered the level of natural light in studio 2 as desirable, while only 22% considered the level of natural light in studio 3 as desirable. However, the ratio of the opening area to the wall was similar in these two studios (Table 1) and both of the studios had two windows with relatively similar area. Further, the side of the placement of the openings was different in these two studios. In studio 3, the openings are located on the north and west sides, where less light enters into the indoor space compared to the south side, and the low distance between the wall with opening and the opposite building creates shadow on the window. The difference between the level of daylighting in these two studios was indicated in table 1. Therefore, the side of the placement and the amount of shading of the openings are considered, leading to the different results in the level of the same openings in a space in terms of the level of natural light entering.

Further, the students' satisfaction level with the lack of outdoor noise in the design studio space was measured. Based on the results, the highest dissatisfaction rate in studio 2 was 31%, the openings of which are located beside the stop space of the entrance of the building and the students gather there at various times for their social activities.

Another factor considered in this research was the students' satisfaction with the outdoor natural landscapes in studios. The results indicated that 75% of students were satisfied with the outdoor natural landscapes in studio 1, 75% were somewhat satisfied with the outdoor natural landscapes in studio 2, and 75% were dissatisfied with the outdoor natural landscapes in studio 3. It is worth noting that there is a significant difference in the satisfaction with the outdoor natural landscapes in studios 1 and 2 although both of these spaces were adjacent to the designed green spaces. This difference is related to the open and closed view in the studios 1 and 2. Based on the attention restoration theory of Kaplan, the natural environments next to the closed spaces should be wide and open and not limited in order to gain the liberation of mind during the continuous activities indoors, which has been tangible in the landscapes of the studios 1 and 2. The designed natural landscape next to the studio 1 is wide and open and the distance from the wall with the opening to the next building is far greater than the distance from the openings to the next wall in the studio 2. This factor can increase the students' satisfaction with the landscapes of the studio 1. The other difference between studio1 and studio 2 is that, there are two sides windows in studio1 in north and south, but the studio 2 only has one side windows in south. This factor could effect on satisfaction level of students from view to natural outside. In studio 2 when students seat in their chair only a little of them can see the outer nature from one side windows but in

studio 1 because of two sides bigger windows a lot of students in many parts of studio have good view from windows.

Further, the present study identified the various factors influencing the students' satisfaction and dissatisfaction with each of these studios. In this regard, the open-ended questions were asked from students and their answers were coded. Based on the results, the students considered the good view and the green space next to the studio 1 as the most influential factor in their satisfaction, and only 18% of the students mentioned outdoor noise as an important factor in their dissatisfaction. Further, 64% expressed the bad view of the classroom to the abandoned and unplanned spaces as the most important factor influencing their dissatisfaction with studio 3. Despite the high statistical results in the dissatisfaction with the lack of natural light, only 5% mentioned the lack of natural light. Accordingly, between two factors: "lack of outdoor noise" and "attractiveness of outdoor visual landscapes" the latter is more important in satisfaction level of students from architectural studio. Also between the factors of "level of natural light" and "attractiveness of outdoor visual landscapes" the latter is more important in satisfaction level of students. These could be explained with respect to the long hours of attending studios and students' mental fatigue according to Attention restoration theory. Accordingly, the most important factor influencing students' satisfaction and dissatisfaction with the three studios is the presence or absence of open natural views designed next to their studios. In total, 91% of students chose studio 1 with good natural landscapes and view as the best studio for architectural design courses, and their lowest selection was studio 3 due to its unplanned and bad view as the most important factor affecting their dissatisfaction.

Finally, "the open and wide view to natural landscape", is considered as the most important factor among those influencing the type of the relationship between an architectural design studio and outdoor environment ("lack of outdoor noise", "attractiveness of outdoor visual landscapes" and" level of natural light") due to the long hours of attending studios and students' mental fatigue. Therefore, it is necessary to pay more attention to the natural landscape design next to the closed spaces in the academic environments, especially in spaces, such as studios, where students spend more time there.

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Psychological And Physiological Benefits Of Plants In The Indoor Environment: A Mini And In-Depth Review

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ABSTRACT

People tend to spend approximately 87% of their time in the indoor environment. There is a possibility that they are exposed to volatile organic compound (VOC) and particle pollution, and to experience stress related disorder. This has potential threaten the well-being of indoor occupants if left untreated. Hence, plants were introduced to alleviate these negative impacts. This paper reviews past literature from 1990 to 2010s, to examine the relationship of plants with indoor environment and identifies how they influence people, psychologically and physiologically, and how they promote indoor environment quality. Most studies suggest that the presence of plants is associated with positive feelings and able to enhance productivity. In addition, they also may help to promote general health such as reducing blood pressure, perceived stress, sick building syndrome, and increase pain tolerance of the patient. Moreover, plants also help in improving the indoor environment quality (IEQ), for instance, they can reduce carbon dioxide (CO^2), indoor ozone (O^3) level, VOC, and particulate matter accumulation through bioremediation process. Despite all the benefits that the plants could offer, several studies pointed out that factors such as gender, perceived attractiveness of the space, physical characteristics of plants, and methods of interaction with plants may lead to non-identical results. Hence, the selection of the right species of plant in an indoor environment becomes mandatory in order to improve the indoor environment quality; to provide restorative effect; to invoke positive feelings and comfort of the people. In conclusion, this review may provide notable insights to landscape architects, gardeners and even interior designers to choose the right species of plant in an indoor environment, to maximize their psychological and physiological benefits, at the same time, improving indoor environment quality.

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1. Introduction

The study of indoor environment in an urban setting has become a concern for scientific community because up to 87% of the people spending their time in the indoor environment, either in their residence (68.7%), office and factory (5.4%), bar and restaurant (1.8%), or inside a vehicle (5.5%) (Klepeis et al., 2001). One of the problems emerged is volatile organic compounds (VOC) outgassed from wood-based product and other household items that contributed to health risk (Aydogan and Montoya, 2011; Zhang et al., 2009). Moreover, particle pollution from outdoor environment that migrates to indoor environment can also negatively influence cardiopulmonary health (Stapleton and Ruiz-Rudolph, 2016). Other than that, lack of tranquillity in urbanized city also contributes to continual distraction, shorten attention span, and trigger stress related disorder, which may lead to psychological and physiological health disorder (Han, 2009).

Urbanization is defined in a different manner depended on its context of studies such as socio-economic and political studies, land use, population and place studies, but in general, it can be described as highly populated areas with a substantial of built-up areas and man-made features (Halfacree, 1993; MacKerron and Mourato, 2013; Yeo et al., 2019). Urbanization has been increasing from 30% in year 1950 to 55% in year 2018, and it is expected to keep increasing up to 68% in year of 2050, worldwide (UN, 2019). The continuous urban sprawl has contributed to the change of natural environment to agricultural land, and built-up areas (Yeo et al., 2019). Due to the increasing rate of urbanization, it is becoming difficult to access to natural landscapes (Turner et al., 2004). For instance, people that live in the urbanized city may not have the opportunity to visit such destination, or they might need to travel a longer distance. In fact, people are happier when engaging with green and natural environments as compared to urban environments (MacKerron and Mourato, 2013). Therefore, designing a greener indoor space is highly encouraged, to ensure that people stay in the indoor environment also have the opportunity to interact with nature, which in turn, may promote their comfortable level, productivity and mental functioning. Besides, the plants also help in reducing volatile organic compounds in the indoor environment (Teiri et al., 2018). Due to various benefits that the plant could offer, they were introduced to improve the indoor environment quality and to promote general well-being of the building occupants. The planting system can be vary and depended on the user needs, it can be a simple potted plant system, up to the advance technology likes green wall biofilter system (Irga et al., 2018). This paper firstly identifies how the plants in the indoor environment influence psychological and physiological health of the building occupants, and how they promote the indoor environment quality. Secondly, this paper presents a list of plant species that were being examined. So, future study can incorporate those species in their experimentation.

2. Method of Review

Mixed methods review was used in this research paper to review the relevant literature (Grant and Booth, 2009). Both quantitative and qualitative approaches were employed. In the quantitative approach, we elicited all the peer-review journals from year of 1990 to 2010s. Some of the keywords used to search the relevant articles included indoor plants/ vegetation/ potted plants, psychological benefits/ impacts, physiological benefits/ impacts, indoor environment quality/ air quality, and indoor environment/ setting/ space. The articles selected from peer-review journals are from the following disciplines, but not exclusively, *Indoor and Built Environment, Environment and Behaviour, Atmospheric Environment, HortScience, HortTechnology, and Indoor Air*. A list of 21 articles regarding how the plants contributed to the improvement of the indoor environment is tabulated. The tabulation is segregated into four categories, there are type of plant species, placement of plants (setting), type of improvement, and the authors (refer Table 1 and table 2). Firstly, the plants species used in this review are listed out in chronological order. Next, the placement of it is explained clearly in the table, e.g. the plants were put on a table or shelf. Lastly, how plants contributed to the well-being of building occupants and improve the environment quality, were explicitly presented in the table.

For qualitative approach, we separated the discussion into two sections. The first section is focused on the discourse of psychological (i.e. moods, feeling, performance, and stressors) and the physiological parameter (i.e. blood pressure, pain tolerance, anxiety, and fatigue), while the other section is focused on the indoor environmental quality (VOC, CO^2, ultra-fine particles). Both the positive and negative results are discussed and compared, in Sections 3 and 4.

3. Psychological and Physiological Benefits

One of the theories explains the benefits of engagament with nature is stress recovery theory by Ulrich (1983). For instance, Ulrich (1984) reported that patients viewed the nature outside of the windows had shorter postoperative hospital stays, and their attitudes also tend to be positive when interating with the hospital staffs, as compared to the patients that viewed the brick wall. Another theory that explains the benefits of nature is attention restoration theory (Kaplan and Kaplan, 1989). For instance, Kaplan (1995) found out that engaging with the natural environment has shown a few restorative benefits, which includes people have a propensity to, i) improve on their task performance, ii) help to mitigate stress related disorder and iii) enhance effective functioning.

There are substantial evidences support or partially support the attention restoration theory and stress recovery theory. For instance, Lohr et al. (1996) examined the impacts of the plants in a windowless computer lab, and they found out that people in lab with the presence of plants feeling more attentive and showed significant increases in their post-task attentiveness (12% faster in computer-based productivity). There are evidences provided by Larsen et al. (1998) and Thomsen et al. (2011) suggest that the plants may promote creative performance, reduce stress, improve mood and invoke positive feelings and comfort of the people. Nontheless, it is also worth to note that too many plants (17.88% of total space) in an office may not contribute to the improvement of productivity that required repetitive action with focused attention. Meanwhile, Bringslimark et al. (2007) suggest different views, their findings demonstrated that more plants in view in workplaces are associated with greater productivity and lesser sick leave, although the number of plants the researchers reported in their study are less than Larsen et al. (1998). Interestingly, Shibata and Suzuki (2004) postulate indoor plants may improve task performance of female occupants than male occupants. On the contrary, indoor plants may enhance the mood of male occupants than female occupants (ibid). In addition, there is evidence suggesting female occupants expressed more satisfaction than male occupants with the presence of plants in an interior rehabilitation centre (Raanaas et al., 2010). It means the impacts of plant on mood condition and task performance

Table 1 Plant species used in the indoor setting that promote psychological and physiological health

Type of Plant Species	Settings	Type of Improvement	Author(s)
Aglaonema sp.,Chamaedorea seifrizii, Dracaena marginata, Dracaena deremensis 'Janel Craig' ,Epipremnum aureum, Homalomena siesmeyeriana, Hoya sp., Philodendron scandens, Sansevieria trifasciata, Scindapsus pictus 'Argyraeus', Syngonium podophyllum	Floor, table, and hanging potted plants were placed in computer lab.	Feeling more attentive, rise in blood pressure was less, increases in post-task attentiveness, and reaction time on a computer-based productivity is increase by12%.	Lohr et al. (1996)
Aglaonema commutatum Schott, Dracaena deremensis 'Janel Craig' , Epipremnum aureum, Philodendron hederaceum, Dracaena fragrans, Philodendron cordatum.	Site 1: Potted plant placed on the window bench (office) Site2: On top of the film viewers (radiology department) Site 3: planter box near wall with bio process system	Complaints were decreased regarding: Site 1: Cough, fatigue, dry or hoarse throat, and dry or flushed facial skin. Site 2: Fatigue, feeling heavy-headed, headache, dry or hoarse throat, and hands with dry, itching, or red skin. Site 3: Headache and dry or hoarse throat.	Fjeld (2000)
Dracaena fragrans cv. Massangeana	Site 1: Room with potted plant Site 2: Magazine rack with book Site 3: No plant and no magazine rack	Female participants performed better than male with the presence of plants. Under no objects condition, both male and female felt less confident and less energized. Mood of male participants was better with the plant.	Shibata and Suzuki (2004)
Dracaena fragrans, Dracaena concinna, Epipremnum aureum, Ficus benjamina, Spathiphyllum wallisii, Beaucarnea recurvata, Schefflera arboricola	Plants were placed on shelves, the tops of filing cabinets, and on the floor in office environments	Plants has less statistically reliable associations with sick leave and productivity, and were not significantly associated with perceived stress due to the measure of stress was not specific to work-related circumstance.	Bringslimark, Hartig & Patil (2007)
Dendrobium phalaenopsis, Spathiphyllum 'Starlight', Epipremnum aureum, Syngonium podophyllum 'Albolineatum', Pteris cretica 'Albolineata', Vinca minor 'Illumination', Trachelospermum asiaticum 'Ogonnishiki'	Potted plants were placed in hospital room	Patients exposed to plants during recovery had significantly enhanced physiologic responses: improved mood and lower systolic blood pressure, lower ratings of pain, anxiety, and fatigue, and feeling more satisfied in hospital room. Patients increased interaction with plants: watering plants, removing dead leaves, touching them, and moving them for a better view or close to the window for better sunlight.	Park and Mattson (2009)
Dracaena reflexa, Rhapis excelsa, Schefflera arboricola, Dracaena surculosa, Epipremnum aureum, Liriope muscari, Aglaonema commutatum, Dracaena fragrans 'Janet Craig'	Potted plant placed on floor in a rehabilitation center	The plant intervention had a positive effect on satisfaction, which women were more satisfied with the interior design than men. No direct effect on self-report health outcome, probably due to the participants were mobile and received variety of treatment and activities at the center.	Raanaas, Patil & Hartig (2010)
Zanzibar Gem, Tradescantia spathacea	Potted plant and posters of plant in a hospital waiting room	Both real indoor plants and posters of plants were equally effective in reducing stress in patients because they improved the attractiveness of the room.	Beukeboom, Langeveld and Tanja-Dijkstra (2012)
Pelargonium odoratissimum, Alocasia Rhizome, Mentha haplocalyx, Lavandula (Lavender), Sansevieria trafasciata, Euphorbia pulcherrima (Poinsettia)	Potted plant in an office environment	Participants' satisfaction increase with slight scent plants (Lavender, S. trafasciata, Poinsettia, and A. rhizome) and small sized plants (Lavender, M. haplocalyx, P. odoratissimum), followed by medium and big sized plants.	Qin et al (2014)
Dracaena deremensis	Actual potted plant and picture of plant	Viewing actual plants may have psychological benefits not replicated by the image through increase Oxy-hemoglobin concentrations. Real plant and picture of plant, both induced feelings of comfort and relaxation.	Igarashi et al. (2015)
Epipremnum aureum	Vertical green system in a lab	Viewing foliage plants associated with positive images and feelings, but the density does not really affect people physiological parameters.	Choi et al. (2016)
Aglaonema commutatum, Epipremnum pinnatum	Potted plant in class room and hallway	Active engagement with plants provide greater stress restoration. Active and passive interaction with plants increase self-reported attention restoration. Distant of plant is not associated with positive impacts.	Han (2017)

for male and female occupants in the indoor environment are possibly non-identical. Future research can investigate this possibility more explicitly, to provide a more concrete evidence.

There is a raft of studies demonstrated that the presence of plants can help in reducing blood pressure (Lohr et al., 1996), perceive stress in a hospital environment, and pain tolerance (Dijkstra et al., 2008; Bringslimark et al., 2009). For instance, Park and Mattson (2009) reported that the patients exposed to plants during recovery had significantly enhanced physiologic responses (i.e. systolic blood pressure, pain tolerance, anxiety, and fatigue), evoked positive feelings and showed higher satisfaction about their hospital room. Another study by Beukeboom et al. (2012) posit both real plants and posters of plants are equally effective in reducing negative psychologic feelings of patients. It is due to both real plants and posters of plants improved the perceived attractiveness of the room. It happened because the stress reduction effect of plants are mediated by the perceived attractiveness of the space (Dijkstra et al., 2008). Besides, attractiveness factor, active interaction with plant also contributed to greater stress restoration, for instance, having physical activities in a garden/ yard, engagement in horticultural activities, gardening and farming (Han, 2017; Korpela et al., 2017). There is study suggested both real plants and the image of plants can induce feelings of comfort and relaxation. Nevertheless, real plants may provide better psychological benefits (Igarashi et al., 2015). The selection between real or image of plants in the indoor environment is therefore depended on the usages of the space. For instance, in a clinical environment, the image of plants maybe more suitable because some species of plant may trigger allergic reaction and infection. Meanwhile, in an office and a home environment with no occupants that are sensitive to infection or allergy, placement of real plants are highly encouraged. In fact, one study suggests that complaints regarding cough, fatigue, feeling of heavy-headed, headache, hoarse throat and dry or flushed facial skin were decreased by 23% to 37% with the presence of plant (Fjeld, 2000). There is also less reliable statistical finding of having more plants in view with lower stress (Bringslimark et al., 2007). The reasons might be due to the plants were perceived less attractive in the indoor environment (e.g. size, shape, species, and colour). For instance, the study of Qin et al. (2014) illustrated that the occupants showed highest degree of satisfaction when green, slight scent and small sized plants, are located in the office environment.

The results provided by Choi et al. (2016) showed no significant difference between the index of greenness (density) and psychophysiological stability, even a small amount of plants can bring positive impacts by stimulating the autonomic nervous system. Despite all the positive impacts that plants could offer, there is a study reported non-statistical significant results. For instance, Raanaas et al. (2010) reported that there is no significant association between the presences of plant with self-reported health in a rehabilitation centre. The insignificant results might be due to the participants were exposed to various treatments and activities taking place at the centre. Similarly, Shoemaker et al. (1992) found no direct association between plants with behaviour, attitudes and work satisfaction in the office environment, however, the employees felt calmer and relaxed with the presence of plants, and make the office a more desirable place to work in general. One of the reasons is that plants do not influence the employees' behavior, attitudes and work satisfaction might be because the employees already satisfied and enjoyed their jobs and the work environment. Hence, the presence of plants seemed to have relatively minor implications.

4. Indoor Environment Quality

Another role of plants is to improve the indoor environment quality (IEQ) and to promote general well-being of the people. Certain species of plants could effectively reduce the carbon dioxide, increase the comfort level in heated interior spaces, and reduce VOC and particulate matter accumulation (Lohr and Pearson-mims, 1996; Tarran et al., 2007). There is a plethora of study suggests the effectiveness of plants in helping to bring down the concentrations of VOC such as benzene, formaldehyde, and trichloroethylene (Wolverton et al., 1989.) Some of the VOC appear to have carcinogenic effects on humans, for example, formaldehyde from aging furniture and pressed wood products (Hun et al., 2010). Other than that, benzene and xylene are also confirmed carcinogens in which short term exposure to them may contribute to respiratory difficulties and feeling of discomfort. Meanwhile long-term exposure to them can result in neurotoxicity, respiratory disease and teratogenic effects (Wood et al., 2006). Hence, putting potted plants in the indoor environment will be a good option because they could act as a less expensive and sustainable indoor air purifier through bioremediation process. For instance, the evidences provided by Liu et al. (2007) demonstrated that there are ten species of plants could effective in reducing benzene, meanwhile three of the species (i.e. *C. portulacea, H. macrophylla and C. Golden Elf*) can remove benzene up to 80%. Similarly, Tarran et al. (2007) demonstrated that some species of plant can reduce total volatile organic compounds (TVOC) up to 75%. Moreover, Xu et al. (2011) discovered that *C. comosum*, *A. vera*, *E. aureum* removed more formaldehyde during day time because of higher photosynthesis and metabolism in plant under soil growing media, meanwhile Aydogan & Montoya (2011) found out that *H. helix* and *C. morifolium* showed quicker removal of formaldehyde under dark condition in hydroponic growing media. Similarly, Wood et al. (2002) provided evidence that *D. deremensis* 'Janet Craig' is effective in removing benzene, while H. Forsteriana is better in removing n-hexane. It is also worth to note that, plants in hydroponic growing media removed VOC slower than potting mix (ibid). This indicates different type of growing media, type of plant species and the light conditions may influence the uptake of VOC distinctively. Hence, introducing copious type of species of plants in the indoor environment are highly encouraged.

The production of CO^2 in the indoor environment is not as critical as VOC, but excessive CO^2 is likely to contribute to narcotic and sick building syndrome (Milton et al., 2000). Early study found out that some species of indoor plants can reduce

Table 2 Different type of plant species contribute to bring down VOC, CO_2, and particulate matter

Type of Plant Species	Settings	Type of Improvement	Author(s)
Aglaonema sp., Chamaedorea seifrizii, Dracaena marginata, Epipremnum aureum, Spathiphyllum sp.	Potted plant in a computer lab and office	Particulate matter on horizontal surfaces can be reduced up to 20%.	Lohr and Pearson-mims. (1996)
Howea forsteriana, Spathiphyllum wallisii, Draceana deremensis 'Janet Craig'	Potted plant and hydroponic, in a test chamber	D. deremensis is good in removing benzene, Howea is good in removing n-hexane.	Wood et al. (2002)
Dracaena deremensis 'Janet Craig', Spathiphyllum 'Sweet Chico',	Potted plant in an office environment	Potted-plants could deduce VOC up to 75%. Three floor-specimens of D. 'Janet Craig' are as effective as six. Potted-plants appeared equally effective under air-conditioned and non-air-conditioned circumstances	Wood et al. (2006)
Crassula portulacea, Hydrangea macrophylla , Cymbidium Golden Elf, Ficus microcarpa var. fuyuensis, Dendranthema morifolium, Citrus medica var. sarcodactylis, Dieffenbachia amona cv. Tropic Snow, Spathiphyllum Supreme, Nephrolepis exaltata cv. Bostoniensis, Dracaena deremensis cv. Variegata	Potted plant in test chamber	All 10 species of plant can remove more than 20% of benzene. C. portulacea, H. macrophylla and C. Golden Elf show notable high benzene removal up to 80%.	Liu et al. (2007)
Aglaonema modestum, Zamioculcas zamiifolia, Dracaena deremensis 'Janet Craig', Spathiphyllum 'Sweet Chico'	Potted plant in test chamber and office	Dracaena and Spathiphyllum (6 specimen) can reduce up to 75% TVOC. A. modestum and Z. zamiifolia can remove benzene (25ppm) effectively to zero in less than 48h. Dracaena reduced CO_2 by about 10% in air-conditioned building and 25% in the non-air conditioned building. CO cut down by 8% to 14% with or without air conditioning.	Tarran, Torpy and Burchett (2007)
Sansevieria trifasciata, Chlorophytum comosum, Epipremnum aureum	Potted plant in test chamber housed inside greenhouse	All plants in this study were effective in mitigating ozone, O_3.	Papinchak et al. (2009)
Chlorphytum comosum, Aloe vera, Epipremnum aureum	Potted plant in a test chamber	C. comosum attained the greatest formaldehyde removal capacity. More formaldehyde were removed during day time because higher photosynthesis and metabolism in plant.	Xu, Wang, Hou (2011)
Hedera helix, Chrysanthemum morifolium, Dieffenbachia compacta, Epipremnum aureum	Potted plant with growstone, expanded clay, and activated carbon under hydroponic growing media in a test chamber	All species can remove formaldehyde (around 90%). Activated carbon alone (AC) showed the highest formaldehyde removal at about 98%. All plants showed quicker removal of formaldehyde under dark condition excluding the aerial part of D. compacta and E. aureum.	Aydogan & Montoya (2011)
Aglaonema commutatum, Schott, Aspidistra elatior Blume, Castanospermum australe A. Cunn ex Hook., Chamaedorea elegans Willd. Dracaena deremensis 'compacta' Engl., Dypsis lutescens (H. Wendl.) Beentje & J., Dransf. Ficus benjamina L., Howea forsteriana Becc.	Potted plant in test chamber	CO_2 removal efficiency was high for two species, F. benjamina and D. lutescens C. elegans, A. commutatum and H. forsteriana recorded greater CO_2 reductions in the low light treatment (well-lit indoor light). H. forsteriana and D. lutescens were capable of net removal of CO2 at very low light levels. Dracaena 'Compacta' suitable for low light situation	Torpy, Irga, Burchett (2014)
Chamaedorea elegans, Peperomia jayde, Chlorophytum comosum 'variegatum', Dracaena deremensis 'Janet Crag', Ficus benjamina, Dracaena marginata, Schefflera arboricola 'Variegata', Juniperus chinensis 'San Jose', Sansevieria trifasciata, Sophora macrocarpa 'mayo', Quercus suber	Potted plant in a test chamber and outside of the chamber	F. benjamina, J. chinensis, significantly reduced UFP (diameter <100mm). Broad leaves, dense, and variegated surface area are effective in UFP reduction.	Stapleton and Ruiz-Rudlph (2016)

CO^2 up to 25%, for example, *F. benjamina, D. lutescens, D. 'Janet Craig'* are among the indoor plant species that are good in CO^2 reduction (Tarran et al., 2007; Torpy et al., 2014). The use of office printing machines, laser printers, ultraviolet lighting may also contribute to the increase of indoor ozone (O^3) level, which can negatively impact the human health. And to bring down O^3 level, placement of plants in the indoor environment will be a good choice (Papinchak et al., 2009). In addition to that, some of the indoor plants also help in reducing ultra-fine particle (UFP) accumulation, especially plants with broad leaves, variegated surface area and dense, are effective in UFP reduction (Stapleton and Ruiz-Rudlph, 2016). Despite all the benefits provided by potted plants as suggested in previous research, Moya et al. (2018) suggest that active vegetation system (green systems in combination with mechanical fans) performs more efficient than passive vegetation system (potted plant) in term of air cleaning rate. For instance, the use of vertical green system integrated into building ventilation system might be one of the possible solutions to promote indoor environmental quality even though the potency might not as good as the conventional HVAC filter (see Irga et al., 2018, p.406). Nonetheless, indoor plants still could help to reduce the dependence of HVAC ventilation, subsequently, reducing energy usage, greenhouse gas emission and carbon footprint (Torpy et al. 2014).

4. Findings and Future Study

Out of 40 articles we had reviewed, only 21 articles were used in eliciting the plant species because some of the studies did not specify the type of species (e.g. Shoemaker et al., 1992; Larsen et al., 1998; Dijkstra et al., 2008; Korpela et al., 2018). All the plant species are listed in Table 3.0. It was found that *E. aureum* (10), *D. deremensis 'Janet Craig'* (8) and *Spathiphyllum sp*. (7) are the most common plants being examined. All these plants have showed adequate positive results in the experiments. However, the researcher cannot verified that whether the psychological and physiological health benefits are actually provided by these plants. This is because in their research design, the experiments conducted was mixed with various other plant species. Nevertheless, there are significant evidences reported that *D. deremensis 'Janet Craig'* and *Spathiphyllum sp*. are effective in removing VOC (e.g. Wood et al., 2002; Wood et al., 2006; Tarran et al., 2007). Other plant species such as *A. commutatum 'Schott'*(4), *C. comosum* (3), *D. marginata* (3), *S. trifasciata* (4), *S. arboricola* (3), and *P. hederaceum* (3) were also among few of the species that frequently being studied. Meanwhile, plant species such as *A. modestum, A. rhizome, A. vera* and some other species (see Table 3) are still not widely being investigated.

Table 3 Type of plant species used in the indoor environment. Pictures Source: EEOB (2020), NCSTATE (2020) and Plant Identification (n.d)

No.	Types of plant	Count	Pictures
1.	Aglaonema sp.	2	
2.	Aglaonema commutatum Schott	4	
3.	Aglaonema modestum	1	
4.	Alocasia Rhizome	1	
5.	Aloe vera	1	
6.	Aspidistra elatior Blume	1	
7.	Beaucarnea recurvate	1	
8.	Castanospermum australe A. Cunn ex Hook	1	
9.	Chamaedorea seifrizii	2	
10.	Chamaedorea elegans	2	
11.	Chlorophytum comosum	3	
12.	Chrysanthemum morifolium	2	

13.	Citrus medica 'sarcodactylis'	1	
14.	Crassula portulacea	1	
15.	Cymbidium Golden Elf	1	
16.	Dendrobium phalaenopsis	1	
17.	Dieffenbachia amoena 'Tropic Snow'	1	
18.	Dieffenbachia compacta	1	
19.	Dracaena concinna	1	
20.	Dracaena fragrans 'Massangeana'	2	
21.	Dracaena marginata	3	
22.	Dracaena deremensis 'Janet Craig'	8	
23.	Dracaena deremensis 'Compacta'	1	

24.	Dracaena deremensis 'Lemon Surprise'	1	
25.	Dracaena reflexa	1	
26.	Dracaena surculosa	1	
27.	Dracaena warnekii (variegata)	1	
28.	Dypsis lutescens	1	
29.	Epipremnum aureum	10	
30.	Epipremnum pinnatum	1	
31.	Euphorbia pulcherrima 'Ponsettia'	1	
32.	Ficus benjamina	2	
33.	Ficus microcarpa 'fuyuensis'	1	
34.	Hedera helix	1	

35.	Homalomena siesmeyeriana	1	
36.	Hoya sp.	1	
37.	Howea forsteriana	2	
38.	Hydrangea macrophylla	1	
39.	Juniperus chinensis 'San Jose'	1	
40.	Lavandula (Lavender)	1	
41.	Liriope muscari	1	
42.	Mentha haplocalyx	1	
43.	Nephrolepis exaltata 'Bostoniensis'	1	

44.	Pelargonium odoratissimum	1	
45.	Peperomia jayde	1	
46.	Philodendron scandens/cordatum/ hederaceum	3	
47.	Pteris cretica 'Albolineata'	1	
48.	Quercus suber	1	
49.	Rhapis excelsa	1	
50.	Sansevieria trifasciata	4	
51.	Schefflera arboricola	3	
52.	Scindapsus pictus 'Argyraeus'	1	
53.	Sophora macrocarpa 'mayo'	1	
54.	Spathiphyllum sp./ 'Supreme'/ 'Sweet Chico'/ wallisii 'Startlight'	7	

55.	Syngonium podophyllum 'Albolineatum'	2	
56.	Vinca minor 'Illumination'	1	
57.	Trachelospermum asiaticum 'Ogon nishiki'	1	
58.	Tradescantia spathacea	1	
59.	Zamioculcas zamiifolia	2	

From the past studies, it is clear that indoor environmental quality plays important role in general well-being of building occupants and interacting with plants can positively change psychological and physiological responses. Previous investigations have emphasized the advantages of including plants in the indoor environment. Nevertheless, one dimension still can be further investigated is the physical characteristic of plants, and their composition in order to improve the overall attractiveness of the room. Qin et al. (2014) also suggest the same, there is a lack of study on plants' inherent characteristics such as colour, odour and size on human comfort. Other than that, the distance between the positions of the plant with the occupants also show inconsistent results (Han, 2017). Hence, future study can seek to explore on the different type of composition (size, colour and smell) of plants and their arrangements (location and proximity).

5. Conclusion

The inclusion of plants in an indoor environment may positively impact our psychological response and physiological health. However, not all of them have shown adequate correlational positive results. And often the results are highly regulated by several factors such as different in gender may express dissimilar level of satisfaction, and different physical characteristics of plants may change the perceived attractiveness of the space and thus affecting the efficacy of stress reduction. Nevertheless, the functions of plants to improve the indoor environment quality through bioremediation are undeniable. Thus, people are becoming more interested to place the plants in their indoor environment, not just mainly for the restorative effect that plants could offer, but also for their function as a low-cost air purifier. This review has shown substantial evidences on how plants can contribute to the betterment of indoor environment and how they improve the psychological and physiological health of the occupants. In practice, this review opens a new insight for the landscape architect, interior architect and designer to select the appropriate type of plant species in an indoor environment, not just purely for the aesthetic aspects, but also the functional aspects.

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Perceived Effect Of Urban Park As A Restorative Environment For Well Being In Kuala Lumpur

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Abstract

A restorative environment tells how certain types of environment help heals people mentally and physically, and many studies in the related field have drawn connection that natural and green places are more likely to be restorative to a person's health, especially when compared those living in cities. In Kuala Lumpur, rapid urbanization and previous poor city planning result in residents becoming increasingly susceptible to mental fatigue and urban stress. Residents frequent for the very few urban parks available as a place to restore themselves, thus the restorative qualities of the urban parks are critical to elevating the quality of life. This study investigates the theory of restorative environment and highlighting its criteria in the context of Kuala Lumpur, by analyzing an existing urban park as a case study: the Perdana Botanical Garden. The methods used include site observation, interview, and a questionnaire to evaluate the quality of the environment as well as user perception. Data from finding confirms the restorative theories as perceived by users and its suggested space criteria and shows that most users come to the park as green therapy and to relieve stress and relax, as they find that the natural scenery and engaging landscaping inside the park are restorative to their overall well-being.

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1. Introduction

Numerous studies have shown that natural environment, commonly associated with green spaces and blue spaces can be restorative to a person's well-being and heal their daily stress and mental fatigue (Cooper Marcus & Barnes, 1995; Kaplan, 1995; Mazuch & Stephen, 2005; Völker & Kistemann, 2011; Jiang, 2014; Finlay et al., 2015; Akpinar et al., 2016; Wood et al., 2017).

1.1 Urban Setting and the Need for Urban Park

In urban settings, access to nature is limited due to the rapid rise of the concrete environment. People become increasingly susceptible to many urban stressors with no way to negate resulting in mental fatigue and related problems such as stress, depression and anxiety which nowadays has become an arising issue for city dwellers (Finlay et al., 2015; Wood et al., 2017; Founder, 2018; Curry, 2018; "Environmental Stressors," n.d.). Thus, the existence of a breathing space in the city, specifically urban park is essential to tackle this problem.

Previous studies by Finlay et al.,(2015) and, Wood et al., (2017) mentioned that the existence of breathing space in the cities, specifically urban parks, as a means for rejuvenating and healing oneself is vital for these users. Kaplan (1995), Volker & Kistemann (2010), and Finlay et al.,(2015) agreed on the idea that green and blue spaces, as well as specific facilities in the park, can offer a place where one can be active physically and mentally. Such areas can promote a sense of self of self-restoration and rejuvenation, reduce mental stress, and offer a place for social well-being.

Hartig et al., (2011), in his findings, agreed that with a concentrated urban population, naturally, people often feel the need to escape overwhelming human-made concrete jungles of the cities. Nature, especially urban parks, often involve getting away from those urban settings, besides being an exciting and engaging experience. Furthermore, elements of green and blue spaces in the urban park can promote a sense of well-being and restoration that does not tax the mind by offering pleasantness, tranquil, and calmness (Finlay et al.,2015; Hartig et al. 2011).

1.2 Restorative Environments

The restorative environment in the context of environmental psychology is referring to the process of recovery of both psychological or physiological being that is mainly due to specific elements or configuration in the environment, thus, the term restorative environments (Steg et al., 2013).

The term associated with this research of restorative settings such as healing garden, therapeutic landscape, has been coined to refer to how a space with natural affinity can improve human well-being and their daily lives. Kaplan and Kaplan (1989), one of the pioneers in the field of restorative environment, have concluded from their findings that humans that have access to a close natural environment are comparatively healthier overall than others with no access to the natural environment.

Finlay et al., (2015) supported the concept of therapeutic landscape and well-being indicate that nature plays a nuanced and influential role in the everyday lives of an older adult.
They draw these conclusions based on an interview with the participant aged 65-86 years old who described their daily experience with green and especially blue space in Vancouver, Canada.

Additionally, Hartig et.al (2003) talked about restoration in natural and urban field settings and their comparison and found out that walking in nature fostered a blood pressure change that indicates a reduction in stress than afforded by walking in urban environments.

Similarly, Wang et al., (2016) also take a further look at stress recovery effects of different videotaped scenes of six urban parks and urban roadway scenes in efforts to study the natural environment benefits to human health and well-being. They described urban parks as a human-made environment with components from nature, such as shrubs, lawns, trees, and many more. His study further confirmed previous findings that nature-based urban park scenes restored stress and attention level.

1.3 Historical Background of Restorative Environment and Its Related Theories

Collective research that delves into the topic of the restorative environment has primarily been guided by two theoretical explanations, each with its own set of ideas and definitions of what is mean by restoration.

Stress Recovery Theory (SRT: Ulrich,1983; Ulrich et al., 1991), which is primarily focused on restoration due to the stress that occurs when an individual encounters with least favourable and threatening situations to his or her well-being. Ulrich (1999) proposed that when humans perceived a natural environment that is peaceful, relaxing, and safe such as a forest or a garden, stress is reduced. The environment then affords users of five factors:

1. Sense of security
2. Sense of control
3. Capacity to increase social support
4. Provision for physical movement and exercise, and
5. Access to nature and other positive distractions.

These five factors thus are essential to make humans feel comfort and aids in restoration.

Attention Restoration Theory (ART: Kaplan,1995; Kaplan & Kaplan, 1989). This theory gives focuses on the restoration from attentional fatigue that occurs after prolonged engagement in a task that is mentally exhausting and fatiguing. Mental fatigue, according to Kaplan et al., (1998) is a situation that wears down one's mind and attention, as a result of directed attention, a mental effort to focus, as agreed by Herzog et al., (2003). Attention Restoration Theory (ART) by Kaplan et al., (1998) proposes that after a period of continuous use of directed attention, the capacity of a person to fend off distractions become depleted. An attentional fatigue person suffers from difficulty in concentrating, becomes impulsive in action and easily irritated, and also prone to errors on the task that require cognitive abilities (Kaplan et al.,1998).

By contrast, viewing or being in a natural setting that does not require reliance on directed attention, allows the mind to effortlessly rest and recover from the exhausting attention capacity and thus help to reduce mental fatigues and restore their overall well-being (Kaplan et al., 1998; Herzog et al., 2003; (Staats et al., 2003 (Akpinar et al., 2016; Allison et al., 1998)
As described in ART, to recover from mental fatigue, a setting should have four qualities; being away, extent, fascination, and compatibility (Kaplan et al., 1998).

Being away qualities refers to a personal sense of being taken away from his or her everyday monotonous or hectic environment into some other geographical place that is either soothing or calming. (Herzog et al., 1997; Hartrig & Staats, 2003; Staats et al., 2003). Extent is the quality of settings that

are rich and interesting enough in contents that engage the mind and promoting exploration, effortlessly, and involuntarily.

Fascination is where an environment can automatically grab and engaged an individual's attention effortlessly without requiring cognitive effort from stressful demands. Studies by Herzog et al., (2002), suggest how ordinary natural environments to be highly effective in restoration, where they engage soft fascination that allows viewers to attain two restorative benefits; attention and reflection (Herzog et al., 1997, Said, 2008). Soft fascination allows directed attention a moment of pause, giving room for mental reflection, which is put, the ability of a person to find out what is bothering his mind (Kaplan et al., 1998, Said 2008). Compatibility refers to how a setting can accommodate what a person wants to do, must do, and can do in the environment. In other words, the setting fits for a user's purpose, inclination, and activities. (Staats, et al., 2003; Steg et al., 2013).

According to restoration theory, any environment or settings that have one or more of these restorative properties can thus be said to be restorative (Kaplan and Kaplan 1989). The natural environment has proven to be consistent in positively affecting human well-being and are preferred for restoration. Additionally, Kaplan & Kaplan & Ryan (1998) also described a restorative environment as spaces with the following characteristics.

1. Quiet fascination
2. Wandering in small spaces
3. Separation from distraction
4. Wood, stone and old
5. View from window

These characteristics of spaces, as highlighted by Kaplan & Kaplan & Ryan (1998), are effortlessly found in nature and any natural settings that are designed to take one's mind off of things. Even by having a window view towards nature can be as beneficial. There also exists the culture of 'ikigai/ forest bathing' in Japan, where one spends time outdoor in woods to recharged and be healed. These thus relate back to the above-hypothesized relationship between environment and health by Parsons, Ulrich, & Tassinary, (1994), whereby one perceived natural environment, immediately their mental and physical are improved as their stress level decreased.

ART and SCRT, are theories that focus on human perception towards viewing and exploring natural environments.

However, though literature looked into the restorative environment and its related theory, few works of literature focused on how the theory pan out, its validity, and if it is perceived by users in real-life situations, especially in Malaysia. Therefore, this study aims to address that gap and understand the criteria of a restorative environment and user' perception in the urban park as a medium for healing and restoration. In conjunction, the objectives of this research are to investigate the characteristics and qualities of outdoor settings that give the effect of healing and restoration to human well-being, focusing on an urban park as a case study that has a combination of both natural and built environment. This study will be beneficial to assist professionals to design a better restorative space.

2. Methodology

2.1 Case Study Method

Based on Robert K. Yin (2014), a single case study method was best used to investigate the theory of restorative environment within an existing and real-life context, especially when the gap between the restorative phenomena and context is not specified, specially in terms of scientific numbers. Hence for this study, the case study method would be imperative in investigating whether the restorative element theory exists in real life and relate to urban park context and if its effect perceived by the user.

Furthermore, this research aims to understand the theory of restorative environment. Thus, only one case study was used. One of the main rationalities in choosing one single case study rather than a multiple-case study is when that single cast study represents the critical test of a significance theory (Yin, 2014). Since this study is mainly to confirm, challenge, and or extend the theory, the single case study meeting all the conditions for testing was used to determine the validity of the theory and its relevancy.

2.2 Case Study Selection & Justification

Perdana Botanical Garden in Kuala Lumpur was chosen as a case study based on its location, functional value, the community around, and design criteria. It is located in a strategic urban centre that is easily accessible and the park amenities are adequate to study the restorative elements (see Figure 1).

2.3 Observation

Based on the studied theory, the case study park displays qualities and criteria that make for a successful healing and restorative environment with its well thought out spaces and amenities around. There are many species of trees and plants planted around to create an extensive botanical collection complete with the info on each species. The park upon observation is also well maintained and free from rubbish. The overall impression of the facilities surrounding the park also shows the parks are regularly maintained as there is no broken facilities insight (see Figure 2). These findings, however, do not show the users perception towards the park, thus findings from the survey were analysed thoroughly to relate to the successfulness of the park as a medium for healing and restoration.

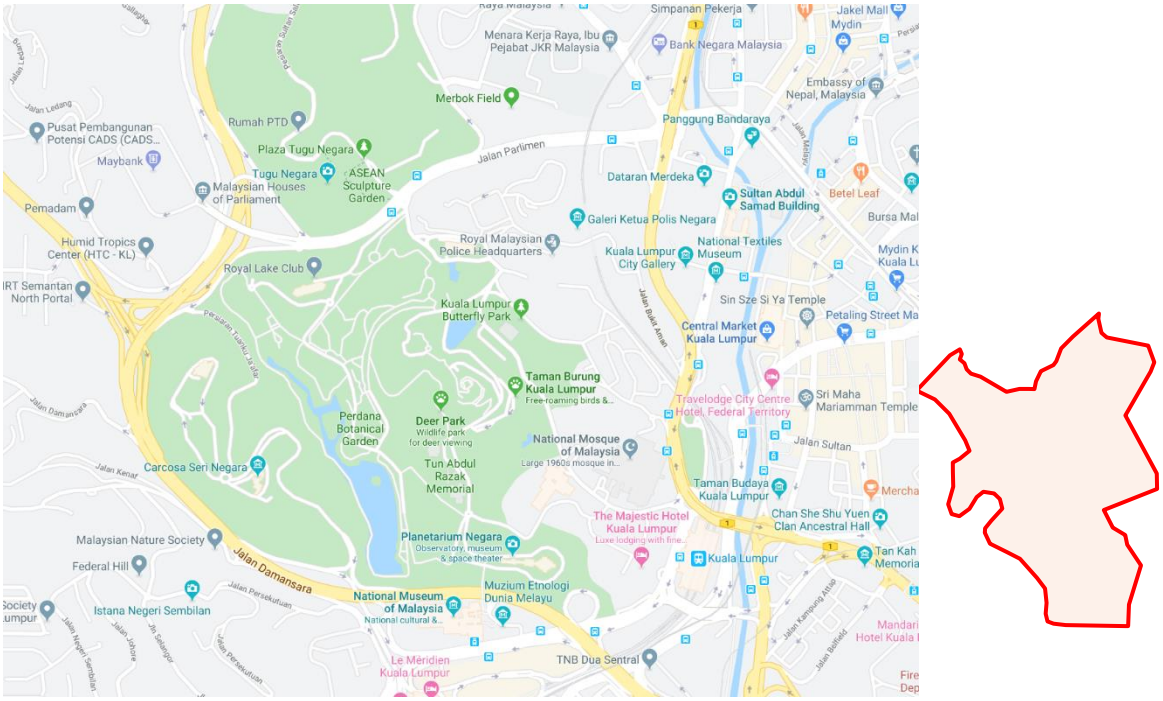


Figure 1 Figure showing the location of case studies in Tun Abdul Razak Heritage Park. (source: (Maps.google.com, 2019).

2.4 Questionnaire Survey

The questionnaire was developed from the set of criteria of a restorative environment and its theories, as previously discussed. Some points that were deemed relevant to be studied that were not initially listed in the literature review were also taken to study. The questions are constructed to test the hypothesis and theory of the restorative environment in the urban park and to validate and identify user behavior and perception of the place concerning space quality.

The respondents were randomly recruited based on random techniques approach; users are chosen based on their willingness to partake in the survey, their availability in the vicinity as well as their ability to respond to the questions (Rea & Parker, 1997). Similarly, this research data collection was completed through questionnaire surveys self-filled out by park users.

i. Structure of the Survey Questions

The survey was divided into sections to find out users' use, activity, preference, and perception of the parks as a medium for healing and restoration. Users were given brief information on the survey aim to help them thoughtfully answer the questions on what they perceived.

Two-level of measurements: nominal and ordinal were used to find out user response and perception. Nominal measure was used to measure either a two-way question or multiple-choice question and adjective checklist question to determine the variables (Said, 2013). Some of the questions were open-ended or close-ended to give users more freedom to express their perception, satisfaction, and opinion.

Ordinal measure, the Likert scale was used to measure the agreement of users on five ordinal response categories, which are;

1: Disagree 2: Slightly Agree 3: Moderate
4: Considerably Agree 5: Extremely Agree

Said (2013) stated that, to discover users' perception, impression, beliefs, feeling, and attitudes on certain experiences and environments, the Likert scale was appropriate and suitable to be used. Thus, some of the questions on the constructed questionnaire apply the method of Likert scale as well to get a measure of people's responses.

Nominal measure, for example, in Section A was to find out the demographic info of the respondent such as their gender, age, occupation, and their primary purpose in coming to the park, as well as the preference of time and frequencies of them coming to the park. It will also give an in-depth review of who the park most often serves as well as the primary purpose of the users who come to the park. Section B investigated the general perception of users in an urban park from their perspective, their most favourite elements as well as the activities they normally do. Section C looked into the validity of the restorative elements, as stated in the ART theory and whether the users of the park agree and feel the restorative effect. This is to prove if the theory is relevant and felt by the users. The

hypothesis is that since the case studies possess all the qualities as stated in the ART theory (validated by observation finding), would the end-user be able to feel restored as per suggested in theory?

Section D investigated users' perception of the park concerning the SCRT theory. From the literature review, SCRT proposed that stress is reduced when the environment affords the users these five elements: sense of security, sense of control, capacity to increase social support, provision for physical movement and exercise, and access to nature and other positive distractions. Therefore, the questions in these sections were designed accordingly to attest to the validity of the elements and whether users of the park agree with the statement that reflects the theory

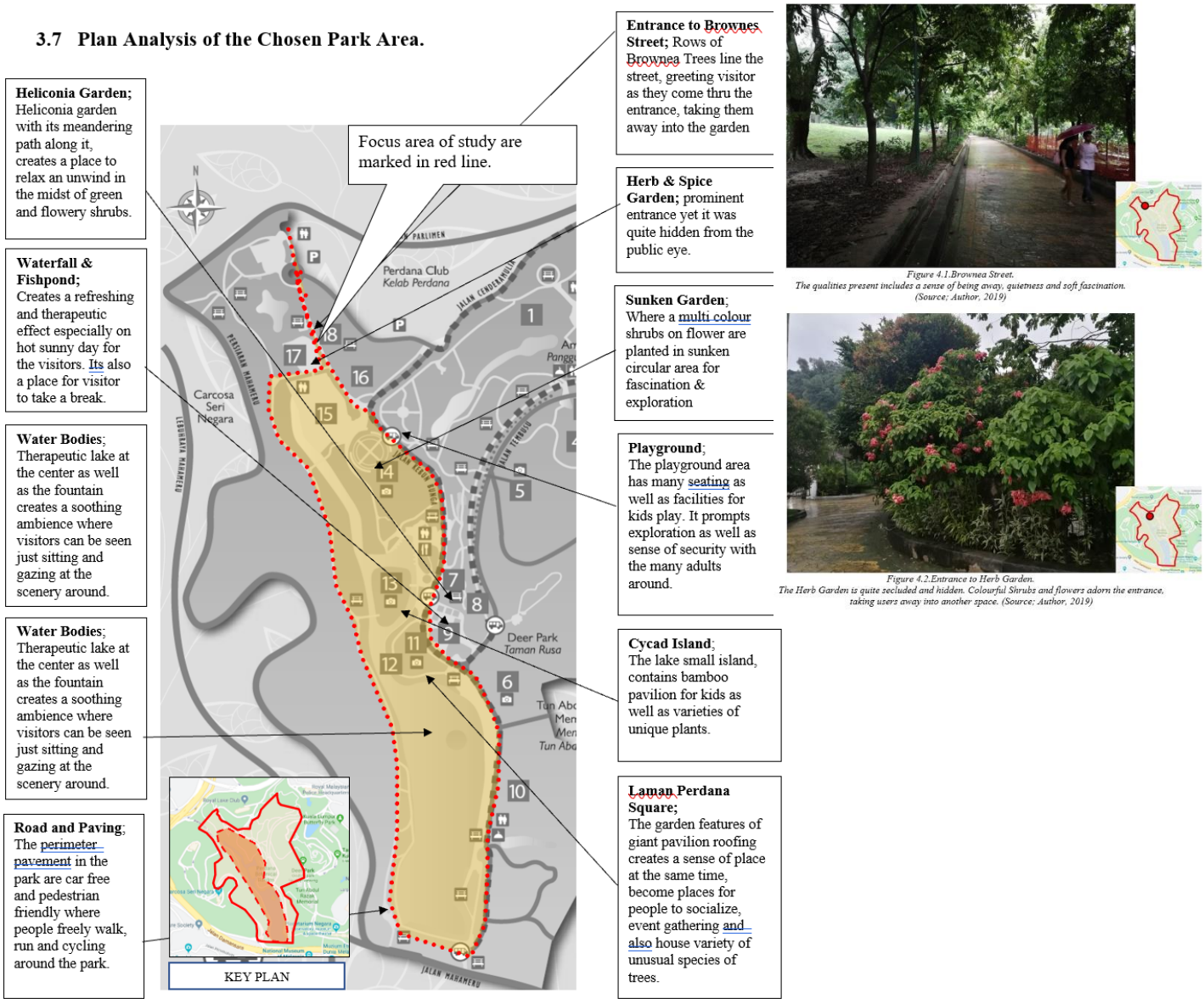


Figure 2. Summaries of plan analysis of the chosen park area for study, highlighting the perceived effect of restorative qualities felt during field observation. (Source from http://de.maps-kuala-lumpur.com/perdana-botanical-garden-anzeigen 2019)

2.5 Interview

A structured interview is conducted to gather more supplementary information on the case study, its design and intention, problems, and to support the primary data collection. These interviews are conducted towards the authorities and the landscape architect who is responsible for the case study chosen through a phone call, email, and face-to-face interview.

2.6 Data Analysis

Data collected from the survey, interview, and site observation over three weeks on a randomized date includes weekday and weekend. These data were then categorized accordingly to each question to focus on the response of each to give a brief overview of data discovered. This method of analysing data provides a triangulation between data gathered survey questionnaire, in observation (using field notes and photos), interview with authority. Data then was cross-referenced with the literature review to confirm if the findings coincide with what the literature theorizes on the restorative environment and urban park as a medium for restoration, which will be discussed in the next session.

3. Results & Discussion

3.1 Findings from Questionnaire Survey

Section A |General Background Information

There were a total of 77 respondents (64.9% female and 35.1% male). These large number of the female, which is 29.8 % more than male may be contributed to the number of female ratios that is higher than men. Furthermore, females are more likely to seek stress reliever by taking a stroll in a green urban park as compared to men.

Most respondents (40.3%) were from the 19-25 years group. This group of people was primarily of college and university students and recent graduates. They have allocated the majority of their time for recreation and relaxations when compared to other age groups. The second-largest number of respondents (22.1%) is from the age group of 25 to 30 years old. The survey also revealed that most of them 42.9% work in the private sector. 40.3% are still studying, which ties back to the number of age groups between 19-25 years old.

Most of them (41.6%) came to the park to take a break and as a stress reliever. The second most popular choice of the answer at 26%, is recreations, exercise and to train their bodies. This data strongly ties back to the theory that people are more relaxed, less stressful, and feel restored when being in contact with nature, thus the reason they come to the park. A few respondents voiced out that recreations and exercise in the park are better compared to other urban areas due to the cleaner air and green surrounding. Sightseeing in the park is also a form of restoration for some people where they can change sceneries, unwind, and gather back their thoughts.

In terms of the frequency of users coming to the park, 39% seldom come to the park. 26% answered that this is their first time coming to the park, and 18.2 % answered that they come to the park monthly. This shows that most of the people who come to the park are seldom there, which may be due to the burden of hectic daily tasks and responsibilities and stress. This finding is also may be due to the distance between their house and the park is quite far, in addition to the lack of parking area and public transport. Some of them who stated that this is their first time might be due to not being a local. During data findings, a few respondents are foreigners and come to the park as part of their exploration in Kuala Lumpur.

53.2%, prefer to come to the park during the evening, which is between 5 pm to 9 pm. This is because the evening being a popular time to relax after work and socializing with the sun shining less hot. Meanwhile, 33.8 % of them prefer to come in the morning. From observation, there are considerably fewer people, and the sun is still shining, but the air is colder and less hot as compared to during the afternoon time when the sun is high. Nevertheless, they are still 13 % of them who prefer to come during noontime, which ranges from 12 pm to 5 pm. This number is in accordance with the types of activity they carry out there, which suits the noon times, for example, picnic, social gathering, and photography that are best enjoyed at noon.

Section B | User Perception in Urban Park

Section B investigates user perception in an urban park.
50.6% choose greenery and shady trees as their most preferable element in the park. 18.2 % of them choose the lake as their second most preferred element of the park. Another 11.7% choose the playground area. This data revealed that people mostly prefer greenery and shady trees as a component in the restorative environment, with soothing blue elements such as lake and water feature coming in second. This data may reflect our innate need for biophilia, which is the desire to connect with nature, as innately nature soothes.

When in the park, 53.2% of the respondents stated that relaxing was their usual activity, 44.2% prefer enjoying scenery and greenery, and 33.8% favour physical activities like exercising. This data further proves that the park has the restorative qualities that attract people to relax, exercise, and perform other activities while enjoying the scenery and greenery at the same time for maximum self-restoration.

When talking about positive mood change, the majority of the respondents with 61% pinpoint that fresh air in the park is the factor that triggers their mood to change for the better. 55.8% choose greenery and trees, and 33.8% of them prefer nature sound such as birds singing, tree leaves rustling, and water stream sound as the trigger for positive mood change. The other significant factor that users choose includes water bodies and plants with colourful flowers. This data may be because people are already weary to the polluted city air and the urban noise such as car horns and construction sound in everyday life. Therefore, being in a park with greenery, fresh air, and natural sound is an effective therapy that gives a mood boost.

The next question asks whether users agreed with the statement that urban park could be a medium for healing and restoration. They are to state the reason for their answer. From finding, only 1.3% of the respondent stated 'No' as they did not agree with the statement given. The rest of the respondents agree, and some of them have given their reason. Below is a list of some of their detailed out and interesting reasoning;

*(i) Yes, because we always **feel relax** when in the garden.*

*(ii) Yes, because I find my **inner peace and relaxing while being surrounded by nature***

*(iii) Yes, personally, humans are **part of nature**. When we are in a place where we are part of it, we **feel belonged, and this sense of belonging makes us comfortable.***

*(iv) Yes, because it allows people who live in the urban **city to escape from urban stress** by having the chance to connect with nature.*

*(v) Yes, because I can **create inner peace and relax** while being surrounded by nature.*

*(vi) Yes, because it symbolises of **zen mood, which causes calming nature and positive vibes** energy.*

*(vii) Yes, because people tend to like to see beautiful things and **sceneries as they calm people naturally.***

*(viii) Yes, because **greenery has a relaxing effect, especially to our eyes, that have been exposed to blue light** regularly in a massive amount that may be damaging them.*

These opinions have generated few common keywords related to the theories of restoration, such as *'relaxing effect', 'calming', 'inner peace', 'a sense of belonging in nature', 'biophilia', 'escape and being away', 'positivity', and others.* These respondents' answers gave light on their self-perception of the urban park that were strongly related to the theory discussed. It can be agreed that these users have indeed perceived the calming and healing effect of nature in the urban park that they are all saying the same things in agreement, which in fact, related to the theory of restoration discussed.

Figure 3 The percentage of user rating on the current park design.

This question aims to understand user ratings on the current park qualities and if they are satisfied with the current design. The majority (40.3 %) of users give a rating of "Good", a fair number (32.5 %) of people give a rating of "Very good", and 16.9 % gives a rating of fair (see Figure 3).

7.8 % of the respondents give a rating of excellence, and very few give the lowest rating, which is considered weak. This considerably high rating shows that most of the users are generally very satisfied with the current park design as a medium for healing and restoration, as it fulfilled their desires and objectives in the park, as it can be seen in earlier question findings. Thus, this can be perceived that the park is a good medium for healing.

Section C | Attention Restoration Theory (Art)

Section C investigates the validity of attention restoration theory related to the urban park. The question is designed to reflect the component, as stated by the Attention Restoration Theory. (see Figure 4)

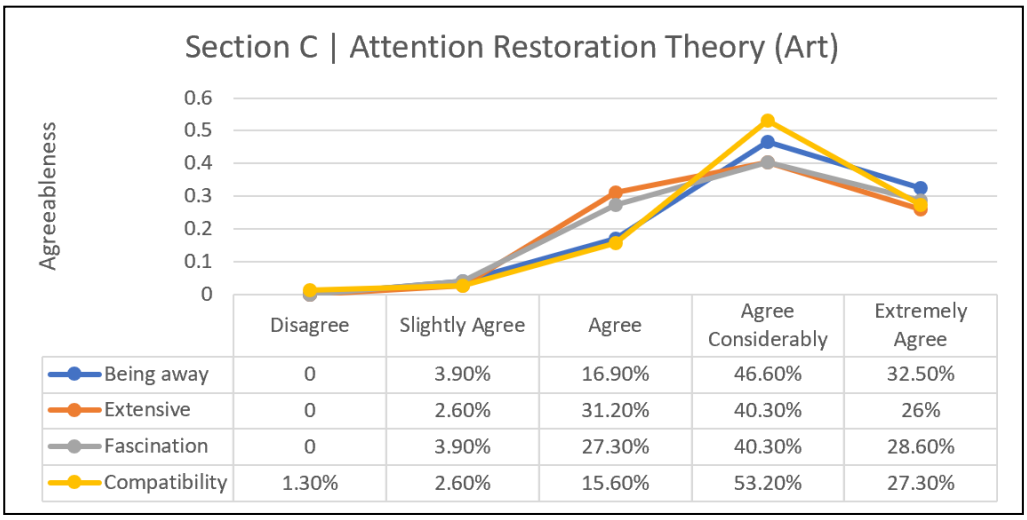
Component: ***being away qualities***. Most respondents (46.8%)
Component: ***Extensive rich and engaging to both the mind and body***. The majority of the respondents (40.3%) put on a rating of 4, which indicates that they agree considerably with the statement. 31.2% of the respondents placed a rating of 3, which indicates a moderate level of agreeableness, whereas 26% of them placed a rating of 5, which indicates extreme agreeableness. Since the educational botanical garden exhibit a wide variety of plant species, settings, and environment, most users feel a sense of put a scale rating of 4, which indicates that they considerably agree with the statements. 25 respondents (32.5%) indicated that they wholly agree with the component that they feel at ease and being away from their daily stress. This high number of positive scales gives an idea that most users feel at ease and being away when dwelling in the park. This may be due to the huge difference in their daily urban living context and the park environment. Furthermore, it is easier to relax in nature, especially when one is away from daily stress.

Component: ***Extensive rich and engaging to both the mind and body***. The majority of the respondents (40.3%) put on a rating of 4, which indicates that they agree considerably with the statement. 31.2% of the respondents placed a rating of 3, which indicates a moderate level of agreeableness, whereas 26% of them placed a rating of 5, which indicates extreme agreeableness. Since the educational botanical garden exhibit a wide variety of plant species, settings, and environment, most users feel a sense of exploration and wonder to explore the park around due to the many natural stimulus. Moreover, the park also educates and engage the users with new information as each type of plant species are labelled.

Component: ***abilities to effortlessly grab and engage user's attention in a positive and relaxing way.*** 40.3 % of the respondents considerably agree that the park can grab and engage their attention effortlessly. 28.6% of them choose to extremely agree with this component. This high level of agreeableness may be due to the various elements in the park that are fascinating enough to grab the user's attention. For example, the sunken garden is filled with varieties of colourful flowers, massive unique

Component: the ***environment is compatible and accommodating to the users' need***. 53.2% of the respondents considerably agrees that the park is accommodating to his or her users need, and 27.3% of them are exceptionally agreed on this. Most users come to the park to relax, de-stress, and do some

exercise and recreations. The users also felt that the park designs are considerably decent and compatible to do their intended biophilic design around the park, the bamboo playhouse structure, and many other elements around the park.



	Disagree	Slightly Agree	Agree	Agree Considerably	Extremely Agree
Being away	0	3.90%	16.90%	46.60%	32.50%
Extensive	0	2.60%	31.20%	40.30%	26%
Fascination	0	3.90%	27.30%	40.30%	28.60%
Compatibility	1.30%	2.60%	15.60%	53.20%	27.30%

Figure 4. Showing the summary of data findings collected in Section C regarding ART theory. (Source: Author)

Section D | Stress Coping Restoration Theory (SCRT)

Section D investigates the stress-coping theory. In SCRT, it states that stress is reduced when the environment affords these factors, Sense of security; Sense of control; Social support; Physical movement and exercise; Access to nature and other positive distractions (see Figure 5).

Factor: ***sense of security***. (42.9% of the respondents) gave a rating scale of 3, which moderately agrees with the statement. It seems most users are quite wary and give a medium rating in terms of safety. This is probably due to the park being so vast and open for the public that results in the data above, as not all people feel safe when being out in the open, no matter how safe the place is.

Factor: ***sense of control***. 33.8% of the respondent gave a medium scale that indicates they moderately agree with the statement. 31.2% of them perceived they considerately agree with the statement, and 20.8% of them agree entirely with such statement. This indicates that most users still have a sense of control while being in the park, probably due to the park at the time of the research are sparsely filled with people. In addition, there were several places and facilities that could have given them this sense of control such as Pavilion and the benches around the park as observed.

Factor: ***sense of privacy***. 40.3% of the respondents considerably agree that the park still offers a sense of privacy at some of the areas, for example, in the pergola, Pavilion's premise and the seating scattered across the park. Some 14.3 % of them even agree entirely with the statements. Sense of privacy is essential to feel a sort of peacefulness when seeking calmness and quietness for a person to sort out their thought, meditate, and de-stresss. The park offers some sense of privacy in specific spaces where people can seek their quiet place if they so desire.

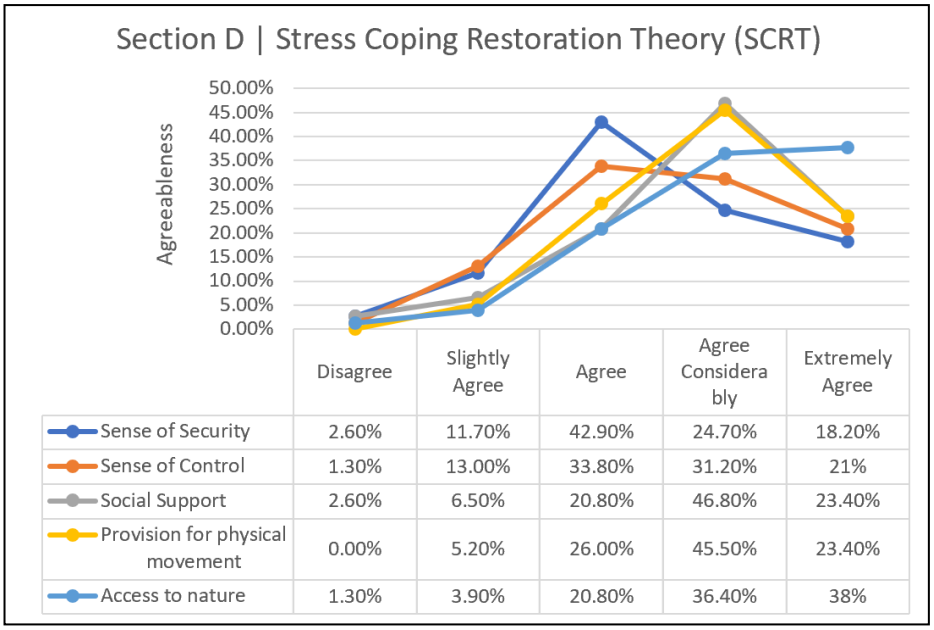
Factor: ***social support element afforded by the park***. Most of them responded are considerably agree that the park makes them comfortable to socialise with friend's families and even stranger at some point. Thus, it can be concluded that they are comfortable to socialize inside the park, and only some of the respondents feel uncomfortable when inside the park. When the respondents are comfortable to socialise inside the park, they are more open and feel more relax, thus enhancing the restoration process. Those who agree might be in the group whose primary purpose when coming to the park is to de-stress, relax, and enjoy time with their friend and family.

Factor: ***comfortable and inclined to do physical movements and exercise when inside the park***. 45.5% of the respondents considerably agree, 23.4 % of them agree entirely with the statement, and some 26% moderately agree with the statements. This data also shows indirectly explain that when facilities are in excellent condition and well maintained, people feel more comfortable and inclined to do physical movement and exercise. When people see others exercising, henceforward, they also socially influenced to be active and moving.

Factor: Perception when being engaged with the natural environment inside the park. The graph chart shows that the majority agree, considerably agree, and extremely agree with the statements. This answer backs the theory that when people are being engaged with nature and greenery, they feel less stress and could restore in terms of mental and physical well-being. Easy access to the natural element from all five senses of the

human body has long been known to make a person happy and relax and henceforth less anxious and stress. Engaging with the natural environment also tends to make people forgot their worries and trouble for a moment before coming back with a refreshed mind.

Factor: ***users' agreeableness that their stress level decrease when being engaged with the natural park*** elements. 41.6% of the respondents are entirely agreeing, 37.7% of them are considerably agreeing, and 16.9% moderately agree with the question. Nature has some biophilia connection to humans, that just by being in nature, a person can be at peace and feel some restoration. Biophilia is the innate human desire since long ago to connect and be at peace with nature.



	Disagree	Slightly Agree	Agree	Agree Considerably	Extremely Agree
Sense of Security	2.60%	11.70%	42.90%	24.70%	18.20%
Sense of Control	1.30%	13.00%	33.80%	31.20%	21%
Social Support	2.60%	6.50%	20.80%	46.80%	23.40%
Provision for physical movement	0.00%	5.20%	26.00%	45.50%	23.40%
Access to nature	1.30%	3.90%	20.80%	36.40%	38%

Figure 5 . Showing the summary of data findings collected in Section D regarding SCRT theory. (Source: Author)

3.2 Analysis And Findings From Interview With The Authority And Landscape Architect

The interview revealed few main concerns regarding the design and implementation of the park studied, these are:

1. Conserve and protect the environment and local species.
2. Showcase the natural local environment plant and species
3. To give knowledge and create environmental awareness and education to the public

One of the main objectives of the implementation of the park was to create a botanical garden that conserves the local plant and unique species. Thus, many plant species from all around were gathered in the park. Therefore, the multitude of the park's element and species adds ***an extensive richness and diversity that is part of the restorative element.***

Another vital role for the park was to be a park that is ***fulfilling*** and environmentally educational to the visitor, and the designers and planners achieve this by showcasing the varieties of natural and local plant species as well as a unique plant from overseas, complete with informative and educational boards at each plant. Visitors can thus explore the park with their family and friends and ***form a sort of social connection to nature by having fulfilling recreational activities***.

The park was also ***designed to promote exploration and wander by having many different themes garden inside,*** to give visitors knowledge and creating environmental awareness. These varsities of different elements inside ***the park create a sort of wonder and fascination to the visitors that this, in effect, reduces stress and gives a sense of restoration.***

The availability of the park and opportunities for ***recreational activities and social interaction cause the users to perceive them as beneficial for self-restoration and rejuvenation for individuals and families.*** Plus, the additional value of the urban park as part of an educational tool to increase the public's environmental awareness can be seen as added benefit aside from being a restorative and healing environment.

When asked if the planners and designers believe in the therapeutic garden stated, planners stated *that "… when talking about the therapeutic garden, usually it was a garden in hospitals, but, yes, it is common knowledge that when looking at the element of greenery, one's stress can be reduced and thus result in the said healing process- "* while designers opinion is that…-*"When a person is looking at or being involved with greenery; the stress hormone in one's*

body will be reduced. It is like horticulture therapy where when one plays with earth and greenery, one naturally forgot all their troubles and daily stress, and a sense of relaxation and satisfaction overcome them. Certain elements in the park such as colorful flowers, informative trees, and engaging natural stimulant are the elements that make the park a healing garden-"

Thus, it can be summarized from their opinion that both agree and believe that urban parks can be a medium for healing and restoration.

3.3 Synthesis Of Data Finding

The survey revealed that most of the respondents are the young generation from 30 below. This generation is of those who are still pursuing their studies, young adults and young families with kids. They come to the park mostly for stress reliever and recreational activities. Interview with the authority and landscape architect revealed the concept for the park as a botanical garden that is educational to the public as well for recreation. Thus, the users can learn, explore, and be fascinated by the plant species they never encountered. Learning new things that are vastly different from their everyday life can be some form of therapeutic experience that takes their minds away from daily habits and usual lifestyle. This concept ties back to the Attention Restoration Theory (ART), where a place that takes you away from daily living and separates from usual distraction can be restorative.

Additionally, the survey revealed that the most preferable element in the park is greenery and shady trees, in contrast with the urban concrete environment. The landscape architect also supported the answer by saying that when one looks at greenery, the body relaxes due to stress negating hormone being release and thus prompt a sense of relief and relaxation. This is further supported by the type of activities being done by users in the park, with the majority of them come with the purpose of relaxing. This data indeed shows how the park has a restorative quality that attracts people to relax and rejuvenate, as it is being surrounded by nature. With the majority of the users living in an urban environment, being in the middle of nature is one way to be away from daily stress (see ART theory), and this urban park provides them easy access to nature (SCRT Theory).

However, the park is not perfect and found some problems as the survey revealed. Some of the users expressed their opinions that the park did not make them feel completely safe; through observation, the park was too broad and vast with so little people and did not emulate a sense of protection. This was supported by the landscape architect herself, in which she stated that for a garden to be therapeutic, a clear perimeter such as hedges or fences must be put and secured in place so that the users feel more comfortable and secure without feeling they might be attacked at any seconds, thus easing them to relax and be rejuvenated (see SCRT theory). From the findings, the design of certain places in the park such as herb garden and conservatory garden are most comfortable for healing as these parts have a well-defined perimeter and plenty of natural stimulation.

To summarize, most of the survey questionnaire results have revealed that though not everyone consciously aware of the restorative environment, they all come to the park majorly for a restoration effect and it was agreed by majority that they all indeed felt that they park are very restorative to their overall well-being, reduce stress and depression, and this was supported by the finding from the interview with the authority that shows the planning of the park was geared towards a fulfilling experience for the users.

4. Conclusion

Previous research pointed out how a restorative space is beneficial due to the way they impact a person's body and well-being, such as renewing a person's cognitive abilities, produce a fulfilling restorative experience, increase the rate of recovery from illness, and encourage physical movements for physical and mental well-being (Mitchell, n.d.). Research also indicates among qualities of a restorative space are: quiet and, secluded is small and enclosed with natural elements (Mitchell, n.d.). This is supported in findings that show that when a park is too wide and open, users do not necessarily feel safe and secure. Interview with the landscape architect also supports the research that to create a fully healing garden, a park needs to feel safe and secure by implementing certain kinds of perimeters around it such as hedges and fencing.

Since today fast-paced urbanisation brings a wealth of positive impact as well as many challenges in terms of urban planning, urban park as a restorative environment plays a tremendous role in being a place for self-regeneration and restoration for city dwellers to reduce stress, increase well-being and promotes happiness. By taking a walk in green areas, viewing blue spaces, and listening to the sound of nature as compared to walking in cities, it can boost a person's mood and reduce stress and blood pressure, as proven by studies done by (Stigsdotter, Corazon, Sidenius, Kristiansen, & Grahn, 2017), whereby they compared the effects of walking in the forest to an urban area by measuring blood pressure and heart rate; psychological measures were also performed.

In Malaysia, it seems the term restorative environment is not widely adopted by the current designers and landscape architect as they are more familiar with therapeutic garden terms used for gardens in hospitals and such, based on the findings revealed by the relevant authorities. Thus, there is huge potential to be tapped if planners and designers also learn and apply the theory of healing environment when designing parks and even inside of building spaces and such, to maximise the healing outcome to the visitor. Since urban dwellers have limited exposure and time to nature, their visit outcome to the park should be maximised.

User perception in the park shows that there is still room for improvement, which suggests that if the planners and designers carefully considered and applied the theory of healing environment and its characteristic to the design implementation, users' perception could potentially increase positively.

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Key Indicators and Dimensional Causes of Accident on Construction Sites

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ABSTRACT

Diverse causes of accidents abound on construction sites, which lead to complexity and difficulty in understanding the key causes of accidents on construction sites. The effect is the increasing rate of accidents. Thus, grouping and identifying the key dimensional and sub causes of accidents is important. However, there is a dearth of research on the dimensionality and indicators of causal factors of accidents on construction sites. This paper aims to create an avenue for easy identification and understanding of the causes of accidents through the development of key indicators and dimensional causes of accidents on construction sites. Adopting a cross-sectional survey research design, three hundred questionnaires were purposely distributed to construction workers who have had experience or witness accidents on a construction sites. Two hundred questionnaires were retrieved and used for analysis representing a 67% response rate. An exploratory factor analysis was used to group and find the significant causal factors from the 64 factors identified in the literature. From the analysis, five key dimensional causes with 22 indicators were identified namely; personal and work factors, design factors, behavioural factors, proximate factors and attitudinal factors. The key indicators identified among others are non-use of PPE, lack of experience, working in confined spaces, disobedience to work discipline and innovative technology. To reduce the occurrence level of accidents, site managers should place the key indicators and dimensional causal factors of accidents on the signboard for easy identification and understanding and as a training guide on construction sites.

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1. Introduction

The construction industry has earned the reputation of the most hazardous industry with the highest accident rate. This is due to the frequent occurrence rate of accidents on construction sites. The construction industry in Nigeria is not exempted from this malice although there is no readily available national record of accidents. Despite this, Eze et al. (nd) investigated the severity rate of accidents on Nigerian construction sites for over five years. 733 cases of mild accidents and 55 cases of fatal injuries or death were reported. Adekunle et al. (2018) investigated the causality rate of accidents in the Nigerian construction industry and found out that the fatality rate of accidents in the year 2015 is 90.8%, with 15% wounded people, 19.5% lost their lives and 34.9% were amputated. Statistics from the year 2001-2015 show that there were 4,777 fatalities in the construction industry. 68% of these fatalities occurred in non-residential construction and specialty trade, 3% occurred in other construction and specialty

trades and 29% occurred among construction workers in the home building industry (Adekunle, et al., 2018). The severity of the accident rate shows that there is a great need to prevent the occurrence of accidents on construction sites. The prevention of accidents starts with a clear understanding of the factors that play a significant role in causation (Al- Tabtabal, 2002). According to Dodoo and Al-Samarraie (2019), if accidents are to be reduced in the workplace, there is a need to place more emphasis on the genesis of accidents. Previous studies (Kadri et al., 2014; González et al. 2016; Williams et al., 2018), identified the various causes of accidents on construction sites but Dodo and Al-Samarraie (2019) noted that the previous studies models have been criticised for not having key indicators that show the causes of incidents in the workplace. For example, Promscorn et al. (2015) worked on the root causes of construction accidents from the perspective of non-human factors. The study only identified the root causes of accidents from the perspective of non-human factors but neglected the other factors like the human factor. Furthermore, the study failed to identify the key indicators of the causes of accidents on construction sites. Williams et al. (2018) grouped the causal factors of accidents according to project participants; the client, the consultants, and the contractors but failed to identify the key indicators that show the causes of accidents on construction sites. Umar and Egbu (2018) investigated the root causes of accidents on road construction projects and concluded that the major causes of accidents can be grouped into equipment/materials, workers, environment and management. However, the key indicators of the grouped causes were not investigated. There seems to be dearth of research on the key indicators and dimensional causes of accidents on construction sites. Thus, the study aims to develop the key causes of accidents on construction sites in Nigeria with the view to creating an avenue for easy identification and understanding of the causes of accidents on construction sites and thus reducing the occurrence rate of accidents on construction sites. The objectives of the study are to identify the key causal factors of accidents on construction sites and to investigate the frequency of occurrence of causes of accidents on construction sites.

Knowledge of the key indicators and dimensional causal factors of accidents will assist site managers and site supervisors to create awareness among construction workers on the significant causes of accidents on construction sites. Furthermore, the key indicators and dimensional causal factors of accidents will be of immense benefit to site workers, as it will help in easy identification and understanding of the causes of accidents on construction sites, thus preventing frequent occurrence rate of accidents.

2. Literature Review

2.1 Accidents

Accidents are events that lead to injury or ill health with consequences such as fatal, major injury, serious injury, minor injury and damage (HSE, 2004). This definition simply describes an accident in terms of its effect without reference to the cause. According to Eaves and Abercrombie (1946), there are two fundamental philosophies to the definition of accidents. While one philosophy defined accidents as 'the hand of fate reaching out to govern the course of human events', the other philosophy defined accidents as an event in which 'human beings are self-determining agents who can guide their destinies and thus avoid accidents'. Thus, the two philosophies described accidents from the perspective of fate and man. Accidents can simply be defined as an event caused by non-human or human factors that leads to injury or ill health.

Expanding on the consequences of accidents from the definition, fatal relates to work-related death while major injury includes any injury or illness that lead to unconsciousness and which require resuscitation or admittance to hospital for more than a day. Serious injury explains when the injured worker is absent from work for more than three consecutive days; minor injury describes when the injured worker is absent from work for less than three days. Damage is associated with damage to property, equipment, environment or production losses (HSE, 2004). Serious injuries and long-term disability are classified as a major accident while insignificant injuries and short-term disability are classified as minor (Yilzmaz and Celebi, 2015). Identifying the root causes of many injuries on construction sites is one of the ways of improving safety in the construction industry (Al-Tabtabal, 2002).

2.2 Theories of Accidents

Several theories exist for accident causation but this study adopts only two theories namely; accident multiple causation theory and accident root causes tracing model.

Accident Multiple Causation Theory

Accident multiple causation theory is based on the premise that there are many contributing factors, causes and sub causes of accidents (Peterson, 1971). The combination of all the factors causes accidents. Thus, the theory posits that not just one factor causes accidents but many factors combine randomly to cause accidents. Linking accident multiple causation theory to this study, the study posits that many factors cause accidents, these factors can be grouped causes (dimensional causes) and sub causes (indicators). Identifying these causes and sub causes will prevent accidents on construction sites.

Accident Root Causes Tracing Model (ARCTM)

Abdelhamid and Everret (2002) developed ARCTM and it is a model developed from the synthesis of previous models. The essence of the model was to provide an avenue in which the root causes of accidents can be easily identified compare to models with complex technical safety terms and definitions. The model shows the conditions that existed at the time of the accident and the antecedent human behaviour.

The main concept of ARCTM is that accident occur due to three root causes; (1) failing to identify an unsafe condition that existed before or after the start of an event (2) proceeding with an event after identifying the existing unsafe condition (3) deciding to act unsafely despite the initial conditions of the work environment

(Abdelhamid and Everret, 2002). Since ARCTM provides an avenue for easy identification of the root causes of accidents as against the complex technical terms, this study proposes that grouping the causes of accidents into dimension and indicators will create an avenue for easy identification of the causes of accidents on construction sites as against complex terms.

2.3 Causes of Accidents

Reports abound on different causes of accidents in the construction industry, however, Abdullah and Wern (2010) note that the reports on accidents only describe the cases of accidents without mentioning the causal factors. Thus, it is pertinent to investigate the causal factors of accidents on construction sites. Although, various causal factors have been reported for construction site accidents, these factors have been reported in diverse ways. While some authors reported the causal factors individually without classifying them into dimensions, others categorised them into dimensions without considering the key indicators that make up the dimension. However, Williams et al. (2018) state that there is a dearth of research in the categorisation of accident causal factors. Furthermore, identifying and understanding these factors will extenuate construction accidents.

Choudhry and Fang (2008) opined accident causal factors among others include unsafe behaviour because of lack of safety awareness, inadequate supervision, inadequate planning, inadequate training, employee error and accident beyond one's control. These factors are majorly due to human error and were not categorised into groups. Causes of accidents according to Bashir et al. (2011) are prior work methods, physical and mental inability of workers, poor communication and poor planning. Masood et al. (2014) identified the major causes of accidents as defective PPE and taking productivity as a priority over safety. Ahmed (2019) concluded that the top five causes of accidents are lack of workers' awareness on safety-related issue, lack of pprotective equipment, lack of design that eliminate safety hazards, unfit equipment and lack of knowledge and training on equipment respectively. Orji et al. (2016) investigated 15 causes of accidents on construction sites and concluded that the major causal factors of accidents are failure to use personal protective equipment, injuries from equipment, sub-standard construction material, ignoring safe procedures and unsafe/incorrect construction method. Ibrahim and Tasiu's (2018) causes of accidents on confined construction sites are material handling, difficulty in providing temporary facilities, congestion, ergonomic hazards, difficulty in managing waste and lack of adequate storage. These causal factors of accidents are individual factors and construction workers may find it difficult to easily understand and identify the factors because they are numerous.

In categorising the causal factors of accidents, Al-Tabtabai (2002) categorised the causes of accidents into three major factors namely; management-related factors, labour and behavioural related factors and job or project-related factors. Olatunji et al. (2007) identified the main causes of accidents as tool problems, psychological problems, health problems, workmanship and material factor, contingencies, corporate health and safety orientation of the organisation. Using content analysis, Tutesigensi and Reynolds (2008) identified the primary causes of accidents on construction sites as casualty error, work method, poor quality kit, poor health, site set up, site conditions, plant operator error, plant failure and packing error. Williams et al. (2018) identified various causal factors of accidents from literature and grouped them under five factors namely client-related, contractor-related, construction workers-related and construction site-related. An attempt has been made by these authors to group the causes of accidents due to numerous factors. However, the grouping of these factors did not include the key accident causal factors, there is, therefore, a need to consider these key factors for easy understanding of accident causal factors on construction sites.

2.4 The Dimensionality of Accident Causal Factors on Construction Sites

The dimensionality of accident causal factors has received little attention while the focus is on the individual causes of accidents. According to Al-Tabtabal (2002), preventing accidents begin with a clear understanding of the causal factors that play a key role in accident causation. There is, therefore, a need to classify these individual causes of accidents into dimensions for easy identification and understanding.

Kadri et al. (2014) examined the causes of accidents on construction sites; the factors were not grouped into major dimensions. The causes of accidents in their study include carelessness, negligence, scaffolds and so on. This study failed to classify accident causal factors into major dimensions. Promsorn et al. (2015) considered just one dimension of accident causal factors -non-human factors-. The factor was further classified into 21 variables and subdivided into three major factors namely, ergonomic design, supporting policy and environment. However, this study failed to consider the key causes of accidents under each dimension on construction sites. Similarly, Lingard et al. (2013) focused on plant-related fatalities in the Australian construction industry, the finding shows that people being run over by moving plant or struck by a moving object is the most common incident type. Lingard et al. study examined the causes of accidents from the perspective of accident types. There is, therefore, a need to differentiate the types of accidents from the causes of accident. Masood et al. (2014) identified the major reasons for accidents as defective equipment, site ergonomics, plant and equipment, the priority of productivity over safety. Likewise, this study failed to classify the causes of accidents into dimensions, also, the key indicators of each accident dimensions were not considered.

Although, some literature considered the causes of accidents from the dimensional perspective, however, the key dimensions were not investigated. For example, Abdul Hamid et al. (2008) grouped the causes of accidents into 6 dimensions namely, unsafe equipment, job site conditions, unique nature of industry, unsafe method, human element and management. This study failed to identify the key causes of accidents under each dimension.

3. Methodology

To achieve the aim of the study, a positivist research paradigm, cross-sectional survey research design and quantitative research approach were employed. A cross-sectional survey research design was adopted because representative samples were taken from the population to generalize findings. Also, the research approach was quantitative because the key indicators and dimensions of accident causal factors were explained through the gathering of data in numerical form. The population of the study comprises site managers, site supervisors, safety officers, project managers working on various construction sites in Lagos state. Data was collected from the respondents through a purposive sampling technique using a structured questionnaire. This is because there are no lists of the population, therefore respondents working directly on site and who have one time or the other witness or experience accidents on construction sites were selected as respondents for this study. Three hundred questionnaires were thus purposely distributed to the respondents and 200 questionnaires were retrieved and valid for analysis representing a 67% response rate.

To measure the causes of accidents on construction sites, 64 observable variables were adapted from previous literature (Abdelhamid and Everett, 2000; Promsorn et al., 2015; González et al., 2016). Respondents were required to state the frequency of occurrence of the causes of accidents on construction sites using a five-point Likert scale, where 1= very low, 2= low, 3= moderately high, 4= high and 5= very high. For example, the frequency of occurrence of an accident due to nonuse of PPE is ….. The 64 observable causal factors of accidents were thus analysed with the use of exploratory factor analysis.

4. Result and Discussion

A total of 200 respondents participated in the survey. Table 1 shows the demographic details of the respondents.

Table 1 Characteristics of Respondents

Respondents' Profile	Freq.	%
Professional background		
Architect	24	12
Builder	123	61.5
Civil engineer	25	12.5
Quantity surveyor	11	5.5
Mechanical engineer	8	4
Electrical engineer	9	4.5
Total	**200**	**100**
Professional qualification		
Nigerian Institute of Architecture (NIA)	24	12
Nigerian Institute of Building (NIOB)	116	58
Nigerian Institute of Quantity Surveying (NIQS)	22	11
Nigeria Society of Engineers (NSE)	34	17
Others	4	2
Total	**200**	**100**
Position in the Company		
Site Manager	64	34
Safety manager	40	20
Site Supervisor	24	44.4
Project manager	37	18.5
Total	**200**	**100**
Years of site experience		
< 5 years	65	32.5
5-10 years	89	44.5
11-15 years	38	19
16-20 years	7	1
> 20 years	1	5
Total	200	100
Categories of organization		
Indigenous	187	93.5
Multinational	13	6.5
Total	**200**	**100**

Freq.= Frequency

Table 1 shows that 61.5% of the respondents are builders by profession, while 12.5 % are civil engineers. Thus, responses can be said to be from professionals in the construction industry, which implies that the information given is reliable. A larger percentage (44.4%) of the respondents are professionals working as site supervisors on construction sites, 34% are site managers while 20% are safety officers. This is an indication that the credibility of the responses is high since the respondents directly work on site. In terms of experience, 44.5% have 5-10 years of working experience while 32.5% have working experience below 5 years. This shows that the respondents can give reliable information on the frequency of occurrence of causal factors of accidents on construction sites since they have appreciable years of working experience. 93.5% of the respondents work in indigenous construction firms while 6.5% work in multinational construction firms. This is because the Nigerian construction industry is characterised by a large number of indigenous construction firms and a low number of multinational construction firms.

4.1 Key Dimensional Causes of Accidents on Construction Sites

The sixty-four causal accident factors variables were factor analysis using maximum likelihood with proximate rotation to arrive at the key causal factors of accidents on construction sitess. The analysis in Table 2 yielded five factors explaining 68.54% of the variance for the entire set of variables with 22 observable variables. The factors were then grouped under five latent

variables of personal/work factors, design factors, behavioural factors, proximate factors and attitudinal factors. Factor 1, labeled as personal/work factors consists of 10 variables and it explains 19.41% of the variance. The second factor 'design factors' consists of 5 variables and it explain 25.80% of the variance while the third factor consisting of three factors was labeled as behavioural factors and it explains 8.78% of the variance. The fourth factor 'proximate' explains 10.47% of the variance with two variables while the last factor labeled as 'attitudinal' factor consists of two variables and explains 3.86% of the variance. To test the factorability of the variables, the Kaiser-Meyer-Olkin (KMO) test of sampling adequacy was used which gave a value of 0.88. This is within the acceptance range of value according to Field (2009). The Cronbach Alphas for the five factors are 0.938, 0.903, 0.837, 0.822 and 0.734 which are above the minimum acceptable value of 0.7 (Field, 2009). Table 2 presents the dimensions of key causal factors of accidents on construction sites.

Table 2 Key Dimensional Causes of Accident on Construction Site

S/N	Causal Factors of Accident	Personal/ Work	Design	Behavioural	Proximate	Attitudinal
1	Lack of judgment	0.623				
2	Lack of experience	0.758				
3	Insufficient instruction and/or orientation	0.97				
4	Insufficient evaluation of needs and risks	0.513				
5	Insufficient definition of policies, procedures, practices or action steps	0.877				
6	Inadequate standards or specifications	0.565				
7	Inadequate storage of materials	0.76				
8	Inadequate control and inspection of construction sites	0.801				
9	Inadequate handling of materials	0.764				
10	Inadequate maintenance of standards	0.569				
11	Vibrations from machines		0.731			
12	Equipment design		0.945			
13	Design of PPE		0.691			
14	Innovative technology		0.788			
15	Standard performance causes discontent		0.676			
16	Carrying overload			0.811		
17	Wrong posture of carrying loads			0.705		
18	Nonuse of PPE			0.865		
19	Difficulty in traffic				0.524	
20	Working in confined space				0.993	
21	Disobedience to work discipline					0.569
22	Uncertainty or hazard					0.943
	Cronbach Alpha	**0.938**	**0.903**	**0.837**	**0.822**	**0.734**

Extraction Method: Maximum Likelihood. Rotation Method: Promax with Kaiser Normalization. a Rotation converged in 7 iterations. KMO= 0.888, Barlett's Test= 3341.405, Df= .231, Sig= 000

The first dimensional causal factor of accidents was labeled 'work/personal factors' because the key indicators reflect accident causes due to individual personality or activity directed at achieving tasks. For example, lack of judgment, lack of experience and inadequate control and inspection of construction sites. The second dimensional causal factor of accidents was labeled 'Design factor' because the key indicators reflect causes that originate from the design of equipment and technology. For example, vibrations from machine or equipment design. The third dimensional accident causal factor of accidents was termed 'behavioural factors'. This is because behavioural factors reflect indicators resulting from unsafe behaviour at work, for example, non-use of PPE. The fourth dimensional accident causal factor was labeled 'proximate factors' because the indicators reflect the closeness of space or lack of space, for example working in confined space. The last dimensional accident causal factor was termed 'attitudinal factor' because the indicators reflect the state of individual belief, feeling, values and dispositions, for example, disobedience to work discipline.

4.2 Causes of Accidents on Construction Sites

The prevalent causes of accidents on construction sites were investigated using the key dimensional causes of accidents. To achieve this, the mean score of each key dimensional causes of accident measured as a latent variable were calculated. The mean values were interpreted using the following scales, 1.00-1.49 for *very low*; 1.50-2.49 for *low*; 2.50-3.49 for *moderately high*; 3.50-4.49 for *high* and 4.50-5.00 for *very high*. Table 3 shows the causes of accidents on construction sites.

Table 3 Causes of Accident on Construction Sites

Accident Causal Factors	1	2	3	4	5	Total	Mean
Work/Personal Factors	**3.6**	**9.6**	**36.8**	**103.4**	**46.6**	**200**	**3.90**
Lack of judgment	3	11	65	84	37	200	3.71
Lack of experience	3	8	23	103	63	200	4.08
Insufficient instruction and/or orientation	3	14	40	97	46	200	3.85
Insufficient evaluation of needs and risks	2	11	30	111	46	200	3.94
Insufficient definition of policies, procedures, practices or action steps	3	7	38	106	46	200	3.93
Inadequate standards or specifications	3	17	33	108	39	200	3.82
Inadequate storage of materials	8	7	45	99	41	200	3.79
Inadequate control and inspection of construction sites	3	8	27	110	52	200	4.00
Inadequate handling of materials	5	10	35	104	46	200	3.88
Inadequate maintenance of standards	3	3	32	112	50	200	4.02
Design Factors	**7.2**	**20.2**	**47**	**93.4**	**32.2**	**200**	**3.62**
Vibrations from machines	7	20	49	92	32	200	3.61
Equipment design	7	26	47	97	23	200	3.52
Design of PPE	4	18	43	104	31	200	3.7
Innovative technology	14	23	52	70	41	200	3.51
Standard performance causes discontent	4	14	44	104	34	200	3.75
Behavioural Factors	**1**	**8.33**	**22**	**93.33**	**75.33**	**200**	**4.17**
Carrying overload	3	8	22	94	73	200	4.13
Wrong posture of carrying loads	0	9	26	93	72	200	4.14
Nonuse of PPE	0	8	18	93	81	200	4.24
Proximate Factors	**7**	**12**	**50**	**81.5**	**49.5**	**200**	**3.78**
Difficulty in traffic	8	14	56	73	49	200	3.71
Working in confined space	6	10	44	90	50	200	3.84
Attitudinal Factors	**16**	**12**	**27**	**97**	**48**	**200**	**3.75**
Disobedience to work discipline	14	9	12	106	59	200	3.94
Uncertainty or hazard	18	15	42	88	37	200	3.56

Table 4 *Key Dimensions* ***Accident Causal Factors On Construction Site***

Accident Causal Factors	1	2	3	4	5	Total	Mean	Rmk
Behavioural Factors	1	8.33	22	93.33	75.33	200	4.17	High
Work/Personal Factors	3.6	9.6	36.8	103.4	46.6	200	3.90	High
Proximate Factors	7	12	50	81.5	49.5	200	3.78	High
Attitudinal Factors	16	12	27	97	48	200	3.75	High
Design Factors	7.2	20.2	47	93.4	32.2	200	3.62	High

The result in Table 4 shows that the frequency of occurrence of all the dimensional causes of accident namely behavioural, work/personal, proximate, attitudinal and design factors are high.

The implication is that the rates at which accidents occur on site due to all the dimensions are eminent. Furthermore, the most prevalent cause of accidents on construction sites is behavioural factors with a mean value of 4.17. This implies that accidents occur mostly on site due to the conduct of site workers. Particularly, Table 3 shows that the non-use of PPE accounts for the highest behavioural factors. Wrong posture of carrying a load and carrying overload are conducts from individual workers, which originate from their behaviour.

The least cause of accidents is design factors with a mean value of 3.62. This shows that the vibration from machines, equipment design, design of PPE, innovative technology and standard performance are the least causes of accidents on construction sites.

4.3 Discussion of Findings

From the gap established in this study, the key indicators and dimensional causal factors of accident must be investigated to identify the genesis of accidents on construction sites for proper training of site workers. Thus, the first objective was to identify the significant accident causal factors indicators, thereafter group the indicators into dimensions. Table 1 shows the key dimensional causes of accidents with their indicators on construction sites. Five key dimensional causes of accident on construction sites namely behavioural factors, work/personal factors, proximate factors, attitudinal factors, design factors were identified from the factor analysis conducted.

Behavioural factors

Findings from the study show that one of the key dimensional causes of accidents on construction sites is behavioural factors. This implies that the genesis of accidents on construction sites originates from the conduct of the individual workers on site. Such conduct includes carrying overload, wrong posture of carrying load and non-use of PPE. Table 3 shows that the non-use of PPE is the most prevalent cause of behavioural causes of accidents. Doddo and Al-Samarraie (2019) emphasised that behavioural conduct such as non-use of protective equipment is one of the factors of unsafe behaviour. Furthermore, Ali et al. (2010) conclude that the non-use of PPE is one of the major causes of accidents on construction sites. It then becomes imperative to identify this unsafe conduct and identify ways of ensuring good conduct on site. Mahalingam and Levitt's (2007) findings show that education and training for changing the mindset and behaviour of workers on safety on construction sites were not effective. However, the strategy of coercive enforcement through the payment of fines was effective. Hon et al. (2014) suggested using the dual approach in changing the mindset of workers to safety conduct on site. Thus, knowledge of behavioural factors as key dimensional causal factors of accidents will assist both the health and safety personnel and construction workers on site.

Work/personal Factors

Another key dimensional causal factor of accidents identified on construction sites in Table 4 is work/personal factors. It explains the key indicators of causes of accidents due to individual personality or activity directed at achieving given tasks. This finding is in line with Al-Tabtabai (2002) in which workers and job factors were identified as two major causes of accidents on construction sites. The workers' factors refer to personal factors while job factors refer to work factors. Although Zhang et al. (2019) found out that poor management was a critical causal factor compare to individual factors, the fact remains that both are causal factors of accidents on construction sites. This suggests that work/personal factors are important causes of accidents on construction sites.

Findings from the result in Table 3 show that lack of experience and inadequate maintenance of standards following workflows, updating, control of the use of standards/processes/rules were the major indicators of work/personal causal factors of accidents. Among the key factors is insufficient instruction or inadequate orientation to workers. This substantiate the findings of Choudhry and Fang (2008) and Ahmed (2019) in which inadequate training and lack of knowledge and training on equipment were found to be major causal factors of accidents on construction sites.

Proximate Factors

Proximate factors, which indicate accidents due to closeness of space, are among the dimensional causes of accidents. Table 3 shows that there are two major indicators of proximate causal factor of accidents; difficulty in traffic and working in confined space. According to McAleenan and McAleenan (1999), many severe accidents happen on site due to confined space. This finding confirms that of McAleenan and McAleenan (1999), Ibrahim and Tasiu (2018) and Naghavi et al. (2019) in that confined space, which is a proximate factor, was said to be a causal factor of accidents. It is necessary to consider the issue of confined space on site as it has different implications. Such implications include among others; difficulty in providing temporary facilities, congestion and ergonomic hazards. The consequence of these implications is the occurrence of accident. (Ibrahim and Tasiu, 2018).

Attitudinal Factors

The fourth dimensional cause of accidents in Table 4 is attitudinal factors. Attitudinal factors are factors that reflect the state of individual beliefs, feeling, values and dispositions. This suggests that individual dispositions toward accidents play a significant role in the causes of accidents. This finding supports that of Tutesigensi and Reynolds (2008) in which individual attitudes towards health and safety were found as a major cause of accidents. For construction workers to have a change of attitude, they must have the ability and willingness to implement safe approaches to work.

Design factors

The result in Table 4 shows that the least cause of accidents on construction sites is design factors. This suggests that the least causes of accidents on construction site are due to the design of equipment or innovative technology. The key indicators of design factors are presented in Table 3. The implication is that most sub causes of design dimensional causes of accidents are equipment design, innovative technology, vibration from machine and design of PPE. These factors are beyond the capacity of site workers and are due to the fault of the design and technology of equipment. The finding supports that of Promosorn et al. (2015) in which design of equipment, innovative technology, design of PPE, vibration from machine were found to be indicators of ergonomic design cause of accidents.

5. Conclusion and Recommendation

Identifying the key indicators of accident causal factors is necessary for the prevention of accidents on construction sites. Thus, the study sought to identify the key indicators and dimensions of the causes of accidents on construction sites. Five key dimensional causes of accidents were discovered with 22 indicators. The study thus concludes that behavioural factors, work and personal factors, proximate factors, attitudinal factors and design factors are the key dimensional causes of accidents on construction sites. Furthermore, the study concludes that the major indicators for each of the dimensional factors are non-use of PPE, lack of experience, working in confined spaces, disobedience to work discipline and innovative technology.

The key accidents causal factors indicators will serve the purpose of self-evaluation and firm evaluation for construction site workers and firms. This will create consciousness on the part of the site workers and management of the firm on the importance of avoiding such acts that can cause accidents on construction sites. Furthermore, site managers can adopt the key indicators and dimensional causes of accidents as a training guide to construction site workers. The indicators can be placed on a signboard on construction sites for easy identification and understanding. It will also serve as a means of awareness and regular self-check which will reduce the frequency of occurrence of accidents on construction sites.

The focus of the study was on the key indicators and dimensional causes of accidents on construction sites. An exploratory factor analysis was employ in determining the key indicators; future study should consider the use of confirmatory factor analysis to confirm the indicators. Furthermore, the key safety accidents prevention measures were not considered in this study, future study should consider the safety prevention measures needed for the key indicators of accidents on construction sites.

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Deconstructing Sustainability Perceptions: Investigating Technological Innovation-Environmental Interaction in Green Buildings and the Influence of Architectural Design

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ABSTRACT

Sustainability principles impact green building infrastructure design, planning and construction decisions. The influence of social perceptions in transforming notions of green architecture and sustainable designs as desirable are also interesting contexts for urban design researchers in addressing environmental impacts. The aim of this paper is to discuss a breadth of available literature on architectural sustainability, and the many effects of urbanisation. Few scholars have attempted to frame qualitative discussions of sustainability perceptions with regards technological interaction with built environments. Research utilises two green building design frameworks to analyse differences between sustainability perceptions of innovation and environmental design aesthetics, namely technological innovation interaction with architecture, and architectural design interaction with nature. Findings from case studies of three examples namely The Port of Portland, The Pompidou Centre Paris, and Frank Lloyd Wright's First Unitarian Society are deconstructed using qualitative approach to demonstrate that while architectural interaction with nature is viewed as ideal characteristics, green building design innovations with technological interactions play a larger role in influencing social perceptions towards sustainability. Findings suggest that green buildings should encompass a wider range of aesthetic-based designs, from passive ventilation to lighting systems and materials, but in order to sustain positive stakeholders' perceptions, social benefits and education among green building policymakers, designers and architects is crucial. Recommendations on how to cultivate a balance in pragmatic, cost-conscious approaches, including interactions with technologies, will be discussed in conclusion.

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1. Introduction

A Every building is sited within an environmental context, producing effects and being impacted upon by its users, occupants, other buildings, its surroundings and society. Sustainability is the art of living while negotiating the ability of future generations to partake in the same assertions through smart resource management and utility (Brundtland Report, 1987: p.49). Sustainable concepts are defined on the three interlocking aspects of economic, social and environmental

performance. Known as the Three Sustainability Pillars (Figure 1), these aspects are imperative in satisfying and fulfilling the Brundtland Commission Report (1987) principles calling the circular ecology model an enabler for economic and environmental goals, achieved through equitable policymaking, utilisation, consumption and management of resources and capital, while at the same time, producing positive long term benefits, thus safeguarding the social wellbeing of communities and nations (Circular Ecology, n.d.).

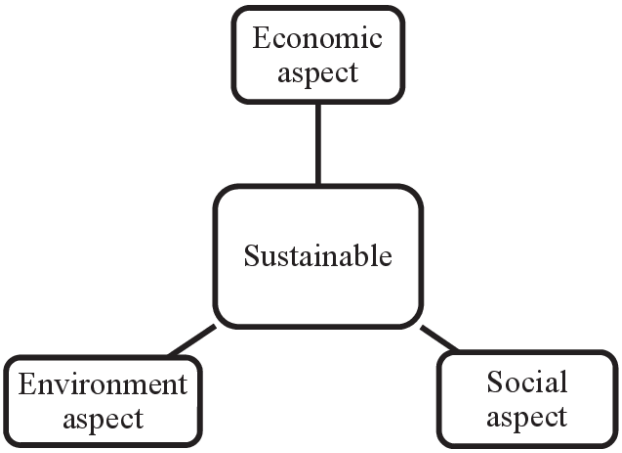

Figure 1: The Three Sustainability Pillars

Using the Three Sustainability Pillars, sustainable architecture could be defined as the systematic processes involving interdisciplinary collaboration to research, plan, design, implement, operate, manage and maintain construction sites, projects, buildings, landscapes and spaces, co-mingling a host of criteria that improves building performance such as aesthetic design, quality of indoor air, lighting and heat, impact on ecology and the surrounding environment, optimisation of social contact, human productivity and wellbeing, ensuring security, viability of economic value through minimising energy costs, delivering and enhancing investment value to stakeholders (Thompson and Sorvig, 2008). These are evaluated via assessment metrics, indices, rating systems or guidelines developed by industrial bodies, certification agencies and institutions (Brophy and Lewis, 2011; Horman, et al, 2006; Lowe, 2010; Trencher et al, 2016; US Chamber of Commerce Foundation, 2017; Woolley et al, 2005; World Green Building Council, n.d.).

1.1 Statement of the Problem & Research Questions

The recent decades have seen a groundswell of passionate advocacy as well as fierce criticisms towards the green building design agenda, whichever side of the debate one chooses, the resulting verdicts and studies seem to infer that social awareness on the ecological impact of urbanisation has heightened. The issue is positioned on how green designs achieve greater potential outcomes for climate change response and adoption of solutions that substantially mitigate climate change conditions such as resource depletion. Adjunct to this debate has been the architectural and construction industries' driving force to transform and improve perceptions of the sustainable built architecture movement. The influence of *liveability* characteristics has led some authors to theorise that the green architecture movement is orientated to favour perceptions of technological innovations as the preferred spatial solutions, rather than a myriad of variable factors, such as cultural heritage or safe, neighbourhood ambiance (Leeuwen and Timmermans, 2006: pp.393-395).

It is interesting to inquire whether there is more to green building design approaches than merely adopting technologies and innovative systems in the industry's feverish phase of eco-consciousness. Research questions guiding this paper include: *What main factors influence perceptions of sustainable architecture? Does technological-environmental design interaction create positive perceptions towards green building design by integrating social and economic benefits such as stakeholder perception of market valuation and investment returns?*

To understand current perspectives on sustainability practices for urban buildings, a scope of relevant factors to illustrate the importance of sustainability principles, will be reviewed. Case examples will investigate green building design interaction with nature, and architecture's interaction with technology. The analysis of findings synthesises these perceptions in order to develop objective recommendations and help readers grasp the scope of issues under discussion.

2. Literature Review

As green-conscious trends become *de rigueur* among urban society, architectural scholars suggest there are definitive correlations between ecological-health with the desire to live, work and thrive in healthy spaces. Sustainability manifests in architectural forms through optimisation of resources from nature, while others incorporate bioclimatic and green material principles, energy-saving, passive systems and flexible construction. Although designed to mitigate environmental impacts, such buildings may turn out to be conventional in its aspirations.

Lowe (2010: pp.57-60) explains why designers need to communicate their beliefs about "aesthetic sustainability" in planning green buildings to ensure long term benefits to health, security, comfort and order. These involve perceptions of *functionality and aesthetics* in constructing, refurbishing or remodelling existing buildings. Sustainability *perceptions* thus frame the basis of urban architectural research in understanding the scope and potential of green buildings reflective of circular ecology systems, but a critical challenge to address is the lack of standards *definitions* of sustainable building design performance, in short, what determines "green-ness" of structures, landscapes and spaces which transfers research data into high performance in actual conditions. Researchers are concerned that sustainability practitioners pick out isolated features to represent the architect or designer's vision, instead emphasising on "whole-building approach" to assessing high performance

environmental design (World Green Building Council, n.d.; Zainordin et al, 2018).

A scope of performance indicators, technical specifications and assessment tools exist to provide frameworks such as USCBC, LEED and WGBC that define design sustainability, yet Horman et al (2006: p.138), in the inaugural *Journal of Green Building*, contend that these are not always comprehensively integrated buildings, facilities, landscapes and built environment projects since "actual conditions on site demand more useful and pragmatic solutions" beyond planning and lifecycle analysis. As the authors explain, there must be closer application of environmental research findings to social and economic impact through mapping its scalability, guidelines for tracking performance, knowledge transfer for future value enhancement.

Curwell, Deakin and Symes (2005: pp.432-442) exposed some shortcomings in perceptions towards aesthetics value of green buildings. Using the Settlement Model to examine the context of designing "high quality living and working environment" as the basis for architecture's ecological response, the authors uncovered surprisingly unfavourable factors, including the long-term management costs of green infrastructure, e.g. waste management systems, interior and exterior climate control strategies, contribution to health, maintenance of landscaping, market and investment evaluation of green building as high-yield property.

The achievement of broader environmental objectives through sustainable architecture is often contentious. A green roof, for instance, integrates a building more closely to the landscape, but its efficiency and performance is negated if the added weight of roofing affects its long-term structural strength and durability. The cost of "reasonable maintenance" is another green design factor that has been discussed by landscape academics, who argue that reduction in energy use costs less that constant replacement (Thompson and Sorvig, 2008: p.334). Recognised green building certifications, with proper monitoring of policy and regulatory adherence, added with guidance by environmental agencies, engineering and built construction experts, play a crucial role in overcoming barriers to green building adoption (Chan et al, 2017).

This was affirmed by a case study in Indonesia on the exactitude of stakeholders' knowledge by Universitas Indonesia civil engineering academic Prof Mohammed Ali Berawi et al (2019). The authors' findings show that while social and economic benefits were valued factors in green building rating systems adoption, the lack of environmental knowledge by building owners and investors themselves are a key hindrance in communicating sustainability project proposals by green building councils to the government.

An ecological standpoint by William McDonough and Michael Braungart who crafted "The Hannover Principles" in 1992, insist on addressing waste as crucial by-products of the human-nature coexistence paradigm in their manifesto, *Cradle to Cradle* (2002). Waste is an inevitable outcome of large-scale mass manufacturing for industries, as products are designed on a linear, cradle-to-grave model; resources extracted for singular products, producing waste pollution and environmental damage perpetually. Marcus Fairs (2013) puts it this way: "Green's message [has fallen] foul of the law of diminishing returns once you've hewn furniture from raw timber, there's not much further you can go". As a social response, Fairs (2009: p.10) notes the trend among younger designers to revert to, and experiment with, low-tech design ideas to improve lifestyle and wellbeing, from urban farming, repurposing used materials for accessories, furniture and interior decoration.

Groat and Wang (2013: p.4) link current research interests in urban sustainable architecture to the "shifting tides" of socioeconomic pressure, involving closer orientation of critical theories of architectural experiences to social realities. Citing work by Kevin Lynch (2000), *The Image of the City* (2013: pp.50-70), the process of living is said to be connected to the way individuals develop *perceptions* and *orientations* on the familiar forms of urban cities. Perception studies find that to gain import and positive perceptions, ideal characteristics of green design which must be visible include being "cost-effective", "easy to implement", "beneficial to health and wellbeing (e.g. comfort and convenience)", "boost for productivity" and "user-friendly" to its occupants, rather than oriented towards conserving nature (Baird, 2014).

At the same time, critics argue that incentivisation through taxation to encourage the production of green materials does not necessarily lead to accelerated adoption, nor stimulate the construction sector to recycle waste or reduce energy usage in processing industrial products (Boostra, Rovers and Pauwels, 2000; van den Bergh and Janssen, 2004; Woolley et al, 2005). More pragmatic measures are the initiatives by social movements to promote circular solutions which serve community needs through for-profit recycling, repurposing and up-cycling practices such as glass processing, metal recovery, and waste composting (US Chamber of Commerce Foundation, 2017).

While idealist notions of sustainable buildings have sustained academic debates for decades, there are specific challenges for populations in developing regions. Socioeconomic forces necessitate a push for rapid urbanisation, with ecological agendas taking a backseat as the consequence. Santosh Ghosh (cited in Boonstra et al, 2000) notes that with millions from lower-income Asian societies demanding urban housing, local authorities have to seek solutions beyond environmental protection and ecological awareness when considering sustainable architecture. Awareness maybe well-grounded; reality, however, could well be different (WBDG, 2016).

Environmental designs inspired by minimalist abstractions such as centralised grids and designated walkways, instead of promoting communal ties, are often inaccessible to certain segments such as the disabled or senior citizens, contributing to the disintegration of traditional geosocial structures (Boonstra et al, 2000). Green design advocates urge for more effective implementation of urban environmental management policies and plans by examining the feasibility of ecological solutions and

resources which ensures *social inclusiveness* of urban spatial design (Czerwinska, 2017; Hanson, 2004). In this regard, urban planners, agencies and experts need to mandate a strong financial case for green building design to promote the concept of long-term urban sustainability. Woolley et al (2005) notes that image perceptions towards sustainability are formed from the tangibility of designs of infrastructures for commercial buildings.

In the pursuit of green design models, positive perceptions on how the building developer or owner improves usage efficiency of electricity and water and practices conservation, play a practical role in incentivising green practices.

Architectural researchers Groat and Wang (2013) note that advanced technological innovations implicate huge financial outlay of capital, in particular, spending or funding of initial R&D, but if fundraising processes lack transparent disclosure or traceability, the scale and costs of maintenance, structural upkeep and repairs increases, raising stakeholders' doubt and resistance to adoption of green buildings. On a larger scale, innovations used in commercial building designs should be representational of the long-term goals of stakeholders. Environmental impact assessments on technological use must be laid down early before deciding whether "to build new or convert an old building or whether the activities need a building at all" (Woolley et al, 2005: p.20). In sum, literature shows that sustainability perceptions hinge on the ability of planners, architects and designers to present the standpoint of *enablement* that green buildings purportedly deliver (Baird, 2014; Cooke et al, 2006; Zainordin et al, 2018). Barriers to green building design and technological innovations must be addressed early, and baseline perceptions on the socioeconomic and environmental benefits established, framed, understood and interpreted clearly by both authorities and professionals certified in sustainability architecture.

3. Methodology

As design researchers' role span beyond the confines of producing empirical data as architectural design scholarship should aim to collect, deconstruct analyse and benchmark evidence demonstrating how people adapt to living in buildings. Qualitative research highlights various aspects of green design's role in architectural innovation, expanding our understanding of sustainability perceptions (Groat and Wang, 2002).

3.1 Case Study Methodology for Sustainability Design Research

The As Yin (1994: pp.77-78) treats case study as an "instrumental" tool for generating theory; this may gain favourable grounds among empirical researchers who are keen to identify aggregation of categorical data and look for consistent patterns of filters which makes sustainable designs significant in practice. Stake (1995) mindfully refers to case studies from the field as mainly "naturalistic" primers, a good approach in formulating social policy and for teaching practical design theories and principles. On the other hand, where narrative cases and ethnographic fieldwork presupposes the importance of unique descriptions to capture phenomenological scopes and to *derive meanings from* ideal conditions, empirical researchers seek broader behavioural and contextual scopes on which they can isolate sustainability conditions and to *put meanings into* them.

Furthermore, case study approaches, according to Yazan (2015), are helpful to diversify and complement educational perspectives towards the subject of research; as a qualitative analysis tool, case studies collates a vast array ideas instead of merely mapping out theories to fit the designed purpose of social science research.

Beyond discussions of rationales for green built environments, qualitative case study research methodology allows for a more critical evaluation of the wider influence of *stakeholder interests*. However, the issue of replicability of qualitative case studies is a downside; every green project is developed based on unique geo-social factors; commercial green buildings cannot be deconstructed using similar assessment factors. Cooke et al (2006) clarifies that perceptions of costs, market valuation and long-term objectives of green buildings must be communicated to stakeholders before *alternative energy technologies* (AET) are adopted. Assessment of what makes for green architecture may thus be derived from case study information, which may implicate future decision-making. Notwithstanding empirical investigations of sustainability, the social and economic *incentives* play a very important role in investment considerations for green projects (Groat and Wang, 2013; Berawi, 2019; Yazan, 2015).

To understanding the dynamic interaction between sustainability, ecological, social and technological outcomes for this paper, qualitative research is used to produce a broader framing of perspectives through analysing technological innovations integration into building designs, and how these could be perceived by stakeholders (Cooke et al, 2006).

The role of sustainability can also be viewed through passive energy conservation strategies, by exploring spatial design for cultural information transfer and aesthetics purposes. Technological innovation will be evaluated for effectiveness in enhancing ambient quality. Findings from the three case examples will be synthesised in the Discussion section to better understand the specific implementation challenges identified in earlier research questions.

4. Analysis and Interpretation of Case Study

Technology has become a crucial driver in the development of modern buildings. Research affirms the progressive shift to technological use as an increasingly critical method to research, plan and implement environmental design sensibilities over several decades of architectural innovations since the 1960s (Curwell et al 2007, Reed and Lister, 2014). Fields of technological knowledge such as service engineering which studies, designs and implements the installation of service systems, adds value to building users or occupants, for instance, in introducing green lifestyle features that lowers carbon

footprint and brings convenience, such as smart access systems for residential homes and offices, and close-circuit monitoring to boost security.

4.1 Case Study I: Technological Interaction with Architecture

Fields methodologies already in use range from digital mapping of processes and patterns of spatial construction (van Leeuwen and Timmermans, 2006); documenting systems and techniques of building and landscape conversion for urban regeneration through 3D modelling (Hanzl, 2007); *Geographic Information System* (GIS) modelling to study socio-spatial conditions and geo-design impact on the urban economy (Roche, 2014); and studying the linkages between community health and the environment (Boonstra et al, 2000). Imperiale (2000: p.31) views digital mapping as a technological representation of real topologies, with the research attempting to connect relationships between surface elements such as buildings and grounds, with human activities shaping them.

Imperative to understanding technology-architecture interaction is the shift from performance ratings to descriptive *appreciation and perceptions* of eco-design via educating society, investors, homebuyers and authorities on technologies which improve waste and renewable energy management (Curwell et al, 2007: p.114). Although technology enables, designing the total environment must also consider the indirect impacts on building occupants.

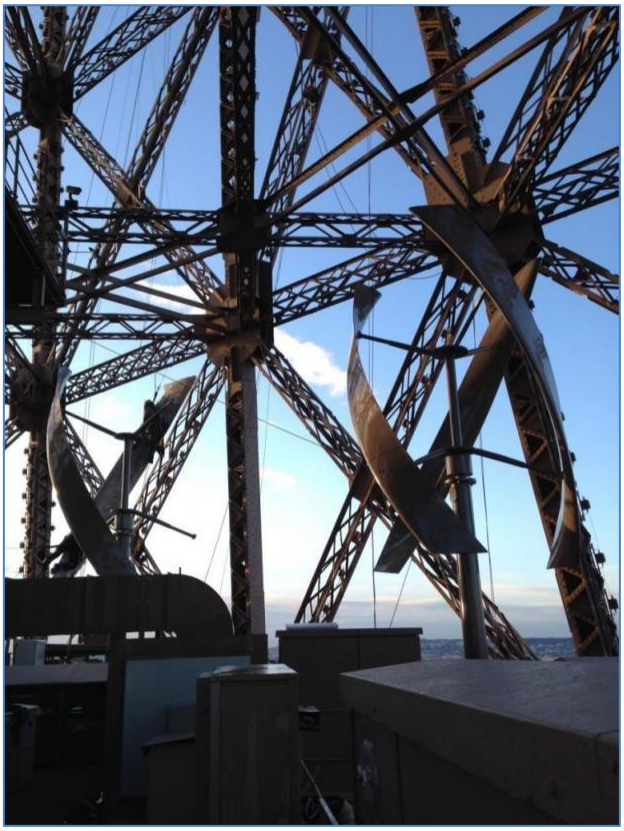

Figure 2 Eiffel Tower wind turbines

Studies on infrastructural, material, geophysical and urban ecology show evidence of beneficial outcomes from urban architecture's trans-disciplinary forms. Hence, technological interaction with ecological knowledge and cultural spaces offers a wide scope of cross-disciplinary research and interesting blending of knowledge through critical approaches to create *adaptable, resilient* and *flexible* urban systems (Reed and Lister, 2014).

High towers were once built chiefly to publicly demonstrate the application of Newton's gravitational laws. The phenomenon itself is encapsulated in these mega-structures. Eiffel Tower (Figure 2) is a complex and high-tech piece of architecture, engineering and art conjoined a recognisable icon of architectural technology and tourism place-making. In 2015, the tower embraced a green ethos by being retrofitted with a renewable energy generator using twin wind turbines worth US$490 billion to generate 10,000 kW/hour of electricity, along with other methods of lowering environmental impact including rainwater collecting system, solar panels and LED lights (*Scientific American*, 2015).

One Another example is cited by Yudelson and Meyer in The World's Greenest Buildings (2013: p.226), is The Port of Portland in Oregon, United States (Figures 3 and 4). Through obtaining sustainability recognition under *Leadership in Energy and Environmental Design* (LEED) certification, architectural leadership and stewardship are demonstrated via the building's sustainable design ecosystem, spread within the 1.4 mil square feet of office headquarters comprising 10-storeys of office space.

Figure 3 The Port of Portland headquarters, inspired by the hull of a ship

The Port of Portland was constructed to apply strategic long-term energy conservation measures include the 'Living Machine' series of wastewater tanks designed to treat and recycle wastewater through organic action of microorganisms. The headquarters also features a renewable heating and cooling system using 200 geothermal wells that pump warm or chilled water through radiant heating panels (depending on the time of year), an *alternative energy technology* (AET) which drastically lowered the occupants' dependency on regular air-conditioning (Halbersberg, 2012). Additionally, natural daylighting and smart

sensor lighting, besides reflective glaze coating to minimise heat absorption enables efficient usage of resources. ZGF Architects designed a prominent façade that heightens the essence of its beautiful structure: a curving lapped-glass curtain wall, inspired by a ship's hull (shipping being one of Portland's historically-important economic thrusts); while an open floor plan and large windows on all the ten levels provides wide vista views of the outside, creating visual unity of the organisation's heritage, business mission and future purpose (O'Brien, 2011).

Figure 4 Daylighting is a green building feature at the Port of Portland

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4.1.1 The Centre Pompidou

High The Pompidou Centre of Art and Technology in Paris offers the potential of a highly flexible design by applying high-tech materials and construction innovation in enriching the narrative evolution of architectural ingenuity through the art of engineering, invention and technology. Acting as a national French cultural centre, the Pompidou's architectural aesthetics, designed by Renzo Piano and Richard Rogers, is expressed in its dramatic infrastructure visibility, with the use of visual mapping techniques to expose a buildings "insides" using material effects such as steel beams, electricity lines, water pipes, air ducts and elevators (Figures 5 and 6). The Pompidou's purported energy efficient design reduces the need for regular wall skin and external wrapping (Meyers, 2011). Murphy (2012: p.84) further points out that the Pompidou's rather naïve *techne* was a 1960s social conjecture for "solutionism", a shift from the previous era's elitist architectural classicism to avant-gardism. Hence, the approach is complementary of its intended purpose as an art and cultural centre. Concurring with this notion, built environment academic Francesco Proto (2005) wrote a critique arguing that the objectification of the Pompidou, through its overt display of a building's insides as fetishistic, which has led many in the field of urban design to perceive sensationally innovative architecture as performing a "ritual of transparency", when it actually masks its potential to be a futuristic architectural form.

Figure 5 Exposed façade of The Pompidou Centre in Paris, with its elevator and interior design turned out

The dematerialisation of sustainability is expressed via 'megalomaniac' symbols throughout its 7,500 sq. metre-floor space to represent mass notions of "liberty" and "freedom" with features such as an escalator snaking around the blatantly exposed glass façade. The interior is coated to emit artificial lighting at night, becoming its frames of recognisable fame, and an intentional representation of utopian mainstream characteristic of social equality by de-materialising the relationships between environmental space and society. Further signifying the separation of space from audiences, the building invites a spectator's response by being nothing more than a surface spectacle (Imperiale, 2000: p.22) with media screens seducing viewers with apparent importance, and various cinema screening activities, performance spaces and museum exhibitions projecting what its architect Piano called as both the "known and yet to be discovered knowledge" of society (The Centre Pompidou, n.d.).

The Pompidou Centre continues to pull urban design theories apart. Its hyper-modern structure demystifies technology as a necessarily 'hidden' aspect of modern architecture (Proto, 2005). The architectural design of the Pompidou signifies the perception that *transparency* is the acceptable standard for postmodernist society, by presenting a seemingly a less elitist and more equitable urban structure, that is unrepeatable as much as it is flexible.

Nevertheless, turning a building inside out to showcase the "gears at work" on the inside, is a reminder of the self-objectification of human society, and makes the building a shrewdly invisible machine that breaks the natural law of reason by inverting innocent individuality and our sacred relationship with nature, into one of arrogant visibility (Porto, 2005: pp.586-587).

Figure 6 The Centre Pompidou to represent water (green), electricity (yellow), air circulation (blue) and people (red)

4.2 Case Study II: Architectural Design Interaction with Nature

Aesthetics of built design also derives from the symbiosis between structural (rational) and emotional concepts of *bioregionalism* (Sim van der Ryn, cited by Lowe, 2010: 66), which states the holistic "harmony of many goods", utility, durability and beauty, as underpinning ecological design principles. The approach of "working alongside or cooperating with nature" is a common perception of ecological design, involving exploration of spatial and emotional connections between ourselves and the aesthetics of natural surroundings via material, surface and structural analysis, and how nature as an external entity impacts place-making in the study of urbanism (Chapman and Gant, 2012; Chatterjee, 2014; Dovey, 2010; Lowe, 2010; van den Bergh and Janssen, 2004).

Figure 7: First Unitarian Society Meeting House with green roof design by Wright

Since 1990s, contemporary architectural and environmental design research has seen a greater focus on phenomenological experiences where cultural heritage value forms a key perception of building architecture, involving the study of social behaviours, characteristics and the emotional outcomes of living surroundings which makes places sustainable as community landmarks (Boonstra et al, 2007; Groat and Wang, 2013).

A pioneering example is found amongst American architect Frank Lloyd Wright's built legacies. The *First Unitarian Society* of Madison (FUS) Meeting House (Figure 7), completed in 1951, located in Wisconsin, was literally topped with a green roof, with solar panels installed on the flat sections to harness passive solar power corresponding to the direction of the sun, generating 90,000 kW-hours of electricity per year. Glass serves both as its walls and windows, creating airy spaciousness and natural lighting, effects which dramatically heightens the prow (front) section of the 500-seat auditorium (Figure 8). Maczulak (2010: p.138) wrote an essay on Wright's characteristic attributes the "organic" method of construction as the essence of form and function working in harmony, its design, being, *like nature*: sloping, flowing, low-pitched, with deep overhangs and horizontal planes (omitting basements and attics), that lessen the separation of spaces between indoor and outdoor.

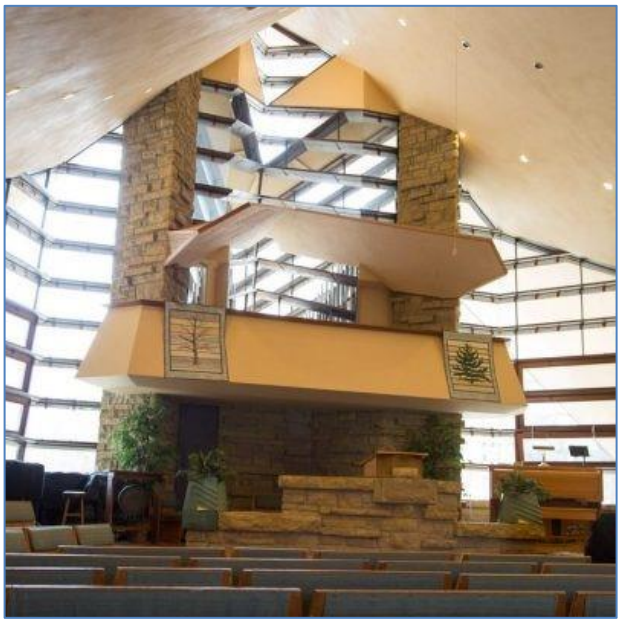

Figure 8: Unitarian Society Landmark Auditorium prow

Wooden grids between the external glass façade harmonises the indoor shades and shadows with outdoor and landscape views (University of Wisconsin, 2016). During its restoration and expansion phase in 2008, solar panels were also installed into its interior atrium wing, along with a geothermal-electric HVAC system, while the green roof was designed to attain a "carbon neutral vision" of the internal ministry team who provided management oversight of the sustainability goals. These initiatives enabled participants and the general public to be included in decision making, and via sponsorship and funding contributions (Legacy Solar Co-Op, 2019). As a result, the

building gained a Gold LEED certification, while preserving the historic grounds of the original structure. As a symbolic representation of architectural design heritage (*Wright on the Web*, n.d.), the FUS shows why it continues to appeal to the American cultural imagination as an inspiring antecedent model for many 21st-century green building designs in modern urban society today.

4. Discussion of the Findings

The case studies presented for analysis in this paper frames a qualitative approach to indicate the importance of stakeholder perceptions, which sustainability researchers and practitioners should acknowledge. The imbalance in stakeholder involvement often results in tangled power conflicts between those who are excluded or ignored by the dominant parties such as developers and management committees (Dovey, 2007: p.29).

Pertinent questions on functionality, resource utilisation and design construction processes further underlie conflicts among stakeholders and decision-makers for green building adoption (Chan et al, 2017; Spiegel and Meadows, 2010: p.4). Undefined sustainability performance goals have produced criticisms over the real value and practicability of green buildings. In some instance, commercial or residential tenants may not be consulted or heard in the developer's choice of energy-saving modes (for heating or cooling utilities). Stakeholders may find little encouragement to adopt green designs if, for example, they are not informed or briefed about the cost benefits of passive systems such as switching off public corridor lights at nights. At this juncture, we ask, why are these cases significant in the evolution of urban architecture?

The design of the Port of Portland suggests that perceptions of innovation through technological adaptation has become the new cultural capital, a symbolic representation of social power through economic progress (Dovey, 2007). This would concur with present critical theories which theorise that sustainable buildings are symbolic of social power, an *enablement* for progress rather than a constraint in the process of urbanisation. The architects behind the Pompidou in Paris pushes the idealisms of aesthetic innovation, by determining flexibility of construction as a factor for long term usage diversity and functioning. In contrast, the case study of Frank Lloyd Wright's classical architecture demonstrates architectural interaction with the environment to perform the function of cultural carrier of information, but this role may no longer resonate today as urban architecture is increasingly perceived to be an interaction between art, technology and the science of building for economic returns.

When deconstructed into 'cause and effect' rationales for green building adoption, these case studies demonstrate that the eco-design architectural discourse goes beyond determining spatiality, functionality, economic viability, valuation and efficient resource (material) consumption. They further suggest that the search for useful innovations embracing aesthetics helps to introduce better technologies for green infrastructure development practices. Ecological conservation cannot be denied or ignored, in the progress from "self-interest to global concerns" (Groat, 2002: p.117), but perceptions of sustainability are affected by and interrelated with how successfully architecture adapts and apply sustainability benchmarks to measure the efficiency of innovations, incorporated into practical use.

However, this finding indicates that sustainable architecture performance should not assume that incorporating technological innovations equal green, neither should sustainability ethos be dismissed as a passing phase in architectural development. In sustainability perceptions, the dominant view is that the physical, social and design dynamics of green buildings are the most crucial factors in determining asset valuation rather than aesthetic or environmental benefits. This suggest the gap will continue to exist between the idealisms of architectural design interaction with nature through passive systems, and technology's active role in enhancing green buildings.

There is thus a need to re-examine perceptions of *green building technology as architecture's ends rather than means*, which has grown notably in this century of heightened eco-consciousness. Another issue is the marketing of sustainable designs. Evidence of false or deceptive claims of fulfilling sustainability criteria based on speculative trends must be monitored and flouting developers publicly censured, especially among premium, commercial green buildings (Oyedokun, 2017).

Another factor is the increase in consumer protection mechanisms through establishing actionable laws. In this regard, industry agencies and authorities play a critical role to strengthen regulatory frameworks against unethical practices (or omissions) that use green-washing agenda such as "eco-marks", "clean technology" and other dubious labels as a marketing or publicity boost (Lane, 2011). For construction and development sectors, compliance with provisions under national green building codes of practice should be tightly monitored with concern for safeguarding users and occupants.

At the same time, professional certification must be encouraged among practitioners who intend to advise authorities and consumers on issues relating to sustainability ratings and information labelling for green building design, manufacture, efficiency, lifecycle and safety assurance (van den Bergh and Janssen, 2004). The education of green building practitioners must be a present priority among developing nations seeking global recognition for promoting urban sustainability concepts. For interior design sectors, compliance with passive design indices that are credible, accurate and comprehensive should be emphasised (Brophy and Lewis, 2011). Issues of conflict may arise as lessons are learned through acknowledging knowledge gaps, attitudinal and perception differences over the environmental advantages, aesthetics and brand image of building fitted with innovative systems and high-tech facilities. To overcome this, stakeholder issues such as barriers to technologies adoption should be transparently discussed to ensure building owners, management, occupants or users' perceptions are heard and documented (Chan et al, 2017). Sustainability perceptions also derive from designing passive

aesthetics that "cooperates with nature". By looking closely at a range of influencing factors, a project may genuinely reflect the *Three Sustainability Pillars* of social, economic and environmental impacts to be holistically communicated.

5. Conclusion

Within the next decade, a major revolution looks certain, with improvements in sustainable technologies and practices of green construction and environmental design. Undeniable is the fact that positive sustainability perceptions could be translated into economic benefits to enhance market valuation among investors keen to consider the financial returns that green office buildings offer compared to conventional buildings in terms of rental yields and sale price (Myers et al, 2007; Oyedokun, 2017).

This research is aimed at enlarging perspectives and understanding of the role of perceptions towards technological innovations in sustainable architectural and environmental design. Architectural scholarship and debates underline practitioners' responsibility to transcend the commercial aspects of sustainable design. As more developers lay claim to green projects' social benefits through marketing green design aesthetics combined with environmental performance, green buildings seem to point the way forward for future urban design approaches. Findings strongly suggest that social perceptions on innovations influence the potential value of green architecture by embodying what stakeholders might view as pragmatic solutions for construction and material use, energy savings, usage diversity, and reduced maintenance.

Yet, as to be seen in the case of the Pompidou's brash design, the real environmental consequences may be hidden from social perceptions if the image "becomes the end rather than the means" of understanding sustainability (Dovey, 2010: p.53). Ecological innovations in architecture must be proved in their abilities to 'future-proof' building designs in order to fulfil their critical function as social enabler for sustainable growth of the human population, which sustainability designer Ezio Manzini called architecture's most noble, powerful purpose (cited in Chapman and Gant, 2012: pp.76-95).

Sustainable urban design today is challenged to create positive attitudinal shifts, to change social perceptions that green buildings are not merely a trend, and that sustainable architecture is a way of experiencing nature in environmental design. Practitioners need to cultivate and sustain stronger sustainability vision through continually thinking of ways to ramp up long-term solutions for creative integration of spatial designs, systems and materials with technological innovations purposed for the urban buildings of tomorrow.

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Perceptions of Youngsters on Interior Space Quality in Relation to Materiality and Spatial Design

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ABSTRACT

Studies discovered that humans spent around 80% of our time indoor and this phenomenon is deteriorating our health physically and psychologically. Thus, it is important to study the effects of different interior designs on our emotions. The previous studies and researches done on interior spaces are mostly focusing on measurable physical attributes of interior whereas the psychological relationships between interior design criteria and human emotions have not been well studied. Therefore, this research paper aims to determine the suitable interior space for youngsters from different backgrounds in terms of spatial quality and materiality. In this paper, 4 types of commonly-used materials in Malaysia, namely Timber, Concrete, Bricks and Stones are selected to be studied and analyzed based on the respondents' preferences and perceptions of warmness or coolness of materials. The results showed that there is no distinctive relationship between respondents' preferences to materials and their educational backgrounds but respondents of different races showed different degree of acceptance towards different finishing materials. The paper proof the respondents prefer to have warm-feeling materials such as timber and bricks for their home design as compared to cold-feeling materials such as concrete and stones. The results will serve as a material-selection guideline for designers.

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1.0 Introduction

From the historical walkthrough of architecture, humans are psychologically associated with architecture in terms of choice of construction materials (Margarete, 2018). Started from prehistoric period where architecture made from natural resources is mainly for survival and reproductive purposes to Neolithic period with vast stone architecture to emphasis spiritual beliefs & power assertion and then modern period where steel and concrete architecture emphasized the mass production in response to industrialization. Now, architecture has become more diversified and a whole range of construction materials is available and considering the fact that we spend tremendous amount of time indoor where around 90% of people spent 22 hours indoor per day (Walden, 2018), and we experience different state of mind in different architecture (Ricci, The Psychological Impact of Architectural Design, 2017), it is very crucial to have researches and studies done on studying how the users perceive an interior space. However, among the studies and researches done on interior spaces, most of them are focusing on measurable physical attributes of interior spaces such as the Indoor Air Quality (IAQ) and lighting designs whereas the psychological relationships between interior design criteria (Interior finishing materials selection, Fenestrations, Spatial Volume Design, etc.) and human emotions have not been well studied. Thus, this research paper aims to determine the suitable interior space for youngsters from

different backgrounds in terms of spatial quality and materiality and 4 primary finishing materials, namely: timber, concrete, brick and stone are selected for analysis.

1.1 Architecture and Materials

In this technological advanced era, architecture has become more diversified and a whole range of construction materials is available to be used for architectural design. Previous research has found that humans are remarkably good at visually perceiving materials (W.Fleming, 2013) which implies that a well-planned and designed indoor space with the right choice of materials is extremely important for us to live a better life (Gander, 2016). Therefore, sufficient researches and studies regarding the materials should be done as reference data for the users or designers when they are choosing materials. For instances, popular materials such as timber, concrete, bricks and stones shall be studied in terms of both physical and psychological attributes.

1.2 Texture of Materials

The word "Texture" is defined as the "quality of something that can be decided by touch; the degree to which something is rough or smooth, or soft or hard" (Cambridge Advanced Learner's Dictionary 4th Edition, 2013). Although only the sense of touch is mentioned in the dictionary, but when texture is perceived aesthetically, it actually involves another sense known as visual sense. Therefore, the texture of a material can be classified into the two following categories, namely tactile texture and visual texture. Tactile texture refers to the 3D properties of a material which allow it to be valued through tangible or touchable measures (DEZIEL, 2013). For example, the texture of a timber panel is characterized by the wood-grain patterns which synthesize feeling of carved-ins and grooves when we touch the surface. Visual texture values a material from the aesthetical perspective and the texture can be either 3D with uneven surfaces or 2D with paints or wallpapers.

1.3 Colour of Materials

Colour is the general term used to describe every hue, tint, tone or shade our eyes see and the colour black, white and grey are known as colours as well (Figure 1). In colour theory, hue refers to the dominant colour family of the specific colour we're looking at and the colour black, white and grey are never referred to as a hue. Tint is the product of adding the colour white into any hue and it is sometimes known as pastel colour. In another word, it is a paler version of hue. Tone is the product made of adding shades of grey into hue. Toned colours are generally considered more pleasing to the eye. They are complex, subtle and sophisticated. That's because bright pure colours are most often associated with children (Williams, 2011). Shade is a darker version of hue when the colour black is added into hue.

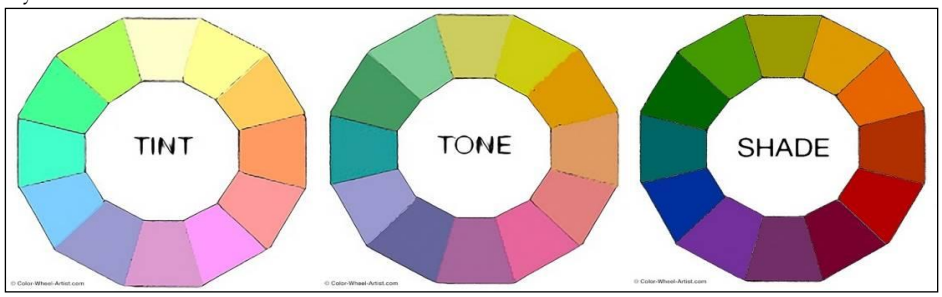


Figure 1 *Colour Tint Wheel, Colour Tone Wheel & Colour Shade Wheel retrieved from the website: https://color-wheel-artist.com/hue/*

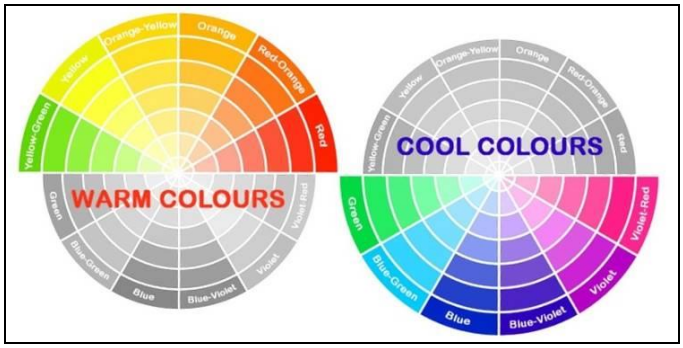


Figure 2 *Warm & Cool Colour Wheel retrieved from the website: https://color-wheel-artist.com/hue/*

Besides of the mentioned properties of colours, colours are being categorized as warm colour or cool colour according to their degree of warmness (Figure 2). Among the 4 selected finishing materials in this paper, timber and brick is perceived as warm while concrete and stone being perceived as cold.

1.4 Color & Emotions

Previous scientific studies and observations have proven that human-environment-reaction in the architectural environment is to a large percentage based on the sensory perception of colour.

For instance, there was a study suggests that "colour can have customer drawing power as well as image-creating potential in retail store design" (Shi, 2013). Although we only perceive colour visually, but actually colours are electromagnetic energy where each of the colours has its own specific wavelength and frequency. This is further proven by a test which showed that a blindfolded person in a room experiences faster pulse rate when he is inside a red room and experiences slower pulse rate when exposed to blue or green (LTD, 2017). The psychological effects of colours are elaborated further in Table 1 below.

Table 1 The Psychological Implications of Colors, retrieved from the website: https://medium.com/studiotmd/the-perception-of-color-in-architecture-cf360676776c

Color	Psychological Effects
Red	**Effect:** exciting, stimulating **Association:** Positive: passionate, fervid, active, strong, warm Negative: intense, aggressive, raging, fierce, bloody
Orange	**Effect:** exciting, stimulating, cheering **Association:** Positive: jovial, lively, energetic, extroverted Negative: intrusive, blustering
Yellow	**Effect:** cheering **Association:** Positive: sunny, cheerful, radiant, vital Negative: egocentric, glaring
Green	**Effect:** retiring, relaxing **Association:** Positive: tranquil, refreshing, quiet, natural Negative: common, tiresome, guilty
Blue	**Effect:** retiring, relaxing **Association:** Positive: calm, sober, secure, comfortable, noble Negative: frightening, depressing, melancholy, cold
Purple	**Effect:** subduing **Association:** Positive: dignified, exclusive Negative: lonely, mournful, pompous, conceited
Brown	**Effect:** subduing **Association:** Positive: warm, secure, stable Negative: oppressive, heavy
White	**Effect:** dis-concerning **Association:** Positive: clean, crisp, bright Negative: empty, sterile
Grey	**Effect:** neutral to calming **Association:** Positive: neutral Negative: boring
Black	**Effect:** ominous **Association:** Positive: deep, abstract Negative: dungeon-like, night, grief, death

1.5 Volume and Scale of Interior Spaces

Other than the choices of materials, spatial design is also another aspect to be studied for a better understanding of how people perceive interior spaces. By referring to the famous Winston Churchill's quote "We shape our buildings; thereafter they shape us" (Parliament, 1943), an interior space too plays a role in facilitating activities and values which defines who we are. In additional to that, space could also notify wealth which might affect our social status (Foye, 2017). Our feeling towards a space and its spatial quality is based on how we understand the volume and size of the space. This could be explained by imagining ourselves being in a living room as compared to the feeling of being inside a bedroom. The feeling will be totally different as the designated function and intimacy level of a living room is more to family interactions and semi-private while bedroom is designated to be a private space with higher security and privacy level. The scale and size of an interior space is highly associated with our lifestyles and behaviours as well, taking the example of UK, having group of friends around, sitting silently and eat as a family is one of the end product due to limited space (Robert-Hughes, 2011).

1.6 Fenestration of Interior Spaces

From architecture point of view, the term "Fenestration" is defined as "The arrangement of windows in a building" according to Oxford Dictionary (Oxford English Dictionary (2nd Edition), 1989). Being one of the important components of a building, windows decide where and how much of daylight coming into the interior spaces and how efficient will the natural ventilation be. By comparing two rooms with different numbers of fenestrations installed, the room with more openings will draws in more daylight to highlight the building elements, materials, spaces, textures and others (TPC, 2017). It is also very crucial to note that windows are the parts of an interior space which connect it to the environment outside to form connectivity and prevent sense of disorientation (Walden, 2018).

2.0 Methodology

This research paper is carried out based on quantitative research methodology where data collection is done through questionnaire distribution to respondents. The questionnaire is in the form of pictorial questionnaire using images rendered from computer 3D visualization. Based on all the data collected, analysis and synthesis are carried out to address the research questions and research objectives.

2.1 Selection of Materials

In this research paper, 4 primary materials which are widely used in architectural field are investigated and studied. The list of materials is as following: MT01-Timber, MT02-Concrete, MT03-Brick and MT04-Stone. The materials are chosen based on their popularity for being used in Malaysian construction industry (Abdul Kadir Bin Marsono, 2015).

2.2 Pictorial Questionnaire

Pictorial questionnaire contains pictures to promote interest and help to visualize the imaginary images among respondents so that they will have a guidance and better understanding of the objective of the questionnaire. Although it could be found usually in children textbooks and study materials, but when it comes to the field of architecture, it is one of the effective ways to collect data from the respondents' aesthetical viewpoints. In this research paper, the respondents are youngsters from different educational and racial backgrounds. This research paper includes 3D visualization of a living space using computerization as medium. The similar space is then rendered into spatial images which made up of different materials. All of these images are then included as part of the questionnaire to be answered, examples of rendered images (Figure 3, Figure 4, Figure 5 & Figure 6):

Figure 3 *Rendered Image of a Living Space Finished with MT01-Timber.*

Figure 4 *Rendered Image of a Living Space Finished with MT02-Concrete.*

Figure 5 *Rendered Image of a Living Space Finished with MT03-Brick.*

Figure 6 *Rendered Image of a Living Space Finished with MT04-Stone.*

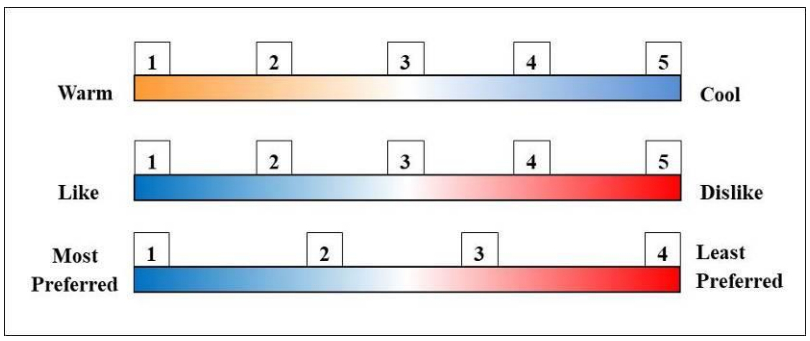


Figure 7 *Scales of Warmness, Likert and Preference*

2.3 Measurement of Data

The collected data are analysed using the Scale of Warmness, Likert and Preference as shown in Figure 7 above.

2.4 Selection of Space

As people feel and experience differently in different spaces due to designated space function, volume, scale and proportion, it is necessary to fix the space to be studied and make it as a constant variable. In this research paper, the living space is selected as the space to be studied. Therefore, a 3D computerized model of a living room is built as a basic unit for research.

2.5 Selection of Study Ground and Respondents

The target group of this research is focused on the Malaysian youngster population from different educational and racial backgrounds. In this research paper, students from University of Malaya (UM) have been selected and classified into 3 groups according to the nature of their respective field of studies. The list is as below:

2.5.1 Architecture

- Defined as "the art and practice of designing and making buildings"
- The students undertaking the architecture program will be learning on how to plan and design buildings or other relevant structures.
- Spatial design-based and construction industry-related.

2.5.2 Civil Engineering

- Defined as "the work of designing, building, and repairing large public structures such as roads, bridges, water systems, and airports"
- The students learn how to design and construction of projects, financing them and managing the construction process. However, their designs are mainly focusing on the structural performance which is different from architectural design.
- Non-spatial design-based and construction industry-related

2.5.3 Biomedical Engineering

- Biomedical Engineering (BME) is a multidisciplinary STEM field which links engineering with biology and implement engineering principles and materials to healthcare and medicine (Mendeley Ltd., 2018).
- The students learn how to apply engineering principles and design concepts to solve problems in medicine and biology.
- Noted that BME is a field that does not have any direct relation to the construction industry.
- Non-spatial design-based and non-construction industry-related.

3.0 Result and Discussion

3.1 Respondents' Demographic Information

The respondents of this research are from the youngster population of different educational and racial backgrounds. As shown in Figure 8 below, 59 (66%) respondents are Malay, 15 (17%) are Chinese, 3 (3%) are Bumiputera other than Malay and 13 (14%) are International students. Referring to Figure 9, equal numbers of 30 respondents are picked randomly from each of the educational program namely: Architecture, Biomedical Engineering and Civil Engineering

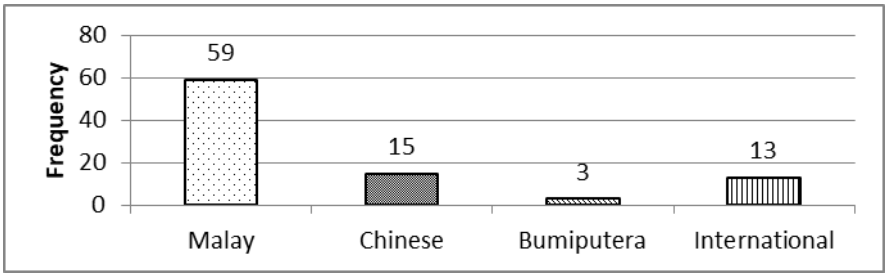


Figure 8 Respondents' Racial Composition

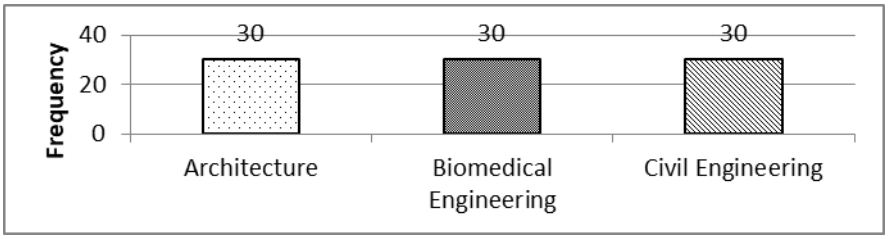


Figure 9 Respondents' Educational Background

3.2 Respondents' Preference on Interior Space Finishing Materials

A series of computer rendered images (Figure 10, 11, 12 & 13) are displayed to the respondents as reference for them when answering the questionnaire. The results of the respondents' preference on finishing materials of interior space are tabulated in Table 2 & 3.

Figure 10 *Living Room with Timber Panel Walls, Floor and Ceiling. (Code B1)*

Figure 11 *Living Room with Cement Finished Reinforced Concrete Walls, Floor and Ceiling. (Code B2)*

Figure 12 *Living Room with Brick Walls, Ceramic Tiled Floor and Plaster Ceiling. (Code B3)*

Figure 13 *Living Room with Stone Veneer Walls and Stone Textured Floor and Ceiling. (Code B4)*

Table 2 *Respondents' Preference on Interior Space Finishing Materials as Compared to Racial Groups*

Races	Most Preferred	Preferred	Less Preferred	Least Preferred
Overall	B1-Timber (2.09)	B3-Brick (2.46)	B4-Stone (2.67)	B2-Concrete (2.79)
Malay	B1-Timber (2.19)	B3-Brick (2.56)	B4-Stone (2.56)	B2-Concrete (2.69)
Chinese	B1-Timber (1.60)	B3-Brick (2.13)	B4-Stone (3.07)	B2-Concrete (3.20)
Bumiputera (Native)	B3-Brick (1.67)	B1-Timber (2.00)	B2-Concrete (3.00)	B4-Stone (3.33)
International	B1-Timber (2.23)	B3-Brick (2.54)	B4-Stone (2.54)	B2-Concrete (2.69)

From Table 2, generally, the Room B1-Timber is the most preferred interior space by the respondents, especially among the Chinese respondents but exclude the Bumiputera respondents. The Room B2-Concrete is rated as the least preferred interior space by all the racial groups except for the Bumiputeras. Both the Chinese and Bumiputera respondents show a high intolerance towards concrete interior space. The Room B3-Brick is the 2nd preferred interior space by the respondents after B1-Timber. The Room B4-Stone is the 2nd least preferred interior space after Room B2-Concrete.

Table 3 *Respondents' Preference on Interior Space Finishing Materials as Compared to Educational Backgrounds*

Educational Background	Most Preferred	Preferred	Less Preferred	Least Preferred
Overall	 B1-Timber (2.09)	 B3-Brick (2.46)	 B4-Stone (2.67)	 B2-Concrete (2.79)
Architecture (AR)	 B1-Timber (1.73)	 B4-Stone (2.53)	 B3-Brick (2.70)	 B2-Concrete (3.03)
Civil Engineering (CE)	 B1-Timber (2.10)	 B3-Brick (2.40)	 B2-Concrete (2.53)	 B4-Stone (2.97)
Biomedical Engineering (BME)	 B3-Brick (2.27)	 B1-Timber (2.43)	 B4-Stone (2.50)	 B2-Concrete (2.80)

From Table 3, Room B1-Timber is the most preferred interior space by the respondents, especially among the AR respondents but exclude BME respondents. Room B2-Concrete is rated as the least preferred interior by both AR and BME respondents but it is rated as the 2nd least preferred interior space by the CE respondents. Preferences for Room B4-Stone and Room B3-Brick fluctuate for different educational backgrounds.

By concluding the data from Table 2 and 3, the Room B1-Timber is ranked as the most favoured and preferred interior space by the respondents where 42% of the respondents ranked Room B1-Timber as the most preferred interior space among the 4 rooms with different material finishes and 19% ranked it the 2nd most preferred interior space. Among the respondents who like the MT01-Timber, 74% of them are because of the colour tone of the material and 67% are because of the naturalness of the material. The colour tone of MT01-Timber as displayed to the respondents is in brown which evokes feelings of warm, secured, comfortable and stable as explained in Chapter 2. The Room B3-Brick is ranked as the 2nd preferred interior space after Room B1-Timber where 22% of the respondents ranked B2-Brick as the most preferred interior space among the 4 rooms with different material finishes and 37% ranked it the 2nd most preferred interior space. The repeating orders of the brick masonry arrangement evoke another aesthetic experience among the respondents, causing them to rank Room B3-Brick as the 2nd preferred interior space.

The Room B4-Stone is ranked as the 2nd least preferred interior space. Among all the respondents who dislike the Room B4-Stone, 52% is because of the stone material being utilized too much throughout all the walls, creating a maze-like, chaotic feeling while 39% is because of the colour tone of the room which appeared to be too grey and lifeless. The Room B2-Concrete is ranked as the least preferred interior space among the 4 rooms with selected materials. Among all the respondents who dislike the Room B2-Concrete, 58% is because of the overall colour tone of the room which is too grey and it evokes feeling of cool, boredom, lost and dullness. If the designer insists on using concrete as the main finishing materials but wanted to maintain end users' satisfaction for the interior space, the designer could actually change some of the wall surfaces or flooring materials into something different from concrete, preferably some warm material to balance off the negative effects of pure concrete finishes.

3.3 Respondents' Preference on Interior Space with Combination of Finishing Materials

Another set of computer rendered images namely Figure 14, 15, 16 & 17 are displayed to the respondents to study on the respondents' preference on interior space with mixture of finishing materials and the results are tabulated in Table 4 & 5.

Figure 14 *Living Room with only Timber Finishes and it represents a Space of Pure Warmness. (Code B5)*

Figure 15 *Living Room with Mixed Finishes made up of Timber, Bricks and Tiles and it represents a Space of Mixed Warmness. (Code B6)*

Figure 16 *Living Room with Mixed Finishes made up of Stones and Concrete and it represents a Space of Mixed Coolness. (Code B7)*

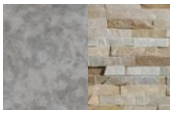
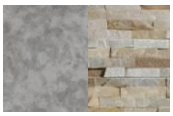
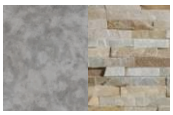
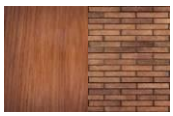
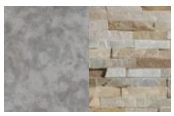
Figure 17 *Living Room with Mixed Finishes made up of Concrete and Bricks and it represents a Space of Warm-cool Mixture. (Code B8)*

Table 4 *Respondents' Preference on Interior Space Finishing Material Combinations as Compared to Racial Groups*

Races	Most Preferred	Preferred	Less Preferred	Least Preferred
Overall	B8-Concrete & Brick (2.20)	B6-Timber & Brick (2.33)	B5-Pure Timber (2.60)	B7-Concrete & Stone (2.87)
Malay	B8-Concrete & Brick (2.03)	B6-Timber & Brick (2.51)	B5-Pure Timber (2.66)	B7-Concrete & Stone (2.80)
Chinese	B6-Timber & Brick (1.73)	B5-Pure Timber (2.27)	B8-Concrete & Brick (2.60)	B7-Concrete & Stone (3.40)
Bumiputera (Native)	B6-Timber & Brick (1.33)	B5-Pure Timber (2.33)	B8-Concrete & Brick (2.67)	B7-Concrete & Stone (3.67)
Inter-national	B8-Concrete & Brick (2.38)	B7-Concrete & Stone (2.38)	B5-Pure Timber (2.46)	B6-Timber & Brick (2.77)

Table 4 showed that the Room B8-Concrete & Brick is the most preferred interior space by the Malay and International respondents while the Room B6-Timber & Brick is the most preferred interior space by the Chinese and Bumiputera respondents. The Room B7-Concrete & Stone is the least preferred interior space by the Malaysian respondents but it is one of the most preferred interior spaces by the International respondents together with B8. The Room B5-Pure Timber is more preferred by the Chinese and Bumiputera respondents but less preferred by the Malay and International respondents.

Table 5 *Respondents' Preference on Interior Space Finishing Material Combinations as Compared to Educational Backgrounds*

Educational Background	Most Preferred	Preferred	Less Preferred	Least Preferred
Overall	 B8-Concrete & Brick (2.20)	 B6-Timber & Brick (2.33)	 B5-Pure Timber (2.60)	 B7-Concrete & Stone (2.87)
Architecture (AR)	 B6-Timber & Brick (2.23)	 B8-Concrete & Brick (2.33)	 B5-Pure Timber (2.37)	 B7-Concrete & Stone (3.07)
Civil Engineering (CE)	 B8-Concrete & Brick (2.17)	 B6-Timber & Brick (2.33)	 B5-Pure Timber (2.47)	 B7-Concrete & Stone (3.03)
Biomedical Engineering (BME)	 B8-Concrete & Brick (2.10)	 B6-Timber & Brick (2.43)	 B7-Concrete & Stone (2.50)	 B5-Pure Timber (2.97)

From Table 5, The Room B8-Concrete & Brick is the most preferred interior space in overall and for both CE and BME respondents while the Room B6-Timber & Brick is the most preferred interior space by AR respondents. The Room B7-Concrete & Stone is the least preferred interior space by both AR and CE while the Room B5-Pure Timber is the least preferred interior space by BME.

By summarizing the data from Table 4 and 5, four combinations with each representing different feeling are compared:

1. B5-Pure Timber which represents pure warmness
2. B6-Timber & Brick which represents mixed warmness
3. B7-Concrete & Stone which represents mixed coolness
4. B8-Concrete & Brick which represents warm-cool mixture

It is found that the respondents prefer the Room B8-Concrete & Brick the most where 36% of the respondents ranked Room B8-Concrete & Brick as the most preferred interior space among the 4 rooms with different mixture of finishing materials and 27% ranked it as the 2nd most preferred interior space.

The results showed that the respondents prefer an interior space made up of a variety of finishing materials. It is explainable for it creates a more diverse spatial experience which in turn provokes more positivity and visual contentment among the dwellers. The Room B8-Concrete & Brick celebrates diversity in terms of materials mixture where concrete of cool nature is mixed with brick of warm nature, fostering a balanced materiality relationship.

3.4 Respondents' Preference on Interior Space in Terms of Color Tone

In order to study the respondents' preference on colour tone of finishing materials of interior space, the Figure 18 & 19 are shown to the respondents for comparison and the results are shown in Figure 20.

Figure 18 *Living Room with finishes made up of lighter toned timber panels. (Code C1)*

Figure 19 *Living Room with finishes made up of darker toned timber panels. (Code C2)*

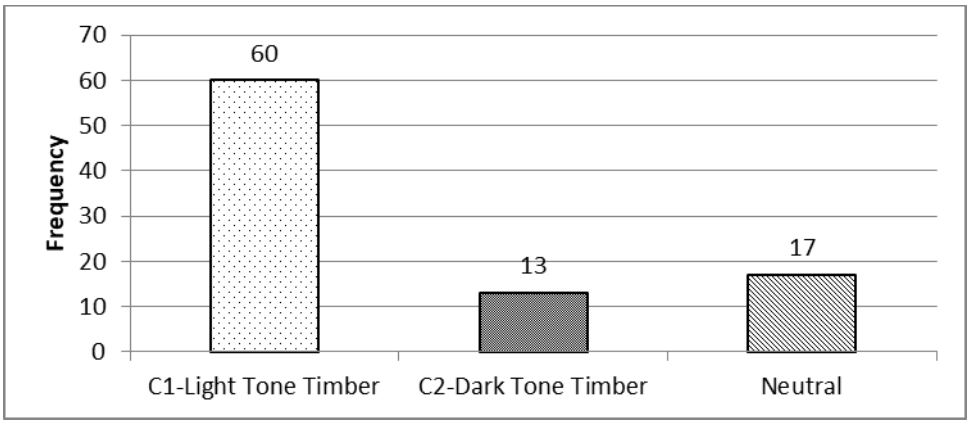


Figure 20 *Respondents' Preferences on Colour Tone of Interior Space*

From Figure 20, 67% of the respondents prefer the Room C1-Light Tone Timber compared to 19% who prefer Room C2-Dark Tone Timber. The remaining 14% respondents remain neutral.

This is explainable by referring to the previous study done on the impact of colour on psychological mood which proven that respondents experienced lowest mood and emotional state within a dark room (Rikard Küller, 2006). A dark room made up of darker toned materials reduce visibility of an interior space especially when there is no any day lighting or artificial lighting designated to light up certain dark corners. The presence of the dark corners will create a gloomy and haunted image for that

room. Therefore, when designing a living room, it is important for the designers to have great considerations on either to choose a light toned finishing materials or utilize day lighting or artificial lighting to ensure a cheerful and friendly ambience for the living room.

3.5 Respondents' Preference on Interior Space in Terms of Spatial Volume

As we experience different emotional feelings in spaces of different volume, it is crucial to study the respondents' preference on that. Thus, Figure 21 & 22 is displayed to the respondents for the respondents to compare spaces made up of different volume and the results are shown in Figure 23.

Figure 21 *Living Room with finishes made up of brick walls, ceramic tiled floor and plaster ceiling within single storey. (Code D1)*

Figure 22 *Living Room with finishes made up of brick walls, ceramic tiled floor and plaster ceiling with double volume design. (Code D2)*

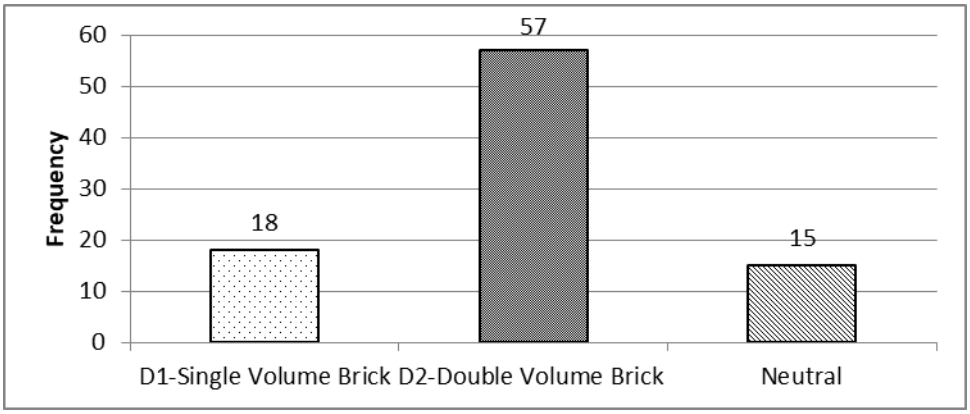


Figure 23 *Respondents' Preferences on Double Volume Design of Interior Space*

From Figure 23, 63% of the respondents prefer the Room D2-Double Volume Brick compared to 20% who prefer Room D1-Single Volume Brick. The remaining 17% respondents remain neutral.

It is explainable by the following facts: A living room is designated as the primary gathering space for a family or community within a house where a lot of human interactions will happen here. Thus, by having a double-volume design in the living room, it provokes grand and welcoming feelings among the dwellers which will in turn encourages more interactions.

Other than that, a double-volume space will creates more seamless flow between the interior and exterior where the dwellers will have a wider view vertically towards the outside and the sky (Andreas Vogler, 2005). This will also increase the amount of day light intake into the space. If it is possible, the designers could always propose a double-volume design for the psychological benefits of the dwellers.

3.6 Respondents' Preference on Interior Space in Terms of Fenestrations

Fenestration is an important element to emphasize on when designing a space for it impacts differently on the dwellers' experience. Figure 24 & 25 are displayed to the respondents to study the respondents' preference on fenestration allocation of an interior space. The results are shown in Figure 26

Figure 24 *Living Room made up of stone veneer walls and marble finished ceiling and floor designed with more openings compared to Figure 13. (Code E1)*

Figure 25 *Living Room made up of stone veneer walls and marble finished ceiling and floor designed with less openings compared to Figure 12. (Code E2)*

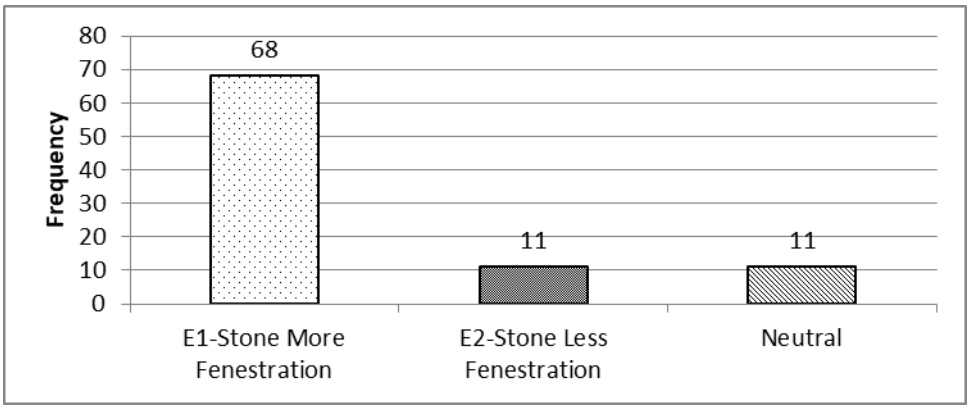


Figure 26 *Respondents' Preferences on Fenestrations of Interior Space*

From Figure 26, 76% of the respondents prefer the Room E1-Stone More Fenestration compared to 12% who prefer Room E2-Stone Less Fenestration. The remaining 12% respondents remain neutral.

The explanation for this result is based on the day light quantity: More fenestrations will ensure a greater amount of day light intake into the space but too much fenestrations will brought in unwanted excessive heat as well.

Day light is indeed a must for a healthy interior space including living room for it not only naturally lights up the interior space but also helps to refresh our minds and inject positivism into our daily life (Wen-Bin Chiou, 2013). It is the job of the designers to find a balance in the quantity and design of fenestration according to the function and the user groups.

4.0 Conclusion

This research paper studied on the Perceptions of Youngsters on Interior Space Quality in Relation to Materiality and Spatial Design and found out that the respondents prefer the material MT01-Timber the most due to the colour tone and the naturalness of timber. It was followed by MT03-Brick as the 2nd preferred materials by the respondents. The material MT04-Stone is ranked as the 3rd preferred materials while MT02-Concrete is the least preferred material by the respondents. MT02-Concrete is disliked by the respondents for its boring, dull and gloomy grey colour tone together with its unfinished and raw surface. When comparing interior space finished with mixture of materials, the results showed that the respondents generally prefer the warm-cool mixture (MT02-Concrete and MT03-Brick) the most for its richness and variety in spatial visual experience while the mixed-coolness (MT02-Concrete and MT04-Stone) is the least preferred combination by the respondents for its coolness and boring greyish colour tone. In additional, the respondents prefer a light toned interior space than a dark toned interior space; prefer a double-volume design over plain single volume design and prefer more fenestrations in an interior space.

Lastly, the suitable interior spaces for Malaysian youngsters from different backgrounds in terms of spatial quality and materiality are concluded as Table 6 below:

Table 6 Conclusion on suitable interior spaces for Malaysian youngsters from different backgrounds in terms of spatial quality and materiality.

Conclusions
Preferences on Finishing Materials: Timber > Brick > Stone > Concrete
Preferences on Finishing Materials Mixtures: Warm-Cool Mixture > Mixed Warmness > Pure Warmness > Mixed Coolness
Preferences on Spatial Colour Tone: Light Toned > Dark Toned
Preferences on Spatial Volume: Double-volume > Single-volume
Preferences on Fenestrations: More Fenestrations > Less Fenestration

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Towards Promoting Efficient Management Of Mass-Housing Reconstruction Schemes

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ABSTRACT

To ensure quick socio-economic recovery of the communities affected by insurgents' attacks in the north-eastern Nigeria, the first phase of the mass-housing reconstruction scheme has been completed but with many issues overshadowing the achievement like unsatisfactory involvement of local beneficiary communities; poor cooperation among key stakeholders; and communication gaps between donors, construction companies and local beneficiaries, which results in low quality housing products. Therefore, it became necessary to ensure that only contractors who satisfactorily passed the efficiency test are allowed to participate in the subsequent phases of the reconstruction scheme. Thus, this paper provides quantitative technique for evaluating the efficiency of contractors in managing the housing reconstruction. It is expected that the technique will seek to guide informed decisions on the efficiency of managing the reconstruction scheme, which is in different phases and locations. Although the evidences on which the results of this study emanate from reconstruction of building structures experiences in some parts of Nigeria, the technique developed could be adopted in other areas faced with similar issues. This paper updated existing knowledge on the management of mass-housing reconstruction works and offers support to decision-makers and practitioners involved in managing reconstruction of building structures affected by insurgency.

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1. Introduction

The wanton destructions caused by the Boko Haram terrorist group in the north-eastern part of Nigeria claimed over twenty thousand human lives, destroyed physical infrastructure and significantly disrupted socio-economic activities in the region (Abdu and Pahirage, 2017; Shettima 2016, Adesoto and Peters 2015). About 293,000 residential housing units were severely damaged (Mariam et al. 2016). Residential houses in the cities and urban centers were mostly affected due to the bomb blasts, shelling and fire.

To date, the Borno State government has repaired about 30,000 housing units in Bama, Damboa, Gwoza, Kaga, Konduga, Mafa, Maiduguri, Mobbar, and Nganzai areas (Mumini, 2019). This figure represents a paltry 4% of the entire 430,000 residential housing units destroyed and the 293,000 units that were severely damaged due to the insurgency. The figure is

considered very low for a mass housing reconstruction scheme that targets a speedy reintegration of the IDPs in their permanent communities. Although the progress of the reconstruction works is hampered by paucity of funds, social sustainability issues and lack of existing strategy for utilizing the donor fund; evidence shows that the poor management of the reconstruction works during the implementation phase remains highly predominant.

Among the poor management practices observed are prolonged procurement procedures; delays in supply of essential project resources; unsatisfactory involvement of local beneficiary communities; poor cooperation among key stakeholders; lack of regulatory framework for enforcing conformance to quality management plans and construction guidelines; communication gaps between donors, construction companies and local beneficiaries, which results in low quality housing products; heavy political influence and involvement of corrupt stakeholders. Corroborating this, previous studies in different climes (Liu and Liu 2012) have identified ineffective project organization and management of the reconstruction process as one the leading factors for unsuccessful reconstruction of residential buildings.

Consequently, it is imperative to pay greater attention to the management practices involved in the reconstruction scheme (Ahmed 2011). However, extensive literature search indicates there is lack a quantitative strategy to evaluate contractors' efficiency in managing the reconstruction project. Thus, this study seeks to introduce a fundamental mathematical tool that can be used to evaluate contractors' efficiency in managing reconstruction project for houses affected by the Boko Haram insurgency. This objective will primarily include the systematic identification of the appropriate criteria to be applied to effectively examine the efficiency level of the management practices adopted for reconstruction scheme and to accurately determine the relative significance of each criteria empirically.

1.1 Original Contribution of the Study

In spite of the strategic importance of efficient management of post-disaster reconstruction of building structures, the enormous funds allocated for housing repair, renovation and reconstruction works worldwide, and the need for a quick resettlement of the displaced people, it is clear from Table 1 that there is a dearth of knowledge in providing a quantitative approach or tool for evaluating the efficiency of the reconstruction works for building structures.

Table 1. Management of post-disaster reconstruction of building structures - A review of related frameworks

Authors	Previous Works
Bilau et al., (2018)	The main contribution of this work is the development of a conceptual framework that could be applied in managing post-disaster housing repair and reconstruction. The paper also determined the barriers influencing the management of housing repair initiatives in developing countries.
Vahanvati (2018)	The author developed a framework for promoting the efficiency of the owner-driven housing reconstruction (ODHR) scheme. The paper further asserts the significance of adopting the ODHR framework as case studies from India were presented to assert the effectiveness of the framework in promoting the repair of a more resilient built environment.
Jamshed et al., (2018)	The central theme of this study is the development of proposed conceptual framework that would significantly enhance the involvement of local community beneficiaries during post-disaster repair, renovation & retrofitting works. One of the salient features of this framework is its potential to serve as a platform for affected local communities to proactively recover socially and economically based on their needs and terms.
Sadiqi et al., (2017)	The authors' contribution is the development of a conceptual framework for active involvement of local communities in the preconstruction stages of post-disaster repair, renovation & retrofitting projects. The framework has the potential to enable reaching synergy between satisfying the needs of the local communities and the project development plans.
Bilau et al., (2015)	A conceptual and pragmatic framework was introduced in this study for handling the managerial impediments often encountered when executing mass housing repair, renovation & retrofitting project. An obvious limitation to this framework is that it does not provide a proficiency index to determine the actual efficiency level of the management practices of construction companies handling the implementation of mass housing retrofitting projects. The proficiency index would indicate the score allocated to each management practice criterion based on the actual management practices proficiency level of a construction organization.
Lu and Xu (2015)	The authors' contribution is the development of a consolidated conceptual framework capable of promoting collaborative efforts among non-governmental organizations participating in the implementation of post-disaster reconstruction.
Ophiyandri (2013)	The main contribution of this work is the development of a model for managing the risks associated with local communities' participation in housing renovation projects. The author further produced a risk response document and established set of factors for efficient implementation of community-oriented housing renovation works in the aftermath of disaster.

Patel and Hastak (2013)	This study introduced a conceptual framework that outlines the strategy to support construction organizations to ensure timely delivery of repair and retrofitted houses to victims of disaster, conflict, or insurgency. It is expected that effective implementation of this framework/strategy would seek to ameliorate the sufferings of the affected communities and ensure quicker socio-economic recovery.
Von Meding et al., (2009)	The authors' contribution was basically to the non-governmental organizations involved in post disaster repair works. A conceptual framework was designed by the authors, which incorporates the principles of disaster, strategic and project management, with each specific management area contributing significantly to the successful implementation of the framework.

For instance, the previous studies of (Bilau et al. 2015, 2018) focused centrally on initiating a conceptual framework capable of facilitating the management of post disaster housing repair/reconstruction works in developing countries. The authors identified the challenges bedeviling the management of repair/reconstruction initiatives as well as the management actions to mitigate the problems in order to achieve desired objectives. Nonetheless, an obvious limitation of the framework developed is that it primarily highlights the main impediments to successful management of post-disaster repair/reconstruction of building structures and the key impediments that were identified, are mostly qualitative in nature. The frameworks developed in the works of (Bilau et al. 2015, 2018) are predominantly conceptual in nature, which could not be used directly to quantitatively evaluate the efficiency of reconstruction works.

While the earlier contributions of (Bilau et al. 2015, 2018) captured most of the essential barriers and procedures for managing post disaster housing repair and reconstruction works, the glaring contribution of other previous research works presented in this study is on the active involvement of the local beneficiary communities in post disaster repair and reconstruction of building structures. Thus, the central theme of these studies does not dwell much on the management aspect of post disaster repair and reconstruction of building structures, rather, it is more towards socio-economic recovery of the beneficiaries. An exception to this, is the contribution of Von Meding et al. (2009), which presented an efficiency-based framework that could be adopted by non-governmental organizations during post disaster repair and reconstruction works. The most salient management input in the framework is the consideration of strategic management, which helps the non-governmental organizations to familiarize themselves with concepts and strategies of permanent reconstruction of affected communities, since they usually operate well outside their expertise and face many daunting challenges as they implement repair and reconstruction programmes.

The quantitative tool (framework) proposed in this study incorporates eight integral management-performance components and uses a proficiency index to ascertain the exact efficiency level of the management practices adopted for each reconstruction project. The efficiency index indicates the score allocated to each management practice criterion according the actual management practices efficiency level for each project. Therefore, each reconstruction project can be evaluated and grouped based on its management practices efficiency evaluation scores. It is expected that the framework will seek to guide informed decisions on the efficiency of the reconstruction scheme, which is in different phases and locations.

Although the evidences on which the results of this study emanate from reconstruction of building structures experiences in some parts of Nigeria, the framework could be adopted in other areas faced with post-disaster reconstruction of structures. This paper updated existing knowledge on the management of post-disaster reconstruction works to building structures and offers valuable help to regulatory decision-makers and practitioners involved in managing reconstruction of building structures affected by insurgency.

2. Criteria for Promoting Contractors' Efficiency in the Management of Building Reconstruction Works

The development of a quantitative assessment tool in this paper involved identifying, determining, and prioritizing the criteria that promote contractors' efficiency in the management of reconstruction works for building structures. In achieving these objectives, a methodical and extensive literature search together with expert-based survey were adopted, which are explained in Section 3 of this paper. The criteria together with their classification into distinct management practice clusters are presented in the following sub-sections.

2.1 Criteria A –Cash Flow and Financial Management

The practices for effective management of project cash flow and financial management for reconstruction schemes can be very daunting particularly when several funding sources are involved (Fengler et al. 2008). Thus, the establishment of a multi-donor trust fund is regarded as a best practice that could help to enhance coordination and efficiency of reconstruction process, reduce administrative costs, and provide strategies for efficient use of donor funds (Koria 2009). In order to ensure transparency, accountability and probity in managing the project cash flows and finances, it is a best management practice to establish a system for monitoring project finances, assessments, and control and to equally set-up a robust system for endorsing financial accounting and reporting using standards (Olshansky et al. 2012). This will help to minimize corrupt acts like embezzlement of reconstruction funds, bribes for award of contracts and inducing local communities to accept poorly reconstructed houses.

2.2 Criteria B - Safety Risk Management

Safety risk management is an important criterion critical to the proficiency evaluation of the management of the reconstruction scheme (Do et al. 2019, Xi et al. 2018, Přibyl et al. 2018). Conducting a vulnerability analysis helps to identify risk factors, nature of hazards, severity levels of the hazards as well as the extent of exposure to the hazards, which will be vital in developing effective building regulations that will ensure reconstruction of safe resilient, and sustainable housing (Nepan and Chen 2015, Trohanis 2010). Thus, implementing this consolidated management approach will seek to promote safety of the buildings and the local communities from susceptibility to any form of hazards.

2.3 Criteria C - Quality Management

The management of quality is central to the successful implementation of any sustainable reconstruction scheme. Across the globe, poor workmanship quality is always a common attribute of many sustainable housing reconstruction schemes (Ophiyandri et al. 2013). Thus, the evaluation and identification of the much-needed skills for housing reconstruction works before workers' mobilization is a good management practice that facilitates good craftsmanship and quality of housing in reconstruction projects. The management agency spearheading the reconstruction projects is expected to provide enhanced building codes, technical guidelines for construction, quality specifications and standards that will enable the efficient delivery of safe and resilient housing (Bilau et al. 2016).

2.4 Criteria D - Supply Chain Management

Sustainable housing reconstruction initiatives are dependent on the delivery of supplies to the point of need (Bilau et al. 2017). For sustainable housing reconstruction works to be executed effectively, it is imperative to ensure that resources are readily supplied as and when due. Among the many factors that may lead to poor supplier performance are the enormous nature of resource procurement, failure of the local markets to meet huge demands, the problems of inflation in the local economy as well as fierce competition among various suppliers (Zuo et al. 2008). Thus, managing sustainable housing reconstruction process requires high-level expertise and proficiency in the management of supply chains. The expertise needed includes effective analysis, evaluations, planning, procurement, delivery of key resource needs for the reconstruction works. Engaging supply chain management experts will seek to ensure scheduled and quality delivery of resource, costs and time savings, and ensure that high value for donor funds is achieved (Chang et al. 2011).

2.5 Criteria E - Manpower Management

Reconstruction projects deal with various human resource challenges (Chang-Richards et al. 2013). The efficient management of manpower for reconstruction initiatives begins with the involvement of specialists to analyze, evaluate and plan the skilled and unskilled human resource requirements that would enable successful implementation of reconstruction works (Bilau et al. 2017). This is necessary as many building reconstruction schemes are usually beyond the local construction industries' capacities, which brings about a dearth of specialists as well as skilled labour. For speedy reconstruction of solidly built, acceptable and sustainable housing, a number of strategies should be established to sort out the human resources requirements. This includes the use of multi-skilled labour approach and engagement of local construction experts that will mobilize and recruit other skilled workmen from the local communities (UNISDR 2015).

2.6 Criteria F - Coordination & Logistics Management

Generally, reconstruction schemes involve the participation of various stakeholders at different levels with contrary perspectives and overlapping obligations for various interconnected works, which makes it quite difficult for a coordinating agency to handle efficiently (Bilau et al. 2017). Thus, it is crucial for project contractors handling reconstruction works to establish an effective communication strategy with proper feedback system to ensure better coordination and enhanced dissemination of information. To effectively coordinate the activities of the various stakeholders involved in reconstruction schemes, it becomes necessary for the contractors to establish a multi stakeholder platform that will enable active participation of stakeholders, promote consensus building among them to attain the reconstruction objectives, sort out resource management issues and promote accountability and operational efficacy (Gajendra et al. 2013).

2.7 Criteria G - Communication Chain Management

The engagement of several stakeholders with divergent background, perspectives, interests, and responsibilities necessitates conducting communication-based analysis to ascertain the perceptions, competencies and expectations of the stakeholders, which will help to develop a framework for effective communication strategy and stakeholder coordination (Jha and Duyne 2010). An efficient communication structure determines communication objectives, identify the major stakeholders involved, and enables the establishment of communication plans for effective management of information and communication. Other operational measure for promoting the proficient communication chain management include the use of appropriate communication channels, conducting regular meeting and seeking communication feedback as these would enable presentation of progress, proffer solutions to challenges and help to establish efficient communication strategy (Tagliacozzo and Magni 2016).

2.8 Criteria H - Monitoring & Control

Despite having comprehensive construction organizations plan in place, many construction organizations projects across the globe are blighted with monitoring and control issues during implementation (Bilau et al. 2016, Ophiyandri et al. 2013). To start with, it is considered a best management practice to establish a multi-tiered institutional strategy that will seek to

promote proficient monitoring and control functions for construction organizations works. This could either be a local monitoring and control committee, regional authority, or dedicated management agency (Mannakkara and Wilkinson 2013). Conducting technical assessments of the new built houses should be done to ensure compliance to standards while guidelines for corrective measure are utilized to remedy the observed defects on the construction organizations retrofitted houses. More so, there is a need for inclusion of structural health monitoring sensors and systems, which is likely to greatly increase the life-cycle cost of the repaired buildings (Li et al. 2014, You et al. 2014). Structural health monitoring systems could ensure increased safety and reliability of the repaired structures while considerably reducing future maintenance and repair costs (Karamloo et al., 2019; Yu et al. 2019; Přibyl et al., 2018; Huang and Nagara 2014).

3. Research Methods

Developing a suitable fundamental mathematical tool that can be used to evaluate the efficiency in managing the reconstruction of buildings requires a lot of technicalities. This primarily includes the systematic identification of the appropriate criteria to be applied to effectively examine the management practices adopted for the reconstruction projects. It is equally essential to accurately determine the relative significance of each criteria empirically. Most importantly, a review of previous works related to the management of ass-housing reconstruction schemes was conducted methodically in order to gather the relevant criteria needed for this study. From the systematic literature search, a list of preliminary criteria was generated, which was subsequently followed by the expert-based survey. The justification for adopting this approach was to obtain accurate information from the experts considering their high level of experience, proficiency and specialization in the subject under study.

Thus, the experts primarily examined and reviewed the original list of criteria presented to them. The experts had to go through this rigorous process in order to avoid repetition of criteria, eliminate redundancies, improve and provide operational explanations when required. Thus, a revised list of eight main criteria along with their eighty-two corresponding sub-criteria was generated. Remarkably, this process was used to prune the criteria list and significantly minimized the researcher's bias in selecting the criteria, thereby consolidating the validity of the findings. In the closing stages of the expert-based survey approach, the experts were tasked with the prioritization of the main criteria for promoting efficiency in the management of housing reconstruction through rank ordering. Thereafter, the participants evaluated the significance of each sub-criterion, which adopted a Likert scale of 1 to 5 that represents 'very low' to 'very high' level of importance.

It should be noted here that mainly professionals with the requisite knowledge and experience on the subject were invited to participate through judgmental sampling. This sampling technique was used to allow the selection of professionals whose experience permit an understanding of how the implementation of reconstruction should be managed efficiently. Thus, the respondents who did not fit the requirements of the expert-based survey were simply excluded. About eighty indigenous and expatriate professionals who are well conversant with sustainable housing reconstruction projects in Nigeria participated in the expert-based survey. They are predominantly contract and procurement managers, project managers, construction managers, and site managers that boast of long years of relevant professional experience in the built environment. Thus, the experts' overall proficiencies increase validity to the findings of the study.

4. Development of the Efficiency Assessment Framework

This section involves the development of a fundamental mathematical technique that can be applied directly to evaluate the contractors' efficiency in managing housing reconstruction projects. The sequence for the development of the proposed mathematical tool is presented in Figure 1.

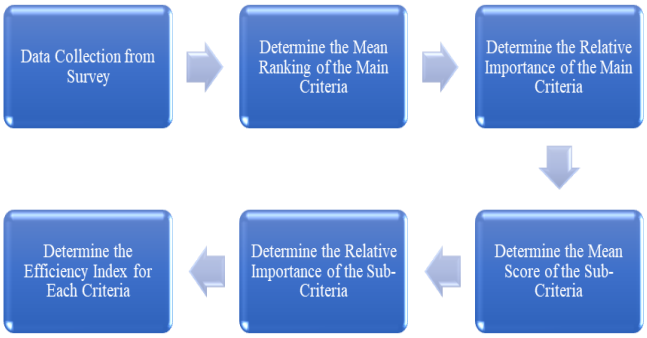

Figure 1 Flowchart for the framework development

4.1 Determining the Mean Ranking and Relative Importance of the Main Criteria

The criteria used for evaluating contractors' efficiency in managing housing reconstruction projects have been mentioned in the previous sections. Thus, the data gathered from the expert-based survey was analyzed thoroughly according to the Mean Ranking (MR) and Mean Score (MS) as applied by Sodangi (2019), Ng et al. (2005) and Assaf et al. (1995). The Mean Ranking of each main criteria was obtained using the equation below:

$$MR_{main\ criteria} = \frac{\sum f \times r}{N} (1 \le MR \le 8) \dots\dots\dots\dots\dots (1)$$

From the equation (1) above, the frequency of the experts' responses to each rating for each main criterion is denoted by *f*, and *r* denotes the experts' ranking assigned to each main criterion while *N* denotes the total number of responses for each assessed main criterion. Thereafter, the figure (value) obtained for the Mean Ranking of each main criteria was duly used to calculate Relative Importance (RI) of each main criterion using the equation below:

$$RIMC_j = \frac{\sum_{i=1}^{N} MR_i}{MR_j} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

From the equation (2) above, the relative importance (RI) of the j^{th} main criterion is denoted by $RIMC_j$ whereas MR_j denotes the mean ranking (MR) of the j^{th} main criterion. Referring to Table 2, it is clear that "cash flow and financial management" was considered the most outstanding main criterion by the survey respondents. This outcome upholds the previous findings of Bilau et al. (2017, 2016) that underlines the implication of cash flow and financial management during the reconstruction of buildings for post-disaster settlements.

Table 2. Main criteria for promoting efficiency in managing housing repair works

Main Criteria	**Mean Ranking (MR)**	**Relative Ranking**	MR_i/MR_j	**Relative Importance (RI)**
Cash flow & financial management	1.107	1	11.751	0.174
Safety risk management	1.238	2	10.508	0.155
Quality management	1.310	3	9.935	0.147
Supply chain management	1.524	4	8.538	0.126
Manpower management	1.702	5	7.642	0.113
Coordination	1.821	6	7.143	0.106
Communication chain management	1.976	7	6.583	0.097
Monitoring & control	2.333	8	5.576	0.082
Total	**13.012**		**67.676**	**1.000**

This highly prioritized criterion is problematic with repercussions for efficient management of sustainable housing reconstruction projects. For instance, the multiple sources of funds have different and competing accounting requirements and time frames, which could lead to circumstances that will adversely compromise the quality and efficiency of the reconstruction implementation. Thus, an early 'needs analysis' is essential to determine the resource requirements for the reconstruction scheme, which could be used by stakeholders to mobilize resources for reconstruction works (Bilau et al. 2015).

On the other hand, "monitoring and control" was rated the least most important main criteria by the respondents despite its huge relevance for promoting efficient management of housing reconstruction works. The ranking obtained does not in any way undermine the significance of this criterion in the successful implementation of housing reconstruction schemes. As pointed out by Bilau et al. (2017), monitoring and control during the implementation of housing reconstruction works could be ensured by providing product quality management plan, timescales, cost plans, and production plans while mobilizing experienced workers and local workers to monitoring units and providing an efficient system for monitoring, controlling and evaluating the reconstruction process. This strategy serves as a basis for monitoring progress, improving production output, quality, speed and efficiency of the reconstruction process.

4.2 Determining the Mean Score and Relative Importance of the Sub-Criteria

This section presents the sub-criteria used by the respondents to evaluate contractors' efficiency in managing housing reconstruction works. Details of these sub-criteria have been provided before now. Therefore, the responses of the experts were analyzed according to the Mean Score (MS). To start with, the Mean Score (MS) for each sub-criterion was calculated using the equation below to ascertain the importance of each sub-criterion.

$$MS_{sub-criterion} = \frac{\sum f \times s}{N} (1 \le MS \le 7) \ldots\ldots\ldots\ldots\ldots (3)$$

In the equation (3) above, the frequency of the experts' ratings for each sub-criterion is denoted by *f*. The score given to each sub-criterion by the experts is denoted by *s* while *N* denotes the total number of responses for each assessed sub-criterion. Furthermore, the figure (value) obtained as the Mean Score of each sub-criterion was then used to calculate Relative Importance (RI) of each sub- criterion using the equation below, where $RISC_{ij}$ denotes the relative importance of the i^{th} sub-criterion under the jth main criterion.

$$RISC_{ij} = \frac{MS_{ij}}{\sum_{i=1}^{N} MS_{ij}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

The summary of the mean scores and relative importance of the sub-criteria are presented in Table 3. From the table, it is obvious that "conducting needs assessment" was rated by the respondents as the top-most significant sub-criterion (MS = 6.93) for assessing the proficiency of the management practices of construction organizations. This is indeed corroborating global initiatives for promoting the efficient reconstruction and delivery of sustainable housing especially to communities blighted by conflicts, insurgency or disasters. Previous studies (Bilau et al., 2017; Ranghieri and Ishiwatari, 2014; Trohanis and Read, 2010; Barakat, 2003) emphasized on the significance of conducting needs assessment as it helps to identify the resource requirements for sustainable housing reconstruction scheme. The studies further emphasized strongly on the importance of engaging local communities in the needs assessment in order to enable comprehensive community level analysis as well as beneficiary satisfaction in financial support.

"Conducting multi-hazard susceptibility evaluation of reconstruction sites" is the next most highly rated sub-criteria with a Mean Score of 6.920. The ranking of this sub-criterion is without any doubt an integral management practice that could make or mar the efficient implementation of any sustainable housing reconstruction process. Conducting thorough assessments of this nature helps to discover risk issues, nature of hazards along with their corresponding severity level and the extent of exposure to them (Sysyn et al. 2019, Bilau et al. 2017, Benson and Twigg 2007, Benson et al. 2007, Pantelic 1991).

Notwithstanding the significance of "providing capacity development avenues for recruited workers" sub-criterion in assessing the efficient management of housing reconstruction process; this sub-criterion obtained the lowest Mean Score (3.220) from the participants. The rating obtained does not in any way undermine the high significance of this sub-criterion. This is because capacity development of the workers develops local capacities for effective engagement, expands skill supply, and promote socio-economic sustainability for the reconstruction project (Schilderman and Lyons 2011, Barenstein and Pittet 2007). Nonetheless, providing capacity development avenues for recruited workers leads to effective transfer of knowledge, decreases costs, increases workers' retention as well as earning potential, which have strong effect on the successful implementation and management of the housing reconstruction scheme.

4.3 Determining the Efficiency Index for Each Criteria

At this stage, the relative importance of each sub-criterion $RISC_{ii}$ and its corresponding main criterion's relative importance $RIMC_i$ are combined with the weighted scores to obtain a performance index for assessing contractors' efficiency in managing housing reconstruction works. Accordingly, the performance index denotes the score given to each criterion based on the actual efficiency level used in managing the reconstruction works. Thus, the performance index is computed using the equation below:

$$PI_{ij} = \frac{RISC_{ij} \times RIMC_j \times PWS}{7} \times 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

In the equation (5) above, the performance index of i^{th} sub-criterion under the j^{th} main criterion is represented by PI_{ij} while *PWS* is the performance weighted score of the seven (7) different performance levels, which are given as; 1 = unacceptable; 2 = very poor; 3 = poor, 4 = acceptable; 5 = good, 6 = very good and 7 = excellent. For instance, excellent performance in "conducting needs assessment" can be calculated using the obtained values from Table 3, where $RISC_{ii}$value for the sub-criterion is 0.110 and the equivalent $RIMC_i$ value of the sub-criterion is 0.174. Meanwhile, Table 3 provides the *PWS* value for excellent performance as 7. Therefore, substituting the above set of values in equation (5), the efficiency index is computed below:

$$PI_{\text{conducting needs assessments}} = \frac{0.110 \times 0.174 \times 7}{7} \times 100 = 1.911$$

Table 3 Efficiency Assessment showing the 'mean scores' and 'relative importance' of the sub-criteria for promoting contractors' efficiency in the management of building reconstruction works

Criteria	**Relative Importance (RI)***	**Performance Weighted Score (PWS)**							**Proficiency Score**
		Unacceptable	Very Poor	Poor	Acceptable	Good	Very Good	Excellent	
		(*1)	(*2)	(*3)	(*4)	(*5)	(*6)	(*7)	
Cash flow & financial management	0.174	2.486	4.971	7.457	9.943	12.429	14.914	17.400	Sub-total (A)
Safety risk management	0.155	2.214	4.429	6.643	8.857	11.071	13.286	15.500	Sub-total (B)
Quality management	0.147	2.100	4.200	6.300	8.400	10.500	12.600	14.700	Sub-total (C)
Supply chain management	0.126	1.800	3.600	5.400	7.200	9.000	10.800	12.600	Sub-total (D)
Manpower management	0.113	1.614	3.229	4.843	6.457	8.071	9.686	11.300	Sub-total (E)
Coordination & Logistics Management	0.106	1.514	3.029	4.543	6.057	7.571	9.086	10.600	Sub-total (F)
Communication chain management	0.097	1.386	2.771	4.157	5.543	6.929	8.314	9.700	Sub-total (G)
Monitoring & control	0.082	1.171	2.343	3.514	4.686	5.857	7.029	8.200	Sub-total (H)
Performance score for all criteria = (A + B + C + D + E + F + G + H)		**14.286**	**28.571**	**42.857**	**57.143**	**71.429**	**85.714**	**100.000**	**Total Score Obtained**

** Relative Importance (RI) obtained from Table 2*

5. Conclusions

The model presented in this paper is a fundamental and direct mathematical tool that could be readily utilized to evaluate contractors' efficiency in managing housing reconstruction. Contractors handling reconstruction works can be evaluated and grouped based on their management practices efficiency evaluation scores. Thus, this evaluation framework can serve as a valuable tool in a wide-ranging managerial, economic and social context to stakeholders responsible for policy formulation and general management of the sustainable housing reconstruction works. The assessment scores generated from the quantitative assessment form demonstrate the management practices efficiency rating for the contractors executing the reconstruction process, and this efficiency rating will underline the management aspects requiring improvements. Therefore, deviations from the best practice measures for managing sustainable housing reconstruction programmes can easily be analyzed and evaluated to come up with logical justifications for successful outcome, failure and the lessons that improve learning, innovation and continuous improvement. Although the evidences on which the results of this study emanate from reconstruction of building structures experiences in some parts of Nigeria, the technique developed could be adopted in other areas faced with post-disaster mass-housing reconstruction. This paper updated existing knowledge on the management of post-disaster retrofitting works to building structures and offers valuable help to regulatory decision-makers and practitioners involved in managing retrofitting of building structures affected by insurgency.

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