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All enquiries to:

Dr Kemi Adeyeye
Lead, WATEF Network

Department of Architecture and Civil Engineering
University of Bath
Email: k.adeyeye@bath.ac.uk

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Development of Sustainable Building Design in Hong Kong: Exploring Lean Capabilities

Edmond WM Lam[1*], Albert PC Chan[2], Timothy O. Olawumi[3] Irene Wong[2] and Kayode O. Kazeem[1]

[1]College of Professional and Continuing Education, The Hong Kong Polytechnic University, Hong Kong, China

[2]Department of Building and Real Estate, The Hong Kong Polytechnic University, Hong Kong, China

[3]School of Computing, Engineering and the Built Environment, Edinburgh Napier University, United Kingdom

ABSTRACT

When a building design fails to meet the end-users' requirements after construction, it is regarded as a faulty design. Faulty designs often lead to renovation, demolition, and material waste. The need to implement innovative tools and systems that continuously provide designers with the end-users' design requirements and feedback in the built environment cannot be ignored. This study explores the potentiality of implementing a Lean Premise Design (LPD) scheme in Hong Kong to facilitate sustainability practices, ensure energy conservation, promote innovative green technologies and water efficiency, and reduce abortive works in high-rise residential (HRR) buildings. A comprehensive review of literature on concepts similar to the LPD scheme and sustainability practices in the design and development of high-rise buildings was undertaken. In addition, interviews were adopted to validate the identified barriers and drivers to the LPD scheme. These facilitated the identification of perceived barriers to the LPD scheme adoption in the local context. Furthermore, the relevant drivers that can promote its implementation were examined. The study focused on sustainable building design relating to users' behaviour patterns and expectations, social needs, green maintenance technologies, and government initiatives. About 77% of the experts affirmed the availability of comprehensive building codes and guidelines. Nevertheless, 62% of the experts confirmed the insufficiency of the current regulations to promote sustainable building design. Similarly, the literature review revealed that while there are many sustainable concepts in the development of high-rise buildings, little or none of these concepts focused on LPD.

Keywords: High-rise buildings; Lean Premise Design; Residential buildings; Sustainability, Waste; Hong Kong.

1. INTRODUCTION

1.1 Background

The concept of sustainability has been gaining momentum for more than four decades [1]. The UN Conference on Human Environment in 1972 was the first major international discussion on sustainability at the global level [2]. Brundtland Report in 1989 included the integration of economic, social and environmental developments in sustainable development [3]. The World Summit on Sustainable Development in 2002 saw a major shift from the environment toward human and economic development. After the financial crisis in 2008, there was a shift in the paradigm to a "Green Economy", which incorporates renewable energy, green buildings, water and waste management [4]. Countries having succeeded in implementing green stimulus programs which are backed up with strong policy incentives and commercial frameworks to

* Tel.: +852 3746-0776

E-mail address: edmond.lam@cpce-polyu.edu.hk

catalyze future green investments are benefiting both financial growth and environmental goals simultaneously [2,5].

The Hong Kong landscape is mostly built-up of high-rise buildings, including skyscrapers, which are in large-scale developments [6]. In 2019, the residential buildings in Hong Kong consumed 61,026 TJ of energy, with 42,937 TJ being electricity [7], while electricity generation accounted for about 66% of total carbon emissions [8]. In the same vein, 31.34 million tonnes of carbon dioxide were generated locally in 2020, contributing to about 0.09% of the world's greenhouse gases (GHG) [9]. As a result, it is important to select low-carbon materials and green construction technologies; however, only a small amount of renewable energy is produced within Hong Kong, which is mainly solar energy, wind energy, biogas, and biodiesel [7]. Therefore, it is necessary to promote renewable energy development and innovative green technologies.

1.2 Research aim and value

According to the recent policy addresses, the HKSAR Government is determined to accelerate the transformation of Hong Kong into a low-carbon city with a target of reducing carbon intensity by 70% of the 2005 level (at most by 2030) and intends to draw up a long-term decarbonization strategy in 2050. The HKSAR Government is also determined to apply commercially available green building technologies in public projects in the immediate years ahead. The Water Services Department is also promoting water conservation at home. The low-carbon transformation will take a multi-pronged approach like reducing waste, enhancing energy efficiency, calling for energy and natural resources conservation, and green building establishments. Public support to use less carbon-based materials or consider sustainable alternatives are necessary for reducing waste [10]. Benefits of climate mitigation in buildings include efficient homes and less wastage, while renovating buildings according to natural retrofit lifecycles is another avenue for energy-saving and low-carbon improvement [11].

The current paper explores the potential in the introduction of the concept of the Lean Premise Design (LPD) scheme to reduce abortive work in residential buildings. LPD means only basic furnishing, such as water and gas supply, waste discharge, sanitary fittings, windows, and the like, will be provided in new residential buildings. Internal finishing, built-in fixtures like kitchen and bathroom cabinets, cooking oven, and air-conditioners will, however, not be installed. The purchaser (potential end-users) can choose to buy a "lean premise" at a lower price or a fully furnished premise at a regular price. When fully developed, the LPD scheme is expected to impact construction cost positively and time as such works (interior finishing work, installation of built-in fixtures, and the like) can be subcontracted at different stages of construction. The study's deliverables will also contribute to conserving energy and natural resources, reducing construction and demolition (C&D) waste, and facilitating the development of a green economy.

2. LITERATURE REVIEW

2.1 Sustainability in Hong Kong: An overview

Hong Kong is a city well known for its high density [12]. Commercial and residential buildings are developed into high-rise establishments due to high land costs [6]. The construction of city buildings and infrastructure has resulted in large-scale consumption of materials and resources, leading to several degrees of environmental pollution during the construction and operational phases [13]. The exploding population and growing economies in major cities of the world have led to increasing urbanization globally as well as a continuous rise in population density in urban areas [14]. High-rise buildings were developed to cope with the dense population in metropolitan cities. Although construction projects can meet social needs and boost the Gross Domestic Product, the subsequent adverse effects on the environment bring much attention.

The rapidly growing world energy use has already raised concerns over supply difficulties, exhaustion of energy resources and negative environmental impacts [15]. Meanwhile, the advent of concepts such as sustainable development and green building has inspired the construction industry and stakeholders to contribute positively and proactively toward environmental protection [16,17].

Hong Kong is a metropolitan city characterized by high-rise developments [6]. Tall buildings are energy guzzlers consuming a large amount of energy in their construction and operation processes with resultant high carbon footprint and GHG emissions [18]; as well as contributing to global warming, energy resource depletion, and local and regional pollution in addition to adverse impacts on natural habitats [19]. There is a need for more application and implementation of sustainable practices as early as the building design stage to incorporate the needs and perceptions of the potential end-users.

2.2 Building Maintenance

Undeniably, maintenance and improvement work of residential buildings consumes natural resources and non-renewable energy while producing a large amount of demolition waste and carbon dioxide to the environment. More than 50% of the latent defects are caused by faulty design [20]. Currently, there is no (effective) feedback system that allows building owners and management staff to reflect end-users' requirements and maintenance problems to building designers (architects and engineers), leading to a reiteration of faulty design. Research efforts were made to bridge this gap by developing relevant End-users-Oriented Design (EOD) principles for sustainable high-rise residential development in the form of a cloud-based EOD platform which will facilitate proper appraisal of project designs, engaging stakeholders as early as the planning and design stage, gathering of post-occupancy feedback, and incorporating necessary feedbacks into future design. Moreover, guidelines of EOD for residential buildings will be formulated to assist building designers to reduce faulty design, thus facilitating sustainable building development.

2.3 Impacts of Faulty Design

Maintenance carries the function of repairing as well as restoring a building towards ensuring that the building element or amenity can perform to the prescribed standard [21]. Errors and defects occurred during the design stage, resulting in high maintenance costs for labour, materials, and energy resources [22,23]. Dismantling the internal finishing and fittings will release the embodied carbon content and overload landfills [24]. Inadequate information, unawareness, wrong assumption and the lack of knowledge contribute to latent defects at the design stage [25]. Fifty-eight per cent of the defects originated from faulty design, of which misjudgment of users' intended use is an important factor [20,22]. Defects due to faulty design will appear during the occupancy stage. The faulty design generally causes more latent defects than workmanship generating many maintenance problems [26]. Currently, there is little or no communication between end-users and building designers globally, especially in Hong Kong, where the preference of end-users for high-rise residential buildings is not considered in the choice of finishing and built-in fittings for their new homes, resulting in frequent abortive work, which ends up with a large amount of C&D waste in most cases.

2.4 Scope and Justification

Several studies in recent literature have investigated the issues regarding sustainability applications in buildings – such as Ref. [27], which examines the economic benefits of green buildings, and Ref. [28], which highlights how sustainability affects building buildability. Other studies have developed sustainability assessment systems for new and existing buildings [29,30]. However, little research has addressed the environmental problems generated from abortive work due to the mismatch between building design and end-users' requirements. Since social issues are important components of sustainable development [31], the relationship between advances in sustainable technologies and the impacts on behaviours of end-users should be studied [32]. Literature on how green maintenance can contribute to economic growth is also limited. Hence, the proposed research will focus on sustainable building design relating to users' behaviour patterns and expectations, social needs, green maintenance technologies, and government initiatives. This paper reports the preliminary findings of the potentials, barriers and drivers of the LPD scheme in the development of sustainable high-rise buildings, and its capabilities to reduce waste and conserve water usage in households.

3. METHODOLOGY

A qualitative research method was adopted to achieve the study aim, which commenced with a comprehensive review of the relevant literature via systematic review and content analysis of the literature and practices to identify concepts similar to the LPD scheme being developed for Hong Kong in this project [33]. In-depth reviews were also conducted in areas such as flexible building design, end-user design preferences, building maintenance and operation, and how Lean principles can enhance the implementation of sustainable practices in HRR buildings and reduce abortive work. Meanwhile, interviews with project stakeholders of HRR buildings were conducted to collect their interpretations of standard building provisions, expectations on ease of maintenance and facilitating measures to promote LPD, and their acceptance of energy/natural resources saving design/appliances.

The relevant findings from the desktop literature review and preliminary interviews were consolidated for further validation via expert interviews to assess how stakeholders in Hong Kong's built environment perceive the LPD scheme to enhance sustainable development in the region. The perceived barriers to the LPD scheme adoption in the local context were also examined as well as the relevant drivers that can promote its implementation. Purposive and snowball sampling techniques were adopted to target the questionnaire survey and interview respondents. Targeted respondents included building designers (architects & engineers), developers, building owners, building managers, maintenance staff, local authorities and end-users. Meanwhile, content analysis was used to synthesize the results from the expert interviews.

4. RESULTS AND DISCUSSION

The semi-structured interviews were conducted online via Microsoft Teams, Zoom App. and Google forms. The latter enabled interviewees to respond to the interview questions at their convenience. In addition, online interviews for qualitative research enable accessibility to participants [34] despite the social distancing restriction during the Covid-19 pandemic. The interviewees were selected based on their willingness to participate in the research interview, professional experience, type of profession, and years of experience in residential building design and/or construction, as outlined in Table 1. The interviewees were selected either as individuals or as representatives of their team, organization, or industry [35]. Questions were asked on the potentiality of the LPD scheme implementation in Hong Kong. The questions included sections on the barriers, drivers and facilitating measures of the LPD scheme. All the interviews were recorded, transcribed and analyzed. While the average duration for the interviews conducted via Video Conferencing Applications (Microsoft Teams and Zoom) was about 60 minutes, the average time for the interviewees who responded to the interview questions at their convenience was not determined.

Table 1. Building stakeholders' information

Code	Sector	Profession	Company Size	Experience (Years)
R1	International	Structural Engineer	>1000	5 - 10

Code	Sector	Profession	Company Size	Experience (Years)
R2	International	Structural Engineer	>1000	5 - 10
R3	Local	Structural Engineer	>1000	> 30
R4	Local	Building Services Engineers	<1000	> 30
R5	Local	Architect	<1000	> 30
R6	International	Building Developer	>1000	> 30
R7	Local	Project Coordinator	<1000	10 - 20
R8	Local	BIM Consultant/Digital Solutions Provider	<1000	20 - 30
R9	International	Building Surveyor	>1000	10 - 20
R10	International	Architect	<1000	10 - 20
R11	International	Digital Manager	> 1000	10 - 20
R12	Local	Facility Manager	<1000	> 30
R13	Local	Building Developer	> 1000	> 30
	Status	**Apartment Floor Level**	**Mismatch between Requirements and Design**	
R14	Homeowner	36/F	Yes	
R15	Tenant	12/F	No	
R16	Tenant	GF	No	

As depicted in Figure 1, the building professionals were asked to give their opinions on the current code of practice, building code and design manuals/guidelines. While about 77% of the interviewees (experts) affirmed the availability of comprehensive building regulations in terms of codes of practice and design manuals/guidelines in Hong Kong, about 62% of the experts confirmed the deficiency of the current building regulations to promote sustainable building design in Hong Kong. For instance, R2 asserted that "codes of practice should allow for simple retrofit and upgrade of the roofing structure to allow for Solar panels and green roofs to flourish if the building owner so wishes to do so later on in the building lifecycle".

In the same vein, R12 opined that "the enhancement and modification in the current guidelines and design manuals are not sufficient enough to meet the fast-growing demand or expectations of sustainable design requirements in Hong Kong." The interviewee further highlighted that "the concept of sustainability was not originally incorporated in the framework of building regulations from the outset, so, to have a better sustainable design, there is a need to review the whole building regulations and set up a framework of what a sustainable building design is". Thus, while there are many existing building regulations in Hong Kong, they have not been aligned with Hong Kong SAR's targets on Carbon Neutrality. Relatedly, 85% of the interviewed professionals have implemented sustainability concepts in the building development projects in Hong Kong (*see* Figure 2). These include the use of Building Information Modeling (BIM), Virtual Reality (VR) technology, incorporation of Internet of Things (IoTs), etc., in the design, construction and operation of high-rise buildings.

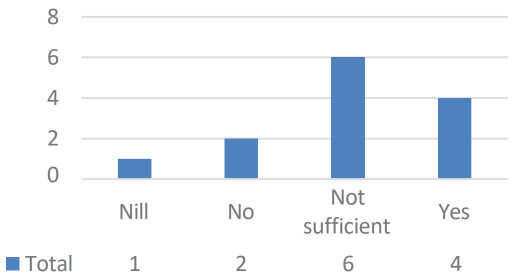

Fig. 1. Professionals' View on Adequacy of the Current Building Code to promote Sustainability in Hong Kong

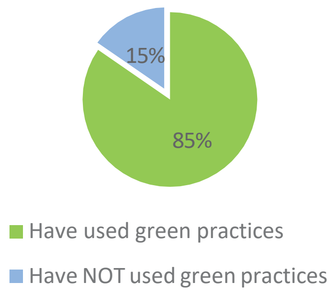

Fig. 2. Sustainability Implementation in Building Development Projects in Hong Kong

The building stakeholders' interviews were in two categories: with building professionals and the building end-users. Sixteen (16) interviews were carried out altogether, including thirteen (13) building professionals and three (3) building end-users. The interviews tried as much as possible to include two representatives from developers, architects, building managers, end-users, maintenance staff and building owners towards obtaining quality information [36]. However, due to time constraints, some of the representatives were replaced with other building professionals with relevant experience in the design and construction of high-rise residential buildings. The interviews included more of the building designer (structural engineers and architects), as revealed in Figure 3.

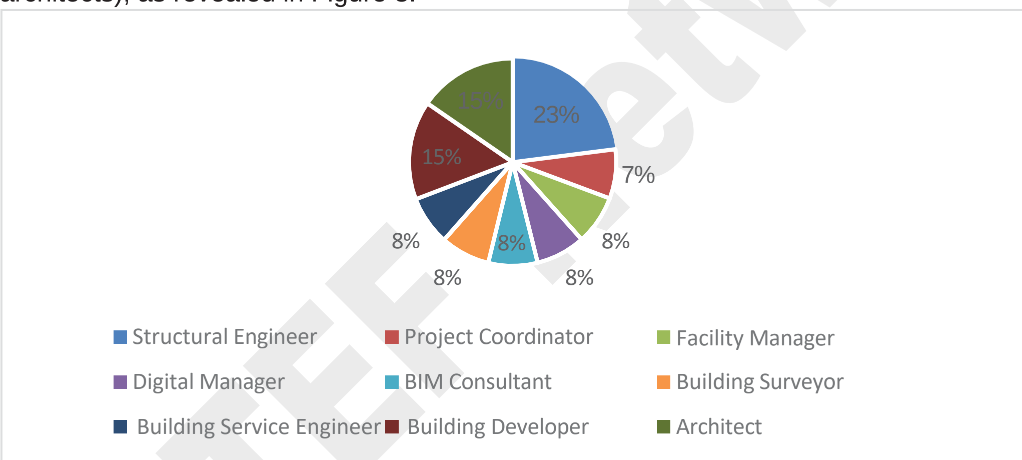

Fig. 3. Professionals' Background

Dehdasht et al. (2020) utilized the Technique for Order of Preferences by Similarity to Ideal Solution (TOPSIS) to identify and classify all the relevant drivers of lean construction implementation [37]. With sustainability as the core focus, the identified drivers were broadly categorized under the three headings of sustainability which are social, economic and environmental. Further classification yielded seven subcategories under which the drivers were grouped. However, these drivers do not specifically address the focus of this research, which is the LPD scheme. The production of buildings is carried out in three phases: design, engineering, and assembly [38]. LPD focuses more on the design and operational stage of the building rather than the manufacturing of the building [39]. Also, since this research focuses on high-rise residential buildings in Hong Kong, there is a need to contextualize the research findings of Ref. [37] for proper application in this research. The drivers were contextualized through the expert interview, as highlighted in Table 2. Relatedly, the barriers to LPD adoption were identified through a literature survey and interviews with relevant building professionals. The identified barriers are detailed in Table 3.

Table 2. Identified Drivers of the Lean Premise Design (LPD) Scheme

S/N	Drivers
Author/Expert Interview	
1	Training for building professionals (e.g., engineers, architects, etc.)
2	Building a communication platform for all stakeholders
3	Government providing bonuses and credits to developers who adopt LPD design, such as extra GFA, achievement awards, etc.
4	Government facilitates buyers to accept LPD design (e.g., reduction in stamp duty)
5	Government promotes public education in LPD
6	Improved circular economy to reduce carbon emission
7	Streamline the design and communication process
8	Clear definition of the LPD objectives in the design stage
9	Shifting from outputs (products) to outcomes philosophy
10	Enhance standardization in building design, construction and management
11	Enhance Modular Integrated Construction (MiC)
12	Easier to adopt offsite construction technology and reduce rework on site
13	Reduction in construction waste
14	Reduction in energy consumption
15	Reduction in material usage
16	Reduction in construction cost
17	Improved efficiency in the design process
18	Reducing workloads in building design and project management by reducing the scope of interior design/provisions
19	Improve company culture
20	Reduction in inventory and spare parts inventory

Table 3. Identified Barriers to the Lean Premise Design (LPD) Scheme Implementation

S/N	Barriers
1	Avoidance of making decisions and taking up responsibility in defining the scope of "lean design"
2	The thought that LPD is only beneficial to developers
3	Developers focus on the ROI (finances, branding, social responsibility, etc.)
4	Compromising profit due to reduction of GFA
5	Implementing LPD may require more time for market research, thus increasing design cost
6	The LPD building units may look less glamourous as compared to traditional design, which renders them less attractive to potential buyers
7	Inability to define peoples' expectations/requirements
8	Expectations of buyers in different price ranges are diverse. (Potential buyers of building pricing from lower to middle range (say 0.5-1000m) may prefer ready-to-move-in conditions while buyers for luxury buildings prefer to renovate by themselves.)
9	Building industry lacks the knowledge and skill of LPD
10	Building professionals are reluctant to new design approach if the current system 'works'
11	End-users' requirements are too diverse
12	Environmental constraints due to differences in site conditions
13	Building industry lacks the knowledge and skill of LPD
14	Lack of support from top management
15	Insufficient management skills of designers and builders
16	Absence of a lean culture in the construction field
17	Lack of communication and feedback among stakeholders
18	Government do not care about sustainability in building development
19	Resistance to change from traditional design practices

S/N	Barriers
20	Lack of communication and feedback from end-users on their requirements in the early stage of the design process
21	Limited application in design-and-build procurement models
22	Stringent requirements and approvals
23	Building designers are not familiar with the concept of LPD

Ref. [40] shows that less than 2.5% of the world's water is fresh, while the rest is seawater. Meanwhile, Hong Kong's total freshwater consumption in 2020 was 1 027 million M^3. Interestingly, 61% was consumed for domestic purposes, as shown in Table 4. This information suggests the potential of conserving a tangible quantity of freshwater resources in high-rise residential buildings in Hong Kong through the LPD scheme.

Table 4. Hong Kong's Annual Fresh Water Consumption by Sector in 2020 [46]

Sector	Quantity (Million m^3 and per cent of total)
Domestic	626 (61.0%)
Industrial	53 (5.2%)
Service Trades	222 (21.6%)
Government Establishment	44 (4.3%)
Construction & Shipping	19 (1.8%)
Flushing	63 (6.1%)

5. CONCLUSION

The research explores the potentiality of implementing the LPD scheme in HRR buildings in Hong Kong. Through literature review and semi-structured interviews with building stakeholders, key barriers, drivers and facilitating factors to LPD implementation were identified. As identified from the stakeholder interviews, there is a need to propose, develop and integrate new sustainable residential building design concepts into the existing codes and guidelines in Hong Kong. Furthermore, there is a need to set up a framework of what sustainable building design is. The LPD scheme considers the users' behaviour patterns, expectations, social needs, green maintenance techniques and government initiatives in the context of residential buildings.

Therefore, these findings have revealed important insights and directions to the next stage of this research project. The next phase of the research will study the end-users' requirements and acceptance of sustainable building design, including water conservation and the developments of the end-user-oriented design (EOD) concepts. Implementing EOD concepts in HRR buildings will promote partnership among stakeholders in order to reduce the consumption of energy and natural resources.

Future Studies. To ensure the study sufficiently cover salient aspects of sustainable building design and water conservations, its next phase investigates areas including but not limited to building end-users' requirements and the willingness and extent to pay on top of the market price for sustainably designed apartments. These aspects include design provision for recycling wastewater from sinks for toilet flushing or watering garden plants; connecting the interior and exterior spaces with balconies, among others. Furthermore, the discussed results will facilitate identifying the latent defects associated with the mismatch of building designs and the end-user's requirements in high-rise residential buildings.

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COMPETING INTERESTS

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