RGC Ref. No.:
UGC/FDS24/E02/21
(please insert ref. above)

RESEARCH GRANTS COUNCIL
COMPETITIVE RESEARCH FUNDING SCHEMES FOR
THE LOCAL SELF-FINANCING DEGREE SECTOR

FACULTY DEVELOPMENT SCHEME (FDS)

Completion Report
(for completed projects only)

Submission Deadlines:
1. *Auditor's report with unspent balance, if any: within **six** months of the approved project completion date.*
2. *Completion report: within **12** months of the approved project completion date.*

Part A: The Project and Investigator(s)

1. Project Title

Development of a Cloud-Based System to Facilitate End-User-Oriented Design (EOD) for Effective Sustainability Practices Implementation in High-Rise Residential Buildings

2. Investigator(s) and Academic Department(s) / Unit(s) Involved

Research Team	**Name / Post**	**Unit / Department / Institution**
Principal Investigator	Dr LAM Wai-ming / Senior Lecturer	Division of Science, Engineering and Health Studies / PolyU SPEED
Co-Investigator (1)	Prof CHAN Albert Ping-chuen / Professor	Department of Building and Real Estate / The Hong Kong Polytechnic University
Co-Investigator (2)	Dr OLAWUMI Timothy Oluwatosin / Assistant Professor	School of Computing, Engineering, and the Built Environment / Edinburgh Napier University, United Kingdom
Co-Investigator (3)	Dr WONG Irene / Registered Architect	The Hong Kong Institute of Architects
Others	Mr KAZEEM Kayode Olatunji / Research Assistant (Funded by this FDS Project)	General Office / PolyU SPEED

3. Project Duration

	Original	**Revised**	**Date of RGC / Institution Approval** *(must be quoted)*
Project Start Date	01/01/2022	N/A	N/A
Project Completion Date	31/12/2023	30/06/2024	06/11/2023
Duration *(in month)*	24	30	06/11/2023
Deadline for Submission of Completion Report	31/12/2024	30/06/2025	06/11/2023

4.4 Please attach photo(s) of acknowledgement of RGC-funded facilities / equipment.

N/A

Part B: The Final Report

5. Project Objectives

5.1 Objectives as per original application

1. To explore the potentiality of the Lean Premise Design (LPD) scheme in Hong Kong to facilitate sustainability practices and reduce abortive work in high-rise residential buildings.

2. To identify the latent defects associated with the mismatch of building designs and the end-user's requirements in high-rise residential buildings.

3. To develop a strategic-mix impact framework to facilitate and promote sustainability practices and the implementation of the LPD scheme in high-rise residential buildings.

4. To develop a cloud-based EOD platform to facilitate related sustainable design networking and engagements of various stakeholders - developers, building designers, local authority, building managers, and end-users - from the building appraisal and design stage to the building occupancy stage.

5.2 Revised objectives

Date of approval from the RGC: _____

Reasons for the change: _____

1. _____

2.

3. ....

5.3 Realisation of the objectives

(Maximum 1 page; please state how and to what extent the project objectives have been achieved; give reasons for under-achievements and outline attempts to overcome problems, if any)

All project objectives have been fully achieved:

Objective 1 - The project successfully explored the potentiality of the Lean Premise Design (LPD) scheme in Hong Kong. A holistic, systematic review and content analysis of extant literature identified potential drivers, barriers, benefits, and facilitating measures for the LPD scheme. Furthermore, preliminary interviews were conducted with building end-users and industry experts to contextualize the identified factors in Hong Kong's high-rise residential (HRR) landscape. The factors mentioned above were finalised through questionnaire surveys and statistical data analysis that facilitated the development of the guidelines and measures for LPD scheme implementation in HRR buildings.

Objective 2 - The project identified latent defects in HRR buildings through a 2-round Delphi Survey. The review of extant literature and consultations with teams of experts were accompanied by the Delphi survey and statistical analyses. The key mismatches between building designs and end-user requirements were identified, highlighting the prevalence of defects arising from inadequate consideration of user needs during the design phase. Thus, the critical latent defects in Hong Kong's HRR buildings were established.

Objective 3 - A strategic-mix impact framework influencing design strategies and stakeholders' roles was developed. First, desktop literature review and content analysis were employed to develop the strategic-mix impact framework. Then, hypotheses were formulated to aid in formulating the conceptual framework. Furthermore, questionnaire surveys and data analysis were conducted to develop the strategic-mix impact conceptual model. Finally, structural equation modelling (SEM) was conducted using the collated data. The Partial Least Squares SEM (PLS-SEM) technique was employed to verify and validate the model. Using Smart PLS version 4, the PLS-SEM analysis was conducted to assess the interdependent effects of stakeholders' requirements, roles, issues, relationships, strategic mix and acceptance of sustainable concepts (such as LPD) in Hong Kong's HRR buildings. The framework's integration of LPD supported effective sustainability practices, reducing defects and operational costs in high-rise residential buildings. The framework was developed and effectively illustrated the interplay between design decisions and their impacts on sustainability and building functionality, emphasizing the critical roles of building end-users, designers and property managers.

Objective 4 - A cloud-based End-User-Oriented Design (EOD) platform was developed to simulate the engagement of various stakeholders from building design to occupancy stages. This platform sought to promote effective communication and real-time feedback among building end-users, developers, building designers, local authorities, and building managers with a view to supporting sustainability and LPD schemes. The EOD system protocols and architecture topology were developed, followed by platform engineering and interface development. Building end-users and construction industry experts were invited to register and explore the platform after its deployment, and its performance was evaluated afterwards. The platform was successfully launched, engaging multiple stakeholders from design to occupancy. It facilitated real-time feedback and sustainable design practices to enable more engagement among stakeholders of HRR buildings.

5.4 Summary of objectives addressed to date:

Objectives *(as per 5.1/5.2 above)*	**Addressed** *(please tick)*	**Percentage Achieved** *(please estimate)*
1. To explore the potentiality of the Lean Premise Design (LPD) scheme in Hong Kong to facilitate sustainability practices and reduce abortive work in high-rise residential buildings.	✓	100%
2. To identify the latent defects associated with the mismatch of building designs and the end-user's requirements in high-rise residential buildings.	✓	100%
3. To develop a strategic-mix impact framework to facilitate and promote sustainability practices and the implementation of the LPD scheme in high-rise residential buildings.	✓	100%
4. To develop a cloud-based EOD platform to facilitate related sustainable design networking and engagements of various stakeholders – developers, building designers, local authority, building managers, and end-users – from the building appraisal and design stage to the building occupancy stage.	✓	100%

6. Research Outcome

6.1 Major findings and research outcome
(Maximum 1 page; please make reference to Part C where necessary)

There is a pressing need to propose, develop, and incorporate new sustainable residential building design concepts within Hong Kong's existing codes and guidelines. More importantly, there is a need to set up a framework for sustainable building design. The study revealed the ability of Lean Premise Design (LPD), when fully implemented, to reduce waste; enhance cost efficiency; and promote the overall sustainability of high-rise buildings. The LPD scheme can help developers improve their sustainability credentials by reducing energy usage and construction waste, promoting energy efficiency, and reducing overall carbon footprints in Hong Kong. Additionally, implementing LPD can save significant costs by minimizing waste and avoiding overruns, substantially impacting the profitability of HRR building construction and the affordability of residential apartments in Hong Kong (Lam et al., 2022; Lam et al., 2023a; Lam et al., 2023b).

The study underscores the potential impact of government incentives on promoting LPD adoption. The government and local authorities could play a crucial role by considering providing credits for LPD adoption in certification schemes like BEAM Plus. While there is significant interest in sustainable building designs and the LPD scheme, the study also highlights the importance of price sensitivity as a crucial factor. Discounts and financial incentives like reduced stamp duty could significantly influence developers' and end-users' decisions to adopt the LPD scheme. The study also emphasizes the importance of involving end-users in the design process, indicating a desire for participation and customized solutions in sustainable building designs. LPD adoption in developing HRR buildings could lead to a more collaborative and user-oriented construction industry (Lam et al., 2023a).

The implementation of the LPD scheme offers a range of benefits, including sustainable management via construction waste reduction, energy consumption reduction, and circular economy. By overcoming the identified barriers, the construction industry in Hong Kong can improve the shortage of effective communication and feedback as well as fostering a lean culture that integrates differing buyers' expectations and requirements to achieve a more sustainable design practice. According to the Delphi technique for identifying latent defects in Hong Kong's HRR buildings, emphasizing experts' viewpoints on building end-user requirements, the most critical latent defects in Hong Kong's HRR buildings are associated with external pipes, poor curtain wall designs, and insufficient working drawings and specifications. Identifying these latent defects has significant implications for HRR building designers and other stakeholders, leading them to create designs prioritizing end-user satisfaction and comfort. Similarly, the study ranking analysis of the significant end-user requirements evaluated by the construction industry experts indicated an increasing need for comfort, energy savings, and a connection to the environment (Lam et al., 2023a; Lam et al., 2023c; Lam et al., 2024).

The study shed light on various dynamic interactions within the HRR building sector. It emphasized the critical role of designers in shaping property management and user satisfaction. Similarly, it highlights designers' and users' influences on the strategic mix and adoption of the LPD scheme. Finally, the evaluation of the EOD platform shows that it can help digitalize the process of facilitating the integration of sustainability and the LPD scheme in HRR buildings in Hong Kong; actively engage the end-users and their requirements at the early stages of the building development; and ultimately reduce faulty design and break the reiteration of faulty design due to ignorance of end-users' expectations to promote a green building economy for the sustainable development of the society at large.

6.2 Potential for further development of the research and the proposed course of action *(Maximum half a page)*

Future research will investigate case studies of high-rise residential (HRR) building design using the LPD framework. The primary focus would be understanding the end-user requirements and the level of acceptance of sustainable building design, with particular reference to resource conservation. Moreover, it is essential to explore the development of other design concepts directed towards meeting end-users' needs and requirements in HRR buildings. More research efforts can be made on expanding the platform's usability to include more cities and regions, adapting the platform to various urban settings and building types, particularly for HRR buildings, and enhancing the platform's analytical capabilities to provide more detailed feedback and predictive insights into building performance and user satisfaction. Future research direction can also focus on collaborating with more stakeholders to refine and further develop sustainable practices that could be standardized across the building industry.

7. Layman's Summary

(Describe <u>in layman's language</u> the nature, significance and value of the research project, in no more than 200 words)

This research developed a cloud-based system that allows residents, designers, and other stakeholders of high-rise residential buildings to share feedback and ideas from the earliest stages of building design to occupancy. The goal was to align building designs more closely with what people need and want, which can lead to buildings that are not only more pleasant to live in but also more environmentally friendly. By incorporating everyone's input early and often, the system helps prevent common design mistakes that can lead to costly fixes later. The aim is to ensure that residents live in a space that meets their needs and expectations which is tailor-made to enhance their comfort and well-being. For designers and developers, it provides real-time feedback that can inform better decision-making, reducing the risk of design flaws and the need for future modifications. As Hong Kong continues to grow and the demand for high-rise buildings increases, having a system that ensures these structures are both people-oriented and environmentally responsible is invaluable. It is the cloud-based system developed through this project which could serve as a model for other cities and countries, promoting a global shift towards more sustainable and human-centred living environments.

Part C: Research Output

8. Peer-Reviewed Journal Publication(s) Arising Directly From This Research Project

(Please attach a copy of the publication and/or the letter of acceptance if not yet submitted in the previous progress report(s). All listed publications must acknowledge RGC's funding support by quoting the specific grant reference.)

The Latest Status of Publications				**Author(s)** *(denote the corresponding author with an asterisk*)*	**Title and Journal / Book** *(with the volume, pages and other necessary publishing details specified)*	**Submitted to RGC** *(indicate the year ending of the relevant progress report)*	**Attached to this Report** *(Yes or No)*	**Acknowledged the Support of RGC** *(Yes or No)*	**Accessible from the Institutional Repository** *(Yes or No)*
Year of Publication	**Year of Acceptance** *(For paper accepted but not yet published)*	**Under Review**	**Under Preparation** *(optional)*						
2023	-	-	-	Lam, E. W. M., Chan, A. P. C., Olawumi, T. O., Wong, I., & *Kazeem, K. O.	Facilitators and benefits of implementing lean premise design: A case of Hong Kong high-rise buildings. Journal of Building Engineering, 80(December), 108013. https://doi.org/10.1016/j.jobe.2023.108013	No	Yes (Appendix 1)	Yes	Yes
2023	-	-	-	Lam, E. W. M., Chan, A. P. C., Olawumi, T. O., Wong, I., & *Kazeem, K. O.	Sustainability concepts in global high-rise residential buildings: a scientometric and systematic review. Smart and Sustainable Built Environment, (ahead-of-print). https://doi.org/10.1108/SASBE-04-2023-0094	Yes	Yes (Appendix 2)	Yes	Yes

The Latest Status of Publications				**Author(s)** *(denote the corresponding author with an asterisk*)*	**Title and Journal / Book** *(with the volume, pages and other necessary publishing details specified)*	**Submitted to RGC** *(indicate the year ending of the relevant progress report)*	**Attached to this Report** *(Yes or No)*	**Acknowledged the Support of RGC** *(Yes or No)*	**Accessible from the Institutional Repository** *(Yes or No)*
Year of Publication	**Year of Acceptance** *(For paper accepted but not yet published)*	**Under Review**	**Under Preparation** *(optional)*						
2024	-	-	-	Lam, E. W. M., Chan, A. P. C., Olawumi, T. O., Wong, I., & *Kazeem, K. O.	Critical factors that influence lean premise design implementation: a case of Hong Kong high-rise buildings. Architectural Engineering and Design Management, 1–17. https://doi.org/10.1080/17452007.2024.2302416	No	Yes (Appendix 3)	Yes	Yes

9. Recognized International Conference(s) In Which Paper(s) Related To This Research Project Was / Were Delivered
(Please attach a copy of each conference abstract)

Month / Year / Place	**Title**	**Conference Name**	**Submitted to RGC** *(indicate the year ending of the relevant progress report)*	**Attached to this Report** *(Yes or No)*	**Acknowledged the Support of RGC** *(Yes or No)*	**Accessible from the Institutional Repository** *(Yes or No)*
2023	Identification and Mitigation of Mismatch-related Latent Defects for Effective Sustainability Practices Implementation in Hong Kong's High-Rise Residential Buildings	World Research Forum for Engineers and Researchers	No	Yes	Yes (Appendix 4)	Yes
2022	Development of Sustainable Building Design in Hong Kong: Exploring Lean Capabilities	Water Efficiency Conference	No	Yes	Yes (Appendix 5)	Yes

10. Whether Research Experience And New Knowledge Has Been Transferred / Has Contributed To Teaching And Learning
(Please elaborate)

The experience and knowledge gained from this research have significantly contributed to teaching and learning within the academic environment. Findings of the research project have updated the lecture contents of the subject, 'Construction Engineering Management' in the final year study of BSc(Hons) in Building Engineering and Management for both full-time and part-time students under the topic of 'Green Labelling Scheme for Construction Materials' which can enlighten students' perspectives in applying sustainability concepts to building projects not only limited to construction materials but also building design. The Lean Premise Design (LPD) concept can further inspire students in the understanding of the benefits of LPD on promoting sustainability practices in Hong Kong and worldwide and the development of the cloud-based platform allows students to appreciate real-time feedback from stakeholders of high-rise residential buildings for information exchange. In particular, the research project has provided research experience for an undergraduate student who worked as student assistant (SA) in the project and developed practical skills in data analysis, literature review, SPSS, and software for scientometric analysis, which are instrumental in academic and professional growth. This hands-on experience has enriched SA's understanding of sustainable building practices and user-oriented design, making the SA a valuable contributor to future research and teaching initiatives.

11. Student(s) Trained

(Please attach a copy of the title page of the thesis)

Name	Degree Registered for	Date of Registration	Date of Thesis Submission / Graduation
N/A			

12. Other Impact

(e.g. award of patents or prizes, collaboration with other research institutions, technology transfer, teaching enhancement, etc.)

N/A

13. Statistics on Research Outputs

	Peer-reviewed Journal Publications	Conference Papers	Scholarly Books, Monographs and Chapters	Patents Awarded	Other Research Outputs (please specify)	
No. of outputs arising directly from this research project	3	2	0	0	Type	No.
					N/A	0

14. Public Access Of Completion Report

(Please specify the information, if any, that cannot be provided for public access and give the reasons.)

Information that Cannot Be Provided for Public Access	Reasons