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Student Housing Safety: Differential Contributions of Liquefied Petroleum Gas and Facilities Management Maintenance Services in Ghana

Iruka Chijindu Anugwo[1] , Williams Miller Appau[2], and Elvis Attakora-Amaniampong[3]
[1] Senior Lecturer, Department of Construction Management and Quantity Surveying, Durban University of Technology, 4001, Durban, South Africa, E-mail: IrukaA@dut.ac.za (corresponding author).
[2] Lecturer, Department of Real Estate, SD Dombo University of Business and Integrated Devlopment Sudies, Box 3 FPLM, SDD-UBIDS, Ghana, E-mail: wappau@ubids.edu.gh
[3] Professor, Department of Real Estate, SD Dombo University of Business and Integrated Devlopment Sudies, Box 3 FPLM, SDD-UBIDS, Ghana, E-mail: aattakora@ubids.edu.gh

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Abstract: The rise in fire outbreaks, with its consequences on student housing safety in Sub-Saharan Africa, is worrisome. While facilities management maintenance services are crucial to preventing and controlling LPG usage in student housing, scholars have yet to quantify their mediating role in student housing safety. Based on this, the study assesses the contributions of facilities management maintenance services to student housing safety in Ghana. A sample of 245 registered off-campus student housing managers in northern Ghana was selected. Using the Post-Occupancy Evaluation technique through surveys and partial least squares structural equation modelling, the study uncovered the positive significance of observed indicators of LPG, Facilities Management Maintenance, and Student housing safety. Also, LPG usage showed strong direct impact on student housing safety. However, LPG recorded moderate effects on student housing safety through Facilities management maintenance service. Based on this, the study recommended a high concentration for observed indicators of FMM to control and manage environmental safety, physical safety, and overall student safety in off-campus student housing in Ghana.

Keywords: Energy, facilities management, ,maintenance, structural equation model, student housing safety.

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1. Introduction

Liquefied Petroleum Gas (LPG), derived from butane and propane (Synák et al., 2019), is frequently used as a cooking fuel in homes. (Babatunde & Samuel, 2024). With Sustainable Development Goal (SDG) 7, which aims to promote access to reliable, affordable, modern, and sustainable energy for all, LPG is a highly favourable energy source, as it is considered a clean energy source (Gould et al., 2020). While LPG is considered cleaner than traditional sources of energy (like firewood or charcoal), it contributes to carbon emissions and safety challenges. Within the Ghanaian context, the rapid growth of the student housing market has given rise to critical concerns regarding safety, maintenance, and comfort. In recent past, student housing in Ghana has witnessed a rise in fire outbreaks and gas-related accidents, often linked to low fire safety awareness and management, lack of storage of flammable materials in safe areas, lack of regular inspection and maintenance of gas cylinders, inaccessibility to fire hydrants, and lack of provision of clear signage of exit routes (Asigri et al., 2021; Agyekum et al., 2016). Furthermore, while Facilities Management Maintenance Services (FMMS) are responsible for ensuring compliance with safety standards in the use of LPG, there are inadequate routine checks and well-structured FMMS policies that control the safety of student housing. Facilities Management Maintenance Services explains the systems, individuals or measures put in place to ensure that occupants of spaces are safe from harm and the lifespan of buildings is prolonged. Student performs exceptionally well when provided with comfortable living conditions (Babatunde and Samuel, 2024), and safety in hostels is ensured by facilities management who develop comprehensive safety programs, regular maintenance, provision of firefighting equipment, and inspection of equipment at regular intervals to ensure effectiveness when the need arises (Daramola et al., 2024).

However, given the increasing demand for student housing and a surge in reliance on LPG as the most common and typical energy use in the Ghanaian student housing market, it is important to assess the effectiveness and contributions of FMMS on student housing safety. Several studies have assessed fire safety in university housing in Ghana. However, there is limited attention on the specific context of the mediating role of FMMS on LPG use and student housing safety. Most of these studies focus on fire safety designs, awareness levels of fire safety, challenges of fire safety, and availability and effectiveness of fire safety equipment in student housing in Ghana, while neglecting the role of FMMS in student housing safety. Additionally, there is a lack of empirical research on the contributions of FMMS to enhancing student housing safety. Based on this gap, this study aims to examine the differential contributions of LPG and FMMS in student housing safety in Ghana. This research is relevant in several ways. It methodologically presents the structural differentials of LPG and FMMS on student housing safety using structural equation modelling. Second, the study conceptually contributes to enhancing safety checks in student housing by assessing the challenges associated with LPG usage and the FMMS required to improve safety in student housing. Practically, the study contributes to a call for a safety framework for student housing that focuses on efficient LPG usage, enhanced FFMS, protecting lives, and promoting energy sustainability.

2. Literature Review

2.1. Systems Theory

The General system theory was developed by Ludwig von Bertalanffy in 1928. The theory is premised on interconnected elements with nonlinear relationships, which system consists of a set of isolable elements with linear relationships, including inputs, outputs, controls and feedback that work together to achieve common objectives (von Bertalanffy, 2008). According to Ragan and Carder (1994), all aspects of an organisation are well-integrated to ensure interrelationships, thereby ensuring the quality of safety management. Goh et al. (2024) is of the view that the systems describe the set of connected components that interact to perform a specific function or achieve a specified purpose. Within the student housing sector, protecting students and management against the risk of harm and investment is necessary (Attakora-Amaniampong et al., 2021). These may include components such as policies that ensure interrelationships related to facilities management practices and student safety (Boyle & Michell, 2017). This theory has received limited application in facilities management, especially in determining the contributions of LPG to student housing safety in sub-Saharan Africa

2.2. The Concept of LPG and Student Housing Safety

Liquefied Petroleum Gas, commonly referred to as LPG, is a fuel obtained from propane and butane. It comes in cylinders of varying sizes and is refillable when empty (Synák et al., 2019). These cylinders can be attached to various burners according to the user's preference. It is preferred by most students for cooking and heating (Gould et al., 2020) as compared to traditional charcoal and firewood. While the use of LPG offers several benefits, such as cost efficiency and cleaner combustion, it also presents significant risks to health and safety. Afroz et al. (2023) have highlighted that users exposed to these health risks are primarily students in higher education and residing in purpose-built student accommodation. Tang and Pfrang (2023) are of the view that cooking emissions are a significant indoor particulate matter which contributes to severe health issues such as cardiovascular disease and lung cancer. Additionally, the quality of indoor air can be impacted by gas leakage (Meris et al., 2020), which is common in faulty LPG appliances or due to user negligence. Gas leakages are not easily detectable, which implies that they can persist for long periods, contaminating the indoor air quality for users by releasing carbon dioxide and being combustible, leading to easy ignition (Terzioglu & Iskender, 2021). Other scholars Nyanana et al. (2024) and Afroz et al. (2023) have found that 26.5% of total burn injuries are cooking-related, with LPG contributing 35%, leading to 7% losing their lives. This implies the need to examine LPG usage in student housing to ensure safety.

2.3. Relationship between Facilities Maintenance Management Services and Safety

Studies on facilities management and safety using LPG in residential buildings are limited. Very few of them have established a direct relationship between facilities management, maintenance, and student safety. For instance, Wang et al. (2022) investigated the relationship between facility maintenance and fire safety, finding a high correlation (R-square = 0.8865) between the levels of maintenance and safety in 24 educational facilities. Their study further found a fair link between the safety and maintenance of the structure and fire protection. The overall maintenance coefficient was found to be 0.7408 of the variance in physical safety. However, other authors have expressed dissimilar arguments on the determinants of these relationships. For instance, Jia et al. (2021) also share the view that the leaked information during unloading reveals a coupling relationship between fire accident causes involving multiple factors and facilities. Their study further highlights the need for emergency training and multi-level supervision, from top to bottom, among managers. Hotur et al. (2024) also found that LPG leakage poses serious risks, leading to fire accidents with potential loss of lives and damage to facilities. They further emphasised the need for regular training of fire safety management procedures and fire drills. In support, Onyekwere et al. (2024) also found a significant gap in the level of awareness and implementation of fire safety systems in Universities. Their study found the need for clear evacuation procedures, regular fire drills, and fire safety training. Liaw et al. (2023) also noted that real-time gas monitoring, the use of fire detectors and sensors, and the provision of feedback on gas usage are critical functionalities for monitoring and managing LPG usage. In sum, Babatunde and Samuel (2024) are also of the view that safety practices are of low standards, which require high surveillance, access, and safety signage. While these studies largely focus on the determinants of safety and contributory effects of LPG usage, there is a huge gap to explain the mediating effects of Facilities management maintenance services in student housing safety.

3. Methodology

The study is quantitative, involving the use of a survey to assess the mediating role of facilities management services on LPG usage and student housing safety in North-Western Ghana. The sample involved 254 registered off-campus student housing residents out of 313 purpose-built student housing residents in 2024. Student housing managers were the targeted respondents. A post-occupancy evaluation approach was used to determine the contribution levels of FMMs to student housing safety. The approach involves three steps. First, the study assessed the nature of LPG supply and management. Second, assessment of maintenance criteria, including evaluation of awareness levels regarding LPG use regulations. The final step involved managers providing feedback on general LPG usage, available FFMs, and safety control measures for student housing. Furthermore, Partial-Least Squares structural equation model approaches were employed to establish the crucial role of FMMS in ensuring the safety of student housing in Northwestern Ghana.

3.1. Variable Definition

The variables for the study were extracted from the literature in Section 2. The Variables were grouped into dependent, independent, and mediating. The dependent variable was defined as student housing safety and grouped into three broad areas: Environmental safety (SHS1), Student Safety (SHS2), and Physical safety (SHS3). Physical safety was defined as the frequency of fire outbreaks and the number of fire accidents. Environmental safety was defined as gas leak contamination and the level of noise pollution. Finally, the student safety aspects describe the level of injuries due to fire outbreaks, and the incidence of respiratory diseases and other forms of skin conditions. LPG use, on the other hand, was used as the independent variable. These were defined as the availability of fire extinguishers and leak detectors (LPU1), proper ventilation of storage systems and kitchen areas (LPU2), students' level of awareness of LPG conservation (LPU3), practices and inspection and maintenance of LPG systems (LPU4), and individual student management of gas supply (LPU5). Lastly, Facilities Management Maintenance Services served as the mediating role. These were defined as, the frequency of scheduled inspections and maintenance of LPG systems (FMM1), timeliness response to maintenance reports (FMM2) ventilation systems of student housing units (FMM3), frequent inspection and maintenance of fire alarm systems, smoke detectors, and fire extinguishers (FMM4), and availability of first aid, emergency exit, trained safety personnel, and signage in student housing (FMM5). Fig. 1 shows the hypothetical relationship between LPU, FMM, and SHS.

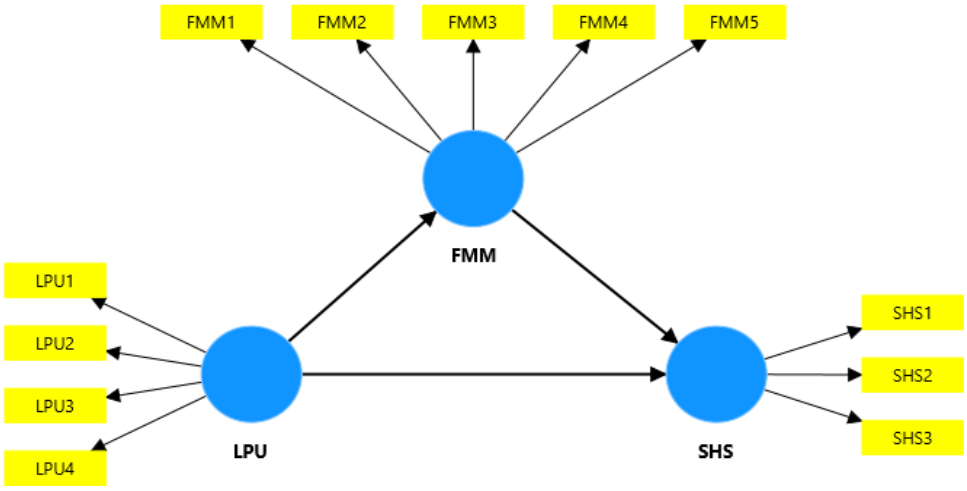

Fig. 1. Hypothetical relationship of the model (source: authors construct, 2024)

3.2. Internal Consistency, Construct Reliability, and Validity

The study used Cronbach's Alpha to determine the internal consistency of the model. According to empirical literature, Cronbach values between 0.60 and 0.70 are considered acceptable, while values ranging from 0.70 to 0.90 are considered satisfactory to good reliability (Hair et al., 2011). The study further relied on 0.5 cut-off values of AVE to assess the variance-explained ability of the constructs.

3.3 Goodness-of-fit of the Model

The goodness-of-fit of this model is assessed by SRMSR, R-squared values, and NFI values, as supported by Hair et al. (2011) and Bentler and Yuan (1999). NFI value of 0.90 was used as a threshold for assessing model fit. Aside from this, SRMSR values less than 0.08 were considered an acceptable threshold (Hu & Bentler, 1998). R-square values higher than 0.75 were classified as substantial to defined model reliability (Hair et al., 2011)

4. Findings/Discussions

4.1. Model Reliability Test

The study examined the internal consistency of the model data using construct validity and discriminant validity. According to construct validity, Table 1 presents good Cronbach's alpha values, indicating acceptable values of FMM (0.905), LPU (0.888), and SHS (0.896), all of which exceed the minimum threshold, as noted in Hair et al. (2011). This implies that the observed variables explain 70% of the variance in FMM services and LPU among the constructs. Thus, FMMs (AVE = 0.727), SHS (AVE = 0.828), and LPU (AVE = 0.751) (see Table 1). Furthermore, the discriminant validity tests also reported a greater Fornell-Larcker criterion for FMM and LPU when comparing their correlations with those of SHS. Moreover,

FMM, LPU, and SHS reported higher Heterotrait-Monotrait Ratio (HTMT) above 0.85 (see Table 2), showing a lack of discriminant validity issues.

Table 1. construct validity test results

Construct	Cronbach's alpha	Composite reliability (rho_a)	Composite reliability (rho_c)	Average variance extracted (AVE)
FMM	0.905	0.911	0.930	0.727
LPU	0.888	0.894	0.923	0.751
SHS	0.896	0.899	0.935	0.828

(source: field data, 2024)

Table 2. Discriminant validity results

Fornell-Larcker criterion			
	FMM	LPU	SHS
FMM	0.852		
LPU	0.905	0.867	
SHS	0.876	0.916	0.910
Heterotrait-Monotrait ratio (HTMT) – Matrix			
	FMM	LPU	SHS
FMM			
LPU	1.014		
SHS	0.967	1.018	

(field data, 2024)

4.2. Model Goodness-of-fit Results

The model fit was reported using the R-squared, SRMR, d_ULS, d_G, NFI, and Chi-square statistics. Table 3 shows that the independent variables in the model primarily explain 81.9%% of the variance in FMM. Similarly, about 85.1% of the variance in SHS, which explains a good amount of explanatory power and justifies including these predictors in this model. SMR results also show a good fit, as SRMR = 0.079 was less than the 0.08 threshold (Hu & Bentler, 1998). Furthermore, Table 4 reports d_ULS = 0.566 and d_G = 0.186, indicating a good and acceptable fit of the model. Additionally, the study reported large chi-square values (327.576), indicating a good model fit. NFI model fit recorded values (0.777) lower than the 0.90 threshold (Hair et al., 2011), but is accepted in this kind of exploratory study (see Table 4).

4.3. Model Results

This section presents results on the direct and indirect effects of LPG on student housing safety in Northern Ghana. Fig. 2 shows that observed indicators of FMM, LPU, and SHS are all significant (FMM>0.7), which suggests a substantial contribution to enhancing student housing safety. On the other hand, FMM recorded a positive relationship and a low direct effect on SHS (see Table 5). This suggests that a one-unit increase in FMM services is expected to affect SHS by 0.260, which is inconsistent with Wang et al. (2022), who found a high correlation between the levels of maintenance and safety in 24 educational facilities. However, the facilitation role of FMM confirms the general systems theory approach that establishes the interconnection of relationships to solve societal problems (von Bertalanffy, 2008; Ragan & Carder, 1994). Additionally, Table 5 shows a strong and positive relationship between LPU and FMM. In effect, the path coefficient explains a strong direct effect of LPU on FMM service. Additionally, this effect suggests that an increase in LPU in student housing results in a 0.905-point increase in FMM services, making LPU a robust predictor of FMM services in student housing. Also, this implies the strong relevance of having facilities management maintenance services in place to control LPG emergency services at all times. Similarly, there is strong and positive relationship between LPU and SHS. Aside from that, the study found that an increase in LPU directly affects SHS by 0.680 units. This result is supported by Jia et al. (2021), who found that a leaked LPG during unloading has a coupling relationship between fire accident causes and safety in facilities.

Table 3. Model explanatory power

Constructs	R-square	R-square adjusted
FMM	0.819	0.818

SHS	0.851	0.850

(source: field data, 2024)

Table 4. Model fit assessment

SRMR	0.079	0.079
d_ULS	0.566	0.566
d_G	0.186	0.186
Chi-square	327.576	327.576
NFI	0.777	0.777

(source: field data, 2024)

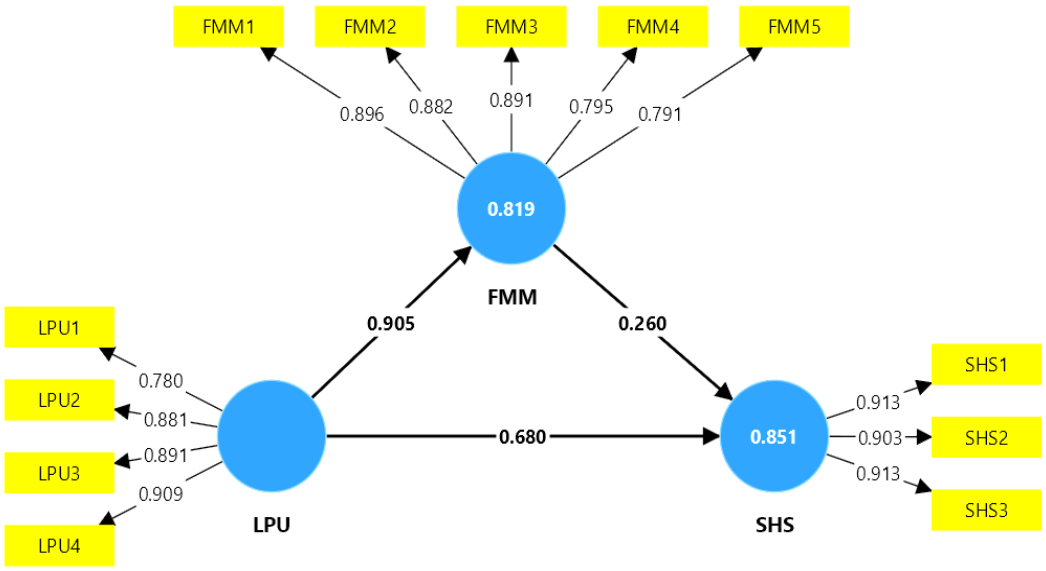

Fig. 2. Path-coefficient and observed results of model (source: authors constract, 2024)

Table 5. Path coefficient results

Construct relationships	Path coefficients
FMM -> SHS	0.260
LPU -> FMM	0.905
LPU -> SHS	0.680

(field data, 2024)

4.4. Mediating effects of facilities maintenance management services on student housing safety

Table 6 illustrates a strong, positive, and significant relationship between LPU and SHS. However, this result suggests that a direct increase in LPU can have significant effects on environmental safety, physical safety, and student safety, which is supported by Tang and Pfrang (2023), Terzioglu and Iskender (2021), and Meris et al. (2020). Indirectly, the study reveals a positive and moderate relationship between LPU and SHS, mediated by FMM. This implies that the greater the LPU increase, the more SHS is reduced through FMM services. These are critical expectations that can be situated within the context of systems theory, where safety management policies can be enhanced by taking into account all observed indicators of LPU (Boyle & Michell, 2017). Additionally, it can be deduced that FMM services play a minimal role in ensuring efficient safety in student housing, which suggests that any intervention designed to control and manage LUP requires optimising FMM services in student housing.

Table 6. Mediating effects results

Type of effect	Effect	Path-coefficient	T-stats	Total remarks

Total effect	LUP-SHS	0.681	8.823	0.000
Indirect effect	LUP-FMM-SHS	0.236	3.297	0.001

(field data, 2024)

5. Implications and recommendations of the study

Theoretically, the study contributes to the general systems theory in two ways. First, the indirect effects of FMMs on student housing safety conform to the interrelation premises of the theory. Secondly, the effects of nonlinear relationships between LPG and SHS indicate that the lack of control over LPG can have a significant direct impact on student housing safety. Conceptually, the good model fit suggests that establishing the interrelationship between LPU, FMM, and SHS provide a solid foundation to appreciate how the nature of student housing condition and LPG usage influences safety. Practically, the strong positive relationship between facilities management maintenance services and LPG usage shows that enhancing the supply, control, and management of LPG usage by student housing managers will ensure student housing safety. Notwithstanding the moderate positive relationship between facilities management maintenance services and student housing safety, student housing managers can rely on the high explanatory power of FMM observed indicators as a decision-making tool for inclusive student housing safety while controlling the cascading effects on environmental, physical, and student safety. The findings from this study are localised but highlight the importance of facilities management in ensuring safe LPG use for improved student housing safety. In Nigeria, for instance, weak regulations for LPG will often cause hostel fires, while cooking within student flats pollutes indoor air in the UK. Universities in Turkey likewise face leakage hazards, and Taiwan has documented LPG-related fire and explosion risks. In India, LPG accidents continue to be a significant safety concern in both student housing and low-income housing. The study establishes the impact of structured maintenance and safety frameworks on various international housing policies. Protecting students while advancing sustainable energy makes these findings significant within the global context.

6. Conclusions

The study aims to examine the role of facilities management maintenance services in ensuring student housing safety in Northern Ghana, using partial least squares structural equation modelling. The findings highlight the significant role of facilities management maintenance services in improving student housing safety in Northern Ghana. Furthermore, the study revealed that although observed values for facilities management maintenance services were high, they reduced the impact of LPG on student housing by 0.236, which is sufficient to ensure student safety, comfort, and overall well-being in Northern Ghana. This finding underscores the relevance of enhancing all the observed FMM services in Northern Ghana. However, the perception of students' satisfaction towards FMM in managing LPG in student housing could be explored in future.

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Author Contributions

Dr. Anugwo contributed largely to the conceptualisation, literature review, and conclusions of the study. Prof. Attakora-Amainampong contributed to research methodology, data analysis, and interpretations. Dr. Appau assisted with data collection, processing, proofreading of the manuscript before submission and publication.

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Dr. Anugwo is a senior lecturer at the Department of Construction Management and Quantity Surveying at the Durban University of Technology, South Africa. He has over 15 years of research experience in construction safety, facilities management, construction engineering, and construction sustainability. Dr Anugwo have contributed to several departmental, faculty and university committees. Specifically, Dr Anugwo have participated in numerous departmental, faculty, and university committees. Dr Anugwo have acted as the Faculty representative for FEBE on several committees, including the DUT Institutional Research and Ethics Committee (IREC), the DUT Institutional Review Committee for Research and Postgraduate Support, and the DUT Institutional M&D Scholarship committee. Dr Anugwo have over 45 acadamic published– journal, conferences and book chapters articles to his credit.

Dr. Appau is a lecturer at SD. Dombo University of Business and Integrated Development Studies, Department of Real Estate, Ghana. His area of research interest is sustainable facilities management and construction management in Sub-Saharan Africa. He is a trainee at the Ghana Institution of Surveyors and a member of Ghana Geospatial Society.

Professor Attakora-Amaniampong is a professor of real estate management and investment at the Department of Real Estate, SD Dombo University of Business and Integrated Development Studies, Ghana. He has over 17 years of experience in teaching and research. He is currently the Head of the Department of Real Estate and a member of Ghana Real Estate Professionals Association.