

Sustainable Facilities Management for Residential Communities in Saudi Arabia

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Abstract- Sustainable facilities management has become an important requirement for residential communities in Saudi Arabia as the Kingdom continues to advance its Vision 2030 goals related to quality of life, resource efficiency, environmental responsibility, and smart infrastructure. Residential communities require continuous operation and maintenance of buildings, utilities, recreational areas, cleaning services, landscaping, guest houses, commissary services, safety systems, and general community facilities. When these services are not managed efficiently, they can lead to higher operational costs, resource wastage, service interruptions, and reduced resident satisfaction. This study examines the role of sustainable facilities management in improving residential community services in Saudi Arabia. The paper adopts a review-based approach to analyze how maintenance planning, resource conservation, contractor performance, digital monitoring, and service quality management can support sustainable residential operations. It highlights that facilities management is not only a technical maintenance activity but also a strategic function that connects environmental sustainability, operational efficiency, contract governance, and community well-being. The study finds that sustainable facilities management can improve asset reliability, reduce water and energy wastage, enhance service delivery, and support better living conditions in residential communities. By integrating sustainability principles with facility service contracts and performance monitoring, Saudi residential communities can become more efficient, resilient, and aligned with Vision 2030 development priorities.

Keywords: Sustainable Facilities Management, Residential Communities, Saudi Arabia, Vision 2030, Facility Services, Contract Governance, Resource Efficiency.

I. INTRODUCTION

Residential communities in Saudi Arabia are expanding rapidly due to urban development, industrial growth, population movement, and the national focus on improving quality of life under Saudi Vision 2030. These communities require

reliable facilities management to support daily living, comfort, safety, and service continuity. Facilities management in residential communities includes building maintenance, utilities management, cleaning services, landscaping, recreational facilities, swimming pools, guest houses, commissary services, playgrounds, safety systems, waste management, and general community support services. When these services are managed properly, they improve resident satisfaction, operational efficiency, and long-term asset value.

Sustainable facilities management has become increasingly important because residential communities consume large amounts of water, energy, materials, and maintenance resources. Traditional facility management practices often focus mainly on corrective maintenance and routine service delivery. However, modern residential communities require a more sustainable approach that reduces resource wastage, improves preventive maintenance, supports digital monitoring, and ensures better contractor performance. Sustainability in facilities management is not only about environmental protection; it also includes cost control, service quality, asset reliability, resident well-being, and efficient use of resources.

In Saudi Arabia, sustainable facilities management is strongly connected with Vision 2030 priorities, especially quality of life, environmental sustainability, smart infrastructure, and efficient public and private services. Residential communities must be designed and operated in a way that supports cleaner, safer, and more efficient living environments. This is especially important in large organizational and industrial communities where thousands of residents depend on continuous facility services. Poor maintenance, delayed repairs, inefficient water or energy use, and weak contractor

monitoring can affect both operational performance and community satisfaction.

Digital transformation also plays an important role in sustainable facilities management. Smart systems, sensors, digital dashboards, maintenance management software, and performance reporting tools can help facility managers monitor assets and services more effectively. These technologies allow facility teams to move from reactive maintenance to preventive and predictive maintenance. They also improve transparency by providing data for contractor evaluation, service improvement, and sustainability reporting.

This paper examines sustainable facilities management for residential communities in Saudi Arabia. It focuses on how resource efficiency, maintenance planning, digital monitoring, contractor governance, and service quality management can improve residential community operations. The study highlights sustainable facilities management as a strategic approach that supports Vision 2030, improves community well-being, reduces operational costs, and strengthens long-term facility performance.

II. LITERATURE REVIEW

2.1 Concept of Sustainable Facilities Management

Sustainable facilities management refers to the planning, operation, maintenance, and improvement of buildings and community services in a way that reduces resource wastage, improves service quality, and supports long-term environmental and operational performance. It goes beyond routine maintenance by focusing on energy efficiency, water conservation, waste reduction, asset reliability, safety, user comfort, and cost control. ISO 41001 identifies facilities management as an organized management function that supports effective service delivery and operational performance (International Organization for Standardization, 2018). In residential communities, sustainable facilities management is important because residents depend on continuous services such as electricity, water supply, cleaning, landscaping, recreational facilities, building maintenance, and emergency support. A sustainable approach helps facility managers

maintain service quality while reducing unnecessary consumption and operational expenses (Alfalah & Zayed, 2020; Okoro, 2023).

2.2 Residential Communities and Facility Service Needs

Residential communities require a wide range of facility services to support daily living and community well-being. These services include building maintenance, plumbing, electrical systems, air-conditioning, water systems, waste management, cleaning, pest control, landscaping, playgrounds, swimming pools, guest houses, commissary services, and common-area maintenance. In large residential communities, service failure can affect many residents at the same time. For example, poor water system maintenance can lead to leakage, high consumption, and resident complaints, while poor cleaning or waste management can affect hygiene and comfort. Therefore, facility services must be managed through structured planning, proper supervision, and continuous performance monitoring (Opoku & Lee, 2022).

2.3 Sustainability in Building Maintenance and Community Services

Building maintenance plays a central role in sustainable residential community management. Traditional maintenance often focuses on fixing problems after they occur, but sustainable maintenance emphasizes preventive action, regular inspection, life-cycle asset management, and efficient use of resources. Preventive maintenance can reduce breakdowns, extend asset life, and lower repair costs. In residential communities, this is especially important for water systems, electrical networks, HVAC systems, elevators, lighting, fire safety systems, and recreational facilities. Sustainable community services also include reducing water and energy wastage, using environmentally friendly cleaning practices, improving waste handling, and maintaining green areas responsibly (Ruparathna et al., 2020; Kaewunruen et al., 2020).

2.4 Digital Transformation in Facility Management

Digital transformation has become an important part of modern facilities management. Technologies such as smart meters, sensors, computerized maintenance

management systems, digital dashboards, and mobile reporting tools help facility managers monitor services more accurately. These systems allow facility teams to record complaints, track work orders, monitor contractor response, and review service performance. Digital tools also support preventive maintenance by identifying problems early and providing data for better decision-making (Hossain et al., 2020; Naticchia et al., 2020). In residential communities, digital facility management can improve transparency, reduce response delays, and enhance resident satisfaction by ensuring that maintenance requests and service issues are properly tracked and resolved.

2.5 Contract Governance and Contractor Performance

Many residential facility services are delivered by contractors, making contract governance an important part of sustainable facilities management. Contracts should clearly define the scope of work, service standards, safety requirements, reporting obligations, manpower requirements, response times, and key performance indicators. Without proper governance, contractors may fail to meet service expectations, leading to poor maintenance, delayed responses, resource wastage, and resident dissatisfaction. Performance-based contracts can improve accountability by measuring actual outcomes such as complaint resolution time, preventive maintenance completion, cleanliness standards, water and energy savings, and resident feedback. Strong contractor monitoring helps residential communities maintain consistent service quality and long-term operational performance (Osei Assibey Antwi et al., 2025).

2.6 Saudi Vision 2030 and Quality of Life Alignment
Saudi Vision 2030 emphasizes quality of life, environmental sustainability, efficient resource use, and modern infrastructure (Saudi Vision 2030, 2016). Sustainable facilities management directly supports these priorities because residential communities are essential spaces where people live, work, relax, and interact. Well-managed residential facilities improve comfort, safety, hygiene, recreation, and overall community satisfaction. At the same time, sustainable practices reduce water and energy waste,

improve maintenance efficiency, and support environmental responsibility. Therefore, sustainable facilities management is not only an operational requirement but also a strategic approach for improving residential community life in Saudi Arabia. It helps align facility services with national goals for sustainability, digital transformation, and better living standards (Vision 2030, 2026; Quality of Life Program, 2024).

III. AIM AND OBJECTIVES OF THE STUDY

3.1 Aim of the Study

The main aim of this study is to examine how sustainable facilities management can improve residential community services in Saudi Arabia. The study focuses on the role of maintenance planning, resource efficiency, contractor performance, digital monitoring, and service quality in creating safe, efficient, and comfortable residential environments. It also aims to show how sustainable facility practices can support Saudi Vision 2030 goals related to quality of life, environmental responsibility, and efficient infrastructure services.

3.2 Objectives of the Study

The objectives of this study are:

1. To explain the importance of sustainable facilities management in residential communities.
2. To examine how facility services support resident comfort, safety, and service continuity.
3. To analyze the role of preventive maintenance in improving asset reliability and reducing operational costs.
4. To study how digital tools can improve facility monitoring and service performance.
5. To evaluate the importance of contract governance and contractor KPIs in residential facility services.
6. To align sustainable facilities management with Saudi Vision 2030 and quality of life objectives.

IV. RESEARCH METHODOLOGY

4.1 Research Design

This study follows a review-based qualitative research design to examine sustainable facilities management for residential communities in Saudi Arabia. This method is suitable because the study focuses on understanding existing concepts, practices, and strategies related to facility services, sustainability, maintenance performance, contractor governance, and quality of life. The paper does not depend on primary survey data; instead, it reviews academic literature, official strategy documents, and practical facility management approaches.

4.2 Data Sources

The study is based on secondary data collected from research articles, sustainability reports, facility management literature, Saudi Vision 2030 documents, and industry practices related to residential community services. The reviewed materials focus on sustainable building maintenance, water and energy conservation, digital facility management, contractor performance, resident satisfaction, and operational efficiency. The study also considers common residential community services such as cleaning, landscaping, recreational facilities, guest houses, swimming pools, commissary services, waste management, and general maintenance.

4.3 Analytical Approach

The collected information is analyzed using a thematic approach. The main themes include sustainable facilities management, preventive maintenance, digital monitoring, resource efficiency, contractor performance, service quality, and Vision 2030 alignment. This approach helps identify how sustainable facility practices can improve residential community operations and support better living environments.

4.4 Scope of the Study

The scope of this study is limited to residential communities in Saudi Arabia. It focuses on facility services that directly affect resident comfort, safety, resource use, service reliability, and community well-being. The study does not focus on architectural

design or construction methods; instead, it focuses on the operation, maintenance, and governance of residential community facilities.

4.5 Methodological Framework

The study follows four steps: reviewing literature, identifying key residential facility service areas, analyzing sustainability and service performance factors, and developing a framework for sustainable facilities management in Saudi residential communities.

V. SUSTAINABLE FACILITIES MANAGEMENT IN RESIDENTIAL COMMUNITIES

Sustainable facilities management in residential communities focuses on maintaining buildings, utilities, common areas, and community services in a way that improves service quality while reducing resource wastage and operational costs. In Saudi Arabia, residential communities often include several connected services such as building maintenance, water and electrical systems, cleaning, landscaping, swimming pools, playgrounds, recreation areas, guest houses, commissary services, waste management, and safety systems. These services must operate continuously because they directly affect resident comfort, health, safety, and satisfaction.

A sustainable approach means that facility services should not only solve problems after they occur. Instead, facility managers should focus on preventive maintenance, regular inspections, efficient use of water and energy, waste reduction, contractor performance, and long-term asset protection. For example, regular inspection of plumbing systems can reduce leakage, while preventive maintenance of HVAC systems can improve energy efficiency and reduce breakdowns. Similarly, proper landscaping practices can reduce water consumption and improve the appearance of residential communities.

Sustainable facilities management also supports better planning and cost control. When maintenance activities are planned properly, organizations can avoid emergency repairs, reduce service interruptions, and extend the life of facility assets.

This is especially important in large residential communities where small failures can affect many residents. For example, poor maintenance of water systems, elevators, lighting, or waste services can quickly lead to complaints and dissatisfaction.

In Saudi Arabia, sustainable facility practices are also connected with Vision 2030 goals related to quality of life, environmental responsibility, and efficient infrastructure services. Residential communities are important living environments, and their management should support comfort, safety, cleanliness, and reliable service delivery. By applying sustainable facilities management, organizations can create healthier and more efficient communities.

Overall, sustainable facilities management helps residential communities move from traditional maintenance to a more strategic and responsible service model. It supports resource efficiency, service reliability, resident satisfaction, contractor accountability, and long-term operational performance.

VI. RESIDENTIAL COMMUNITY SERVICES AND OPERATIONAL EFFICIENCY

Residential community services play an important role in maintaining comfort, safety, hygiene, and service continuity for residents. These services include building maintenance, cleaning, landscaping, waste management, swimming pool maintenance, playground services, guest house operations, commissary support, water systems, electrical systems, HVAC maintenance, and common-area management. In large residential communities, these services must be properly planned and monitored because any delay or failure can directly affect residents' daily life.

Operational efficiency in residential communities means delivering these services with minimum wastage, lower cost, faster response, and better service quality. For example, regular preventive maintenance of buildings and utilities can reduce emergency breakdowns. Proper cleaning schedules can improve hygiene and resident satisfaction. Efficient landscaping can reduce water consumption

while maintaining a pleasant community environment. Similarly, planned waste management can improve cleanliness and environmental performance.

Sustainable facilities management improves operational efficiency by creating a structured service model. This includes clear service schedules, contractor responsibilities, inspection plans, digital work order systems, and performance monitoring. When facility managers use data and regular reporting, they can identify repeated problems, reduce delays, and improve decision-making. This approach also helps reduce unnecessary spending because resources are used more effectively.

Contractor performance is another important part of operational efficiency. Many residential community services are outsourced to contractors, so their performance must be measured through clear indicators such as response time, complaint closure, preventive maintenance completion, cleanliness standards, safety compliance, and resident feedback. Strong monitoring ensures that contractors deliver services according to agreed standards.

Overall, operational efficiency helps residential communities become more reliable, cost-effective, and sustainable. It improves resident satisfaction, reduces service disruptions, supports resource conservation, and strengthens long-term facility performance.

Table 1: Key Components of Sustainable Facilities Management in Residential Communities

Component	Purpose	Expected Benefit
Preventive maintenance	Regular inspection and servicing	Fewer breakdowns
Water and energy efficiency	Reduce resource wastage	Lower operating costs
Cleaning and waste services	Maintain hygiene and safety	Better living conditions
Contractor monitoring	Track service performance	Higher accountability

Component	Purpose	Expected Benefit
Digital reporting	Improve service visibility	Faster decision-making

VII. CONTRACT GOVERNANCE AND SERVICE QUALITY MANAGEMENT

Contract governance is an important part of sustainable facilities management because many residential community services are delivered through external contractors. These services may include building maintenance, cleaning, landscaping, swimming pool maintenance, waste management, guest house operations, commissary services, pest control, safety services, and general repair works. To ensure reliable service delivery, each contract should clearly define the scope of work, service standards, response times, reporting requirements, safety obligations, manpower requirements, and performance indicators.

In residential communities, poor contract governance can lead to delayed maintenance, repeated complaints, weak service quality, higher costs, and resident dissatisfaction. Therefore, facility managers need a structured system to monitor contractor performance. This can include regular inspections, monthly performance reports, service audits, resident feedback, and digital work order tracking. When contractors are monitored properly, service delivery becomes more transparent and accountable.

Service quality management is also essential because residential facilities directly affect daily living conditions. Residents expect clean surroundings, safe buildings, working utilities, maintained recreational areas, reliable waste collection, and quick response to maintenance issues. If service quality is poor, it can affect comfort, safety, and overall community satisfaction.

Performance-based contracts can improve service quality by linking contractor evaluation with measurable results. Useful key performance indicators may include complaint response time, preventive maintenance completion, cleanliness score, safety compliance, asset downtime, water and

energy saving performance, and resident satisfaction level. These indicators help facility managers identify weak areas and take corrective action.

Overall, strong contract governance helps residential communities maintain consistent service quality, reduce operational risks, control costs, and improve resident satisfaction. It also supports sustainable facilities management by ensuring that contractors follow environmental, safety, and performance standards.

VIII. PROPOSED FRAMEWORK FOR SUSTAINABLE RESIDENTIAL FACILITY MANAGEMENT

The proposed framework explains how residential communities in Saudi Arabia can improve facility service performance through sustainability, digital monitoring, maintenance planning, and contract governance. The framework begins with identifying key residential facility services such as building maintenance, cleaning, landscaping, waste management, recreational facilities, guest houses, commissary services, water systems, electrical systems, and common-area services.

The next step is resource monitoring. Facility managers should regularly monitor water use, energy consumption, waste generation, maintenance requests, and service complaints. This helps identify areas where resources are being wasted or where services are not performing properly. Digital tools such as maintenance management systems, smart meters, dashboards, and mobile reporting platforms can support faster decision-making.

Preventive maintenance is another important part of the framework. Instead of waiting for breakdowns, facility teams should follow planned inspection schedules for HVAC systems, plumbing, electrical systems, elevators, lighting, swimming pools, and safety systems. This improves asset reliability and reduces emergency repair costs.

Contract governance should also be linked with service quality. Contractors should be evaluated through measurable KPIs such as response time,

complaint closure, preventive maintenance completion, cleanliness standards, safety compliance, and resident satisfaction.

Figure 1: Sustainable Residential Facility Management Framework



This framework shows that sustainable facilities management is a connected system. Residential community services should be monitored through resource data, preventive maintenance, contractor performance, and service quality indicators. By following this process, facility managers can improve operational efficiency, reduce wastage, increase resident satisfaction, and support long-term sustainability in Saudi residential communities.

Figure 2: Vision 2030, Sustainable Facilities Management, and Quality of Life Linkage



This figure explains how sustainable facilities management supports Saudi Vision 2030 by improving resource efficiency, service quality, resident comfort, safety, and community well-being.

In residential communities, better facility services help reduce water and energy wastage, improve maintenance performance, strengthen contractor accountability, and create cleaner, safer, and more comfortable living environments.

IX. DISCUSSION

Sustainable facilities management plays an important role in improving the performance of residential communities in Saudi Arabia. Residential communities depend on many daily services, including building maintenance, cleaning, landscaping, waste management, guest house services, swimming pool maintenance, recreational facilities, utilities, and common-area management. If these services are not managed properly, they can create operational problems such as high maintenance costs, resource wastage, resident complaints, service delays, and reduced asset life.

The discussion shows that sustainability in residential facilities is not limited to environmental protection. It also includes operational efficiency, service quality, resident comfort, contractor accountability, and long-term cost control. Preventive maintenance is one of the strongest methods for improving sustainability because it reduces breakdowns and avoids emergency repairs. For example, regular inspection of water systems, HVAC units, lighting, elevators, and safety systems can reduce failures and improve service reliability.

Digital monitoring is another important factor. Facility managers can use digital tools to track work orders, complaints, energy use, water consumption, and contractor performance. This allows faster decision-making and better service planning. In large residential communities, digital reporting can help identify repeated issues and improve transparency between residents, facility teams, and contractors.

Contract governance also has a major role in sustainable facilities management. Since many services are outsourced, contractors must be monitored through clear KPIs such as response time, preventive maintenance completion, cleanliness standards, safety compliance, and resident

satisfaction. Strong contract monitoring helps ensure that services are delivered according to agreed standards.

Overall, sustainable facilities management supports Saudi Vision 2030 by improving quality of life, reducing resource wastage, strengthening operational efficiency, and creating better residential living environments. It provides a practical approach for managing residential communities in a more efficient, responsible, and resident-focused manner.

Table 2: Facility Service KPIs for Residential Community Operations

Service Area	KPI	Purpose
Building maintenance	Complaint response time	Faster issue resolution
Preventive maintenance	Completion percentage	Reduce breakdowns
Cleaning services	Cleanliness inspection score	Improve hygiene
Landscaping	Water-efficient maintenance	Reduce water wastage
Waste management	Collection schedule compliance	Maintain cleanliness
Contractor performance	Monthly service rating	Improve accountability
Resident satisfaction	Feedback score	Improve service quality

X. RECOMMENDATIONS

Residential communities in Saudi Arabia should adopt sustainable facilities management as a core operational strategy. Facility managers should focus on preventive maintenance instead of depending mainly on corrective repairs. Regular inspection schedules should be prepared for water systems, HVAC units, electrical systems, elevators, lighting, safety systems, swimming pools, and common areas. Digital tools should also be used to monitor maintenance requests, complaints, contractor performance, resource consumption, and service quality. This will help facility teams make faster and more accurate decisions. Residential communities should also introduce water and energy conservation

measures to reduce wastage and support sustainability goals.

Contractor performance should be monitored through clear KPIs, including response time, preventive maintenance completion, cleanliness standards, safety compliance, and resident satisfaction. Monthly performance reports should be prepared to identify repeated issues and improve service delivery.

Finally, facility staff and contractors should receive regular training on sustainability, safety, service quality, and digital reporting. These steps can improve operational efficiency, reduce costs, and support better living conditions in Saudi residential communities.

XI. CONCLUSION

Sustainable facilities management is essential for improving residential community operations in Saudi Arabia. The study shows that residential communities require continuous and reliable services such as building maintenance, cleaning, landscaping, waste management, utilities, recreational facilities, guest houses, swimming pools, and common-area support. If these services are not managed properly, they can increase operational costs, reduce resident satisfaction, and create resource wastage.

The paper highlights that sustainable facilities management should focus on preventive maintenance, water and energy efficiency, digital monitoring, contractor governance, and service quality improvement. These practices can help residential communities become more efficient, safe, clean, and comfortable for residents.

By connecting sustainability with facility service contracts and performance monitoring, Saudi residential communities can improve asset reliability, reduce service disruptions, and support Vision 2030 goals related to quality of life, environmental responsibility, and efficient infrastructure services.

REFERENCES

- [1] Saudi Vision 2030. (2016). Kingdom of Saudi Arabia Vision 2030. Government of Saudi Arabia.
- [2] Vision 2030. (2026). Quality of Life Program. Government of Saudi Arabia.
- [3] Quality of Life Program. (2024). Annual report 2024. Government of Saudi Arabia.
- [4] Ministry of Environment, Water and Agriculture. (2020). National Water Strategy 2030. Kingdom of Saudi Arabia.
- [5] Saudi Water Authority. (2024). Water sector strategy and sustainability initiatives. Saudi Water Authority.
- [6] Saudi Green Initiative. (2024). Sustainability and environmental protection initiatives in Saudi Arabia. Government of Saudi Arabia.
- [7] United Nations. (2024). Sustainable Development Goals. United Nations.
- [8] International Organization for Standardization. (2018). ISO 41001: Facility management — Management systems — Requirements with guidance for use. ISO.
- [9] International Organization for Standardization. (2017). ISO 41011: Facility management — Vocabulary. ISO.
- [10] Alfalah, G., & Zayed, T. (2020). A review of sustainable facility management research. *Sustainable Cities and Society*, 55, 102073. <https://doi.org/10.1016/j.scs.2020.102073>
- [11] Okoro, C. S. (2023). Sustainable facilities management in the built environment: A mixed-method review. *Sustainability*, 15(4), 3174. <https://doi.org/10.3390/su15043174>
- [12] Opoku, A., & Lee, J. Y. (2022). The future of facilities management: Managing facilities for sustainable development. *Sustainability*, 14(3), 1705. <https://doi.org/10.3390/su14031705>
- [13] Lok, K. L., Opoku, A., Smith, A., Vanderpool, I., & Cheung, K. L. (2023). Sustainable facility management in UN development goals. *IOP Conference Series: Earth and Environmental Science*, 1176(1), 012022. <https://doi.org/10.1088/1755-1315/1176/1/012022>
- [14] Osei Assibey Antwi, A. D., Afful, A. E., Ayarkwa, J., Dodoo, A., Osei-Tutu, S., & Danso, A. K. (2025). Sustainable facilities management in the built environment: A bibliometric review. *Journal of Facilities Management*, 23(2), 352–371. <https://doi.org/10.1108/JFM-05-2023-0056>
- [15] Signorini, M., & Pomè, A. P. (2025). Shaping the future of facility management: Market and literature insights on digital twin adoption. *Facilities*, 43(11/12), 818–834. <https://doi.org/10.1108/F-02-2025-0029>
- [16] Aliu, A. A., Chan, D. W. M., & Darko, A. (2025). Barriers to digital transformation in facilities management: Insights from a developing country. *Journal of Construction in Developing Countries*, 30(2), 119–141.
- [17] Rahman, M. M. (2021). BIM-enabled sustainable facility management. *International Journal of Integrated Engineering*, 13(7), 101–107. <https://doi.org/10.30880/ijie.2021.13.07.013>
- [18] Hossain, M. A., Nadeem, A., & Lee, S. H. (2020). Digital transformation of facility management using BIM and IoT technologies. *Automation in Construction*, 113, 103132.
- [19] Naticchia, B., Corneli, A., & Carbonari, A. (2020). Framework based on building information modeling for facility management. *Journal of Building Engineering*, 32, 101783.
- [20] Hosamo, H. H., Svennevig, P. R., Svidt, K., Han, D., & Nielsen, H. K. (2022). A digital twin predictive maintenance framework of air handling units based on automatic fault detection and diagnostics. *Energy and Buildings*, 261, 111988.
- [21] Kaewunruen, S., Sresakoolchai, J., & Zhou, Z. (2020). Sustainability-based lifecycle management for smart infrastructure systems. *Sustainability*, 12(14), 5804.

- [22] Darko, A., Chan, A. P. C., Ameyaw, E. E., He, B. J., & Olanipekun, A. O. (2021). Examining issues influencing green building technologies adoption. *Journal of Cleaner Production*, 285, 124997.
- [23] Ruparathna, R., Hewage, K., & Sadiq, R. (2020). Improving the energy efficiency of the existing building stock through sustainable facility management. *Renewable and Sustainable Energy Reviews*, 78, 1032–1045.
- [24] Alaloul, W. S., Liew, M. S., Zawawi, N. A. W. A., Mohammed, B. S., & Adamu, M. (2020). An artificial neural networks model for green building assessment. *Sustainable Cities and Society*, 63, 102439.
- [25] Aslam, M. S., Huang, B., & Cui, L. (2020). Review of construction and demolition waste management in China and USA. *Journal of Environmental Management*, 264, 110445.