The following publication Hou H, Au-Yong CP, Wang T (2025), "Evaluating smart facilities management in shopping centers: a participatory KPI method approach". Facilities, Vol. 43 No. 5-6 pp. 277–299 is published by Emerald and is available at https://doi.org/10.1108/F-02-2024-0025.

Evaluating Smart Facilities Management in Shopping Centers: A Participatory KPI Method Approach

Purpose
This study aims to clarify the transformative impact of digital advancements on shopping center operations and to critically analyze the current operation and performance of these technologies. By integrating these two perspectives, the research seeks to provide a detailed insight into both potential and the real-time efficacy of smart technologies, thereby guiding future investment and development decisions in this sector.

Design/methodology/approach
Grounded in the innovation diffusion theory, this study formulates research questions aimed at investigating the operation and performance of smart FM tools from the viewpoint of FM professionals. Employing a participatory approach, the research utilised in-depth interviews to classify smart FM tools into four distinct categories. Additionally, eight focus group discussions were conducted to identify, refine, and rank Key Performance Indicators (KPIs) specific to each tool category, ensuring a comprehensive evaluation framework.

Findings
Based on expert interviews, four categories of smart FM tools have been developed: user-centric, maintenance, hygiene and safety, and sustainability-oriented. Additionally, specific KPIs for evaluating various aspects of smart FM tools are outlined. Focus group discussions further clarify the KPI rankings across these four categories, emphasizing the complexity involved in evaluating smart FM tools.

Originality/value
This study provides a significant contribution to comprehending innovation diffusion within shopping centers and introduces an innovative methodology for evaluating the performance of smart FM tools.

Keywords: Facilities management, smart FM tools, innovation diffusion, key performance indicators (KPIs)

1. Introduction

The development and proliferation of technology in recent years have revolutionised many industries, including the real estate industry (Hou, 2023). The retail mall industry is one sector where technology has had a substantial impact (Wambi et al., 2020). To remain competitive and attract more customers, a growing number of retail mall developers are adopting intelligent technologies (Pantano et al., 2018). These technologies have been implemented in order to improve the overall shopping experience, streamline operations, and strengthen consumer

engagement (Fan et al., 2020). The most commonly recognised smart technologies include mobile apps, digital signage, indoor navigation systems, and augmented reality (Hou and Wu, 2021). The COVID-19 pandemic accelerated the integration of smart technologies in shopping center operations, with innovations such as cleaning robots, touchless lift panels, and mobile payment swiftly implemented to address pandemic-specific challenges (Agarwal et al., 2024). In the post-pandemic landscape, these smart technologies have not only endured but have significantly enhanced customers' shopping experiences. For example, the continued use of cleaning robots ensures a consistently sanitized environment, contributing to a heightened standard of cleanliness that positively influences shopper perceptions; Touchless lift panels have become a standard feature, offering both a hygienic alternative and a modern, convenient experience. Similarly, mobile payment solutions, initially adopted for contactless transactions, have persisted as consumers now expect and appreciate their efficiency. The trend of adopting and evolving smart technologies in shopping centers is expected to continue, aligning with the updated needs of both retailers and consumers, further shaping a tech-enhanced and resilient shopping environment (Agarwal et al., 2024).

The smart technologies integrated into various facets of shopping center operations are constantly evolving, with ongoing considerations for updates, redesigns, or potential replacements by similar tools (Ameen et al., 2022). This continuous process of integration requires substantial investments. Therefore, it is imperative to thoroughly examine the current operation of the adopted smart technologies and assess their performance. This evaluation ensures that the investments made in these technologies align with the dynamic needs of the shopping center, optimizing their impact on operational efficiency and consumer experiences (Hou, 2023). However, the existing literature underscores a notable gap in studies that investigate the adoption and operational performance of these smart technologies within shopping centers.

Drawing from the lens of innovation diffusion theory (IDT), this study argues that merely quantifying the adoption of smart technologies by their number or scale does not accurately capture the diffusion trends or the depth of their real-world application. In the retail sector, the adoption of smart technologies involves multiple stakeholders, including customers and FM professionals who are directly or indirectly influenced by these technologies. While previous research has largely focused on customer acceptance and perception of smart technologies, few studies have delved into their operation and performance, particularly in relation to physical facility management and built environment service delivery. It is essential to categorize smart technologies based on their function and user groups. In this study, such technologies are referred to as "smart FM tools", which are crucial in the landscape of smart technology diffusion. The acceptance, utilization, and evaluation of these tools directly or indirectly influence their diffusion in shopping centers. It is therefore essential to understand how FM professionals perceive and evaluate these smart FM tools. Gaining insights into their

perceptions not only aids in further adopting smart technologies but also facilitates the enhancement of their functionalities.

In order to pursue the investigation, three objectives are designed to investigate the operation and performance of smart FM tools and to guide the research activities implementation.

1) to categorise the smart FM tools adopted in the shopping center based on their functions and their alignment with the shopping center operation
2) to identify the KPIs of shopping center smart FM tools for each of the category
3) to examine the KPI ranking among different categories of smart FM tools

This study employs a participatory research design, utilizing expert interviews and focus group discussions (FGDs) with facilities management (FM) professionals and shopping center operators to collect data. It categorizes smart FM tools into four specific categories: "user-centric", "maintenance", "hygiene and safety", and "sustainability-oriented", based on their functions and business goals. Through eight FGDs, the study not only identifies and refines key performance indicators (KPIs) but also ranks them, ensuring these KPIs are practical and directly informed by FM expertise.

The findings of this study serve as a useful resource for the industry, particularly within the shopping center sector, offering practical guidance on evaluating smart FM tools. Firstly, the study recognizes that smart FM tools differ significantly in terms of their users, functions, and importance to business operations. A structured categorization framework is provided, helping practitioners to clearly define how specific smart FM tools relate to shopping center business activities. Secondly, a comprehensive set of KPIs has been identified, which can be directly applied in practice to assess the practical performance of these tools during business operations. Thirdly, the ranking of these KPIs by FM professionals provides insights into a future roadmap for the adoption and development of certain categories of smart FM tools, indicating which technologies could be prioritized or further developed based on their assessed value and efficacy. This tiered approach not only enhances operational efficiencies but also aligns technology integration with strategic business objectives, fostering a more adaptive and responsive shopping center environment. The findings underscore the principles of IDT by demonstrating that the adoption and effectiveness of smart FM tools are significantly shaped by their perceived utility and compatibility within the shopping center sector. This research emphasizes the essential role of structured evaluations and stakeholder feedback in driving the widespread acceptance and strategic integration of these innovative technologies.

2. Literature review

2.1 An innovation diffusion theory perspective towards new technologies adoption in the retail sector

The innovation diffusion theory (IDT), conceived by Everett Rogers, has proven versatile in various research contexts (Rogers et al., 2014). Across disciplines, the theory finds application in understanding the adoption and dissemination of innovations. In the realm of information technology, it sheds light on the acceptance of new technologies such as smartphones and social media (Kim and Ammeter, 2014). Healthcare researchers leverage it to explore the adoption of medical technologies and innovative practices (Scarbrough and Kyratsis, 2022). Business and management scholars utilize the theory to examine the adoption of organizational innovations, and in environmental sustainability, it guides studies on the diffusion of green practices (Karakaya et al., 2014). Public policy, communication, and media studies also benefit from the framework to explore the adoption of policies, media innovations, and social interventions (Madan and Ashok, 2023). Across these diverse fields, the IDT provides a comprehensive understanding of how innovations spread, encompassing the innovation-decision process, communication channels, and the role of opinion leaders in influencing adoption patterns. IDT has been commonly utilised to examine the smart technologies spread in the retail sector (Adapa et al., 2020; Alexander and Kent, 2021; Fazal-e-Hasan et al., 2021). The retail sector is undergoing a profound revolution fuelled by digital transformation, reshaping traditional shopping paradigms and prompting a re-evaluation of business strategies within shopping centers (Fan et al., 2020). As consumers increasingly demand seamless and technologically enriched shopping experiences, shopping center operators are compelled to embrace digital transformation (Priporas et al., 2017). A primary driver of digital transformation in shopping centers, as viewed through the lens of innovation diffusion theory, stems from evolving consumer expectations.

From an IDT perspective, the integration of IoT, AI, and data analytics contributes to the creation of smart, connected environments within shopping centers. The diffusion of smart technologies in shopping centers follows a systematic process guided by the five phases of IDT: knowledge, persuasion, decision, implementation, and confirmation (Yang and Bayapu, 2020; Fazal-e-Hasan et al., 2021; Sulaiman et al., 2021; Konanahalli et al., 2022). Initially, shopping center management gains awareness and understanding of new smart technologies (Knowledge), evaluating their benefits and potential drawbacks through expert opinions and peer experiences (Persuasion). They then make a strategic decision on whether to adopt the technology (Decision). Upon deciding to proceed, the technology is installed and integrated, and staff are trained for optimal use (Implementation). Finally, the effectiveness of the technology is continuously monitored against pre-set KPIs, with feedback influencing whether the technology is expanded, adjusted, or discontinued (Confirmation). This structured approach enables shopping centers to integrate smart technologies effectively, aligning them with operational goals and enhancing overall efficiency and customer experience. To align with the principles of IDT in examining the impact of digital technologies on shopping centers, three refined research questions are proposed:

First, *how are smart facilities management (FM) tools categorized based on their functionalities and aligned with the operational objectives of shopping centers?* This explores the "Knowledge" and "Decision" stages by identifying and classifying technologies according to their primary functions and strategic fit. Categorizing smart FM tools by function and user ensures that each technology fits precisely within a shopping center's operational needs, enhancing decision-making in the early stages of adoption.

Second, *what are the key performance indicators (KPIs) for each category of smart FM tools, and how do these reflect the operational impact of the technologies*? This question ties into the "Implementation" and "Confirmation" phases, focusing on the measurement and validation of technology effectiveness post-implementation. Evaluating these tools against defined KPIs allows for continuous monitoring and adjustment, ensuring they meet performance expectations and contribute positively to business objectives.

Lastly, *how are the KPIs for different categories of smart FM tools ranked in terms of their importance to the strategic goals of shopping centers, exploring the prioritization in the "Decision" and "Confirmation" stages and revealing management's priorities in enhancing operational efficiency and customer experience*? These questions collectively provide a comprehensive framework for understanding the adoption, implementation, and evaluation of smart technologies within shopping centers. Ranking the KPIs by FM professionals directly informs strategic decisions on technology development and prioritization, aligning innovations with actual operational needs and user feedback.

2.2 Service-based smart FM tools

This study uniquely addresses the domain of smart Facilities Management (FM) tools within shopping centers, a distinctive focus that deviates from the prevalent trend of studies concentrating on building-level, system-level, and component-level FM operations evaluations. Traditionally, FM tools have predominantly served building operations, offering services to enhance the efficiency of systems and components. They may primarily focus on optimizing building operations, maintenance efficiency, or system performance, often without a direct emphasis on end-user experience or satisfaction. However, in the context of shopping centers, the emphasis shifts to service-based smart FM tools explicitly designed to cater to the needs of building users and businesses. For instance, technologies like Virtual Reality (VR) and Augmented Reality (AR), typically employed for simulating maintenance scenarios and informing decision-making, are repurposed in shopping centers to elevate shoppers' overall shopping experiences (Bonetti et al., 2019). These tools prioritize features like real-time navigation, personalized recommendations, and interactive elements to engage and satisfy shoppers. Similarly, smart parking systems, while integral to modern smart buildings, are evaluated in terms of user satisfaction and their impact on business revenue, highlighting a departure from the conventional focus on building operation efficiency (Al-Turjman and Malekloo, 2019). The emphasis of smart parking is on optimizing parking efficiency to enhance

the overall shopping experience and increase customer satisfaction, directly impacting the shopping center's financial success. This distinctive perspective underscores the significance of adapting FM tools to the unique demands and objectives of shopping center environments, where user experience and business outcomes play pivotal roles in assessing tool effectiveness. Service-based smart FM tools for shopping centers are characterized by their user-centric focus, impact on business outcomes, prioritization of hygiene and safety, integration with customer interaction, and consideration of long-term economic value. These distinctions highlight the specialized nature of these tools in the context of enhancing the overall shopping center experience.

2.3 Key performance indicators (KPI) as a performance evaluation tool

The comprehensive review of Key Performance Indicator (KPI) studies in the field of facilities management highlights its widespread adoption as a performance evaluation tool across diverse facility contexts. The examined studies encompass various facility types, including campuses, supply chains, office buildings, hotels, hospitals, healthcare facilities, clinics, and general buildings. Table 1 categorizes these studies based on the specific aspects of facilities management evaluated using KPIs in each context. The identified aspects include FM practice performance (Project-level/Building-level), Maintenance/ Retrofitting (M/R) strategy performance, System-level (Sys-) performance, Sustainability (Sus-) performance, and Facilities Management Service-level (FM Ser-) performance.

Table 1. KPI studies in the field of facilities management

Source	FM practice P/B	M/R	Sys-	Sus-	FM Ser-	Facilities context
Abdul Lateef et al., 2010		x				Campus
Li et al., 2018				x		Campus
Kim et al., 2018						Campus
Al Dakheel et al., 2020		x				Campus
Alrashed, 2020	x		x			Campus
Morgado et al., 2022			x			Campus
Naji et al., 2023	x					Campus
Jiang and Kurnitski, 2023				x		Campus
Gunduz et al., 2023	x					Campus
Gunduz et al., 2024	x					Campus
Yoon and Cha, 2018	x					Office building
Marzouk and Seleem, 2018	x					Office building
Yoon and Cha, 2018			x			Office building
Dasandara et al., 2022	x				x	Hotel
Fang et al., 2022			x			Hotel
Luo et al., 2023			x			Hotel
Ali and Hegazy, 2014			x			Hospital
Cho et al., 2015			x			Hospital
Enshassi and El Shorafa, 2015		x				Hospital
Sonmez and Pintelon, 2020			x			Hospital
Amos et al., 2020					x	Hospital

Amos et al., 2021	x			x	Hospital
Lai et al., 2022a	x				Hospital
Lai et al., 2022b	x				Hospital
Ginthotavidana and Waidyasekara, 2022				x	Healthcare
Demirdoegen et al., 2022			x		Healthcare
Shohet and Nobili, 2016		x			Clinics
Lavy et al., 2014a	x				General buildings
Lavy et al., 2014b	x				General buildings
Li et al., 2020			x		General buildings
Ho et al., 2021			x		General buildings

The literature reveals a predominant focus on specific aspects depending on the facility context. For instance, in campus settings, KPI studies emphasize FM practice performance, with a notable interest in project-level and building-level evaluations. Maintenance and retrofitting strategies also receive attention in campus environments. The trend continues in healthcare facilities, including hospitals and clinics, where the emphasis extends to sustainability performance, aligning with the critical importance of eco-friendly practices in healthcare settings. Notably, KPIs in hospitals often cover multiple aspects, including FM practice, system-level efficiency, sustainability, and service-level performance.

The overall trend in the literature suggests that the choice of specific KPI aspects aligns with the unique demands and priorities of each facility context. The method's popularity is evident in its application to purpose-designed facilities, such as campuses and hospitals, where tailored evaluations contribute to effective facilities management practices. This nuanced understanding of KPI application across various facility types emphasizes its adaptability and effectiveness as a versatile tool for evaluating and enhancing performance in the field of facilities management.

While the existing body of research extensively explores KPI applications across various facility contexts, ranging from campuses to healthcare facilities, supply chains, office buildings, hotels, and general buildings, there is a conspicuous absence of studies focusing on KPIs for smart FM tools in shopping centers. This gap in the literature suggests a critical need for dedicated research to tailor performance evaluation metrics for the unique dynamics and requirements of shopping center environments. Understanding and establishing KPIs for smart FM tools in shopping centers would not only contribute to the academic discourse on facilities management but also offer practical insights for industry professionals seeking to enhance the operational efficiency, sustainability, and overall performance of shopping centers through the strategic integration of smart FM tools. The absence of such studies signals an opportunity for future research endeavors to address this specific and crucial aspect within the broader landscape of facilities management literature.

3 Research methodology

This study adopts a participatory and systematic research approach, initially conducting expert interviews with facilities management (FM) professionals and shopping center operators to gather insights into the functionalities and impacts of smart FM tools. These insights lead to the systematic classification of the tools into four categories: “user-centric”, “maintenance”, “hygiene and safety” and “sustainability-oriented”. Building upon these categorised insights, the study then employs eight focus group discussions (FGDs) with these professionals to collaboratively develop and refine key performance indicators (KPIs) for each category. The interview and FGD participants were recruited for the research using the snowball sampling method, which started with two initial participants, identified as “seeds”, who met the interview criteria and were found through LinkedIn and events hosted by professional FM associations. These “seeds” were then asked to refer additional potential interviewees from their networks who also fulfilled the specified criteria. As these new interviewees joined, they also provided referrals, thereby expanding the sample size progressively through this referral chain. The methodology is designed to ensure a practical and applicable evaluation framework that is directly informed by industry expertise, facilitating a better understanding of the tools’ functionalities and enhancing their real-world applicability in managing and optimizing shopping center operations.

3.1 Expert interviews

Background information for experts involved in the study was gathered, encompassing details such as their job title, organizational affiliation, and years of professional experience. A group of seven Facilities Management (FM) experts, specifically with hands-on experience in shopping malls or retail settings, were extended invitations to partake in the interview sessions. The interviewees are either working for a specific shopping center or working for a consultancy company/property service companies that were involved in projects operated by various shopping centers. These shopping centers have diverse shopping environments across Hong Kong, each tailored to specific consumer needs. They range from upscale shopping centers featuring high-end luxury brands, attracting a discerning clientele, to large family-oriented complexes that combine retail with entertainment options, drawing in families and a diverse range of shoppers. The malls that the interviewees mentioned in the interviews are all gigantic mixed-retail hubs, serving a high volume of diverse customers daily, from local shoppers to international tourists. Some cater specifically to the fashion-forward youth with trendy and international brands, while certain shopping centers in commercial hotspots blend accessibility with luxury, drawing both casual shoppers and those seeking premium products. The management teams of these shopping malls are adept at navigating their unique retail landscapes, from providing bespoke services in luxurious settings to managing the dynamic and bustling environments of family and large size shopping centers.

The interview questions in the interview guideline were designed to align with the research questions. They were framed in an open-ended nature and no “right” or “wrong” answers were

expected. The guideline consists of a total of three main questions and additional questions were used in the interviews for probing purpose. The three questions are:

1) Can you name some main smart FM tools that are frequently used in the shopping centers (that you are working at / you worked at)?
2) what are these smart FM tools' purposes and operation?
3) how would you evaluate the performance of these smart FM tools?

3.2 Focus group discussions (FGDs)

Using the snowball sampling method, approximately 200 FM professionals were approached, resulting in 46 FM professionals with current or past work experience in shopping centers in Hong Kong being confirmed to participate in the focus group discussions (FGD). A FGD protocol was sent to each FGD participant in the invitation email, explaining the purpose and procedure of the FGD, the definition of each category of smart FM tool (Table 2) and the definition of the four aspects of KPI (Table 3). Each participant was asked to reply to the invitation email by indicating their consent and the category of smart FM tools they prefer for sharing their insights.

Based on the participants' preferences, eight FGDs were formed and implemented (two FGDs on "user-centric" smart FM tools, two on "maintenance" smart FM tools, two on "hygiene and safety" smart FM tools, and two on "sustainability-oriented" smart FM tools). Each FGD last around 40-45 minutes.

During each FGD, each participant was provided with a guideline, elaborating the FGD procedure, the definition of the specific category of smart FM tools, and a list of KPIs identified through the expert interviews and their definitions (Table 3). The participants were required to first, raise a few examples of the smart FM tools under that category so that they have an agreeing understanding of the smart FM tools, followed by a Q&A session for the researcher (FGD facilitator) to address the participants' enquiries. After that, they were led to discuss the KPIs one by one from the four aspects: user experience aspect, economic value aspect, reliability aspect and effectiveness aspect. Based on the discussion results, they need to assign an importance ranking for each KPI separately using a scale from "1" to "7", with "1" as "not important at all", "2" as "unimportant", "3" as "slightly unimportant", "4" as "neutral", "5" as slightly important", "6" as "important", and "7" as very important". Lastly, the participants were further asked to raise KPIs which are not included in the list but considered as valid KPIs for evaluating the smart FM tools.

Two sets of data were generated from the FGDs, qualitative data and quantitative data. The qualitative data is the discussion results, including the participants' comments on each KPI; the quantitative data is the importance ranking assigned to each KPI listed by the FGD participants. The ranking results were used to assist the determination of the final KPI list.

3.3 Data analysis

Qualitative data analysis plays a pivotal role in extracting meaningful insights from non-numeric data, providing a rich understanding of complex phenomena. This study main collected qualitative data and used coding technique as the main analytic method for explorative and theoretical analysis. Qualitative data analysis, particularly through coding, facilitates the discovery of emergent themes, patterns, and relationships that might not be evident through quantitative methods. Coding involves systematically categorizing and labeling segments of textual or visual data based on recurring themes, concepts, or patterns.

The first step typically involves open coding, where the authors examine the data closely, assigning descriptive labels or codes to relevant portions. This process helps identify initial patterns and themes within the dataset. Subsequently, these codes are grouped into broader categories during axial coding, elucidating connections and relationships between different codes. Finally, selective coding involves refining the overarching themes and selecting the most salient categories that encapsulate the essence of the data. Appendix 1 illustrates the detailed coding process regarding questions 2 and 3 for expert interviews.

4 Interview results

4.1 Categorisation of the four group of smart FM tools

The interviewees systematically articulated the application of smart FM tools based on the purposes they serve. Table 2 provides a summary of the participants' profiles.

Table 2. Profile of the experts

Experts	Job title	Organisation background	Year of experience
Expert 1	Assistant shopping mall manager	Shopping center A	3.5 years
Expert 2	Customer service manager	Project consultancy company (working on a few projects with four shopping centers)	4 years
Expert 3	Assistant general manager	Property service company (working on one project with one shopping center)	3 years
Expert 4	Property and facility manager	Shopping center B	8 years
Expert 5	Senior Shopping centre officer	Shopping center C	6 years
Expert 6	Technical service officer	Shopping center D	4.5 years
Expert 7	Facilities management officer	Facilities service consultancy company (working on technical projects with multiple shopping centers)	5 years

During the interviews, the key terms they used to describe the purposes of the smart FM tools include "customer services purpose", "customer convenience purpose", "service delivery

purpose", "maintenance purpose", "environment protection purpose", "ESG (environment, social, government) purpose", "environmental-friendly purpose", "security purpose", "cleaning purpose", "safety purpose". Each smart FM tool was developed and operated based on one of the purposes identified by the shopping center operators. Based on these findings obtained from the interviews, this study has categorized the smart FM tools based on their purposes and four categories were applied to summerise the major purposes: (1) user-centric, (2) hygiene and safety, (3) maintenance, and (4) sustainability-oriented. Table 3 illustrates the definition and examples of the four categories of smart FM tools.

Table 3. The four categories of smart FM tools adopted in the shopping center

Category	**Definition and example**
User-centric	**D:** User-centric smart tools consist of technologies designed to improve the shopping experience for customers
Hygiene and safety	**D:** Smart tools that aim to improve hygiene and safety conditions contain technologies designed to guarantee a safe and sanitary environment for customers and employees. **E:** This can include technologies such as touchless payment systems, automatic doors, and air filtration systems that prevent the spread of pathogens. Moreover, technologies such as thermal imaging cameras and contact tracing systems can aid in the identification of potential health hazards and the prevention of the spread of infectious diseases. Also, cleaning robot is one types of the popular smart tools adopted in shopping mall.
Maintenance	**D:** Smart tools used to support facilities maintenance contain technologies designed to enhance the efficacy and efficiency of facility maintenance. **E:** This can include technologies such as water leakage sensors and predictive maintenance tools that use data analytics to identify and resolve maintenance issues before they become significant issues. In addition, technologies such as intelligent lighting systems and energy management tools can aid in reducing energy consumption and operating expenses.
Sustainability-oriented	**D:** Smart tools that are sustainability-oriented contain technologies designed to reduce the environmental impact of retail mall operations. **E:** This includes solar panels, precipitation harvesting systems, and intelligent waste management systems that utilise data analytics to optimise waste reduction and recycling efforts. In addition, technologies such as energy-efficient HVAC systems and eco-friendly construction materials can help shopping malls reduce their carbon footprint.

4.2 Identifying the KPIs for each category of the smart FM tools

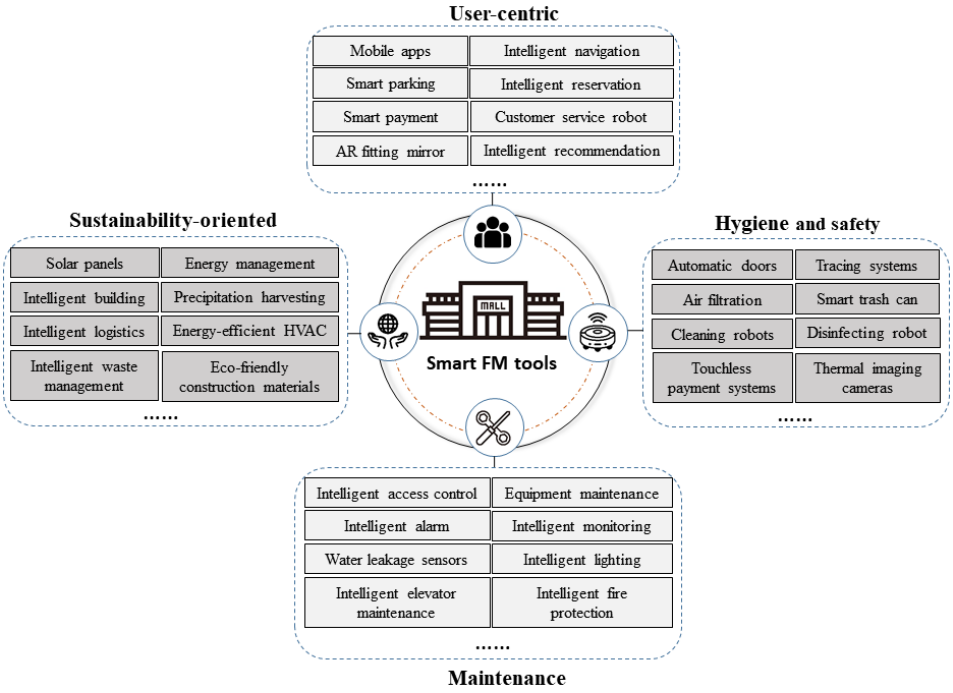
Based on the sharing from the interviewees, four aspects of KPIs are proposed, namely user experience aspect, economic value aspect, reliability aspect and effectiveness aspect. The first aspect refers to how the users perceive their experience of using the smart FM tools; the second aspect measures the economic value of the smart FM tools; the third aspect examines whether the smart FM tools are operated in a reliable manner and the fourth aspect evaluates the benefits of the smart FM tools generated to multiple stakeholders.

Under each aspect, a series of KPIs are proposed. Table 4 illustrates the proposed KPIs under each aspect and their definitions. Figure 1 shows a summary of the four smart FM tool categories and smart FM tool examples mentioned by the interviewees.

Table 4. Four aspects of the smart FM tools performance and proposed KPIs

Four aspects of KPIs	**Key performance indicator (KPI)**	**Definitions of each KPI**
User experience aspect	Ease of use	-The user finds the smart tool easy to use.
	Usage rate	-How frequently the smart tool is used by the targeted users
	User satisfaction	-User satisfaction level on using the smart tools
	Complaint rate	-Complaint record received during the application of the smart tool
	User-friendly interface	-The interface enables the users to indicate command and the smart tool to provide information/services.
Economic value aspect	Actual cost (development/investment cost)	-The cost on developing/purchasing the smart tool (including cost spent in the tendering process).
	Maintenance cost	-The cost on maintaining the smart tool (including actual financial cost and time spent), such as labour cost on monitoring the tool, cost on repairing the tools, cost on liaising with contractor to replace the tool, etc.
	Payback period	-The amount of time it takes to recover the cost of the smart tool investment.
	Return on investment (ROI)	-Direct and indirect financial return to the shopping center after adopting the smart tool.
Reliability aspect	Breakdown rate	-How often breakdown is occurred to the users during the application process
	Accuracy	-The information provided by the smart tools are accurate and updated
	Responsiveness	-The smart tools can provide timely feedback information to the users
Effectiveness aspect	Service quality (performance)	-The services delivered by the smart tools achieve the service standards
	Integration with shopping centre operations	-An effective smart tool should seamlessly integrate with the mall's overall operations. This includes coordination with mall staff, security personnel, and other autonomous systems to ensure a smooth workflow and avoid any conflicts.
	Adaptability and customization	-The smart tool can be adapted to different requirements and surface types within the shopping center

Figure 1. Four categories of smart FM tools and examples



The results of the expert interviews contributed to the development of a KPI mechanism, which includes the categories of the smart FM tools and identification of a series of systematic KPIs. The KPI mechanism was used to facilitate the FGDs in the second stage of the research. The FGDs were organised to validate the KPIs proposed after the expert interviews.

4.3 Identifying the KPIs for each category of the smart FM tools

For the second question – "how would you evaluate the performance of these FM tools". Some interviewees suggested that the evaluation should base on three aspects: who are the users of the smart FM tool, how the users feel when using it, and how it benefits the users. These three aspects are clear, but it is also difficult to clarify.

For example, mobile Apps are mainly developed for customers to use. Thus, how customers feel like the Apps is very important and one of the most important KPIs for evaluating the APPs. However, Apps were developed and maintained by the shopping center operators and ultimately, benefits not only the customers, but also the shopping centers. The information collected through the Apps provide management direction to the shopping center operators. Another example is cleaning robot. The users are FM team in the shopping centers. But the service provided by the cleaning robots benefit customers and the shopping center operators.

Some other interviewees raised another point, claiming that the smart FM tools should align with the long-term interest of the shopping centers; and their long-term effects are more important than their perceived effectiveness in the short run. This has raised the significance of the economic value of the smart FM tools. Among various smart FM tools, some are of device size, while the others can be as sophisticated as a comprehensive system. Smart parking system and water leakage sensor are two examples. While the former one is a long-term investment involved a considerable amount of financial input, the latter one is relatively cheap and easy to witness the effectiveness.

Based on the sharing from the interviewees, four aspects of KPIs are proposed, namely user experience aspect, economic value aspect, reliability aspect and effectiveness aspect. The first aspect refers to how the users perceive their experience of using the smart FM tools; the second aspect measures the economic value of the smart FM tools; the third aspect examines whether the smart FM tools are operated in a reliable manner and the fourth aspect evaluates the benefits of the smart FM tools generated to multiple stakeholders.

Under each aspect, a series of KPIs are proposed. Table 5 illustrates the proposed KPIs under each aspect and their definitions.

Table 5. Four aspects of the smart FM tools performance and proposed KPIs

Four aspects of KPIs	**Key performance indicator (KPI)**	**Definitions of each KPI**
User experience aspect	**(U_1)** Ease of use	The user finds the smart tool easy to use.
	(U_2) Usage rate	How frequently the smart tool is used by the targeted users
	(U_3) User satisfaction	User satisfaction level on using the smart tools
	(U_4) Complaint rate	Complaint record received during the application of the smart tool
	(U_5) User-friendly interface	The interface enables the users to indicate command and the smart tool to provide information/services.
Economic value aspect	**(Ec_1)** Actual cost (development/investment cost)	The cost on developing/purchasing the smart tool (including cost spent in the tendering process).
	(Ec_2) Maintenance cost	The cost on maintaining the smart tool (including actual financial cost and time spent), such as labour cost on monitoring the tool, cost on repairing the tools, cost on liaising with contractor to replace the tool, etc.
	(Ec_3) Payback period	The amount of time it takes to recover the cost of the smart tool investment.
	(Ec_4) Return on investment (ROI)	Direct and indirect financial return to the shopping center after adopting the smart tool.
Reliability aspect	**(R_1)** Breakdown rate	How often breakdown is occurred to the users during the application process

	(R_2) Accuracy	The information provided by the smart tools are accurate and updated
	(R_3) Responsiveness	The smart tools can provide timely feedback information to the users
Effectiveness aspect	**(Ef_1)** Service quality (performance)	The services delivered by the smart tools achieve the service standards
	(Ef_2) Integration with shopping centre operations	An effective smart tool should seamlessly integrate with the mall's overall operations. This includes coordination with mall staff, security personnel, and other autonomous systems to ensure a smooth workflow and avoid any conflicts.
	(Ef_3) Adaptability and customization	The smart tool can be adapted to different requirements and surface types within the shopping center

The results of the expert interviews contributed to the development of a KPI mechanism, which includes the categories of the smart FM tools and identification of a series of systematic KPIs. The KPI mechanism was used to facilitate the FGDs in the second stage of the research. The FGDs were organised to validate the KPIs proposed after the expert interviews.

5. Focus group discussion results

Each focus group participant was asked to give an importance ranking for each KPI proposed for specific category of smart FM tools. There were two FGDs dedicated to each category of smart FM tools: "user-centric", "maintenance", "hygiene and safety", and "sustainability-oriented". The importance ranking scores provided by participants within the same category were synthesized and analyzed collectively to assess the perceived importance of each KPI for that specific category of tools. For example, in the "user-centric" category, 12 FM professionals participated in the two FGDs. To calculate the mean score for each aspect of smart FM tools within this category, the sum of the importance ranking scores for each aspect was divided by the number of participants, which was 12. This method provided a mean score representing the average perceived importance of each aspect based on the participants' evaluations.

Figure 2 outlines the mean scores of the importance ranking by participants from the four categories of FDGs. Figure 3 shows the comparative analysis of the mean scores for the proposed key performance indicators (KPIs) among different categories of smart FM tools reveals distinct patterns. Table 6 shows the specific mean scores of the KPIs and their rankings from each category of smart FM tools.

In Figure 2, the priority rankings of key performance indicators (KPIs) for diverse smart FM tool categories in shopping centers are encapsulated, including "user-centric", "maintenance", "hygiene and safety", and "sustainability-oriented". "Ease of use", "user satisfaction", and "return on investment" were emphasised by the user-centric FGD participants. FGD participants from the "maintenance" category smart FM tools prioritize efficiency, while those

from “hygiene and safety” category focus on “integration with mall operation”, “accuracy”, and “responsiveness”, and those from “sustainability-oriented” category highlighted “integration with mall operation”, “adaptability and customization”, and “user satisfaction”, offering nuanced insights into the preferences of FM professionals and shopping center operators across different tool categories.

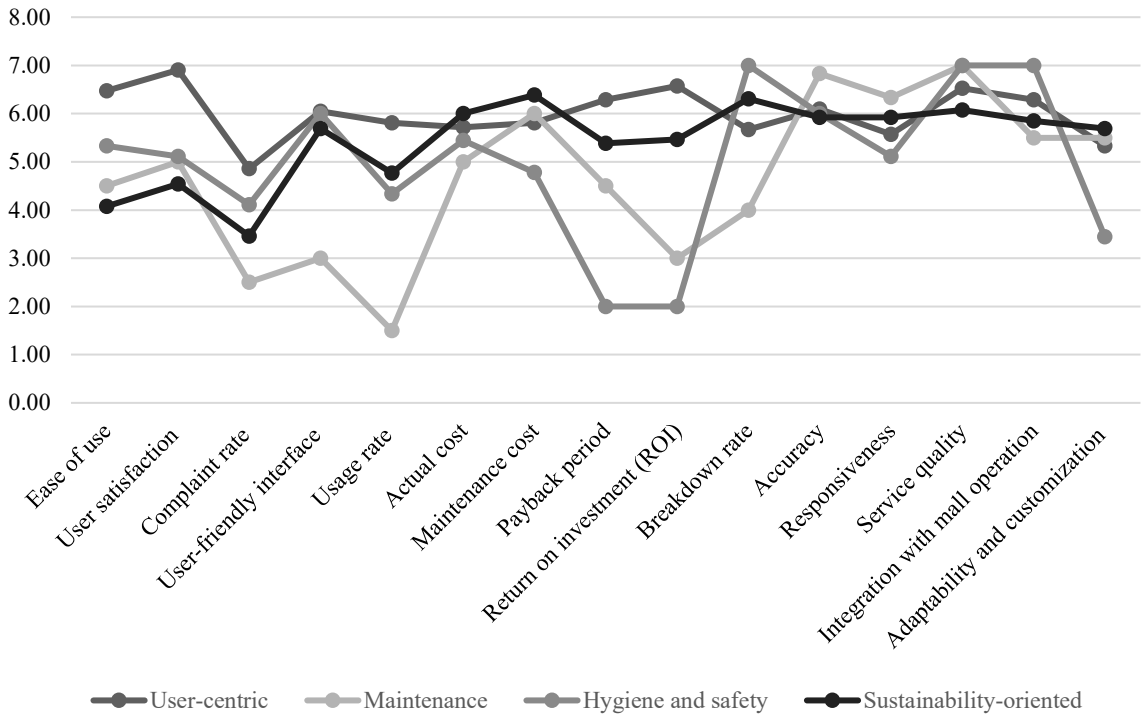


Figure 2. Mean scores of the importance ranking for each KPI under the four categories

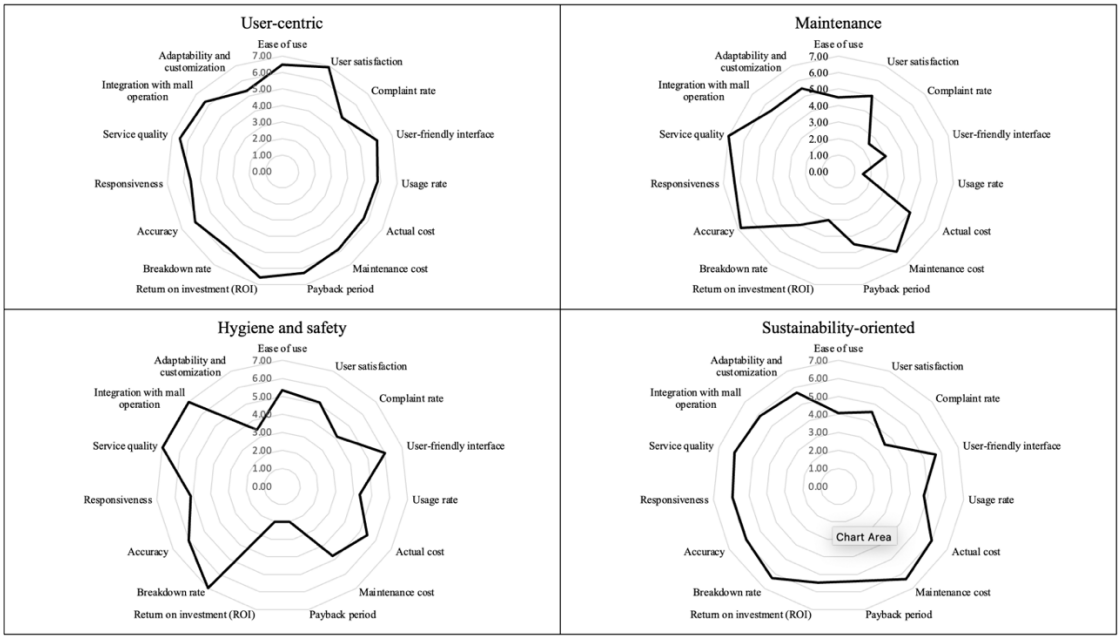


Figure 3 Comparative analysis of the mean scores for KPIs from different categories

In the "user-centric" category, KPIs like "user satisfaction", "ease of use", and "return on investment (ROI)" received high scores, indicating a strong emphasis on user experience and financial returns. On the other hand, participants from the "maintenance" category prioritized "breakdown rate", "service quality", and "integration with mall operation", suggesting a focus on ensuring the smooth operation of FM tools without a significant emphasis on financial metrics. The participants from "hygiene and safety" category placed substantial importance on "breakdown rate", "service quality", and "adaptability and customization" aligning with the critical nature of these tools in maintaining a safe and hygienic shopping environment. Lastly, those from the "sustainability-oriented" category leaned towards KPIs like "integration with mall operation", "actual cost", and "maintenance cost", indicating a strong consideration for the tools' integration capabilities and the associated costs in sustainable operations. Overall, the diverse priorities across these categories underscore the nuanced nature of evaluating smart FM tools in shopping centers based on their distinct functionalities and purposes.

Table 6. KPI rankings under each category of smart FM tools

User-centric (N=12/2 groups)		**Maintenance (N=12/2 groups)**		**Hygiene and safety (N=9/2 groups)**		**Sustainability-oriented (N=13/2 groups)**	
Proposed KPIs	**Ranking**	**Proposed KPIs**	**Ranking**	**Proposed KPIs**	**Ranking**	**Proposed KPIs**	**Ranking**
User satisfaction	6.90 **(1)**	Service quality	7.00 **(1)**	Integration with mall operation	7.00 **(1)**	Maintenance cost	6.38 **(1)**
Return on investment	6.57 **(2)**	Accuracy	6.83 **(2)**	Service quality	7.00 **(1)**	Breakdown rate	6.31 **(2)**
Service quality	6.52 **(3)**	Responsiveness	6.33 **(3)**	Breakdown rate	7.00 **(1)**	Service quality	6.08 **(3)**
Ease of use	6.48 **(4)**	Maintenance cost	6.00 **(4)**	Accuracy	6.00 **(2)**	Actual cost	6.00 **(4)**

Integration with mall operation	6.29 **(5)**	Adaptability and customization	5.50 **(5)**	User-friendly interface	6.00 **(2)**	Responsiveness	5.92 **(5)**
Payback period	6.29 **(5)**	Integration with mall operation	5.50 **(5)**	Actual cost	5.44 **(3)**	Accuracy	5.92 **(5)**
Accuracy	6.10 **(6)**	Actual cost	5.00 **(6)**	Ease of use	5.33 **(4)**	Integration with mall operation	5.85 **(6)**
User-friendly interface	6.05 **(7)**	User satisfaction	5.00 **(6)**	Responsiveness	5.11 **(5)**	Adaptability and customization	5.7 **(7)**
Maintenance cost	5.81 **(8)**	Payback period	4.50 **7)**	User satisfaction	5.11 **(5)**	User-friendly interface	5.69 **(8)**
Usage rate	5.81 **(9)**	Ease of use	4.50 **(7)**	Maintenance cost	4.78 **(6)**	Return on investment	5.46 **(9)**
Actual cost	5.71 **(10)**	Breakdown rate	4.00 **(8)**	Usage rate	4.33 **(7)**	Payback period	5.38 **(10)**
Breakdown rate	5.67 **(11)**	Return on investment	3.00	Complaint rate	4.11 **(8)**	Usage rate	4.77 **(11)**
Responsiveness	5.57 **(12)**	User-friendly interface	3.00	Adaptability and customization	3.44	User satisfaction	4.54 **(12)**
Adaptability and customization	5.33 **(13)**	Complaint rate	2.50	Return on investment	2.00	Ease of use	4.08 **(13)**
Complaint rate	4.86 **(14)**	Usage rate	1.50	Payback period	2.00	Complaint rate	3.46

In Table 6, the mean scores were employed as the ranking scores for the proposed KPIs, with scores lower than 4.0 (on a scale of 1 to 7, where 1 signifies "not important at all" and 7 denotes "very important") highlighted in grey. The FGD participants from the "user-centric" category unanimously agreed on 100% of the proposed KPIs, while those from the "sustainable-oriented" category reached a consensus on 90% of the proposed KPIs. In the "maintenance" category, key metrics such as "return on investment", "user-friendly interface", "complaint rate", and "usage rate" received relatively low scores. Participants from the "maintenance" category, predominantly FM professionals specializing in maintenance tasks, contended that maintenance is not closely aligned with the marketing strategies of a shopping center. They emphasized that the primary goal of adopting smart FM tools in maintenance is operational support rather than generating additional financial benefits, thereby deeming "return on investment" as a less critical performance KPI. Moreover, in the context of the "maintenance" category, where participants consisted predominantly of FM professionals specializing in maintenance tasks, the significance of certain KPIs was downplayed. Specifically, "return on investment" was considered less critical, as the primary objective of adopting smart FM tools in maintenance is operational support rather than generating additional financial benefits. Additionally, the familiarity of users with the interfaces of these tools diminished the importance of "user-friendly interface" as a pivotal KPI. Furthermore, KPIs such as "complaint rate" and "usage rate" were deemed less representative within the maintenance category, highlighting the distinctive perspectives and priorities of FM professionals specializing in maintenance tasks. In the "hygiene and safety" category, KPIs such as "adaptability and customization", "return on investment", and "payback period"

received scores below 4.0. This suggests that adaptability and customization are challenging for smart FM tools in hygiene and safety due to their specialized design, and economic factors take a back seat in the evaluation as these tools primarily serve the fundamental needs of shoppers rather than aiming for financial returns.

6. Discussion

6.1 Contributions to the existing theoretical literature and practice

The primary aim of this study is to deepen our understanding of how innovations are adopted within the retail sector, specifically focusing on shopping centers, through the lens of Innovation Diffusion Theory (IDT). Insights derived from expert interviews reveal that the adoption and dissemination of innovations in this context are well-documented (Kim and Ammeter, 2014). The diffusion of smart FM tools in shopping centers mirrors the broader trend of smart technology diffusion across various disciplines, adhering to an innovation-decision process characterized by continuous feedback and evaluation (Adapa et al., 2020; Alexander and Kent, 2021; Fazal-e-Hasan et al., 2021). Unlike purely customer-driven smart technologies, the adoption and evaluation of smart FM tools are primarily influenced by the opinions of FM professionals. Their feedback on the functionality and performance of these tools significantly impacts their further development and diffusion within the industry (Kim and Ammeter, 2014; Rogers, 2019).

Secondly, the categorization of smart FM tools enables a more scientific evaluation tailored to the specific goals and functionalities of each tool category. By grouping these tools into four categories: user-centric, hygiene and safety, maintenance, and sustainability-oriented, FM professionals or shopping center operators can establish a structured framework for assessing their effectiveness. User-centric tools, aimed at improving the shopping experience, can be assessed based on user satisfaction, ease of use, and integration with mall operations. Hygiene and safety tools, focused on creating a safe and sanitary environment, may be evaluated using criteria such as adaptability, responsiveness, and their contribution to health and safety. Maintenance tools, designed to support facilities management, can be assessed for efficiency, cost-effectiveness, and preventive capabilities. Sustainability-oriented tools, targeted at reducing environmental impact, may be evaluated based on their contributions to energy efficiency, waste reduction, and eco-friendly practices. This systematic categorization not only streamlines the performance evaluation process but also ensures that the unique characteristics and objectives of each type of smart FM tool are appropriately considered, providing a comprehensive and tailored assessment for optimizing shopping center operations.

The third contribution of this study revolves around its innovative methodology, which engages FM professionals and shopping center operators in proposing and ranking KPIs for the performance evaluation of smart FM tools. This participatory approach adds a distinctive and valuable dimension to the study, as it taps into the practical insights and expertise of individuals directly involved in the implementation and operation of these technologies within shopping

centers. By incorporating the perspectives of FM professionals and operators, the study ensures that the proposed KPIs are not only theoretically relevant but also grounded in the day-to-day challenges and priorities faced by those responsible for managing shopping center facilities. The methodology's strength lies in its ability to capture the diverse viewpoints of professionals with different roles and responsibilities, providing a well-rounded and comprehensive set of KPIs that reflect the multifaceted nature of smart FM tools in a real-world context. This approach contributes to the broader field by offering a methodology that is not only academically rigorous but also pragmatically relevant to industry practitioners.

Furthermore, each category of FM tools may require distinct evaluation criteria based on their intended purposes and outcomes. The KPI evaluation framework provides direct and practical insights to the FM industry and the shopping center operation. For instance, economic value metrics like "return on investment" may be critical for tools in the "user-centric" category tools, where enhancing the overall shopping experience is a key goal. On the other hand, tools in the "maintenance" category may prioritize operational efficiency over financial returns. Categorization facilitates the identification of nuanced evaluation criteria. The categorization ensures that discussions are tailored to the expertise and perspectives of the participants, leading to more insightful and detailed conversations, and allows decision-makers to understand how different types of tools align with strategic goals and to make informed decisions on resource allocation, investment, and implementation strategies.

6.2 Limitations of approach and findings

The study on smart FM tools in Hong Kong's shopping centers provides valuable insights, yet several limitations must be considered. Firstly, the findings may lack generalizability beyond the specific context of Hong Kong, as variations in the facility types, indoor built environment, consumer behavior, technological infrastructure, and regulatory environments in other regions could impact the applicability of proposed KPIs and smart FM tools. Another limitation lies in the rapidly evolving nature of smart FM technologies. Given the study's reliance on expert interviews and focus group discussions, the findings may become outdated as new technologies emerge. A more comprehensive understanding could be achieved by complementing qualitative methods with quantitative approaches or case studies. Finally, the short-term focus of the study, despite participants emphasizing the importance of long-term effects and economic value, suggests a potential gap in exploring the enduring implications of adopting smart FM tools. Addressing these limitations would enhance the study's robustness and broaden its relevance across diverse contexts and stakeholders.

6.3 Future research

In light of the study's findings, future research will explore the cross-cultural variances in the adoption and performance evaluation of smart FM tools in shopping centers, shedding light on how cultural contexts influence technological preferences and challenges. Additionally, there is a need for in-depth studies on each type of smart FM tools to unravel how shoppers or users

interact with and perceive smart FM tools. For example, for sustainability-oriented smart FM tools, it is necessary to conduct further assessment on the sustainability impact of adopting eco-friendly technologies in shopping centers and investigate the actual environmental footprint and energy efficiency of these solutions. Furthermore, the integration of emerging technologies like blockchain and advanced AI applications into FM practices and the establishment of globally applicable KPIs could be pivotal areas for future research, fostering continuous improvement and innovation in the field.

7. Conclusion

This study has thoroughly examined the role of smart FM tools in shopping center operations from FM practitioners' perspective, guided by the principles of IDT. By strategically categorizing these tools into user-centric, maintenance, hygiene and safety, and sustainability-oriented groups, the research aligns technological innovations with the core operational goals of shopping centers. The participatory approach, involving expert interviews and focus group discussions, has been crucial in developing and refining key performance indicators (KPIs) that are specific to each category, ensuring they are practical and reflective of real-world applications. This method has not only bridged the gap between theoretical constructs and practical implementation but has also highlighted the significant role of smart technologies in enhancing operational efficiency and customer experience.

However, the findings are contextual to Hong Kong's unique market and technological landscape, suggesting that broader applicability may require additional research in different geographic and operational contexts. The dynamic nature of digital technology also necessitates ongoing updates to the KPIs to ensure they continue to capture the impact of new innovations effectively. Future research should therefore focus on expanding the geographic scope of the study, exploring the integration of emerging technologies, and continuously refining KPIs to keep pace with technological advancements. This study not only advances the academic understanding of technology adoption in retail environments but also provides actionable insights for shopping center management on leveraging smart technologies to enhance operational effectiveness and customer satisfaction.

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Appendix I. Coding process - Codes and their description

Question 2: what are their (smart FM tools') purposes and operation?	
Codes	Description of codes
User-centric • User-based • Customer-based • Customer-oriented	User-centric smart tools consist of technologies designed to improve the shopping experience for customers
Hygiene and safety • Health • Well-being • Security and safety	Smart tools that aim to improve hygiene and safety conditions contain technologies designed to guarantee a safe and sanitary environment for customers and employees.
Maintenance • Predictive maintenance • Repair and maintenance	Smart tools used to support facilities maintenance contain technologies designed to enhance the efficacy and efficiency of facility maintenance.
Sustainability-oriented • Sustainability • Environment friendly • ESG (environment, social and government) • Green practice	Smart tools that are sustainability-oriented contain technologies designed to reduce the environmental impact of retail mall operations.

Question 3: how would you evaluate the performance of these smart FM tools?	
Codes	Description of codes
User experience • Easy to use • Willingness to use • Customer satisfaction • Complaints	Describe how the smart FM tools users evaluate their performance

• Usefulness • Accessibility	
Economic value • Development cost • Maintenance cost • Payback period • Return on investment (ROI)	Describe the cost of developing and maintaining the smart FM tools and their future value brought to the shopping center
Reliability • Whether the smart FM tools frequently fail • Cannot function properly • Whether generate accurate information • Whether help to predict problematic issue • Whether response timely	Describe whether the smart FM tools function in a proper and reliable manner
Effectiveness • Service delivery outcome • Support the shopping mall operation • Can be further adapted to suit future needs	Describe whether the smart FM tools deliver good quality service and can support the shopping mall operation in a sustainable manner