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Optimizing Post-Pandemic Facilities Management: A Strategic Framework for Sustainable and User-Centred University Environments

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ABSTRACT

The COVID-19 pandemic has necessitated a rapid evolution in Facilities Management (FM) to foster resilient and inclusive higher education environments. While FM practices are critical to institutional sustainability, limited research explores how post-pandemic dimensions influence user satisfaction and long-term expectations. This study investigates the impact of space organisation, safety and health, and digital infrastructure on user experience in UK universities, aligning with SDG 3 (Good Health and Well-being) and SDG 9 (Resilient Infrastructure). Using a quantitative design with 100 participants, we employed robust linear regression and bootstrap mediation analysis. Findings reveal that all three dimensions significantly enhance user satisfaction, a prerequisite for SDG 4 (Quality Education), with safety and health emerging as the primary predictor. Satisfaction partially mediates the relationship between FM dimensions and future service expectations, accounting for up to 63% of the variance. By prioritizing health-oriented design and digital integration, universities can optimize campus resilience and operational performance. This research provides a strategic framework for institutions to transition toward sustainable, adaptive FM systems that support both human well-being and long-term educational excellence in the post-pandemic era.

1. Introduction

The COVID-19 pandemic fundamentally reshaped the operational priorities and strategic functions of facilities management (FM) within higher education institutions worldwide [1]. Traditionally, universities functioned primarily as centralised physical environments for teaching and research. However, the pandemic accelerated the transition towards decentralised, and hybrid institutional models characterised by digitally mediated teaching, distributed learning activities, and flexible patterns of student engagement [2]. This transformation not only altered the spatial configuration of university campuses but also redefined institutional expectations regarding digital infrastructure, public health management, and operational resilience [3].

Within the United Kingdom, university FM departments have historically been responsible for maintaining campus infrastructure, ensuring regulatory compliance, and supporting academic and

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administrative activities through technical and operational services [4]. Following the pandemic, however, FM responsibilities expanded substantially due to new public health regulations and evolving stakeholder expectations. Universities were required to implement enhanced cleaning regimes, improve indoor air quality standards, expand digital infrastructure to support blended learning, and redesign campus spaces to accommodate greater operational flexibility. At the same time, Universities UK [5] highlighted the growing tension between increasing demands for service quality and governmental pressure to reduce operational expenditure, particularly within FM-related activities. This contradiction reflects a broader institutional challenge: balancing financial sustainability with the provision of safe, high-quality, and digitally integrated learning environments [6].

The rapid adoption of information and communication technologies (ICT) during the pandemic further accelerated the digital transformation of FM practices across UK universities. According to Bygstad *et al.,* [7], three major developments emerged during this period: the expansion of remote service delivery capabilities, the intelligent transformation of data management systems, and the optimisation of administrative processes through digital integration. Importantly, these technological adaptations extended beyond short-term emergency responses and contributed to the development of more resilient, transparent, and adaptive FM systems in the post-pandemic context [8]. Consequently, FM increasingly evolved from a traditionally operational support function into a strategic mechanism for enhancing institutional resilience and organisational adaptability.

1.1 Epidemic-induced Condition

The Haddon Matrix developed by Shamsir *et al.,* [9] categorises university epidemic preparedness into three interrelated phases: emergency response, transition, and long-term recovery. Drawing upon this framework, the evolution of FM practices in United Kingdom universities during the COVID-19 pandemic can be understood as a progressive shift from reactive risk control towards adaptive operational support and ultimately strategic transformation.

The initial phase, referred to as the outbreak response period, commenced on 23 March 2020 following the nationwide lockdown measures introduced in the UK [10]. During this stage, the primary objective of FM teams was to ensure campus safety and operational continuity under conditions of extreme uncertainty. Universities established emergency command structures in collaboration with regional public health authorities to coordinate institutional responses [11]. FM interventions during this period largely focused on infection prevention and physical risk containment, including campus closures, enhanced cleaning and disinfection procedures, access restrictions, and the provision of isolation facilities [9]. Consequently, FM functions in this phase were predominantly characterised by high levels of operational reactivity and rapid crisis responsiveness, with emphasis placed on safeguarding physical infrastructure and mitigating immediate health risks.

As universities gradually adapted to pandemic conditions between 2021 and 2022, FM priorities shifted from emergency containment towards instructional support and resource reallocation. The rapid transition to online and hybrid learning environments required substantial modifications to campus infrastructure and service delivery models. Watermeyer *et al.,* [12], based on a survey involving 1,148 UK university staff members, identified significant demands for classroom reconfiguration, ventilation enhancement, isolation management, and expanded digital infrastructure. Similarly, qualitative findings reported by Singh *et al.,* [13] highlighted the increasing need for operational flexibility to support hybrid teaching arrangements integrating both online and face-to-face learning activities. This transitional stage therefore reflected the growing adaptive capacity of FM, as universities reconfigured physical spaces and support services to maintain educational continuity under evolving public health constraints.

Following the acute stages of the pandemic, the post-2022 recovery phase accelerated broader structural transformation across the higher education sector. In particular, the pandemic served as a catalyst for the digitalisation of FM practices and the re-evaluation of traditional campus operating models. Emerging digital FM technologies contributed to improvements in health monitoring, sustainability management, and space utilisation efficiency within universities [14]. At the same time, the widespread adoption of remote and technology-enhanced learning lowered institutional resistance towards active and digitally mediated pedagogical approaches. Previous studies have demonstrated that large-scale exposure to online learning environments significantly enhanced students' adaptability to digital learning resources [15]. Although conventional implementations of digital education have historically faced limitations associated with insufficient professional support and technical readiness, the pandemic-induced expansion of digital infrastructure and institutional experience partially mitigated these barriers [16]. Robson *et al.,* [17] further argued that many educational innovations initially introduced as temporary emergency measures gradually evolved into long-term pedagogical transformations. Accordingly, FM increasingly assumed a strategic role not only in operational support but also in enabling institutional resilience, digital transformation, and sustainable campus development.

Overall, FM practices within UK universities demonstrated distinct priorities and operational characteristics across different stages of the pandemic, evolving from emergency risk control to adaptive service reconfiguration and eventually long-term strategic transformation. This progressive evolution highlights the increasing significance of FM as a critical component of organisational resilience and institutional sustainability within higher education environments.

1.2 Strategic Framework for the Future of British University Assets

Kassem *et al.,* [18] proposed a three-dimensional framework for FM transformation within UK universities, comprising space occupancy optimisation, health and safety enhancement, and digital infrastructure integration. This framework provides an important theoretical lens for understanding the post-pandemic evolution of FM strategies across higher education institutions. Analysis of university estates strategy plans indicates that these dimensions have become increasingly interconnected in post-pandemic FM governance. More importantly, user experience has progressively shifted from a secondary operational consideration to a central strategic priority within university FM policies [19]. Table 1 summarises these evolving institutional priorities.

Evidence from leading UK universities demonstrates a clear transition from traditional infrastructure-centred FM approaches towards digitally enabled and user-orientated management models. Prior to the pandemic, University College London (UCL) primarily focused on estate refurbishment and space densification within its Sustainable Plan 2019–2024, with limited attention given to flexible learning environments, health-related standards, or digital service integration [19]. However, following the disruption caused by COVID-19, UCL's revised Estates Strategy 2022–2027 increasingly emphasised operational resilience, educational continuity, and digitally integrated campus management [21]. The incorporation of the Data Strategy 2023–2027 into the wider estates framework further reflected a strategic transition from managing physical assets towards leveraging data assets and enhancing user experience value [22].

Table 1

Estates Strategy Plan before and after Covid-19 at three universities

University	Before Covid-19	After Covid-19
University College London (UCL)	• Emphasis on asset growth and building density optimisation [20] • Expansion of space integration services research [20] • Less focus on resilience and health standards [20]	• Emphasis on “spatial adaptability” and multi-purpose layouts [21] • Focus on health-oriented design and sustainable air systems [22] • Enhanced blended learning support facilities and digital collaboration spaces [21]
King’s College London (KCL)	• Investing in Large-Scale Physical Expansion [23] • Focus on Science Research Facilities & Campus Landmarks [23] • Digital Infrastructure Non-Core Topics [23]	• Introduction of indoor air quality monitoring and non-contact facilities [24] • Introduction of space booking systems and digital feedback mechanisms [24] • Strategy 2023 prioritises “digital quality of service” as an indicator [25]
Manchester Metropolitan University (MMU)	Estate Masterplan - Infrastructure expansion focusing on large buildings and condominium [26]	• Introduction of smart FM tools with spatial monitoring [27] • Enhanced spatial data analytics to support hybrid teaching and learning [27] • Establishment of user satisfaction-driven feedback mechanisms [27]

A comparable transformation can be observed at King’s College London (KCL). Before the pandemic, KCL’s campus development strategy concentrated primarily on major infrastructure projects, including the redevelopment of the Science Gallery and Guy’s Campus facilities [23]. During the post-pandemic reopening period, however, FM priorities expanded to include digital classroom booking systems, contactless access control technologies, and indoor air quality monitoring as part of broader health and safety resilience initiatives [24]. Porter *et al.,* [25] further noted that “digital service quality” and “health and safety resilience” were formally incorporated into KCL’s governance effectiveness assessment framework, indicating the growing institutionalisation of user-centred and technology-enabled FM governance.

Manchester Metropolitan University (MMU) demonstrates an even more pronounced strategic transition. Prior to the pandemic, MMU invested approximately £379 million in its Estate Masterplan, largely reflecting the traditional FM paradigm of physical infrastructure expansion [26]. In contrast, the university’s post-pandemic strategy increasingly prioritised data-driven resource allocation, hybrid learning environments, and responsive service delivery models. MMU [27] identified user-centred facility feedback systems as a critical mechanism for transforming FM from static operational maintenance towards dynamic and adaptive service management.

Collectively, these institutional cases illustrate a broader paradigm shift in university FM practices following the pandemic. As summarised in Table 2, the most substantial transformation has occurred in the strategic role of digital infrastructure. Intelligent technologies are no longer viewed merely as operational support tools, but as core mechanisms for enhancing educational continuity, operational resilience, and user engagement within campus environments [19,28]. Consequently, digital infrastructure development has evolved into a strategic FM priority that extends beyond conventional logistical support functions, enabling universities to achieve more flexible, resilient, and user-centred campus management systems.

Table 2
Comparison of Estates Strategy Plan

Strategic dimension	Major shifting trends	Typical case examples
Space utilization	Transition from fixed space to flexible, appointment-based, multi-purpose layouts [28]	• UCL "adaptive use" [21] • MMU optimises classroom deployment through space usage data [27]
Health and safety	• Moving from routine cleaning to health-orientated design and technology-induced infection protection • CIBSE identifies ventilation and indoor air quality as important issues for building design and operations in the aftermath of the epidemic [29]	• KCL deploys indoor air quality monitoring and contactless access control systems [24]
Digital infrastructure	• The demand for distance teaching has driven the deployment of virtual teaching platforms, online collaboration tools and IT support systems • Moving from an auxiliary tool to a core component of FM, supporting the dual goals of teaching and facility operations	• UCL and KCL both include digital booking, distance learning support platforms in strategic level FM objectives [21,24] • MMU implements smart FM systems with occupancy analytics [27]
User experience mechanisms	Moving from reactive maintenance to user feedback orientated responsive mechanisms	• KCL collects user opinions and campus space satisfaction through apps [25] • MMU incorporates satisfaction surveys into facility performance metrics [27]

1.3 The User's Perspective on FM

The COVID-19 pandemic substantially reshaped how students and staff evaluate and interact with university facilities, leading to significant changes in expectations towards FM services. The widespread adoption of remote learning and hybrid working models accelerated demand for digitally integrated, flexible, and wellbeing-oriented campus environments, thereby redefining the criteria through which FM performance is assessed within higher education institutions.

From the student perspective, the rapid transition to online learning exposed limitations in existing digital infrastructure and support systems. Data from the National Student Survey (NSS) 2021 revealed that student satisfaction with learning resources declined significantly from 85.8% in 2020 to 73.6% in 2021 [30]. Several studies attributed this decline to insufficient digital competencies, unreliable online platforms, and the challenges associated with emergency remote teaching [31-33]. Nevertheless, Dhawan [34] argued that satisfaction levels gradually improved as students adapted to more flexible learning arrangements over time. More recent evidence suggests that student expectations have increasingly shifted towards digitally enabled and adaptable learning environments. Neves *et al.,* [35] reported that 62% of students demanded improvements in digital infrastructure, while preferences for flexible and reconfigurable physical learning spaces also increased substantially following the pandemic experience. These findings indicate that student evaluations of FM are no longer limited to physical infrastructure quality alone, but increasingly encompass digital accessibility, flexibility, and wellbeing support.

The pandemic also transformed faculty and professional staff experiences regarding campus facilities and support services. During periods of campus closure, staff engagement with physical facilities decreased considerably due to prolonged remote working arrangements. Watermeyer *et al.,*

[12], based on a survey involving 4,731 professional service staff across UK universities, together with findings from JLL Technologies [36], suggested that reduced physical campus interaction contributed to changing perceptions of FM effectiveness and workplace support. At the same time, hybrid working models emerged as a dominant organisational preference in the post-pandemic period. Watermeyer *et al.,* [12] reported that 71% of service professionals preferred blended working arrangements, reflecting growing expectations for workplace flexibility and digital accessibility.

In addition to operational flexibility, staff wellbeing has become an increasingly important consideration within post-pandemic FM strategies. Rahman *et al.,* [37] found that 29% of respondents experienced professional burnout during the pandemic, with disproportionately higher risks among women and marginalised groups. Furthermore, Robson *et al.,* [17] argued that the rapid expansion of online teaching significantly increased institutional awareness of the importance of technological infrastructure and digital teaching capabilities. Rather than requiring complete physical reconstruction, many universities recognised the value of adapting existing learning environments to support hybrid educational delivery through targeted technological enhancement and flexible space utilisation.

Collectively, these studies demonstrate that post-pandemic FM has progressively evolved towards a more user-centred and adaptive model. The findings suggest that digital transformation, health and wellbeing support, and spatial flexibility have emerged as the principal strategic priorities shaping FM practices within contemporary higher education institutions. Consequently, FM is increasingly expected not only to maintain physical infrastructure, but also to support institutional resilience, user experience, and long-term organisational adaptability.

1.4 Research Gap and Research Objectives

The post-pandemic transformation of university FM has generated increasing pressure on higher education institutions to balance operational resilience, digital transformation, and financial sustainability. According to Mordor Intelligence [38], four strategic priorities currently dominate UK university FM development: data-driven decision-making, flexible spatial design, intelligent infrastructure upgrading, and sustainable transformation. However, the implementation of these strategies is constrained by substantial financial pressures facing the higher education sector. In addition to the high costs associated with technological modernisation, significant investment is required to upgrade ageing assets and achieve long-term net-zero carbon objectives [39]. Following the COVID-19 pandemic, UK universities experienced severe financial disruption, including an estimated £2.6 billion loss in tuition-related income and substantial accommodation revenue deficits [40]. Universities UK [5] further projected a £1.4 billion sector-wide budget reduction for the 2025–2026 academic year, thereby significantly limiting institutional capacity for FM investment.

Beyond financial constraints, universities also face strategic challenges associated with digital inclusion, workforce adaptation, and evolving stakeholder expectations [41-43]. In response, Universities UK [5] proposed a diversified demand balance strategy aimed at supporting universities in reconciling competing operational priorities within constrained financial conditions. This strategy emphasises collaborative governance, resource integration, and cost-effective service delivery in order to maintain institutional resilience and user satisfaction.

The effectiveness of such user-orientated FM strategies can be conceptually explained through Oliver's Expectation Confirmation Theory (ECT) [44]. ECT proposes that user satisfaction is determined by the extent to which actual experiences align with or exceed prior expectations. Positive confirmation increases satisfaction and future acceptance intentions, whereas unmet expectations reduce user satisfaction and engagement. Within the context of post-pandemic FM, this theoretical perspective suggests that students' and staff members' evaluations of current FM services may significantly influence their future expectations regarding campus management and service provision. Consequently, understanding the relationship between current FM performance, user satisfaction, and future expectations has become increasingly important for strategic decision-making in higher education institutions.

Despite the growing body of literature examining post-pandemic FM transformation, several important research gaps remain. First, most existing studies focus primarily on the early stages of the pandemic (2020–2021), resulting in limited longitudinal understanding of post-2022 FM developments. Second, previous research has often examined digital infrastructure, health and safety, and physical space management as separate issues, while insufficient attention has been paid to their integrated effects on user satisfaction and future expectations. Third, the majority of FM studies adopt organisational or managerial perspectives, with relatively limited empirical investigation into the experiences and expectations of everyday campus users, particularly students and academic staff. Finally, little research has explored the mediating role of user satisfaction in linking current FM practices with future expectations regarding FM.

To address these gaps, this study investigates the relationships between key FM dimensions—digital infrastructure, health and safety, and spatial design—and user satisfaction and future expectations within UK universities. In particular, the study examines whether satisfaction mediates the relationship between current FM practices and future expectations towards FM development. By adopting a user-centred perspective, this research contributes to the emerging literature on post-pandemic FM transformation in higher education and extends current understanding of how user experiences shape strategic FM priorities. The findings also provide practical implications for university administrators seeking to balance financial constraints, operational resilience, and user-orientated service delivery within increasingly complex educational environments.

Accordingly, this study addresses the following research questions (RQ):

RQ1: How do current FM practices in UK universities influence the satisfaction levels of students and staff?

RQ2: How do current FM practices shape students' and staff members' future expectations regarding FM services?

RQ3: Does user satisfaction mediate the relationship between current FM practices and future expectations towards FM development?

2. Methodology

2.1 Conceptual Framework and Variable Definition

This study adopts the Stimulus–Organism–Response (SOR) framework as the theoretical foundation for examining the relationships between university FM practices, user satisfaction, and future expectations within the post-pandemic higher education context. The SOR model, originally proposed by Mehrabian and Russell [45], suggests that external environmental stimuli influence individuals' internal cognitive or emotional states, which subsequently shape behavioural or attitudinal responses.

Within the context of this study, the dimensions of university FM serve as the external stimuli (S), user satisfaction represents the internal evaluative state or organism (O), and future expectations towards FM development constitute the behavioural response (R). This framework is particularly suitable for investigating how users' perceptions of current FM practices influence their satisfaction levels and subsequently shape their expectations regarding future campus environments and FM services.

2.1.1 Stimulus variables: dimensions of university FM

The independent variables in this study consist of three key dimensions of university FM identified in the post-pandemic higher education literature: spatial design and flexibility, health and safety support, and digital infrastructure quality. These dimensions were selected based on their consistent prominence within recent studies on FM transformation in UK universities [3,19].

Spatial design and flexibility refer to users' perceptions of the adaptability, efficiency, and functionality of physical learning and working environments. Health and safety support encompasses perceptions of cleanliness, indoor environmental quality, health protection measures, and wellbeing-related facilities. Digital infrastructure quality relates to the availability, reliability, and effectiveness of digital systems and technologies supporting teaching, learning, and campus services. The operational definitions and measurement items for each construct are summarised in Table 3.

Table 3
Conception of independent variable

Independent variable	Concept Definition
Spatial Arrangement	Users' perception of the planning, design and optimal allocation of physical spaces within the university campus.
Safety and Health	Users' perception of the systematic measures implemented in the campus environment to ensure the physical and mental health as well as the property safety of the security personnel.
Digital Infrastructure	Users' perception of the technological ecosystem that supports the digital operation of universities, which includes hardware, software and network services.

2.1.2 Mediating variable - student and faculty satisfaction (O)

The mediating role of user satisfaction in this study is theoretically grounded in cognitive appraisal theory [46], which suggests that individuals' behavioural expectations and responses are shaped not only by external environmental conditions, but also by their internal cognitive and emotional evaluations of those conditions. Within the context of university FM, users initially evaluate tangible and functional aspects of the campus environment, such as cleanliness, spatial efficiency, health support, and digital infrastructure. These cognitive evaluations subsequently generate affective responses, particularly in the form of satisfaction or dissatisfaction with current FM services.

This emotional and evaluative process constitutes an important psychological mechanism linking present experiences with future expectations. In other words, users' perceptions of current FM performance influence their level of satisfaction, which in turn shapes their expectations regarding future FM development and service quality. Accordingly, in Table 4, satisfaction is conceptualised in this study as a mediating variable between users' evaluations of existing FM practices and their future expectations towards university FM. From this perspective, satisfaction reflects not merely an immediate emotional reaction, but also a broader evaluative judgement regarding the effectiveness and adaptability of FM services in the post-pandemic university environment.

Table 4
Conception of mediating variable

Mediating variable	Concept Definition
User satisfaction	Subjective evaluation by students and staff of the functionality, comfort and reliability of the physical environment, security services and digital infrastructure provided by the university based on actual experience.

2.1.3 Dependent Variable - Future FM Expectations (R)

Table 5 presents the conceptual and operational definitions of the dependent variable adopted in this study.

Table 5
Conception of dependent variable

Dependent Variable	Concept Definition
Overall Expectation	The overall expectations of students and faculty members regarding the management of university facilities can be evaluated from the following aspects: the preset standards for the functionality, comfort, and adaptability of the campus physical environment; the minimum requirements and ideal standards for the campus environment in terms of risk prevention, physical and mental health protection, and emergency response; and the psychological expectations for the technological advancement, stability, and support efficiency of the campus digital services.

2.2 Conceptional Model and Research Hypotheses

Based on the previous analysis, a theoretical model was initially constructed, as shown in Figure 1.

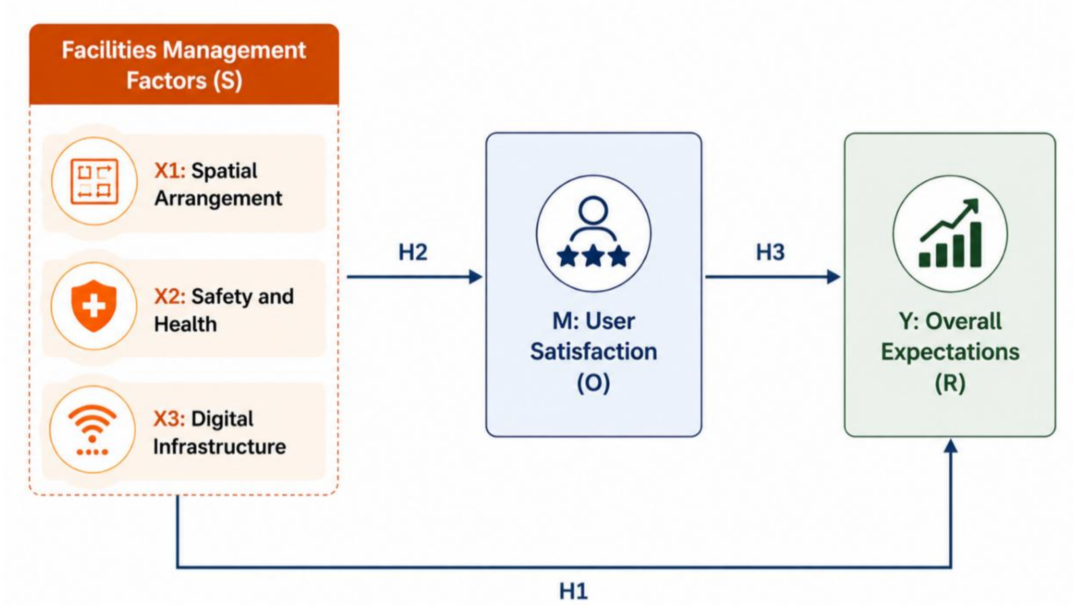

Fig. 1. Theoretical model

Drawing upon the conceptual framework and research questions, the study proposes a set of research objectives and associated hypotheses, as summarised in Table 6.

Table 6

Research objectives and hypotheses

Objective 1: Investigate the relationship between the current FM practices of British universities and the expectations of students and staff regarding future FM.	
H1a	Spatial arrangement positively influences users' future expectations regarding FM
H1b	Safety and health positively influence users' future expectations regarding FM
H1c	Digital infrastructure positively influences users' future expectations regarding FM
Objective 2: Explore the impact of current UK university FM on student and staff satisfaction.	
H2a	Spatial arrangement has a significant positive influence on users' satisfaction with FM
H2b	Safety and health have a significant positive influence on users' satisfaction with FM
H2c	Digital infrastructure has a significant positive influence on users' satisfaction with FM
Objective 3: Analyse the relationship between student and staff satisfaction and their expectations of future FM administration.	
H3	The satisfaction of students and staff with the current FM has a significant positive impact on their future expectations
Objective 4: Examine the mediating role of student and staff satisfaction with FM in UK universities.	
H4	Student and faculty satisfaction plays a mediating role in the influence of current FM factors on users' future expectations

2.3 Research Design

This study adopts the "Research Onion" framework proposed by Saunders [47] to guide the overall methodological design. The framework provides a systematic structure for aligning research philosophy, methodological approach, data collection, and analytical techniques. Given the study's objective of examining the relationships between FM practices, user satisfaction, and future expectations within post-pandemic UK universities, a positivist research philosophy was adopted. Positivism assumes that observable social phenomena can be objectively examined through empirical measurement and statistical analysis. This perspective is particularly appropriate for investigating the causal relationships between FM dimensions and users' evaluative responses within higher education environments. Accordingly, a quantitative research approach was employed to collect objective and measurable data regarding users' perceptions of university FM practices. Quantitative methods are widely used to examine relationships between variables, test hypotheses, and identify statistically significant patterns within social and educational research contexts [48].

2.4 Data Collection

Data were collected using an online structured questionnaire administered through Google Forms. The use of an online survey platform facilitated efficient distribution, response management, and data security throughout the research process. The target population consisted of current and former students and staff members from UK universities. A non-probability sampling strategy combining convenience sampling and snowball sampling was adopted to recruit participants. The questionnaire was distributed through social media platforms and email networks in order to increase accessibility and participation. Data collection was conducted over a three-week period, resulting in 100 valid responses, including 73 student participants and 27 university staff members. The sample size was considered adequate for the statistical analyses employed in this study, particularly for regression and mediation analysis within exploratory social science research contexts.

2.5 Questionnaire Design and Measurement

The questionnaire was designed to examine users' perceptions, satisfaction levels, and future expectations regarding FM practices in UK universities following the COVID-19 pandemic. The instrument consisted of seven sections. The first section collected demographic information to support subgroup and comparative analysis. Sections Two to Four assessed users' perceptions of current FM practices across three core dimensions identified in the literature: spatial configuration and flexibility, health and safety support, and digital infrastructure quality. The fifth section measured overall satisfaction with university FM services, while the sixth section examined future expectations regarding FM development. Future expectations were operationalised across three dimensions: spatial expectations, health and safety expectations, and digital expectations. Composite scores for overall future expectations were calculated using the mean values of these dimensions. The final section included an open-ended question intended to capture participants' broader views regarding the most important campus facility issues within their institutions. To minimise respondent fatigue, the number of items within each construct was intentionally limited. The estimated survey completion time was approximately 5–8 minutes. A five-point Likert scale was employed as the primary measurement instrument throughout the questionnaire. Likert scales are widely used in educational and social science research due to their reliability, simplicity, and effectiveness in measuring subjective attitudes and perceptions [49]. Consistent with previous quantitative studies, Likert-scale responses were treated as continuous variables for statistical analysis.

2.6 Data Analysis Procedures

Data analysis was conducted using Jamovi statistical software. The analytical process consisted of several stages. First, descriptive statistical analysis was performed to summarise the characteristics of the sample and examine respondents' evaluations of FM dimensions, satisfaction levels, and future expectations. Frequencies, percentages, means, and standard deviations were calculated. Second, reliability and validity assessments were conducted for all major constructs, alongside normality testing. The results indicated violations of normal distribution assumptions; therefore, non-parametric statistical techniques were employed for subsequent analysis. Spearman correlation analysis was conducted to examine the relationships between key variables. To test hypotheses H1a–H1c, H2a–H2c, and H3, robust multiple regression analysis was employed. Robust regression was selected in order to reduce the influence of non-normality, heteroscedasticity, and potential outliers within the dataset. Furthermore, mediation analysis using percentile Bootstrap estimation with 5,000 resamples was conducted to test H4 and evaluate the mediating role of user satisfaction. Finally, ranking analysis and frequency statistics were used to identify the FM trends and service priorities most strongly expected by university users in the post-pandemic context.

2.7 Reliability and Validity Assessment

The questionnaire items and measurement scales used in this study were developed based on established literature and theoretical frameworks related to FM and user satisfaction in higher education contexts. This approach helped ensure the content validity and conceptual relevance of the measurement instrument. Prior to the main data collection process, a pilot study was conducted involving two university faculty members and eight students from UK universities. The pilot testing aimed to evaluate the clarity, readability, and appropriateness of the questionnaire items, as well as the overall structure and completion time of the survey. Minor revisions were subsequently made to improve wording clarity and measurement consistency. The internal consistency reliability of the measurement scales was assessed using Cronbach's alpha coefficients. The preliminary analysis indicated that all constructs exceeded the recommended threshold value of 0.70 commonly adopted in social science research, demonstrating satisfactory reliability of the measurement instrument. Overall, the findings suggest that the questionnaire possessed acceptable levels of methodological reliability and content validity for the purposes of this study.

2.8 Ethical Considerations

This study was conducted in accordance with ethical guidelines for social science research within the United Kingdom. Formal ethical approval was obtained from the relevant ethics committee of the affiliated institution prior to data collection. All participants were provided with an information statement explaining the purpose, procedures, and voluntary nature of the study before completing the questionnaire. Informed consent was obtained from all respondents prior to participation. Participants were informed that they could withdraw from the study at any stage without consequence. To ensure confidentiality and privacy protection, no personally identifiable information was collected during the survey process. All responses were anonymised and used solely for academic research purposes. The collected data were securely stored and accessed only by the researcher throughout the analysis process.

3.0 Results

This chapter presents the empirical findings derived from the quantitative analysis of survey data collected from students and staff members within UK universities. The analysis is organised according to the research questions and hypotheses proposed in the methodology section. Descriptive statistics were first conducted to summarise the demographic characteristics of the respondents and examine overall patterns relating to users' perceptions, satisfaction levels, and future expectations regarding FM. Reliability, validity, and normality assessments were subsequently performed to determine the appropriateness of the statistical procedures employed. Since the data violated normality assumptions, non-parametric analytical techniques and robust statistical methods were adopted. Hypotheses H1–H3 were tested using robust multiple regression analysis, while H4 was examined through Bootstrap mediation analysis with 5,000 resamples. The results of these analyses are presented in the following sections.

3.1 Descriptive Results

3.1.1 Sample characteristics

The final sample consisted of 100 valid responses collected from current and former students and staff members across ten UK universities. Among the respondents, 73% were students (n = 73) and 27% were university staff members (n = 27). Participants represented a range of academic disciplines and institutional backgrounds within the UK higher education sector. The gender distribution of respondents was relatively balanced. A substantial proportion of participants (64%) were affiliated with UCL, reflecting the concentration of responses from that institution. In terms of academic background, the majority of respondents were associated with business and management-related disciplines. A detailed summary of the sample characteristics is presented in Table 7.

Table 7

Sample descriptive statistics

Demographic Variables	Variables	Count	% of Total
Role	Students	73	73.0%
	Teaching Staff	27	27.0%
Gender	Male	53	53.0%
	Female	47	47.0%
University	King's College London	10	10.0%
	The London School of Economics and Political Science	5	5.0%
	University of the Arts London	4	4.0%
	University College London	64	64.0%
	University of Bristol	5	5.0%
	University of Manchester	5	5.0%
	University of Nottingham	1	1.0%
	University of Warwick	2	2.0%
	Birkbeck College London	1	1.0%
	University of Leeds	3	3.0%
Department	STEM (Science, Technology, Engineering, Mathematics)	15	15.0%
	Business and Management	51	51.0%
	Social Sciences	16	16.0%
	Arts and Humanities	11	11.0%
	Other	7	7.0%

3.1.2 FM perceptions

Descriptive statistical results for the three key dimensions of FM are presented in Table 8. Among the three dimensions, spatial arrangement received the highest overall evaluation from respondents. In particular, the allocation of functional zones for learning, relaxation, and communication obtained the highest mean score (M = 4.05, SD = 0.479), indicating generally positive perceptions regarding campus spatial organisation. Other spatial indicators, including accessibility and spatial configuration, also received relatively favourable evaluations. Although the score for space utilisation was comparatively lower within this dimension, the median value for overall spatial arrangement remained at 4.00, suggesting an overall positive assessment of campus spatial design.

The health and safety dimension received a moderate overall evaluation (M = 3.60, SD = 0.679). Hygiene conditions (M = 3.68, SD = 0.695) and health and safety inspection measures (M = 3.73, SD = 0.548) received relatively higher ratings within this category. In contrast, air ventilation recorded the lowest score within the health and safety dimension (M = 3.39, Median = 3.00, SD = 0.737), indicating comparatively lower levels of user satisfaction in relation to indoor environmental quality. Digital infrastructure received the lowest overall evaluation among the three FM dimensions (M = 3.32, SD = 0.780). Relatively large standard deviation values were observed for network connectivity and hardware provision, suggesting greater variation in respondents' perceptions of digital service quality. Although e-platform services and printing facilities received comparatively higher ratings within the digital infrastructure category, their mean scores remained lower than those observed for the spatial arrangement and health and safety dimensions. Overall, respondents demonstrated relatively positive perceptions towards campus FM practices, particularly regarding spatial organisation. However, comparatively lower evaluations were identified in relation to air ventilation, network connectivity, and hardware support, indicating areas where users perceived lower levels of FM performance.

Table 8
FM perceptions descriptive statistics

Variables	Number	Mean	Median	Standard Deviation	Minimum	Maximum
Spatial Arrangement	**100**	**3.84**	**4.00**	**0.561**	**2**	**5**
Spatial layout	100	3.78	4.00	0.561	2	5
Functional zone allocation	100	4.05	4.00	0.479	3	5
Space accessibility	100	3.93	4.00	0.455	2	5
Space utilisation	100	3.60	4.00	0.636	2	5
Safety and Health	**100**	**3.60**	**4.00**	**0.679**	**1**	**5**
Hygiene	100	3.68	4.00	0.695	2	5
Air ventilation	100	3.39	3.00	0.737	1	5
Health & Safety Inspections	100	3.73	4.00	0.548	2	5
Digital Infrastructure	**100**	**3.32**	**3.00**	**0.780**	**1**	**5**
Network connectivity	100	3.07	3.00	0.902	1	5
Hardware provision	100	3.27	3.00	0.863	2	5
Printing facilities	100	3.50	3.50	0.503	3	4
E-platforms	100	3.43	4.00	0.728	2	5

3.1.3 Overall satisfaction

Descriptive statistics for overall satisfaction with university FM are presented in Table 9. The mean satisfaction score on the five-point Likert scale was 3.65 (SD = 0.50), indicating a generally positive level of user satisfaction with current FM practices within UK universities.

Table 9
Overall satisfaction descriptive statistics

Descriptive	N	Mean	Median	Standard Deviation	Minimum	Maximum
Current Satisfaction	100	3.65	4.00	0.500	3	5

3.1.4 Overall expectations

Descriptive statistics for respondents' future expectations regarding university FM are presented in Table 10. Overall, respondents reported relatively high expectations across all three FM dimensions. Among the three dimensions, digital expectation received the highest mean score (M = 3.86), suggesting comparatively stronger expectations for further investment in digital infrastructure and technology-enhanced campus services. Spatial expectation recorded the second-highest mean score (M = 3.71), indicating positive expectations towards more flexible and adaptable physical learning environments. Health and safety expectation received the comparatively lowest mean score (M = 3.67); however, the results still reflected generally positive expectations regarding future improvements in campus health protection and safety management measures. All three dimensions reported standard deviation values below 1.00, indicating relatively limited variability in respondents' evaluations and a moderate degree of consistency in user expectations across the sample.

Table 10
Overall expectation descriptive statistics

Variables	Number	Mean	Median	Standard Deviation	Minimum	Maximum

Space Expectation	100	3.71	4.00	0.478	3	5
Safety & Health Expectation	100	3.67	4.00	0.493	3	5
Digital Expectation	100	3.86	4.00	0.472	3	5

3.2 Normality Assessment

Prior to conducting inferential statistical analyses, normality testing was performed for all major study variables. As presented in Table 11, the Shapiro–Wilk test results indicated statistically significant deviations from normality across all principal constructs, including perceptions of health and safety, digital infrastructure, overall satisfaction, and future expectations ($p < 0.05$). These findings suggest that the data did not satisfy the assumptions of normal distribution required for conventional parametric testing. Further examination of skewness and kurtosis statistics revealed moderate deviations from normality in several variables. In particular, the spatial arrangement construct demonstrated a negative skewness value of −0.845, while the overall expectation variable showed a skewness value of −0.542, indicating negatively skewed distributions. In addition, the spatial arrangement variable exhibited a kurtosis value of 3.600, suggesting a relatively peaked distribution compared with a normal distribution. The digital infrastructure and overall satisfaction variables also demonstrated moderate kurtosis values. Given the observed violations of normality assumptions, subsequent analyses employed non-parametric statistical techniques and robust analytical procedures, including Spearman correlation analysis and robust regression methods.

Table 11
Descriptive Statistics and Normality Tests of Study Variables

Variables	Number	Skewness	Standard Error	Kurtosis	Standard Error	Shapiro–Wilk	*p*
Spatial Arrangement	100	-0.845	0.241	3.600	0.478	0.841	<0.001
Safety and Health	100	-0.416	0.241	-0.269	0.478	0.934	<0.001
Digital Infrastructure	100	-0.194	0.241	-0.903	0.478	0.954	0.001
Overall Satisfaction	100	-0.390	0.241	-1.257	0.478	0.651	<0.001
Overall Expectations	100	-0.542	0.241	-0.420	0.478	0.764	<0.001

3.3 Reliability and Validity
3.3.1 Reliability analysis

Reliability analysis was conducted using Cronbach's alpha coefficients to assess the internal consistency of the questionnaire scales. The results are presented in Table 12. Among the three FM dimensions, the spatial arrangement construct demonstrated the highest reliability ($\alpha = 0.891$), followed by digital infrastructure ($\alpha = 0.873$). Both coefficients exceeded the recommended threshold of 0.80, indicating high levels of internal consistency among the measurement items. The health and safety construct reported a Cronbach's alpha value of 0.760, which remained above the commonly accepted threshold of 0.70 in social science research, suggesting acceptable reliability for this dimension. Reliability analysis was also conducted for the composite construct measuring users' future expectations regarding FM development, which comprised three sub-dimensions: spatial expectations, health and safety expectations, and digital expectations. The overall Cronbach's alpha coefficient for this construct was 0.887 in Table 13, indicating strong internal consistency across the three subscales and suggesting that the items reliably measured the broader construct of future FM expectations. Overall, the reliability results indicate that the measurement scales used in this study demonstrated satisfactory internal consistency for subsequent statistical analysis.

Table 12
Reliability test of FM perception

Construct	Cronbach's α
Spatial Arrangement	0.891
Safety and Health	0.760
Digital Infrastructure	0.873

Table 13
Reliability test of overall expectation

Construct	Cronbach's α
Overall Expectations	0.887

3.3.2 Validity analysis
3.3.2.1 KMO and bartlett's test

Prior to conducting Exploratory Factor Analysis (EFA), the suitability of the data for factor extraction was assessed using the Kaiser–Meyer–Olkin (KMO) measure of sampling adequacy and Bartlett's test of sphericity. For the three FM dimensions, the Bartlett's test of sphericity was statistically significant, $\chi^2(55) = 598$, $p < .001$, indicating that the correlation matrix significantly differed from an identity matrix and that sufficient correlations existed among the items for factor analysis. The KMO coefficient was 0.743, exceeding the recommended threshold value of 0.70 [50], thereby indicating satisfactory sampling adequacy for factor extraction (Table 14). A separate assessment was conducted for the construct measuring users' future expectations regarding FM development, which comprised three sub-dimensions: spatial expectations, health and safety expectations, and digital expectations. The Bartlett's test of sphericity remained statistically significant, $\chi^2(3) = 231$, $p < .001$, confirming the suitability of the correlation matrix for factor analysis (Table 15). The KMO value for this construct was 0.669, which fell slightly below the recommended threshold of 0.70 but remained above the minimum acceptable level of 0.60, indicating acceptable sampling adequacy for exploratory factor analysis. Overall, the results suggest that the measurement constructs demonstrated acceptable construct validity and were suitable for subsequent factor-based statistical analyses.

Table 14
KMO and Bartlett's Test of independent variables

Kaiser–Meyer–Olkin Measure of Sampling Adequacy		0.743
Bartlett's Test of Sphericity	Approx. Chi-Square	598.000
	df	55
	Sig.	< .001

Table 15
KMO and Bartlett's Test of dependent variables

Kaiser–Meyer–Olkin Measure of Sampling Adequacy		0.669
Bartlett's Test of Sphericity	Approx. Chi-Square	231.000
	df	3
	Sig.	< .001

3.3.2.2 EFA

EFA was conducted on the independent variables using Principal Axis Factoring with Varimax orthogonal rotation. The results are presented in Table 16. Three factors with eigenvalues greater than 1 were extracted, collectively accounting for a satisfactory proportion of the total variance. The factor structure generally aligned with the theoretical dimensions proposed in the conceptual framework. The first factor represented the spatial arrangement construct, with factor loadings ranging from 0.758 to 0.883. The second factor corresponded to the digital infrastructure construct, with factor loadings ranging from 0.722 to 0.917. The third factor represented the health and safety construct. Most items within this dimension demonstrated satisfactory loadings, although the "air ventilation" item exhibited a comparatively lower loading value of 0.560 relative to the remaining items within the same construct. Overall, the extracted factor structure demonstrated acceptable alignment with the theoretically proposed FM dimensions, thereby providing support for the construct validity of the measurement scale. A separate EFA was subsequently conducted for the construct measuring users' future expectations regarding FM development. As presented in Table 17, the analysis extracted a single factor, indicating a unidimensional structure for the expectation construct. Spatial expectation and health and safety expectation demonstrated very high factor loadings of 0.958 and 0.957, respectively. Digital expectation reported a comparatively lower loading of 0.652 and a relatively high uniqueness value of 0.575, suggesting that this item was less strongly associated with the common latent factor compared with the other two indicators. Nevertheless, all three expectation dimensions loaded adequately onto a single factor, supporting the aggregation of these sub-dimensions into an overall future expectation construct for subsequent statistical analysis.

Table 16
EFA test of independent variables

Variable	Factor 1	Factor 2	Factor 3	Uniqueness
Spatial layout	0.833			0.219
Functional zone allocation	0.758			0.416
Space accessibility	0.855			0.253
Space utilisation	0.811			0.334
Hygiene			0.911	0.165
Air ventilation			0.560	0.667
Health & Safety inspection			0.745	0.425
Network connectivity		0.917		0.132
Hardware provision		0.722		0.479
Printing facilities		0.778		0.387
E-Platform		0.844		0.285

Note. Principal axis factoring extraction method was used in combination with a varimax rotation.

Table 17
EFA test of dependent variables

Variable	Factor 1	Uniqueness
Space expectation	0.958	0.081
Safety & Health Expectation	0.957	0.084
Digital expectation	0.652	0.575

3.4 Hypothesis Test

3.4.1 Correlation analysis

Spearman correlation analysis was conducted to examine the relationships among the major study variables. The results are presented in Table 18. The correlations among the three FM dimensions were generally weak and statistically non-significant. Spatial arrangement demonstrated a negligible positive correlation with health and safety (ρ = 0.007, p = 0.942) and a weak negative correlation with digital infrastructure (ρ = −0.126, p = 0.212). Similarly, health and safety and digital infrastructure showed no statistically significant association (ρ = 0.042, p = 0.677). These findings suggest that the three FM dimensions were relatively distinct constructs within respondents' evaluations. All three FM dimensions demonstrated statistically significant positive correlations with overall future expectation. Among these, health and safety exhibited the strongest association with overall expectation (ρ = 0.509, p < .001), followed by digital infrastructure (ρ = 0.456, p < .001). Spatial arrangement demonstrated the weakest, although still statistically significant, correlation with overall expectation.

Table 18
Spearman Correlation Matrix

Variables	Statistic	Spatial Arrangement	Safety and Health	Digital Infrastructure	Overall Satisfaction	Overall Expectation
Spatial Arrangement	Spearman's rho	1	0.007	-0.126	0.247	0.304
	df	1	98	98	98	98
	p-value	1	0.942	0.212	0.013	0.002
Safety and Health	Spearman's rho	0.007	1	0.042	0.475	0.509
	df	98	1	98	98	98
	p-value	0.942	1	0.677	<0.001	<0.001
Digital Infrastructure	Spearman's rho	-0.126	0.042	1	0.405	0.456
	df	98	98	1	98	98
	p-value	0.212	0.677	1	<0.001	<0.001
Overall Satisfaction	Spearman's rho	0.247	0.475	0.405	1	0.928
	df	98	98	98	1	98
	p-value	0.013	<0.001	<0.001	1	<0.001
Overall Expectation	Spearman's rho	0.304	0.509	0.456	0.928	1
	df	98	98	98	98	1
	p-value	0.002	<0.001	<0.001	<0.001	1

Note. df-degrees of freedom; p-value-the statistical significance of the correlation coefficients.

These findings indicate that more positive evaluations of current FM practices were associated with stronger future expectations regarding FM development. Accordingly, the correlation analysis provided preliminary support for hypotheses H1a, H1b, and H1c. A similar pattern was observed in the relationships between the FM dimensions and overall satisfaction. Health and safety demonstrated the strongest positive correlation with satisfaction (ρ = 0.475, p < .001), followed by digital infrastructure (ρ = 0.405, p < .001). Spatial arrangement exhibited the weakest, but still statistically significant, relationship with overall satisfaction (ρ = 0.247, p = 0.013). These findings suggest that more favourable perceptions of current FM dimensions were associated with higher levels of user satisfaction. Therefore, preliminary support was also identified for hypotheses H2a, H2b, and H2c. Overall satisfaction demonstrated a very strong positive correlation with overall future expectation ($\rho = 0.928$, $p < .001$). This result indicates a close association between users' current satisfaction with FM services and their expectations regarding future FM development. The findings provide initial support for hypothesis H3 and further justify the subsequent mediation analysis examining the role of satisfaction in shaping future expectations.

3.4.2 Robust regression analysis

To address potential heteroscedasticity and deviations from normality identified during the preliminary diagnostic tests, robust multiple regression analysis was employed using ordinary least squares (OLS) estimation with robust standard errors. All predictor variables were mean-centred prior to analysis in order to improve model stability and reduce potential multicollinearity effects. The use of robust standard errors allowed for more reliable statistical inference under conditions of heteroscedasticity and non-normal residual distributions.

3.4.2.1 Hypothesis testing for H1

A robust multiple regression model was constructed to examine the effects of the three FM dimensions—spatial arrangement, health and safety, and digital infrastructure—on users' overall future expectations regarding FM development. The model demonstrated satisfactory explanatory power, with an R^2 value of 0.634 and an adjusted R^2 value of 0.622 (Table 19), indicating that approximately 63.4% of the variance in overall expectation was explained by the three predictor variables. The overall regression model was statistically significant, $F(3, 96) = 55.340$ (Table 20), $p < .001$, suggesting that the FM dimensions collectively exerted significant effects on users' future expectations. Analysis of variance further indicated that all three predictor variables significantly contributed to the model. Health and safety demonstrated a substantial effect size ($F = 49.66$, $p < .001$, $\eta^2p = 0.403$), while digital infrastructure also exhibited a strong effect ($F = 53.69$, $p < .001$, $\eta^2p = 0.403$). Spatial arrangement remained statistically significant, although its effect size was comparatively lower ($F = 40.87$, $p < .001$, $\eta^2p = 0.278$). The parameter estimates presented in Table 21 further confirmed that all three FM dimensions positively predicted overall future expectation. Health and safety and digital infrastructure demonstrated comparatively stronger standardised regression coefficients, whereas spatial arrangement exerted a weaker, though still statistically significant, predictive effect. The regression findings indicate that users' positive perceptions of current FM practices were significantly associated with stronger expectations regarding future FM development. Accordingly, hypotheses H1a, H1b, and H1c were supported.

Table 19
Model fit (H1)

R^2	Adj. R^2	df	df(res)	F	p
0.634	0.622	3	96	55.3	<0.001

Note. R^2-the proportion of variance in the dependent variable explained by the regression model; Adjusted R^2 – the number of predictors included in the model; df-degrees of freedom; df (res) - the residual degrees of freedom; F - the overall F-statistic to evaluate the significance of the regression model; p - the statistical significance level of the model.

Table 20
ANOVA tests (H1)

Source	SS	df	F	p	$\eta^2 p$
Model	11.844	3	55.340	<0.001	0.634
Spatial Arrangement	2.631	1	40.874	<0.001	0.278
Safety and Health	4.630	1	49.657	<0.001	0.403
Digital Infrastructure	4.621	1	53.693	<0.001	0.403
Residuals	6.849	96			
Total	18.693	99			

Note. SS - the sum of squaresl; df-degrees of freedom; F - the overall F-statistic to evaluate the significance of the regression model; p - the statistical significance level of the model; $\eta^2 p$ - partial eta squared; Inferential tests and p-values of the effects are adjusted for heteroscedasticity.

Table 21
Regression Coefficients (H1)

Predictor	Estimate	SE	95% CI Lower	95% CI Upper	β	df	t	p
(Intercept)	3.747	0.027	3.694	3.800	0.000	96	137.199	<0.001
Spatial Arrangement	0.354	0.055	0.238	0.470	0.380	96	6.393	<0.001
Safety and Health	0.397	0.056	0.299	0.495	0.499	96	7.047	<0.001
Digital Infrastructure	0.336	0.046	0.253	0.419	0.503	96	7.328	<0.001

Note. SE - standard error of the estimated coefficient; 95% CI Lower – 95% lower confidence intervals; 95% CI Upper - 95% upper confidence intervals; β - the standardized regression coefficient; df-degrees of freedom; t – t-statistic used to test the significance of individual regression coefficients; p - the statistical significance level of the model; Inferential tests and p-values of the effects are adjusted for heteroscedasticity.

3.4.2.2 Hypothesis testing for H2

A robust multiple regression model was constructed to examine the effects of the three FM dimensions, spatial arrangement, health and safety, and digital infrastructure, on overall user satisfaction. In Table 22, the regression model was statistically significant, $F(3, 96) = 33.80$, $p < .001$, indicating that the three predictor variables collectively explained a substantial proportion of variance in overall satisfaction. The model demonstrated satisfactory explanatory power, with an R^2 value of 0.514 and an adjusted R^2 value of 0.499, suggesting that approximately 51.4% of the variance in user satisfaction was explained by the FM dimensions. In Table 23, analysis of variance further indicated that all three FM dimensions exerted statistically significant effects on overall satisfaction ($p < .001$). Among the predictor variables, health and safety demonstrated the largest effect size ($\eta^2 p = 0.309$), indicating that this dimension represented the strongest predictor of user satisfaction. Digital infrastructure exhibited the second strongest effect, while spatial arrangement demonstrated a comparatively smaller effect size. The standardised regression coefficients presented in Table 24 further confirmed these relationships. Health and safety demonstrated the strongest positive predictive effect on satisfaction (β = 0.467), whereas digital infrastructure and spatial arrangement exhibited comparatively weaker, although still statistically significant, effects. The regression findings indicate that positive perceptions of current FM practices were significantly associated with higher levels of user satisfaction. Accordingly, hypotheses H2a, H2b, and H2c were supported.

Table 22
Model fit (H2)

R^2	Adj. R^2	df	df(res)	F	p

0.514	0.499	3	96	33.8	<0.001

Note. R^2-the proportion of variance in the dependent variable explained by the regression model; Adjusted R^2 – the number of predictors included in the model; df-degrees of freedom; df (res) - the residual degrees of freedom; F - the overall F-statistic to evaluate the significance of the regression model; p - the statistical significance level of the model.

Table 23
ANOVA tests (H2)

Source	SS	df	F	p	η^2p
Model	12.722	3	33.849	<0.001	0.514
Spatial Arrangement	2.582	1	23.478	<0.001	0.177
Safety and Health	5.376	1	35.831	<0.001	0.309
Digital Infrastructure	4.735	1	34.886	<0.001	0.282
Residuals	12.028	96			
Total	24.750	99			

Note. SS - the sum of squaresl; df-degrees of freedom; F - the overall F-statistic to evaluate the significance of the regression model; p - the statistical significance level of the model; η^2p - partial eta squared; Inferential tests and p-values of the effects are adjusted for heteroscedasticity.

Table 24
Regression Coefficients (H2)

Predictor	Estimate	SE	95% CI Lower	95% CI Upper	β	df	t	p
(Intercept)	3.650	0.036	3.580	3.720	0.000	96	101.077	<0.001
Spatial Arrangement	0.351	0.072	0.197	0.504	0.327	96	4.845	<0.001
Safety and Health	0.428	0.071	0.298	0.557	0.467	96	5.986	<0.001
Digital Infrastructure	0.340	0.058	0.230	0.450	0.443	96	5.906	<0.001

Note. SE - standard error of the estimated coefficient; 95% CI Lower – 95% lower confidence intervals; 95% CI Upper - 95% upper confidence intervals; β - the standardized regression coefficient; df-degrees of freedom; t – t-statistic used to test the significance of individual regression coefficients; p - the statistical significance level of the model; Inferential tests and p-values of the effects are adjusted for heteroscedasticity.

3.4.2.3 Hypothesis testing for H3

A robust linear regression model was constructed to examine the effect of overall satisfaction on users' future expectations regarding FM development. In Table 25, the regression model demonstrated strong explanatory power, with an R^2 value of 0.847 and an adjusted R^2 value of 0.846, indicating that approximately 84.7% of the variance in future expectation was explained by overall satisfaction. The overall model was statistically significant, suggesting that satisfaction represented a substantial predictor of future expectation in Table 26. As presented in Table 27, the regression coefficient analysis indicated a strong positive relationship between overall satisfaction and future expectation. The unstandardised regression coefficient demonstrated that a one-unit increase in overall satisfaction was associated with an average increase of 0.800 units in future expectation. Furthermore, the 95% confidence interval for the regression coefficient remained entirely above zero (95% CI [0.732, 0.868]), confirming the statistical significance and positive direction of the effect. The findings indicate that higher levels of satisfaction with current FM services were significantly associated with stronger expectations regarding future FM development. Accordingly, hypothesis H3 was supported.

Table 25
Model fit (H3)

R^2	Adj. R^2	df	df(res)	F	p
0.847	0.846	1	98	544	<0.001

Note. R^2-the proportion of variance in the dependent variable explained by the regression model; Adj R^2 - Adjusted R^2; df-degrees of freedom; df (res) - the residual degrees of freedom; F - the overall F-statistic to evaluate the significance of the regression model; p - the statistical significance level of the model.

Table 26

ANOVA tests (H3)

Source	SS	df	F	p	$\eta^2 p$
Model	15.840	1	544.037	<0.001	0.847
Overall Satisfaction	15.840	1	329.028	<0.001	0.847
Residuals	2.853	98			
Total	18.693	99			

Note. SS - the sum of squaresl; df-degrees of freedom; F - the overall F-statistic to evaluate the significance of the regression model; p - the statistical significance level of the model; $\eta^2 p$ - partial eta squared; Inferential tests and p-values of the effects are adjusted for heteroscedasticity.

Table 27

Regression Coefficients (H3)

Predictor	Estimate	SE	95% CI Lower	95% CI Upper	β	df	t	p
(Intercept)	3.747	0.017	3.713	3.781	0.000	98	216.042	<0.001
Overall Satisfaction	0.800	0.044	0.732	0.868	0.921	98	18.139	<0.001

Note. SE - standard error of the estimated coefficient; 95% CI Lower – 95% lower confidence intervals; 95% CI Upper - 95% upper confidence intervals; β - the standardized regression coefficient; df-degrees of freedom; t – t-statistic used to test the significance of individual regression coefficients; p - the statistical significance level of the model; Inferential tests and p-values of the effects are adjusted for heteroscedasticity.

3.4.2.4 Mediation analysis for H4

To examine Hypothesis 4, mediation analysis was conducted using overall satisfaction as the mediating variable between the three FM dimensions, spatial arrangement, health and safety, and digital infrastructure and overall future expectation. The mediation model is presented in Table 28. The regression results indicated that all three FM dimensions significantly predicted both overall satisfaction and overall future expectation. However, when overall satisfaction was introduced into the regression model as a mediator, the direct effects of spatial arrangement, health and safety, and digital infrastructure on future expectation were reduced. In addition, overall satisfaction exerted a significant positive effect on future expectation (B = 0.626, β = 0.720, p < .001), suggesting the presence of a mediating relationship.

Table 28

Analysis of mediating role

	Overall Expectation					Overall Satisfaction					Overall Expectation				
	B	SE	t	p	β	B	SE	t	p	β	B	SE	t	p	β
Constant	-0.156	0.321	-0.487	0.628		-0.365	0.426	-0.857	0.394		0.072	0.181	0.398	0.692	
SA	0.354**	0.058	6.073	0.000	0.380	0.351**	0.077	4.540	0.000	0.327	0.134**	0.036	3.730	0.000	0.144

SH	0.397**	0.049	8.056	0.000	0.499	0.428**	0.065	6.550	0.000	0.467	0.129**	0.033	3.883	0.000	0.162
DI	0.336**	0.042	8.048	0.000	0.503	0.340**	0.055	6.148	0.000	0.443	0.123**	0.028	4.449	0.000	0.184
OS											0.626**	0.043	14.492	0.000	0.720
R^2	0.634										0.886				
Adj. R^2	0.622										0.881				
F	F(3,96)=55.340, p=0.000					F(3,96)=33.849, p=0.000					F(4,95)=184.371, p=0.000				

Note. SA - Spatial Arrangement; SH - Safety and Health; DI - Digital Infrastructure; OS - Overall Satisfaction; R^2-the proportion of variance in the dependent variable explained by the regression model; Adj R^2 - Adjusted R^2; F - the overall F-statistic to evaluate the significance of the regression model; B - Unstandardized regression coefficient; SE - Standard error of the estimated coefficient; df-degrees of freedom; t – t-statistic used to test the significance of individual regression coefficients; p - the statistical significance level of the model; β - Standardized regression coefficient; *p<0.05; ** p<0.01; p - the statistical significance level of the model.

The significance of the indirect effects was further examined using percentile Bootstrap mediation analysis with 5,000 resamples. The results are summarised in Table 29.

For the pathway "Spatial Arrangement → Overall Satisfaction → Overall Expectation", the total effect was statistically significant (c = 0.354, p < .001). The indirect effect was also significant (ab = 0.220, SE = 0.062, z = 3.566, p < .001), and the 95% Bootstrap confidence interval [0.116, 0.359] did not include zero. Since the direct effect remained significant (c′ = 0.134, p < .01), the results indicate partial mediation. Similarly, the mediation pathway involving health and safety demonstrated a significant total effect (c = 0.397, p < .001). The indirect effect through overall satisfaction was statistically significant (ab = 0.268, SE = 0.065, z = 4.103, p < .001), with a 95% Bootstrap confidence interval of [0.211, 0.467]. The direct effect also remained significant (c′ = 0.129, p < .01), indicating partial mediation. For the digital infrastructure pathway, the total effect was statistically significant (c = 0.336, p < .001). The indirect effect through satisfaction was also significant (ab = 0.213, SE = 0.059, z = 3.607, p < .001), and the 95% Bootstrap confidence interval [0.210, 0.440] excluded zero. The remaining direct effect (c′ = 0.123, p < .01) further suggested partial mediation. Overall, the mediation analysis demonstrated that overall satisfaction partially mediated the relationships between the three FM dimensions and users' future expectations regarding FM development. Accordingly, Hypothesis 4 was supported.

Table 29
Mediation analysis

Pathway	c (Total Effect)	a	b	*a × b* (Indirect Effect)	*a × b* (Boot SE)	*a × b* (*z*)	*a × b* (*p*)	*a × b* (95% Boot CI)	*c′* (Direct Effect)

Spatial Arrangement → Overall Satisfaction → Overall Expectation	0.354**	0.351**	0.626**	0.220	0.062	3.566	0.000	0.116 – 0.359	0.134**
Safety and Health → Overall Satisfaction → Overall Expectation	0.397**	0.428**	0.626**	0.268	0.065	4.103	0.000	0.211 – 0.467	0.129**
Digital Infrastructure → Overall Satisfaction → Overall Expectation	0.336**	0.340**	0.626**	0.213	0.059	3.607	0.000	0.210 – 0.440	0.123**

Note. a - effect of the independent variable on the mediator; *b* - effect of the mediator on the dependent variable; *c* - total effect; *c′* - direct effect after including the mediator in the model; z - the standardized test statistic used to examine the significance of the indirect (mediation) effect in the bootstrap mediation analysis; Boot SE = bootstrap standard error; CI = confidence interval; *p<0.05; ** p<0.01; Bootstrapping was performed using the percentile bootstrap method.

3.5 Interpretation and Comparison with Previous Studies

3.5.1 Spatial arrangement and user experience

The findings indicate that spatial arrangement positively influenced both user satisfaction and future expectations regarding FM. This suggests that effective spatial design, functional zoning, accessibility, and efficient space utilisation remain important contributors to users' overall campus experience. These results are consistent with previous studies demonstrating that well-designed learning environments can improve students' learning experiences, social interaction, and overall institutional perceptions [51]. However, compared with the other FM dimensions, spatial arrangement demonstrated relatively weaker predictive effects. This finding suggests that, in the post-pandemic context, users may increasingly perceive spatial configuration as a fundamental operational requirement rather than a primary determinant of satisfaction. This interpretation aligns with the observations of JLL Technologies [36], which argued that user priorities in higher education environments have shifted towards health security and service resilience following the COVID-19 pandemic. Nevertheless, spatial arrangement continues to function as an important foundational component within university FM systems.

3.5.2 Safety and health as the strongest predictor factor

One of the most significant findings of this study is that health and safety emerged as the strongest predictor of both user satisfaction and future expectations. This result is particularly noteworthy given that much of the recent FM literature has emphasised digital transformation as the dominant strategic priority within UK universities. The findings suggest that the COVID-19 pandemic has fundamentally reshaped users' perceptions of campus environments, particularly regarding hygiene, ventilation, safety transparency, and institutional preparedness. Consistent with Jun *et al.,* [52], users now demonstrate heightened sensitivity towards environmental health risks and place greater importance on visible health protection measures within educational settings. From a theoretical perspective, this finding may be interpreted through the lens of cognitive appraisal theory. Users' evaluations of campus safety conditions appear to generate strong affective responses, which subsequently influence both satisfaction and future expectations regarding FM development. In this sense, health and safety functions not only as an operational requirement, but also as a psychological reassurance mechanism that shapes users' trust and confidence in institutional management.

3.5.3 Digital infrastructure and the formation of future expectations

The results further demonstrate that digital infrastructure significantly influenced both user satisfaction and future expectations, thereby supporting existing literature which identifies digital transformation as a central strategic direction in university FM [53]. Efficient digital platforms, stable network connectivity, integrated administrative systems, and technology-supported learning environments have become increasingly important within contemporary higher education operations [54]. Notably, digital infrastructure exerted a comparatively stronger influence on future expectations than on present satisfaction. This finding suggests that users increasingly perceive digital services not merely as supporting tools for current campus activities, but as essential components of future university development. This pattern may reflect the long-term behavioural and organisational changes generated during the pandemic period. The expansion of blended learning, remote administration, and digital service delivery has increased both reliance upon and expectations towards digital FM systems [55]. Consequently, users may now evaluate campus quality not only through physical infrastructure, but also through the effectiveness, responsiveness, and integration of digital service environments. From a broader FM perspective, the findings suggest that digital transformation increasingly functions as a strategic mechanism shaping users' expectations, service standards, and perceptions of institutional capability. As users become more satisfied with digitally enabled FM services, their expectations for future intelligent and user-centred campus environments may continue to increase.

3.5.4 The mediating role of satisfaction in post-pandemic FM

The mediation analysis further demonstrated that overall satisfaction partially mediated the relationships between FM dimensions and future expectations. This finding provides empirical support for the SOR framework adopted in this study, in which users' perceptions of FM practices (stimuli) influence internal evaluative responses (organism), which subsequently shape behavioural and attitudinal outcomes (response).

More specifically, users' evaluations of spatial arrangement, health and safety, and digital infrastructure contributed to future expectations indirectly through satisfaction. This suggests that future expectations regarding FM development are not formed solely through direct evaluations of current services, but also through users' broader emotional and cognitive assessments of their campus experience.

The findings also extend expectation confirmation theory by demonstrating that satisfaction with current FM performance significantly shapes expectations regarding future FM improvement. In the post-pandemic context, users no longer evaluate campus facilities only in terms of functional adequacy, but increasingly in relation to adaptability, resilience, and digitally integrated service quality.

4.0 Conclusion

This study investigated the relationships among FM dimensions, user satisfaction, and future expectations within the post-pandemic context of UK universities. Drawing upon the SOR framework, the study examined how perceptions of spatial arrangement, health and safety, and digital infrastructure influenced satisfaction and future expectations regarding FM development. Using survey data collected from students and staff members across UK universities, the study employed reliability testing, exploratory factor analysis, robust regression, and Bootstrap mediation analysis to evaluate the proposed conceptual model.

The findings demonstrate that all three FM dimensions positively influenced both user satisfaction and future expectations. Among these dimensions, health and safety emerged as the strongest predictor of satisfaction and future expectation, highlighting the continuing importance of environmental health, hygiene, and institutional safety assurance in the post-pandemic university environment. Digital infrastructure also demonstrated substantial predictive effects, particularly in shaping users' expectations regarding future campus development, reflecting the increasing strategic importance of digitally integrated FM systems within higher education. Spatial arrangement exerted comparatively weaker, though still significant, effects, suggesting that users increasingly perceive effective spatial organisation as a foundational requirement rather than a distinctive determinant of satisfaction.

One of the study's principal theoretical contributions lies in demonstrating the mediating role of satisfaction between current FM perceptions and future expectations. The findings indicate that users' expectations regarding future FM development are shaped not only through direct evaluations of current services, but also through broader cognitive and affective responses to their campus experiences. In this respect, the study extends the application of the SOR framework and expectation confirmation theory within the context of higher education FM by empirically validating satisfaction as an important psychological and evaluative mechanism linking current service performance with future expectations.

Furthermore, the study contributes to the evolving FM literature by integrating spatial, environmental, and digital dimensions into a unified analytical framework. Unlike previous studies that focused primarily on operational efficiency or isolated FM dimensions, this research adopts a user-centred perspective that captures the multidimensional and dynamic nature of post-pandemic university FM environments.

From a practical perspective, the findings suggest that UK universities should increasingly adopt integrated and user-orientated FM strategies that balance environmental safety, digital transformation, and spatial adaptability. In particular, the strong predictive influence of health and safety indicates that visible environmental management measures continue to shape users' trust and confidence in institutional operations. At the same time, the growing influence of digital infrastructure highlights the need for universities to prioritise resilient and technology-enabled FM systems capable of supporting hybrid learning, digital administration, and data-driven campus services.

Despite these contributions, the study has several limitations. First, the relatively small and uneven sample distribution between students and staff may limit the generalisability of the findings. Second, the cross-sectional design restricts the ability to examine how user perceptions and expectations evolve over time. Third, the reliance on self-reported survey data may introduce common method bias and subjective evaluation effects.

Future research could address these limitations by adopting longitudinal research designs, expanding cross-institutional and cross-national comparisons, and incorporating objective FM performance indicators alongside perceptual survey data. Further studies may also explore additional psychological or organisational mechanisms influencing users' expectations regarding future FM development, particularly in relation to sustainability, digital governance, and intelligent campus management systems. Moreover, recent machine learning tools can be used to enhance the outcomes [56, 57, 58].

Author Contributions

Conceptualization, Yan Chen; methodology, Yan Chen; software, Junpeng Lyu; validation, Junpeng Lyu; formal analysis, Junpeng Lyu; investigation, Yan Chen; data curation, Yan Chen; writing—original draft preparation, Yan Chen; writing—review and editing, Yan Chen; visualization, Yan Chen; supervision, Junpeng Lyu; project administration, Michael Pitt. All authors have read and agreed to the published version of the manuscript.

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Data Availability Statement

The datasets generated and analysed during the current study are not publicly available due to privacy and ethical restrictions but are available from the corresponding author on reasonable request.

Conflicts of Interest

The authors declare no conflict of interest.

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