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Continuous briefing for the future university campus
An evidence-based approach to match spatial supply and demand

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Continuous briefing for the future university campus: an evidence-based approach to match spatial supply and demand

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Abstract

Purpose – To plan the future university campus, campus executives need decision-making support from theory and practice. Matching the static campus (supply) with the dynamic (demand) - while safeguarding spatial quality and sustainability - requires management information from similar organizations. This study presents an evidence-based briefing approach to support decision-makers of individual universities with management information when making decisions for their future campus.

Design/methodology/approach – For the proposed evidence-based briefing approach, the continuous Designing an Accommodation Strategy (DAS) framework is used in a mixed-method research design to evaluate the past to plan for the future. Five campus themes and three campus models (solid, liquid, and gas) are introduced to describe the development and diversification of university campuses and their impact across different university building types. Based on this theoretical framework, first, qualitative interview data are analyzed to understand which standards campus managers expect; second, a quantitative project database is used to demonstrate what is actually realized.

Findings – The findings demonstrate that remote working and online education will become more common. Academic workplaces and learning environments are more adaptive to changes than laboratory spaces. The analyses reveal different effective space use strategies to meet the current demand: they include space-efficient mixed-use buildings, and mono-functional generic educational and office spaces. These results show that operationalized evidence-based briefing can help design the future campus.

Originality/value – The study adds knowledge during a critical (post-COVID) period when decision-makers need evidence from others to adapt their campus management strategies to hybrid and sustainable ambitions.

Keywords Continuous briefing, PREM, DAS, Campus management, Evidence-based decision-making, Matching supply and demand, University

Paper type Research paper

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Introduction

Decision-makers in university (and college) management need support to plan the future campus. This need stems from the shared urgency to tackle global challenges, such as meeting the demand for diversifying campus functions, new digital technologies, and changes in financial schemes and student numbers (Den Heijer *et al.*, 2016; OECD, 2021a, b). Dutch universities acquired their campus real estate autonomy in 1995, when ownership was transferred from the government. Since then, student numbers and demand for non-academic functions on campuses have risen (TU Delft, 2018), while space use for primary campus activities, including education and office functions, has become much more efficient (Den Heijer *et al.*, 2016). The forced COVID-19 pandemic lockdowns and restrictions between 2020 and 2022 intensified these global challenges and impeded strategic decision-making in campus management, increasing the demand for relevant information (Valks *et al.*, 2021). These contingencies required multiple building adaptations over their life cycles; effective space use to match supply and demand became fundamental to Dutch strategic campus operations, which include both facility and public real estate management. (Arkesteijn *et al.*, 2015; Valks *et al.*, 2021; VSNU, 2020).

All the matters described above - the increasing pressure on spatial, functional, financial, and human resources on university campuses in general and in the case of the Netherlands in particular - are unique challenges of campus (space) management that aim to maximize effective use of campus real estate while responding to (current) changing institutional demands and future needs (Abdullah *et al.*, 2012; Rymarzak, 2014). Effective management of limited campus resources and facilities while planning and adjusting the space to future needs requires relevant management information about building programs and functional and physical standards from various reference projects (Abdullah *et al.*, 2012; Rymarzak, 2014). In this context, evidence-based decision-making, which aims to identify and optimize institutions' long-term goals concerning spatial and functional demands and sustainability interventions, has emerged as a critical strategic and operational activity in campus (space) management (Abdullah *et al.*, 2012; Curvelo Magdaniel *et al.*, 2019a; Den Heijer, 2011, 2021). Contemporary campus real estate portfolios, on the other hand, represent a wide range of spatial, physical, and functional diversity (related to numerous campus activities, including education, research, and administrative tasks) (Catalano *et al.*, 2023). This consequently poses a challenge to obtaining relevant management information for evidence-based strategic decision-making. Accordingly, universities strive for collaboration and knowledge exchange (Den Heijer, 2011) to ensure effective campus management.

Briefing, known as architectural programming in the USA (van Meel and Størdal, 2017), is a crucial process in project design and development that can facilitate such knowledge transfer for evidence-based decision-making. Facility management and real estate disciplines conduct briefing in various ways, leading to different perspectives, such as briefing as a stakeholder process, a decision-making process, a communication process to determine client requirements and expectations, or a cultural learning process (Jensen, 2011; Vahabi *et al.*, 2022; van Meel and Størdal, 2017; Jensen, 2011, ; Loosemore and Chandra, 2012). A brief is the output of these different processes, explored in three main categories: strategic, functional, and technical (Blyth and Worthington, 2010; Jensen, 2011; van Meel and Størdal, 2017).

Traditionally, a demand-led design brief with fixed requirements initiated a project and defined the supply response (Jensen, 2006, 2011; Nutt, 1993). Researchers have argued that this approach ignores user needs, post-occupancy management processes, and building performance. Essentially, it becomes problematic in tackling the continuous challenges of (large-scale) public real estate including university buildings, hospitals, museums, and libraries. Instead, they envision a dynamic briefing approach that identifies an organization's requirements and resources and matches them to long-term goals (Blyth and Worthington, 2010; Elf *et al.*, 2012; Jensen, 2006, 2011, 2012; Nutt, 1993). Others have suggested that this dynamic approach should adopt a holistic life cycle perspective supported by post-occupancy performance evaluations, feedback mechanisms, and project databases updated regularly for new data on reference buildings (Bogenstätter, 2000; Khosrowshahi, 2015; Bordass *et al.*, 2001; Den Heijer, 2011; Den Heijer *et al.*, 2023; Jensen, 2012; Shen *et al.*, 2012, 2013).

Alternative to the static demand-focused brief, Jensen (2006) calls this dynamic approach "continuous briefing", emphasizing that briefing is a process. Continuous briefing iteratively integrates past and current project input to enable knowledge transfer during the briefing process: post-occupancy evaluations of existing buildings are used to match demand and supply in the design and construction phases of new buildings (Jensen, 2012). The term later evolved into a building design phase component of the typology of transfer mechanisms developed by Jensen (2012, 2019). Several authors from FM and construction industry-related domains, more recently, developed frameworks concerning dynamic feedback and continuous knowledge transfer mechanisms of continuous briefing, such as New Value Adding Management, which is inspired by the Deming cycle aiming to reach an organization's desired goals (Van der Voordt and Jensen, 2021) or Pegoraro and Paula's "requirements process" (2017). However, these frameworks are conceptual. Other authors highlighted the importance of new technologies such as ICT and BIM (Jensen *et al.*, 2019) to utilize knowledge transfer between different projects; on the other hand, they also pointed out their limitations in operating solely as data-storing repositories. Nevertheless, the implementation and operationalization of continuous briefing warrant more evidence-based frameworks (Rasmussen *et al.*, 2017).

Aims and scope

Instead of considering the brief as a static document for public real estate in general and campus real estate in particular, this study focuses on the dynamic continuous briefing process (Jensen, 2006, 2011, 2012). This allows the brief to respond to contemporary university campus real estate's diversified spatial demand and supply requirements and support decision-makers of individual universities with information when making decisions for their future campus. To fill the demonstrated gap in the literature regarding the implementation and operationalization of continuous briefing, this study proposes a new, evidence-based briefing approach that matches the static existing campus supply for space with the dynamic campus demand by using Public Real Estate Management (PREM) and the continuous Designing an Accommodation Strategy (DAS) framework. The latter is a decision-making technique that balances supply and demand for long-term decisions and is used in PREM to assess the past and plan the future. The continuous DAS framework is operationalized via continuous backward evaluation and forward planning cycles, as illustrated in Figure 1. This evidence-based briefing ideally analyzes two campus data sources to feed the DAS cycles (Figure 1b). Qualitative interview data emphasizes (expected) developments on the demand side and their (potential) effect on the available supply of space; the quantitative project database shows how the supply side has evolved to accommodate the demand.

To operationalize the continuous DAS framework, first, the interview data from the campus managers of 13 Dutch universities in 2020 and 2021 (excluding the Open University) are analyzed to provide an overview of the current situation. These interviews were conducted during the lockdowns, which influenced their future campus vision. Second, 52 university buildings from the 2016 project database of all 14 Dutch universities (including the Open University) are analyzed to provide learning experiences on existing buildings' functional and physical characteristics for any future campus construction. Lastly, transformation patterns obtained from the analyses are discussed as a supplementary output to this briefing approach to illustrate the changing space requirements of the future campus and provide practical answers for decision-makers and facility managers.

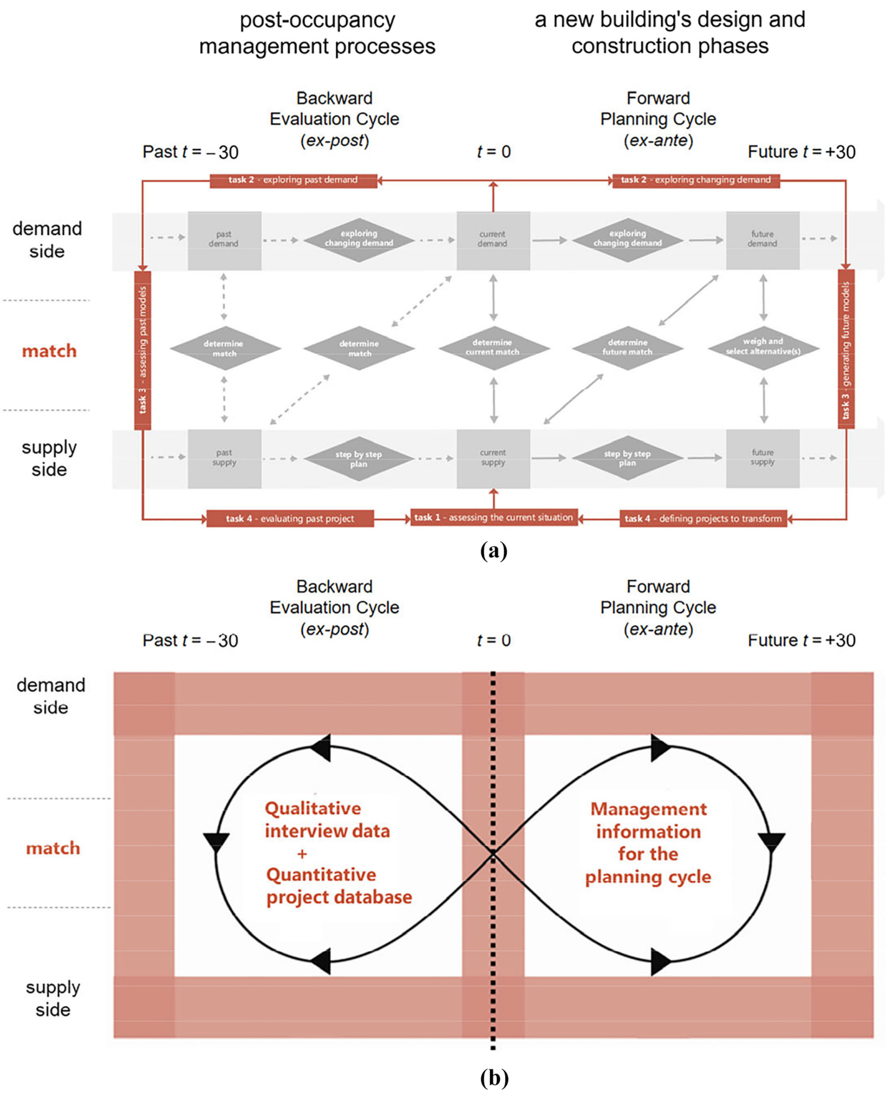

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Figure 1.
a) Continuous DAS framework with planning and evaluation cycles based on De Jonge *et al.* (2009) b) The simplified version of the continuous DAS framework, explained in the theoretical background, highlights the added information flows

Accordingly, the following research questions are addressed:

RQ1. Substantively, what kind of information and support can be provided for management through implementing evidence-based briefing (via the continuous DAS framework) to plan the future campus?

RQ2. Procedurally, in which ways can the proposed briefing approach contribute to theory and practice with the information and support it provides?

Theoretical background

Within this context, operationalizing continuous briefing (Jensen, 2006, 2011, 2012), representing the FM perspective, is accomplished by using two approaches which stand out among evidence-based supply and demand matching strategies. First, the continuous DAS framework, representing the PREM perspective (De Jonge *et al.*, 2009; Den Heijer, 2011, 2021), is used to create a continuous briefing framework. Second, campus themes and models are used further to operationalize this framework for implementation. Both angles enable knowledge transfer in strategic decision-making from a life cycle perspective, which evaluates the past to plan the future to support facility managers and decision-makers, particularly in tackling the continuous challenges of campus real estate management.

Continuous DAS framework. This study encompasses campus real estate in the Netherlands under the broader term of public real estate, which is also exemplified by other building types that share similar characteristics, including hospitals, museums, and libraries. These similar characteristics include having a public purpose, public funding, hosting a public function, and public accessibility (Van Der Schaaf, 2002; Den Heijer, 2021). Within this context, PREM is the management of public real estate portfolios to improve their performance by balancing organizational, financial, functional, and physical factors and connecting operational and strategic processes in portfolio decisions (Den Heijer, 2021).

In public and corporate real estate management, matching supply and demand is a long-standing issue (De Jonge *et al.*, 2009; Heywood and Arkesteijn, 2017). Dynamic demand is mostly determined on a time scale of three years against a static campus building supply that has lifespans of 20–50 years. “Supply” oftentimes denotes large-scale buildings generating high environmental impact and project and operating costs (Den Heijer, 2021). Heywood and Arkesteijn (2017) evaluated existing Corporate Real Estate alignment models that are, or can be, used in PREM and developed a comprehensive theory, identifying the organizational value co-produced by (corporate) real estate (supply) and organizational strategies (demand). They suggest that framework models, which use a simple geometrical structure offer more strategic and flexible alignment, by setting an overall, future-shaping direction with systematic, tactical, and operational evidence-based decision-making and feedback tools and techniques employed in delivery.

Providing continuous improvement via such tools and techniques, integrated into an organization’s strategy, has been an integral part of contemporary debates on management models in general and PREM/CREM and FM frameworks in particular (Van Der Schaaf, 2002; Alauddin and Yamada, 2019; Van der Voordt *et al.*, 2016). Correspondingly, for this study the DAS, which is often used in PREM, is selected. DAS is an evidence-based, four-step technique for multi-level decision-making to balance supply and demand at the operational and strategic levels for long-term decisions (Den Heijer, 2021). The original DAS framework focuses on the future via the forward planning cycle (ex-ante) (as shown on the right side of Figure 1 a) to match the supply of and demand for space (De Jonge *et al.*, 2009; Den Heijer, 2011, 2021; Riratanaphong, 2021; Van der Zwart *et al.*, 2009). This framework moves along two axes, from demand to supply (down the vertical axis) and from current to future (left to right on the horizontal axis), it addresses four key issues: (1) “What we need” versus “what we have”: determines the mismatch between current demand and current supply; (2) “What we need in the future” versus “what we have now”: determines the (mis)match between future demand and current supply; (3) “Alternatives of what we could have”: design, evaluate, and select solutions for the mismatch; (4) “Step-by-step plan to realize what we want to have in the future”, i.e. how to transform the current supply into the selected future supply (De Jonge *et al.*, 2009; Den Heijer, 2021; Van der Zwart *et al.*, 2009). This framework assesses the current situation at different levels (i.e. the overall campus real estate situation, the campus at the portfolio level, and the building level within a campus portfolio).

To operationalize continuous briefing, this research used the continuous DAS framework, conceptualized by Den Heijer (2021). The continuous DAS framework resembles the iterative, four-step Deming (also known as Plan-Do-Check-Act) Cycle in total quality management. This cycle helps ensure the continuous improvement of processes and products to support organizations in making evidence-based decisions (Van der Voordt and Jensen, 2021). Corresponding to the iterative continuous improvement cycles of the Deming cycle aiming to reach an organization's desired goals, the continuous DAS framework adds the backward evaluation cycle (ex-post) that evaluates the past (as shown on the left side of Figure 1a) to the original DAS framework with the forward planning cycle (ex-ante). Changing the questions, accordingly, such as (1) "What did we need" versus "What did we have": shows the mismatch between past demand and past supply at a particular time. Based on these cycles, the continuous DAS framework equally looks at the past and the future within 30 years (Figure 1) to evaluate the past and plan the future in the long term. While the backward evaluation cycle (ex-post), illustrated between $t = -30$ and $t = 0$, facilitates the post-occupancy management processes in practice, the forward planning cycle (ex-ante), illustrated between $t = 0$ and $t = +30$, supports the design and construction phases and provides management information for the planning cycle. From a practice-based perspective, these cycles of the DAS framework enable applicable methodological points to develop evidence-based planning strategies for the future campus and support facility managers in coping with the continuous functional, financial, and demographic change.

The mixed-method research design used to implement the continuous DAS framework based on the qualitative interview data and the quantitative project database is explained in the materials and methods section.

Campus themes and models. To further operationalize this theoretical design, this study utilizes campus themes and models developed by Den Heijer (2011, 2021), Den Heijer *et al.* (2016) for two reasons: first, to elaborate on the development and diversification of university campuses, and second, to focus on the impacts of campus trends across different space types at universities. Campus themes and models have been designed to set out universal parameters of the general campus environment via similar trends and strategies observed in different international contexts (Curvelo Magdaniel *et al.*, 2019b). In this study, they are applied to the case of the Netherlands via the analyses of the qualitative interview data and the quantitative project database. The generalizable strategies and recommendations derived from the analyses are set out in the discussion section.

Below, brief definitions of the campus themes and campus models are presented.

Campus themes. In addition to the campus models, the five campus themes below, are selected from various publications (Den Heijer *et al.*, 2016; Den Heijer, 2021), as the basis for space configurations with the purpose of aligning the functional and physical variables of the qualitative interview data with the quantitative project database. This part of the mixed-method research design will be explained in the following section.

Theme-1 Changing the academic workplace. Theme-1 focuses on the academic workplace (including open and closed office spaces, meeting places, and related on-campus businesses), which occupies one-third of Dutch university campuses (Den Heijer *et al.*, 2016).

Theme-2 Creating a hybrid learning environment. Theme-2 is about educational facility developments. The increasingly centralized educational buildings that serve the whole university include lecture halls, classrooms, and study and exam spaces.

Theme-3 Renewing faculty home bases. Faculty buildings are a specific mixed-use building type much larger than the average building size (Den Heijer, 2021). Multi-functional faculty buildings are strategic (long-term) campus assets, demanding careful decision-making due to their large scale (Den Heijer, 2021).

Theme-4 Investing in state-of-the-art laboratories. Theme-4 encompasses the core on-campus research infrastructure, including laboratories and related on-campus businesses such as start-ups. The specialized laboratory functions demand high investment and operating costs (Den Heijer, 2021).

Theme-5 Enriching the campus with non-academic functions. The formerly mono-functional university campuses have become multi-functional urban complexes (Den Heijer, 2021), including residential, retail, and infrastructural amenities.

Campus models. Over the years, three models have summarized the development and diversification of university campuses, distinguishing territorial, shared, and off-campus space use and the degree of mobility and cohesion of campus users; the names refer to the three physical states of matter (Den Heijer, 2021, p. 49):

The **Solid** model represents the traditional university and campus – fixed structures, hierarchy, exclusiveness, and the need for territory.

The **Liquid** model represents the network university and campus – flexible structures, multidisciplinary, and open and interconnected shared campus spaces.

The **Gas** model represents the virtual university and campus – individual autonomy, mobility, and freedom to work and study anytime and anywhere, online and off-campus.

The interviews were conducted during the coronavirus crisis, when university activities were predominantly accommodated in the gas state due to campus lockdowns. In the analyses, the general trends from the crisis' possible impact are separated.

Following the theoretical background based on the continuous DAS framework and campus themes and models, the subsequent section focuses on the research design, empirical material, and analyses.

Materials and methods

This study aims to operationalize continuous briefing via an evidence-based approach to plan the future campus. To achieve this objective, it explores the continuous DAS framework. The backward evaluation cycle is executed by analyzing the qualitative interview data and the quantitative project database. These resources provide evidence-based management information for the forward planning cycles (Figure 1b). Such an approach requires a mixed-method research design (Creswell and Clark, 2017), as explained below. In Figure 2, a procedural flow chart for the continuous DAS framework is provided to summarize the theoretical framework, materials and methods, and analyses results.

Mixed-method research design

Increasingly used in real estate studies (Bollo, 2019; Christensen *et al.*, 2016), mixed-method research integrates qualitative and quantitative methodologies and provides more evidence than single-method studies (Bergin, 2018; Creswell and Clark, 2017; Molina-Azorin, 2012).

This study equated the qualitative interview data and the quantitative project database (via expansion and complementarity) to probe the research topic (Molina-Azorin, 2012). The typology development approach interconnected the interview data and the project database (in which nexus analysis of the former provided a framework to analyze the latter) (Creswell and Clark, 2017). The interview data were subjected to qualitative content analysis, and the project database was interrogated through cluster analysis. The comparison of the analyses provided management information about matching the static supply and dynamic demand within a process of continuous briefing.

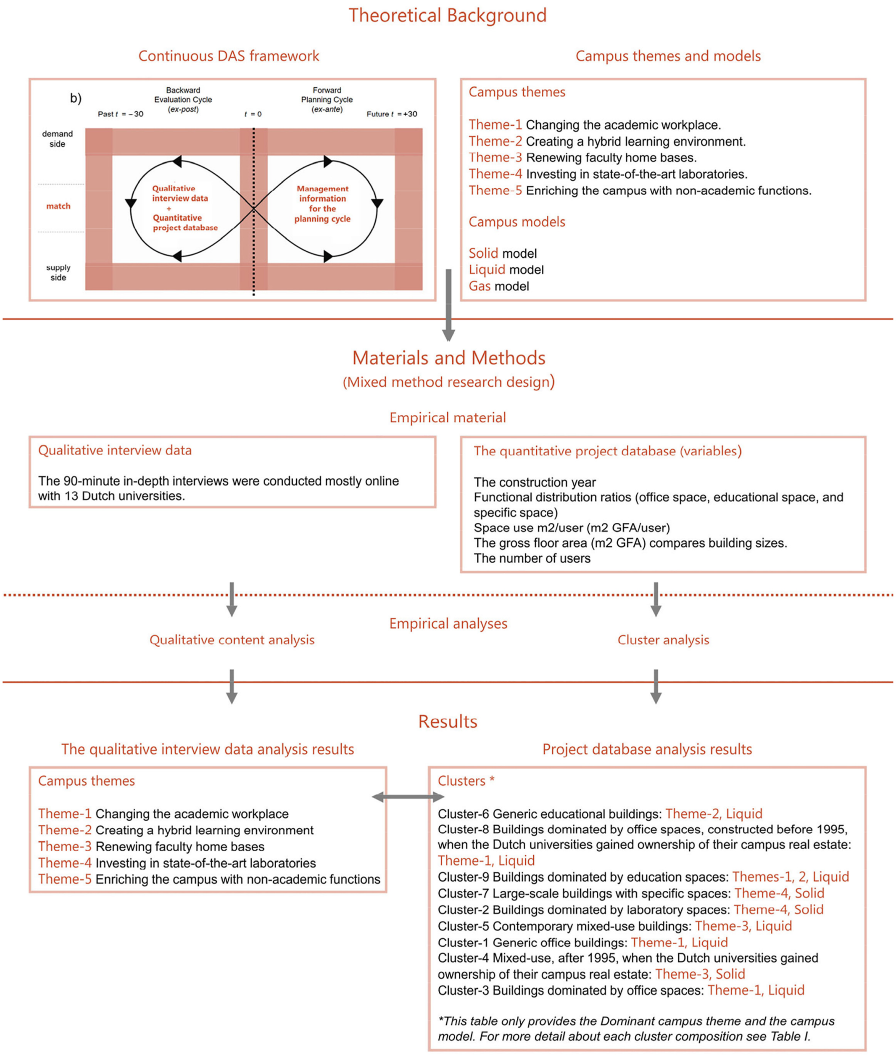

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Figure 2. Procedural Flow Chart for the continuous Designing an Accommodation Strategy (DAS) framework

Empirical material

Qualitative interview data. The interviews tapped the real estate challenges which Dutch universities have recently faced, mainly centered around the continuous functional, financial, and operational challenges of campus management. They were conducted during the lockdowns between October 2020 and January 2021, a period when the COVID-19 pandemic's unpredictability worsened these challenges and increased the demand for evidence-based decision-making. The 90-min in-depth interviews were conducted mostly online with 13 Dutch universities (excluding the Open University due to its different educational methods and campus setting) (Supplementary material 1, Table I). Expertise in the subject matter was the main interview criterion. Thirty campus experts (real estate and facility directors, their assistants, and policy officers) participated, providing an adequate sample size. The attendees were informed of the interview content and purpose beforehand and were assured of anonymity. Due to the nature of the research, recorded verbal consent was deemed sufficient. At the beginning of each interview, participants verbally consented to the data collection and their quotes being used in this article. These consents were recorded.

The quantitative project database. Performance data on campus buildings should support strategic decision-making in campus management (Den Heijer, 2011). The project database (a management information source to benchmark campus projects) was initiated in 2005 based on demand from the Dutch university network VSNU (currently UNL: Universiteiten van Nederland) and has been updated several times, with the last update in 2016. It includes 64 projects from all 14 Dutch universities and 19 building attributes. To evaluate the past in the long term, as suggested in the DAS framework via the backward evaluation cycle (Figure 1), the project database includes both recent projects as well as projects constructed around 30 years ago.

Several iterations of control mechanisms were applied during the data collection and analysis phases to ensure the quality, validity, and reliability of the quantitative project database. During the data collection phase, these included site visits, comparisons with similar buildings for benchmarking and triangulation, and meetings with campus managers. Researchers selected variables from the project database that different institutions within the university can objectify and validate, ensuring further data validity and reliability during the data analyses. Subsequently, preprocessing (such as the identification of outliers and data cleaning) and multiple cluster validation techniques were applied. “Empirical analyses” subsection elaborates on these techniques. Two internal and one external expert carefully interpreted the analysis results to ensure consistency within the clusters and compliance with the research objectives. The integration of quantitative measures with expert assessments led to a deeper understanding of the analysis results. Subsequently, researchers created cluster descriptions to effectively communicate the results of the cluster analysis. These descriptions are presented in the “Project database analysis results” subsection of the “Results” section and further comprehended in the “Discussion” section.

The five functional and physical variables that were selected (based on Dutch standards NEN2580 [m^2]) matching the campus models and themes include:

(1) The construction year (demonstrating the initial building year for new projects and the last major renovation year for heritage buildings) assesses spatio-temporal change.

(2) Functional distribution ratios (office space, educational space, and specific space) evaluate building typologies by function and connect clusters obtained from the project database analysis to campus themes.

(3) Space use m^2/user (m^2 GFA/user) assesses the effective space use to match the clusters with the campus models. A smaller m^2 GFA/user indicates the liquid model.

(4) The gross floor area (m^2 GFA) compares building sizes.

(5) The number of users, including both staff and students as permanent occupants, determines the planned building capacity.

In the project database, laboratories, which match Theme-4 Investing in state-of-the-art laboratories, and recreational spaces, which match Theme-5 Enriching the campus with non-academic functions, are categorized as specific spaces. When necessary, internet sources were checked to differentiate these spaces. Faculty functions were also validated via the internet. A list of these web resources (for each building) is provided in Supplementary material 1, Table II List of Internet Resources.

Empirical analyses

Qualitative content analysis. In the qualitative content analysis, the five campus themes provide the overarching concepts, and the content of each is arranged according to the three campus models to express how general trends are expressed differently in each theme. Atlas.TI V9 was used for the data analysis stages that involve familiarizing, coding, and categorizing. Deductive coding is applied for cross-checking and corroboration of the analysis results (Bergin, 2018; Ding *et al.*, 2007). A second researcher checked the produced material (including codes, quotes, and themes), while an external researcher conducted the inter-coder reliability (O'Connor and Joffe, 2020).

Cluster analysis. Physical and functional patterns in a project database help to convey the state of campus building supply. This study uses cluster analysis, which is a multivariate unsupervised data mining technique (Kassambara, 2017; Tardioli *et al.*, 2018). Cluster analysis identifies patterns of homogenous groups in a dataset (Gross and Źróbek, 2015).

Building information (Aerts *et al.*, 2014; Li and Chen, 2021; Ma *et al.*, 2017; Schaefer and Ghisi, 2016; Tardioli *et al.*, 2018) and PREM studies (Chinyio *et al.*, 1998; Gross and Źróbek, 2015) have applied cluster analysis. The most common clustering types are *K-means* clustering and hierarchical clustering. Hierarchical clustering integrates single items into bigger groups from the bottom up (Ma *et al.*, 2017). Unlike K-means, hierarchical clustering does not predetermine the number of clusters (Li and Chen, 2021). The results are displayed in a dendrogram to represent the multi-level cluster hierarchy (Kassambara, 2017). In the dendrogram, the vertical lines depict the groupings: more distant groupings are less similar, and the horizontal cutline of the dendrogram determines the cluster numbers (Ma *et al.*, 2017).

Data preprocessing. Preprocessing data improves cluster analysis performance. Mahalanobis Distance was used to detect outliers in multivariate analysis. The observations with p-values of less than 0.001 were deleted from the database based on the Mahalanobis Distance (Schaefer and Ghisi, 2016; Tabachnick *et al.*, 2007). In total, 12 observations with missing data points or outliers were deleted, leaving 52 observations for analysis.

Analysis adjustments. Factoextra (Kassambara and Mundt, 2020) and cluster packages (Maechler *et al.*, 2022) were used to implement Cluster analysis in R (R Core Team, 2022). The Agglomerative Nesting (Agnes) function was used to compute the agglomerative coefficient for each clustering linkage method to determine the rules to unify two clusters in a dendrogram (Aerts *et al.*, 2014).

Based on the results, Ward's method that "minimizes the total within-cluster variance" (Kassambara, 2017, p. 71) was applied (Supplementary material 2, Table I). Ward's method merges cluster pairs with a minimum between-cluster distance at each step (Kassambara, 2017). The similarity between clusters was measured using the Euclidian distance (Gross and Źróbek, 2015; Schaefer and Ghisi, 2016).

Cluster validation. Cluster validation ensures the reliability of the analysis. This study applied the internal validation method in the "clValid" function (Brock *et al.*, 2008) and the average silhouette width method (Supplementary material 2, Table II, Figure 1) to determine the number of clusters. In the internal validation method, nine clusters provide the optimum result, with the highest Dunn and Silhouette index values and the lowest connectivity index value. The average silhouette width method suggests eight clusters. The dendrogram provides cutlines for eight and nine clusters (Figure 3). For an even distribution of observations among the groups, nine clusters were chosen as suggested by the internal validation method.

Results

Based on the research design, empirical material, and empirical analyses explained in the previous section, this part initially discusses the qualitative interview data analysis results to

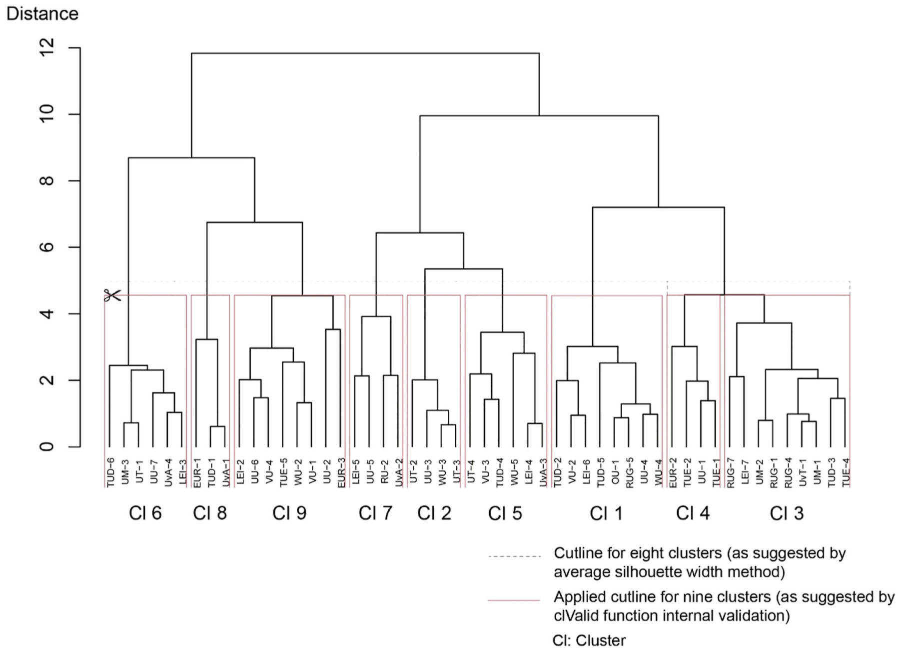

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Figure 3.
Demonstrates the dendrogram, where the vertical lines depict the groupings and the more distant groupings are less similar. Two horizontal cutlines here represent the cluster validation techniques used for this study. The internal validation, which provides nine clusters, is selected for the analysis results

assess the current transition patterns of the university campuses. Subsequently, the quantitative cluster analysis results demonstrate the functional and physical transformation patterns of campus buildings. Together, these results demonstrate that implementing the continuous DAS framework, as suggested in the first question, can provide management with information and support. The "Discussion" section further elucidates these results by offering additional insights into the study's theoretical and practical contributions.

The qualitative interview data analysis results

The interview data analysis showed how each campus theme reflected differently the continuing changes on university campuses. To highlight these differentiations, the content of the themes is structured according to the three campus models. The following subsections describe these changes per theme.

Theme-1 Changing the academic workplace. Office spaces are the dominant functional type on Dutch university campuses (Den Heijer *et al.*, 2016). Office space interventions can affect campus staff and lead to resistance to change.

The traditional workplaces are valued for their experiences of "the club feeling" and "community belonging," supporting on-campus working: *"People come to the club they like, not to an anonymous office landscape. You want to have the feeling of your involved group"* (8:41). However, the respondents said workplaces are becoming liquid: *"We have traditional workplaces but also shared facilities"* (19:38). Reducing *"the old way of working"* (19:2) and creating a hybrid working environment that is "*more shared [and] partly at home*" (15:2) define the future of the workplace. These shared workspaces (such as attractively designed common rooms) replace solid workspaces (such as private rooms). Campus managers respond to the changing demand with a variety of on-campus workplaces: *"Some like to work* *together, the others prefer individually. If all goes well, both are possible, and it will become an organic process, which differs per department"* (9:34).

Universities have created incentives and rules to promote remote working: *We also have an incentive for people to work from home; the reimbursement for travel expenses shifts to a work-from-home allowance* (15:15). However, remote working reduces interaction and physical activity; hence, it is a downside of the gas model. Moreover, keeping an on-campus office space while remotely working increases the number of workplaces and confronts decision-makers with limited resources. Universities aim to benefit from all models while avoiding their downsides.

Theme-2 Creating a hybrid learning environment. For the last decade, there has been a trend towards liquid learning environments with more shared study places: "*The learning environment is also gradually moving from solid to liquid*" (13:38). Accordingly, contemporary educational buildings serve the whole university, not specific groups or faculties. This solid-to-liquid transformation results in flexible central facilities shared throughout faculties to balance student numbers: *"We have more than 200 lecture rooms, and they are located in a central pool"* (14:3). Such buildings demand flexibility at the room level: *"We are building a new education building. Here, we have tried to give even more [weight] to the flexibility of the layout of the rooms. How can you build in such a way that halls can become larger or smaller very quickly?"* (21:5). Campus lockdowns also showed the need for flexibility to provide online and face-to-face engagement in education at the same time. Campus administrators, however, struggle with occupancy rates and time-sharing despite the increasing number of shared areas.

Decision-makers recommend online teaching associated with the gas model for large-scale lectures which lack interaction and teamwork. Concurrently, decision-makers promote on-campus meetings, studying, and education for their social value. They also consider urban facilities in student neighborhoods as potential educational spaces.

Theme-3 Renewing faculty home bases. The respondents indicate that *"faculties want their facilities"* (17:7), demonstrating the demand for ownership of a home base. Therefore, unlike offices and educational spaces, faculty buildings mostly belong to the solid model. Nevertheless, the demand for liquid faculty buildings is increasing: *"Buildings belong to the university and not to the faculty"* (18:6). Trade-offs are necessary for the solid-to-liquid transformation of faculty buildings. *"We have to go down to fewer square meters, and what we build next has to be of high quality and optimally support the primary process"* (18:13). The respondents also acknowledge the adaptive reuse potential of faculty buildings, the largest facilities in campus portfolios (Den Heijer, 2021). Consequently, creating collective facilities requires multi-functionality and flexibility.

Theme-4 Investing in state-of-the-art laboratories. Due to the limited sharing options, *"the laboratories are still very solid"* (13:39) with ineffective space use patterns. Several respondents addressed the actions to increase laboratory use: *"We do not build laboratories for one faculty. We build laboratories for those who use them"* (20:9). Meanwhile, the growing need for laboratories, combined with financial restrictions, has increased space-sharing and faculty partnerships, leading to more liquid laboratories: *"We now have a collaboration between four faculties, and these are shared labs. These are institutes where knowledge about the faculties is brought together and where people work together"* (10:36). However, unique laboratory functions and safety and security issues hamper sharing laboratories. [1] Therefore, laboratories' solid-to-liquid transition is slower than office and educational spaces: *"We still have some small computer labs that are very faculty-bound. They have [a] low occupancy, so not much is going on here with us; the urgency for sharing is not great"* (14:24).

Theme-5 Enriching the campus with non-academic functions. The burgeoning non-academic functions, including decentralized university restaurants (replacing faculty restaurants), cafés, food trucks, start-ups, student housing, and research facilities for campus-based companies, demonstrate a dynamic solid-to-liquid transformation at campuses. As one respondent remarked, *"It is not the case that every faculty wants its own canteen. Provision is spread across the campus. Food trucks also offer extra during peak times"* (10:22). Such facilities also increase the number of shared spaces on campus and attract more third-party businesses.

In the gas model, these non-academic functions are performed online or off-campus. Science parks are one type of off-campus venues, which facilitates company and start-up cooperation. Infrastructure networks (such as fast cycle routes) can effectively integrate urban non-academic functions with the university campus. Thus, in all but exurban or isolated campus contexts, decision-makers should avoid duplicating urban functions on campuses.

Project database analysis results

The cluster analysis of the quantitative project database reveals patterns concerning buildings' functional and physical characteristics. Figure 3 shows the dendrogram with two main groups, based on the m^2 GFA/user ratio and the specific space ratio. The clusters in the first group (Clusters-6, 8, and 9) have the smallest m^2 GFA/user ratio means (between 6.1 and 7.7) and comprise 32.7% of the database. The clusters in the second group (Clusters-7, 2, 5, 1, 4, and 3) have much higher m^2 GFA/user ratio means (between 15.8 and 41) and constitute 67.3% of the database. The specific space ratio mean is almost negligible in the first group (between 0 and 0.04), while Clusters-8 and 9 have the highest user number means. This outcome indicates that decision-makers excluded the specific functions (essentially the technical and laboratory functions) to use space effectively.

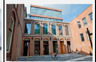
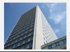
The following section discusses the nine clusters, each with a name that stems from its distinctive characteristics. The clusters are presented based on their order in the dendrogram. Table 1 summarizes the assigned campus themes and models for each cluster and the mean values of the five variables for all clusters. The highest and lowest values are bolded in the table. Some clusters match one theme from the interview data analysis, whereas others span multiple themes.

Cluster-6 Generic educational buildings. Cluster-6 relates to Theme-2 and the liquid model. Cluster-6 (Table 1) has the highest educational space ratio and the lowest m^2 GFA/user ratio. Therefore, Cluster-6 represents generic central education buildings that serve different faculties and symbolize development strategies that transcend faculty-bound educational programs.

Cluster-8 Buildings dominated by office spaces, constructed before 1995, when the Dutch universities gained ownership of their campus real estate. Cluster-8 is associated mainly with Theme-1 and the liquid model due to the high ratio of office spaces and low m^2 GFA/user ratio. The buildings in this cluster also include educational spaces; therefore, it is also identified with Theme-2 and Theme-3 (due to its mixed-use composition).

The average year of construction of the buildings included in this cluster is 1991 (Table 1), and were constructed before 1995, the year when ownership of the Dutch universities' real estate was transferred from the government to the universities. The low m^2 GFA/user ratio demonstrates that effective space-use strategies were already in place before the ownership exchange in 1995.

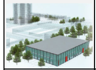
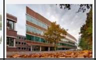
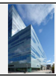
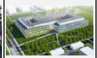
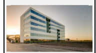
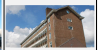
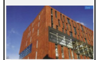
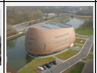
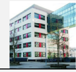
Cluster-9 Buildings dominated by education spaces. Cluster-9 (Table 1) is linked to Theme-2 and the liquid model due to the high educational space ratio, the highest user numbers, and a low m^2 GFA/user ratio, respectively. The mixed-use composition (Theme-3), which includes office spaces (Theme-1) and excludes specific spaces, increases the effective space use of the large-scale buildings in Cluster-9.

Cluster Title	Dominant campus themes [1]	Other identified campus themes	Campus model	Construction year	m2 GFA	Functional distribution ratios			Number of users	m2GFA/user	Number of observations	Percentage of the cluster within the quantitative project database
						Educational space	Office space	Specific space				
Cluster 6 Generic educational buildings	Theme-2	-	Liquid -	2010	5467	**0.36**	**0.08**	0.04	904	**6.1**	6	11.5%
				 **UU-7** Drift 25	 **UM-3** Zwingelput 4	 **UvA-4** UAC - new	 **TUD-6** Pulse	 **LEI-3** Schouwburgstraat	 **UT-1** Noord &Oost Horst			
Cluster-8 Buildings dominated by office spaces, constructed before 1995, when the Dutch universities gained ownership of their campus real estate	Theme-1	Themes-2, 3	Liquid	1991	14375	0.10	0.38	**0.00**	3029	6.8	3	5.8%
				 **TUD-1** TBM Faculty	 **UvA-1** REC-E Faculty	**EUR-1** L-Building						
Cluster-9 Buildings dominated by education spaces	Themes-1, 2	Theme-3	Liquid	2007	24629	0.21	0.23	0.02	**4110**	7.7	8	15.4%
				 **TUE-5** Metaforum	 **UU-6** Buys Ballot	 **WU-2** Forum Building	 **VU-1** OZW Building	 **VU-4** Initium	 **LEI-2** Kamerlingh Onnes	 **UU-2** Hijmans van den Bergh	 **EUR-3** T-Building	
Cluster-7 Large-scale buildings with specific spaces	Theme-4	Themes-1, 3	Solid	2009	**48563**	0.06	0.17	0.21	1480	**41.0**	4	7.7%
				 **LEI-5**	 **UU-5**	 **RU-2**	 **UvA-2**					

(*continued*)

Table 1. Campus themes, campus models, and mean values per variable for all clusters and the buildings included in each cluster (in grey)

Table 1.

				Sylvius	Kruyt Building	Huygens	FNWI faculty					
Cluster-2 Buildings dominated by laboratory spaces	Theme-4	Theme-1	Solid	2007	6742	0.03	0.19	**0.33**	**178**	39.3	4	7.7%
												
				UT-2	**WU-3**	**UU-3**	**UT-3**					
				West Horst	Rikilt	Jeanette Donker-Voet	Meander					
Cluster-5 Contemporary mixed-use buildings	Theme-3	Themes-1, 2, 4, 5	Liquid	2012	20513	0.15	0.16	0.30	1344	15.8	6	11.5%
												
				LEI-4	**UvA-3**	**VU-3**	**TUD-4**	**UT-4**	**WU-5**			
				Sterrewacht	REC-D	ACTA Building	TNW	Carre Building	Orion			
Cluster-1 Generic office buildings	Theme-1		Liquid	2009	**5192**	**0.00**	**0.47**	0.04	187	24.7	8	15.4%
												
				TUD-5	**VU-2**	**UU-4**	**TUD-2**	**LEI-6**	**OU-1**	**WU-4**	**RUG-5**	
				Yes!Delft	Optopping (extra floor) W&N Building	Drift 10	L&R extension	Willem Einthoven	M. Keynes Office	Actio	FEB Offices	
Cluster-4 Mixed-use, after 1995, when the Dutch universities gained ownership of their campus real estate	Theme-3	Theme-1, 2, 4, 5	Solid	2000	21143	0.13	0.20	0.16	984	27.2	4	7.7%
												
				EUR-2	**UU-1**	**TUE-1**	**TUE-2**					
				J-Building	NITG Building	Helix	Vertigo Faculty					
Cluster-3 Buildings dominated by office spaces	Theme-1	Theme-2, 3	Liquid	2007	7862	0.10	0.21	0.02	484	17.0	9	17.3%
												
				RUG-7	**UM-2**	**LEI-7**	**RUG-1**	**TUD-3**	**TUE-4**	**TiU-1**	**RUG-4**	**UM-1**
				Eriba	Bonnefantenstraat 2	Anna van Bueren	Smitsborg	Mijnbouwstraat 120	Black Box	E Building	Bernoulliborg	UNS 60 Building

Note(s): The campus themes and models are explained in the "Theoretical background" section and summarized in the procedural flow chart on the continuous DAS framework in Figure 2
Source(s): Table and images by authors and corresponding universities

Cluster-7 Large-scale buildings with specific spaces. Cluster-7 (Table 1) identifies with Themes-1, 4, and 3, and signifies a solid model since it has the highest m^2 GFA and m^2 GFA/user ratio. The specific spaces included in Cluster-7 negatively impact overall space use. Cluster-7 has a low educational space ratio compared with the mixed-use clusters (such as Clusters-4 and 5).

Cluster-2 Buildings dominated by laboratory spaces. Cluster-2 (Table 1) is identified mainly with Theme-4 (in which territorial areas, such as laboratories, for specific end-user groups dominate over buildings) and the solid model. It comprises the highest specific space ratio, the lowest user numbers, and a high m^2 GFA/user ratio. This cluster contains small-scale buildings with low m^2 GFA and also includes office spaces (as identified with Theme-1).

Cluster-5 Contemporary mixed-use buildings. Cluster-5 identifies with all five themes and the liquid model (Table 1). It has moderate m^2 GFA, educational, and office space ratios, but a high specific space ratio. The mixed-use composition and the m^2 GFA of this cluster resemble Cluster-4, while the specific space composition is higher than Cluster-4.

A comparison of Cluster-5 with other clusters. Clusters-2, 4, and 7 have high specific space ratios and m^2 GFA/user ratios (specific space ratios and m^2 GFA/user ratios of these clusters are 0.16/27.2, 0.33/39.3, and 0.21/41.0, respectively). Despite the high specific space ratio (0.30), Cluster-5 has a smaller m^2 GFA/user ratio (15.8). Therefore, Cluster-5 signifies a new liquid model in mixed-use buildings. Two strategies could decrease the m^2 GFA/user ratio, making such mixed-use compositions or more liquid buildings. First, including non-academic functions rather than laboratories leads to more shared spaces. Increasing non-academic functions, such as rentable office spaces and recreational functions, also help decision-makers readapt large-scale faculty buildings. Second, blending laboratories with educational space optimizes the space use in campus buildings. Lastly, unlike Cluster-6, Cluster-5 demonstrates that teaching and research cannot be completely separated; hence, mixed-use campus buildings will always be needed.

Cluster-1 Generic office buildings. Cluster-1 (Table 1) is identified with Theme-1 and the liquid model. The buildings included average the highest ratio of office spaces within the project database. The mono-functionality of this cluster resembles that of Cluster-6; both representing generic buildings used by different user groups and faculties as identified with the liquid model.

Cluster-4 Mixed-use, after 1995, when the Dutch universities gained ownership of their campus real estate. Cluster-4 is associated with Theme-3 because it includes all themes and signifies the solid model with low user numbers and a high m^2 GFA/user ratio. Cluster-4 (Table 1) represents buildings constructed right after the ownership exchange.

Cluster-3 Buildings dominated by office spaces. Cluster-3 (Table 1) is identified with Theme-1 and the liquid model (due to the medium m^2 GFA/user ratio in Cluster-3). This cluster is also associated with Theme-2 and Theme-3 due to the co-existence of educational functions. Clusters-3 and 9 comprise buildings with office and educational spaces, but not specific spaces. However, the differences in m^2 GFA, number of users, and m^2 GFA/user ratios of these two clusters generate different footprints.

Discussion

The evidence-based five themes and nine clusters (summarized via Figure 2 and Table 1) are the results of the qualitative interview data and the project database analyses based on the campus themes and models and, concerning space usages they contribute to, knowledge on (matching) the static supply and the dynamic demand to plan the future campus. Subsequently, the discussion section assesses these findings within the context of continuous briefing and the continuous DAS framework.

The continuous brief for the future campus

Supporting a university's real estate decisions with data from other universities can contribute to campus management. Thus, this study's main contribution is an evidence-based briefing approach to provide management information in order to evaluate the past and plan for the future via knowledge transfer. To this end, the continuous briefing, representing the FM perspective, has been operationalized using the continuous DAS framework (Figures 1 and 2). To implement this framework, the qualitative interview data and quantitative project database were analyzed. These themes and clusters (as the result of the analyses) feed into the briefing cycles of the continuous DAS framework (Figures 1 and 2) and provide collective management information (about matching the static supply and dynamic demand) for decision-makers. Therefore, the suggested approach links theory and practice. The findings coincide with those of Riratanaphong (2021), who demonstrated that the DAS framework provides management information for strategic decision-making.

Planning strategies for the future campus

The interviews were conducted around the campus lockdowns (2020–2021) when the gas model was experienced intensively, although it had emerged recently at such a large scale. Conversely, universities have experienced the solid model for centuries and the liquid model for decades (Den Heijer, 2021). Campus decision-makers can now evaluate all three evidence-based models to plan the future. The analytic results presented in the previous section based on the continuous DAS framework highlight different dimensions of the Dutch university campuses' current transformation patterns and respond to the fundamental research questions (RQ1 and RQ2) posed in the introduction concerning the kind of information and support that can be provided via the evidence-based briefing approach (operationalized via the continuous DAS framework) and the potential contribution of this approach to theory and practice. These results are discussed based on the three campus models and, subsequently, the transformation patterns addressed below, and they are further elucidated in the following subsections with respect to research questions.

Solid. Though the solid model supports community belonging and an inclusive academic workplace, it has drawbacks, including inefficient space use (concerning Themes-1, 3, and 4 and Clusters-2, 4, and 7). In the project database analysis (Table 1), the m^2 GFA/user ratio increases in buildings with laboratory spaces, as demonstrated in Cluster-2, and leads to a "solid" expression. However, Cluster-5 (Table 1), which comprises more recent buildings with laboratory spaces, has a lower m^2 GFA/user ratio, and it is identified with the liquid model. These findings demonstrate that solid is still valued, but fewer solid buildings are constructed.

Liquid. Since the forced campus lockdowns (100% gas), the focus has returned to the liquid model that facilitates on-campus interaction. The transition towards more shared work and educational spaces, observed in the interview data analysis, validates this trend. As demonstrated in the cluster compositions (Table 1), the project database analysis supports this argument at the building level. As evidenced in monofunctional Clusters-1 and 6 (generic office and education buildings with low m^2 GFA/user ratios, Table 1), buildings in these clusters are shared by different user groups and faculties across the university.

The solid-to-liquid transformation of laboratories is slower compared with office and educational spaces. Cluster-5 demonstrates that mixing laboratory spaces with office and educational spaces decreases m^2 GFA/user ratios while increasing effective space use. Whereas Cluster-5 points to an increase in non-academic building functions, respondents particularly mentioned decentralized catering areas. They also addressed the start-ups dominating university campuses.

Gas. Before the interviews, the decision-makers had experienced the gas model's advantages and disadvantages due to the recent COVID-19 developments. While the quantitative analysis lacks evidence on the gas state given that the project database focuses solely on on-campus buildings, the interview analysis indicates that remote working and online education will persist. However, decision-makers want to offset the negative impacts of this trend.

The transformation patterns addressed above are a supplementary output to the evidence-based briefing approach, yet, based on the analyses of the qualitative interview data and the quantitative project database. They provide both practical answers to the research questions addressed in the introduction and raise theoretical and methodological points that are beneficial to decision-makers.

Substantively, some of these patterns highlight the supply and demand requirements of the future campus, and they provide information that can be applied in different campus contexts. Though generic office and education buildings (presented with monofunctional and liquid Clusters-1 and 6, Table 1), which serve the entire campus, have become more popular at Dutch universities in the last decade, the longstanding mixed-use (faculty) buildings will also become more common in a more space-efficient way (as seen in Cluster-5). Thus, in the future campus, the typologies will be diverse. Solid laboratory-dominated buildings will be less common, while non-academic functions and off-campus spaces will increase.

Recommendations and implications

The five themes and nine clusters (Figure 2, Table 1) derived from the data analyses are useful for decision-makers and facility managers with varying portfolio sizes. While campuses can include several patterns identified in the results, a larger portfolio can be related to more themes and clusters.

The Dutch experience (based on the analyses results concerning the themes and clusters, Figure 2, Table 1) presents fundamental transformation patterns, practical implications, and recommendations for decision-makers from other FM contexts. First, the qualitative analysis demonstrates that all three campus models (solid, liquid, and gas) will exist in future spaces (like laboratories, teaching facilities, and workplaces). Decision-makers and facility managers embrace the positive sides of each campus model (such as the solid model's home-like feel for workplaces) while avoiding their downsides (such as the gas model's lack of interaction and physical activity) by offering a mix of all three models (Den Heijer *et al.*, 2016; Den Heijer, 2021). The Dutch context, via the clusters based on the different compositions of campus themes and models, also reveals diverse spatial strategies, including both generic mono-functional and mixed-use buildings (as seen in Clusters 1, 5, and 6, Table 1), responding to the continuous and universal challenges of campus management. Therefore, it is recommended that facility managers and decision-makers have the institutional capacity and knowledge to generate different spatial strategies to meet the dynamic campus demands.

In this study, the qualitative interview data analysis demonstrated how each campus theme and model are reflected differently in the continuing changes on university campuses. The project database analysis produced clusters demonstrating the functional and physical transformation patterns of campus buildings. These analyses constructed the backward evaluation cycle of the continuous DAS framework and provided management information for the forward planning cycle based on practical applications. Therefore, these substantive results prove that by regularly applying the continuous DAS framework, decision-makers can use the suggested evidence-based briefing approach to find reference projects and define their future campus, including how much solid, liquid, and gas they pursue in their campus portfolio.

This study builds upon existing PREM and FM research by exploring how continuous briefing can be implemented via the evidence-based continuous DAS framework to support decision-makers of individual universities with management information and to help management adapt campuses to changing needs. Therefore, the study contributes to campus (space) management both at the practical and theoretical levels. At the practice level, the study demonstrates the kind of information and support that can be provided by implementing evidence-based continuous DAS framework. Moreover, based on continuous briefing and the PREM protocol, the proposed evidence-based briefing approach can help individual universities in decision-making for their future campus by operationalizing the continuous DAS framework regularly (or at other intervals set up to meet the needs of each institution). This process can lead to more informed decision-making and facilitate benchmarking for FMs, allowing them to adjust performance and strategic planning decisions as well as comply with space use standards. Regular adaptation of space based on user needs enables flexible and adaptive use of space. Furthermore, informed decisions and space usage optimization via continuous feedback can support financial predictability. At the theoretical level, the study provides a procedural framework that engages complementary domains related to campus (space) management, campus FM, continuous briefing, and PREM. Engaging these fields can promote several research frontiers, such as more collaborative and integrated campus (space) management frameworks, grounded on evidence-based decision-making and effective space use that takes into account changing user demands. Furthermore, expanding the evidence-based approach introduced here to include qualitative and quantitative information from various stakeholders, including students, faculty, and the public can provide more stakeholder engagement in campus (space) management. This ensures that the continuous DAS framework incorporates various demands from different stakeholder perspectives into the briefing processes.

Limitations and future directions

In the future, more research is needed to allocate scarce human capital, financial, and energy resources at university campuses, while improving their sustainability and spatial and functional qualities (Den Heijer, 2021; Ninnemann *et al.*, 2020). Such studies should also thoroughly assess the well-being of the campus staff and students (Den Heijer, 2021).

Different clustering techniques and cluster numbers create different patterns. Two validation strategies are used to overcome this limitation. Exploratory multivariate analysis techniques are suitable for the proposed briefing approach, because patterns that emerge from new data resources (Den Heijer *et al.*, 2023) will support management information.

Conclusion

Based on the findings, the main research questions can be revisited: substantively, what kind of information and support can be provided for management via implementing evidence-based briefing (via the continuous DAS framework) to plan the future campus?

Procedurally, in which ways can the proposed briefing approach contribute to theory and practice with the information and support it provides? For the former question, the substantive results of this study, derived from an evidence-based approach via analyzing the qualitative and quantitative data sets, highlight the simultaneous effective space use strategies that can meet the dynamic campus demand (such as space-efficient mixed-use buildings and mono-functional generic educational and office spaces). Moreover, it offers practical insights to decision-makers and facility managers on how to operationalize this information, particularly in the “Planning strategies for the future campus” and “Recommendations and implications” subsections of the “Discussion” section. For the latter question, these functional and physical transformation patterns also demonstrate how the continuous DAS framework, as an evidence-based approach, can engage complementary domains related to campus FM, continuous briefing, and PREM by linking theory (campus themes and models) and practice (data sources such as interviews and databases). Therefore, it contributes to the studies that aim to provide more integrated management frameworks by bringing together different domains in the field of campus (space) management studies (Van der Voordt, 2017). Moreover, it lays the groundwork for the much-needed collaborative campus management frameworks that can take the changing demands of various stakeholders on university campuses into account.

Consequently, the transformation patterns of universities discussed in this study provide insights into the possible future supply and demand requirements of university campuses. For instance, the interview data analysis shows the solid-to-liquid transition for each theme and demonstrates that the gas model will become a serious alternative for solid and liquid forms via remote working and online education. The comparison of both analyses reveals that the solid-to-liquid transition is easier in the academic workplace and learning environments than in laboratory spaces. The project database analysis also reveals coexisting effective space use strategies, including contemporary mixed-use buildings (Cluster-5) and generic educational and office spaces (Clusters-1 and 6). Moreover, recent advances (Den Heijer *et al.*, 2023) show that more up-to-date data resources will be accessible to support decision-makers and facility managers in operationalizing such briefing approaches in the near future.

The authors aspire this study can be used as input by researchers and practitioners in campus management who explore evidence-based briefing approaches with respect to campus transformation patterns.

Notes

1. Technical laboratories require the provision of a wide range of discipline-specific equipment to conduct research. These specific pieces of equipment can obstruct space sharing for different functions. (Van den Dobbelsteen and Van Gameren, 2021)

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Supplementary material

The Supplementary Material for this article can be found online.

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