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BIM, GIS AND BI TOOLS FOR A UNIVERSITY ASSET MANAGEMENT SYSTEM SUPPORTING SPACE MANAGEMENT, OCCUPANCY EVALUATION AND OPTIMIZATION STRATEGIES

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SUMMARY: *Integrating Building Information Modelling (BIM) and Geographic Information System (GIS) into Business Intelligence (BI) tools is promising for developing Asset Management Systems (AMS), especially for large and widespread building assets, such as university campuses. The AMS can provide valuable insights about asset performance and resource uses, improving cost and time savings, sustainability, and overall efficiency. A web-based AMS application (AMS-App) via BIM-GIS-BI integration is proposed, enabling the reliable digital representation of university assets by combining spatial, performance, and operational data with the related analytics and visualization dashboards. The AMS-App was developed under the umbrella of the University of Turin's strategic plan as a pilot case to apply a data-driven approach aimed at improving asset management procedures. Indeed, the managerial complexity of university campuses involves multiple actors exchanging information through still document-based and fragmented databases, often leading to untimely and ineffective decision-making processes. The AMS-App represents a valuable decision support system aimed at monitoring and improving the users' experience living in the asset, providing better and more sustainable decisions concerning spaces, occupancy flows, and indoor environmental quality (IEQ) in the learning environments. Aiming at demonstrating the effectiveness of the BIM-GIS-BI integration through the AMS-App, several topics were implemented with the following objectives: (i) the digitalization and georeferencing of the university building stock; (ii) the optimization of courses timetables according to spaces availability; (iii) the optimal management of workstations; and (iv) the monitoring, analysis and optimizing of IEQ and user comfort via IoT sensing. The paper presents the developed methodology and its applicability and replicability, illustrating the implemented topics on selected pilot buildings and discussing the results underlining advantages, challenges, and further developments needed for improved efficient and scalable university asset management.*

KEYWORDS: *Asset Management System, BIM, GIS, Business Intelligence, Information Management, Campuses.*

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1. BACKGROUND AND MOTIVATION

The organization and maintenance of updated and promptly available property data is a long-standing challenge in managing real estate assets (Sánchez et al., 2016; Veale, 2020). Property management firms, dealing with large portfolios, frequently tackle widespread properties with different construction types, spatial characteristics, and usage patterns (i.e., how the asset is used in terms of space allocations, occupancy, equipment, and schedules). In this context, university properties, especially the Italian context, often pose considerable management issues due to fragmented, incomplete, and low accessible databases impeding the precise identification and optimization of usage patterns, as well as the standardization of management processes. (Haynes & Nunnington, 2014; Heijer, 2011; Magdaniel, s.d.; Qian & Papadonikolaki, 2020; Vermiglio, 2011).

Recently, a global digital transition trend can be observed, unfolding across various levels, with diverse approaches. This is related to the intrinsic capacity of the digital world to preserve and integrate data providing complete information, crucial in enhancing management and decision-making processes efficiency across all the valuechain of different sectors.(Mergel et al., 2019; Zaoui & Souissi, 2020; X. Zhu et al., 2021)

Such a digital transition has been involving also the Architectural, Engineering, Construction, and Operations (AECO) industry and proved to be an excellent solution for overcoming the challenge related to information loss throughout the asset lifecycle (Bhattacharya & Momaya, 2021, 2021; Eastman, 2018). The AECO industry deals with the adoption of data-driven approaches, digital tools and processes formalization, and involves the integration of Information and Communication Technologies (ICT) into operations, representing a progressive process that impacts nearly all sectors worldwide. (Biswas et al., 2024; Daniotti et al., 2020)

For a successful digital transition process, it's key to structure a framework aligned with the specific objectives of asset management (Zhang, Q. et al 2022). Indeed, such a sector is characterized by endemic difficulties in sharing information among different stakeholders throughout various phases, leading to information losses and subsequent waste of time and resources (Kassem et al.,2013). Accessing updated and reliable information about buildings and their surrounding supports the acquisition of accurate insights on real estate assets and their efficient management. Structuring information in a coherent and reasoned way depending on asset management objectives refined by the directorates' KPIs (Key Performance Indicators) can facilitate information exchange among diverse stakeholders. Applying information management approaches in the built environment can further enhance the efficiency and effectiveness of this exchange, ensuring consistency and interoperability throughout the asset lifecycle. (Mathieu, Robitaille et al., 2021; Moretti et al., 2022)

As a matter of fact, the role of governments can boost the success of digitalization, and the main driver for introducing BIM into construction processes often consists in its gradual imposition through application in public works. Aiming at obtaining the efficient digital implementation into processes, governments and institutions must plan and structure tailored and adaptable strategies. (Bhattacharya & Momaya, 2021; Marocco et al., 2023). Indeed, the European Directive 2004/18/EC, later replaced by the Directive 2014/24/EU in 2014, served as a starting point for introducing BIM and digitalization in several European countries, enabling Member States to "require the use of specific electronic tools, such as electronic simulation tools for building information or similar tools." (art.22, paragraph 4) through dedicated legislative measures.

In the Italian law, this directive was implemented through the Legislative Decree (L.D.) No. 50/2016, known as "The Contracts Code" followed by its implementing decree, the Ministerial Decree (M.D.) No 560/2017), and replaced by the recent L.D. No. 36/2023, which reinforces the importance of digitalization throughout the entire procurement lifecycle. This decree outlines the gradual, mandatory introduction of BIM in public procurement and requires public clients to establish an "Organizational Act" involving a comprehensive plan for staff training, hardware and software acquisition and maintenance for digital decision-making and information management processes, emphasizing the importance of an organizational framework structuring the control and management of information and related aspects throughout the asset lifecycle. Furthermore, the new Contracts Code was preceeded by the M. D. No 312/2021 stating that information models should be accompanied by decision-support workflows. Thus, public and private organizations have been started to develop and implement digital transition strategies at different scales for the correct introduction of new digital approaches. As highlighted by the literature, several obstacles hinder the wider adoption of BIM so far, among them the inadequacy of institutions in understanding the market, the high associated costs for purchasing software and hardware, and the need for training. (Elmualim & Gilder, 2014) However, one of the main limitations lies in the lack of well-defined standards and structured change management approaches (Ahmed et al., 2017). Indeed, the most successful cases worldwide include governments or organizations with established plans, guidelines, and standards for effectively guiding and managing the needed change to make the transition effective. Already in 2007, for example, in the United States, the General Services Administration (GSA) introduced the use of BIM through standards and guidelines developed by the National Institute of Building Sciences (NIBS) (National Institute of Building Science, 2017). A structured information management approach is also strongly recommended by the pioneering case of the National Digital Twin Britain, involving the definition of a IM Framework (Hetherington, J. & West, M., 2020)

Adopting tailored guidelines and modelling protocols enables to provide comprehensive information depending on the lifecycle phase and the level of information need (LOIN) for the management process, this is crucial for successfully implementing BIM in organizations (G. Di Giuda et al., 2023; ISO 19650, 2018). To establish tailored guidelines during the initial stages of BIM adoption, both from public and private organizations, ensuring clear objectives and actions throughout all project phases can enable the effective adoption of a paradigm shift. Structured guidelines, based on the principles of information management, can support organizations in communicating their requirements accurately, promoting seamless collaboration through standardized practices, as well as the fulfillment of their clearly identified needs. As mentioned above, the guidelines should be part of a new logic of implementation within practices not always formalized and regulated but still difficult to change (Errida & Lotfi, 2021). For this reason, they should be based on a deep knowledge of the Organization's specifications and processes, defining the aforementioned "Organizational act" for the digital transition process (ISO 19650:2018; L. D. No. 36/2023). An optimal information management strategy is still a relevant challenge, especially information protocols to provide accurate information to the proper subject, at the right time, and in the required format (Chen and Deng, 2015). It is also important to identify the roles and responsibilities of each actor in each process and within the information exchanges, to ascertain the accountability and thus the reliability of data (G. Di Giuda et al., 2023; ISO 19650, 2018; Sacks et al., 2018)

Moving from these assumptions, dealing with the managing of large and diffused real estate assets such as university assets, information should be structured at various levels (Beck et al., 2020), requiring to establish a specific framework to gather information through standardized processes, supporting management operations while enabling analysis for promoting potential improvement strategies. In order to do that, the integration of different technologies and systems has been identified as a promising approach in the field of asset management (Fewings & Henjewele, 2019). There is an increasing interest in creating scalable databases for multiple purposes, especially during the Operations and Maintenance (O&M) phase, which has been estimated as the most expensive of the lifecycle and complex to handle due to the need for comprehensive data held by multiple stakeholders (Lu et al., 2020; Seghezzi et al., 2021). At this aim, the combined use of BIM and GIS has been widely studied in the literature, yielding significant benefits in understanding real estate characteristics and consistency across different scales (Celeste et al., 2022; Cheng & Deng, 2015; Liu et al., 2017; Moretti et al., 2022). The introduction of such digital approaches facilitate the collaboration and the sharing of information flows between stakeholders, resulting in improved accuracy, reduced errors, and better-informed choices (Biswas et al., 2024; Eastman, 2018) with benefits in data quality and effective decision-making processes (Munawar et al., 2020; Munir et al., 2019). Space management can be improved according to actual occupancy and usage patterns, considering the needs for supplies and services with high impacts on resource usage, and operation and maintenance costs (Bosch et al., 2015; Lytras & Visvizi, 2021; Nicał & Wodyński, 2016). For a long time, integrating information at different scales has been linked to the topic of "BIM-GIS Integration" which poses challenges due to differences in modeling, georeferencing, and data management (Beck et al., 2020). Therefore, to evaluate how to exploit them combined to best fit the project, standardizing and officializing the framework is a concrete step to implement the strategy. Although BIM and GIS have the common purpose of managing information, they differ significantly in various aspects, including scales, scopes, storage methodologies, and the use of different exchanged data (J. Zhu et al., 2018). According to the literature, in order to effectively integrate them, there are three different patterns: (i) from BIM to GIS, (ii) from GIS to BIM, and (iii) from both data schemas to a third system (Marzouk & Hanafy, 2022; Rodrigues et al., 2022). Exploiting the third solution enables to bypass the aforementioned issues with a third system for data collection and management. For this purpose, BI tools can be used to integrate and systematize different information sources, driving the management of widespread assets, enabling data collecting from different sources, and supporting decision-making by simplifying data analysis, updating and visualization (Bao et al., 2023; Lwin et al., 2019; Wickramasuriya et al., 2013; Zhang et al., 2022; Moreno et al., 2021).

The presented research is developed under the umbrella of the University of Turin (UniTO) strategic plan 2020-

2026 aimed at digitalizing one of the largest Italian university assets and optimize its management through a web-based application, namely UniTO AMS-App. UniTO represents the fourth largest Italian mega-university with approximately 81,000 enrolled students in the 2023-2024 academic year. Its real estate portfolio consists of 120 elements (i.e., buildings and lands), mostly scattered within the territory of Turin, with few buildings spread across two regions, six provinces, and nineteen municipalities. UniTO well represents the average Italian mega-campus, covering both urban and suburban areas and representing a “city in the city” with a large catchment area, also due to its role as a “city hub” offering activities beyond purely academic ones such as museums, exhibitions, and open events to the wider public. These factors lead to management difficulties due to the scale and complexity of the university and its different types of users (e.g., students, lecturers, researchers, administration officers, citizens, etc.). Managing such an extended campus represents a complicated task, dealing with historical and modern buildings, different types of constructions and properties, and management approaches that differ depending on the considered technical or administrative area. Furthermore, despite its size and management complexity, UniTO only recently begun a digital transition process, introducing a structured and digitized AMS to support the optimization of resource use and increase the sustainability of management choices, both economically and environmentally. Under the Italian government push, envisaging mandatory BIM for public works above one million euros from 1 January 2025, and pushing for its introduction in all contracts regardless of the amount through the definition of rewarding criteria (L.D. 36/2023; M.D. 312/2022), UniTO developed its latest Strategic Plan aiming at correctly implementing the digital transition of its processes to be ready for the change. Thus, standards for the digital transformation process of the university are currently being defined through specific guidelines as part of the aforementioned "Organizational Act" which establishes the directives and requirements that UniTO must follow to adopt advanced digital practices and information systems in its asset management procedures. Such guidelines aim to ensure efficiency, transparency, and consistency in administrative and decision-making processes. Until then, UniTO management approach has been strongly based on siloed databases handled by different technical and administrative areas, still heavily relying on document-based processes. As a result, information is often fragmented and it is challenging providing accessible, updated, and correlated data of various types (such as space dimensions, planned and actual spaces occupancy and equipment) for timely and effective decisions concerning the effective use of resources, suitable space management, high service quality and augmented user experience. The involvement of internal university users and external ones such as citizens engaged in activities within the urban environment further complicates UniTO management processes. The implementation of a digitized, structured, data-driven and accessible at various levels AMS, from territorial to individual spaces, considering urban surrounding is helping decision makers in facing the challenges in understanding actual university assets consistency and utilization. The system is accessible through a web-based AMS-App, providing the visualization of the georeferenced university asset through a queryable 3D maps combined with BIM models and analytics, aimed at monitoring, and identifying usage patterns and potential for optimization. The main goal of the AMS-App consists of improving information management and decision-making processes, providing more accessible, comprehensive, and updated information, shareable with different levels of accessibility according to the management scope or end-user. At the same time, data management procedures can be mapped and formalized, identifying the Organization needs and information exchanges between stakeholders. Indeed, even a little improvement in management processes and resources wastage can provide significant savings as the yearly UniTO management expense is estimated amounting to around 40 million euros. After this background introductory section, the paper is structured in other three sections. Section 2 describes the replicable methodology developed to define and implement the AMS-App within the UniTO management system. Due to its features, UniTO serves as an exemplary case study for testing and showcasing the potential of such a digital decision support system. The results are illustrated and discussed in Section 3, where is shown how the AMS-App can provide updated, integrated and complete information, in the specified format and promptly available when required within the management process, effectively supporting decision-making and facilitating information exchanges. Finally, Section 4 illustrates the advancements in development aimed at providing proprietary guidelines and modelling protocols which can be easily adaptable to similar cases. Indeed, Italy counts about 70 public universities, included among the largest Italian real estate owners with similar organizational structures, as well as management issues, replicating the presented approach could have significant impacts overall.

2. METHODOLOGY

As introduced, the AMS primary purpose consists in supporting UniTO asset management in different decision-making processes, dealing with topics such as buildings management, policy evaluation, spaces occupancy optimization, or staff and educational activity administrations. Thus, the replicable methodology developed for the AMS-App creation (Di Giuda et al., 2023) aims at integrating several types of information, related to different management issues with multiple information detail levels. In addition, the structure of its components aims to promote collaboration and information sharing between the developers and maintainers of the system, with the administrative staff responsible for data providing and updating. The AMS-App methodological framework illustrated in Figure 1, structures a workflow for managing UniTO assets, emphasizing information exchange points highlighted in yellow.

- **Section A**: Analysis of current management processes, defining information requirements, and assessing data completeness. Incomplete data prompts missing or updating data requests.
- **Section B**: Identification and formalization of the Organization information exchanges and Information Requirements (IRs), and cloud-based collection of related spatial and non-spatial data.
- **Section C**: data integration, BIM modeling (via Autodesk Revit© and Dynamo©) and exportation (via Tracer for Revit©), georeferencing and GIS map customization (using QGIS© and the localisation platform mapbox©).
- **Section D**: Integration of data, BIM models, and customized maps into the BI tool (Microsoft PowerBI©) for feeding the web-App and enable the visualization of analytic dashboards.
- **Section E**: Continuous monitoring of data updating, if data need to be updated or new data entered, the steps from section B are repeated, otherwise the process ends.

This framework ensures a seamless transition from data collection to the development of an AMS-App integrating BIM, GIS and other data into the BI tool.

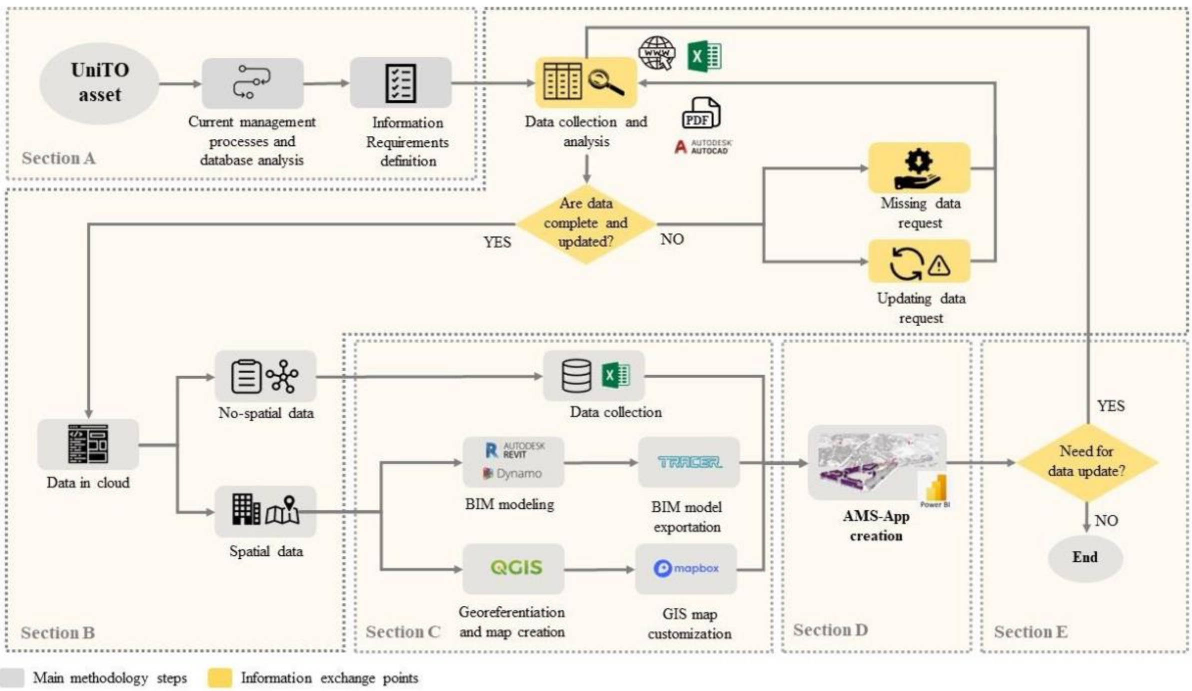

Figure 1: AMS-App methodological framework with information exhange points highlight in yellow and the tools or formats used in the different steps.

2.1 Analysis of current database structure and management strategies

The definition of the methodological framework started with the current management strategies analysis (Figure 1, section A), also involving database structure and information flow among stakeholders. The investigation was conducted to understand the AMS-App expected use, aiming at providing an effective decision-support tool in real case applications. At first, the UniTO organizational structure was analyzed to identify the technical and administrative areas involved in the AMS-App development and implementation. These areas deal with various activities such as building management and maintenance, staff and schedule management, space use and quality, and the management of educational and work activities and services. Then, meetings and interviews with the technical areas staff and managers enabled providing an overall understanding of their different management objectives and practical needs. This brought to the definition of the organization needs and related IRs, as well as the AMS-App objectives depending on the identified university asset management processes and users involved. This phase highlighted that the UniTO organization is structured by technical and administrative areas, with specific commitments and competencies, producing and handling large amounts of data. Nonetheless, it pointed out the lack of a shared methodology for storage, processing, and sharing data, resulting in a fragmented and low- digitalized information management strategy. By analyzing the actual procedures, related challenges, and the organization the data structures, formats, and content for each area involved in the AMS-App was identified, as well as their nature and scope, providing a better integration through the AMS under development. At the end of this phase, the AMS objective, data types and relations, types of visualization of the information required and data exchanges were defined, also identifying the end-users and the staff members who should be involved in the system creation, application and updating.

2.2 Organization information exchange and information requirements formalization

After the analysis phase, it was clear how the major challenges dealt with the information exchange between the areas. Accordingly, information exchanges were formalized to overcome such issues, proposing a structured information management methodology coherent with the current processes. In a change management strategy, disruptive modifying current tasks often leads to the unsuccessful implementation of new systems and tools within an organization (Mergel 2019; Kraus et al., 2022). Thus, aiming a smoother transition, the information exchanges were structured without compromising each area's internal tools exploitation, integrating their outputs into a shared information system, as will be better illustrated in Section 4. The identification of the IRs allowed the definition of the AMS database structure and the formalization of the information exchanges between the areas. These IRs were defined based on the analyses carried out in the previous phase, preserving existing datasets as much as possible. Then, the IRs translated into datasets, were structured according to the information subjects, considering the receiver and the compiler, and separating eventual sensitive or confidential data. Table 1, describes the data involved into the university buildings mapping, required through the IRs datasets from the Technical and Administrative Area dealing with property acquisition and management, providing information such as building identification on the territory, status, and use. Furthermore, Table 1, reports indications related to the dataset compilation (i.e., type, number of digits, available values).

Table 1: Example of Information Requirements form for university real-estate consistency identification.

Field name	Data source	Type	Feature	Feature Detail	Example
Building code	Technical, and administrative areas	Text	Restricted field in digits.	5 Digits	029_B
Building name	Technical, and administrative areas	Text	Free field.	-	Campus Luigi Einaudi
Main address	Technical, and administrative areas	Text	Free field.	-	Lungo Dora Siena 100
Municipality	Technical, and administrative areas	Text	Free field.	Extended name	Turin
Main use	Technical, and administrative areas	Text	Free field.	-	Classroom/ educational and research services/Departments/Libraries
Building Type	OpenSIPI, Technical, and administrative areas	Text	Restricted field in values	Available values: Building, Portion of Building, Agglomeration of Buildings, No Type, ND	No Type
Status	OpenSIPI, Technical, and administrative areas	Text	Restricted field in values	Available values: Decommissione d, In use, Under construction, No Status, ND	In use

Moreover, to support the information exchanges between the areas and information flow management through the AMS-App, the introduction of a new technical area, namely Data Analysis Unit, has been proposed, as a linking node between the existing areas and the AMS. The components of this unit should be designated not only to interact with the areas but also to be responsible for the AMS-App in its operation phase. Furthermore, at this stage, it was core also the formalization of the university spaces' encoding system, aiming at uniquely identifying building spaces and linking data across the database. This enabled to overcome current issues linked to duplicated codes, preventing the correct space identification, and leading to multiple assignments in some cases. Aiming at facilitating a smooth transition from the current management system to the AMS-App, each room, floor, and building of the UniTO building stock was associated with a code according to the current university encoding system, enabling relations with different kinds of data.

The encoding structure is as follows:

$$PR^1\_00^2\_III^3\_E^4\_P00^5\_XXXX^6$$

PR[1]: Province Code, 2 Digits, Text Type 00[2]: Venue Code, 2 Digits, Number Type III[3]: Settlement Code, 2 Digits, Text Type E[4]: Building Code, 1 Digit, Text Type

P00[5]: Floor Code, 1 Digit, Text Type, 2 Digit, Number Type XXXX[6]: Room Code, 4 Digits, Text or Number Type.

Indeed, datasets, map elements, and BIM models can be semantically associated thanks to such an encoding system, as shown in Figure 2. The encoding system can be exploited partially, as for the building encoding used to relate maps and territorial datasets, or entirely, as for the room encoding, exploitable to relate the BIM model

and the buildings singles entities dataset. As Figure 2 illustrates, the relations between datasets, BIM models and GIS-based maps can be managed through Microsoft PowerBI, relating the different system components in one-to-one (1-1), one-to-many (1-*), and many-to-many (*-*) relationships using to the encoding system.

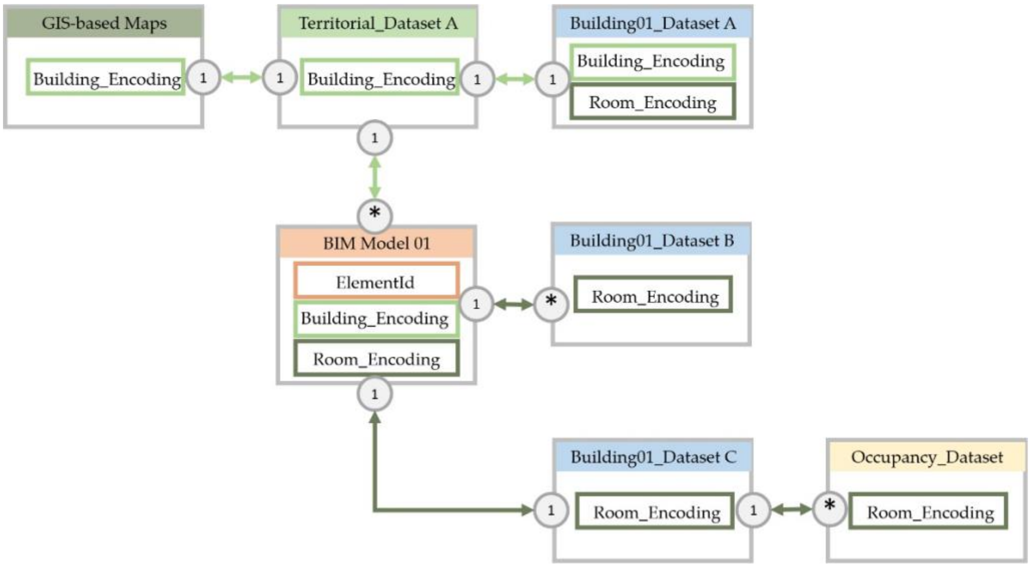

Figure 2: Example of semantic association between datasets, map elements and BIM models using the coding system.

2.3 AMS-App components development: approaches, technologies, and tools selection

As highlighted by literature, digitalization and information technologies represent growing effective resources in the field of asset management, highlighting how asset management and O&M phase can benefit from BIM and GIS exploitation, especially when integrated into BI tools (Rodrigues, F., 2022). Indeed, GIS-based maps, allow the asset overview and identification on a territorial level, while BIM enables the single-building visualization and analysis. Moving from this assumption, the methodology takes advantage of information technologies tools and systems, exploiting the following tools: (i) QGIS-based maps for asset identification and territorial analysis, (ii)

Autodesk Revit 2023 BIM models for buildings' investigations, (iii) and Microsoft PowerBI software for creating the AMS- App, integrating all the previously mentioned components in a structured application. Indeed, the AMS-App can integrate data of different types and from several sources, serving specific analysis and different stakeholders. Additional tools have been exploited for smooth components integration and visualizations, such as Proving Ground Tracer for BIM model visualization into Microsoft PowerBI, and Mapbox for maps visualization, publishing, and map design customizations. All this software have been chosen for improved interoperability and data management, avoiding disruptive changes in current procedures. The analysis conducted in the first phase, helped in identify Microsoft Excel and Office suite as the software mainly exploited by the university staff. Thus, Microsoft PowerBI, recognized as one of the most suitable software to handle large amounts of data (Shaulska et al., 2021), was selected to achieve the best interoperability through already existing tools, also preventing original data losses by working on datasets without changes to the source dataset. Anyway, even if the AMS-App was developed exploiting some authoring software, minor adjustments can enable to replace them with other solutions, in particular open-source ones.

For instance, the IFC standard (ISO 16739, 2013) can replace the Autodesk Revit .rvt format, further improving interoperability as also required by current regulations (L.D. 36/2023; ISO 19650:2018). Thus, contemporarily to the identification of the IRs and datasets definition, they are being mapped against the IFC standard and listed in the modelling protocols attached to the guidelines under definition, also identifying any gaps to be fulfilled. In the future, open-source software can be tested and exploited both for BIM modelling and BI applications. Their introduction is under evaluation with respect to their stability and staff competences required, avoiding high disruptive changes which can lead to the failure of the digital transition process and implementation of the AMS-App within UniTO organization.

The current (proprietary) flow of information, in fact, was tested by considering multiple factors such as the needs of the Organization, the staff knowledge, as well as the long-term goals of the project. The decision to implement IFC and open formats within the information flow will be key, but the flow is tested exclusively on procedures within the Organization to date, not yet within procurement and outsourcing.

2.3.1 Data collection, processing, and storage

Obviously, data collection, processing, and storage have a central role (Figure 1, section B). Aiming at easier information management, and avoiding information loss, redundancy, or errors, data were formalized through the table-forms presented above (Table 1) as standardazed IRs. Then, the forms were compiled by collecting and processing data from different sources (Table 2), exploiting both public (e.g. university website, Piedmont Geoportal and web map and feature serivices) and private ones thanks to the collaboration of the technical and administrative areas. Although efforts have been made to collect data via standardised forms with a view to minimising their manipulation, some data processing steps are still required for the application to function correctly.

Table 2: Data sources and features with the Units involved reported in the "Data Processing Role" coloumn.

Source	Information	Type	Temporal definition	Data structure	Data Processing Role
Department offices, technical and administrative areas	Courses schedule, personnel information, buildings construction site, department and areas allocations, buildings addresses	Text and numbers	Dynamic (on long term - yearly)	Tables	Technical and administrative areas (form compiler) Data Analysis Unit (collector and processor)
Technical areas	Buildings drawings.	Drawings	Static	CAD	Technical areas (compiler at the source) Data Analysis Unit (collector and processor)
OpenSIPI	Name, encoding, address, floor numbers, geometries, organizational structure, rooms use category	Text, numbers, and drawing.	Static	Tables and images	Technical and administrative areas (compiler at the source) Data Analysis Unit (collector and processor)
University official website	Lecture schedules, courses information, building property lists and economic information	Text	Dynamic (on long term - yearly)	Tables	Technical and administrative areas (compiler at the source) Data Analysis Unit (collector and processor)

Source	Information	Type	Temporal definition	Data structure	Data Processing Role
IEQ Platform	Environmental sensors measurement on air quality, indoor comfort, and electrosmog (e.g. PM 10, PM 2.5, VOC, CO_2, temperature, lighting, humidity, etc.)	Numbers.	Dynamic (on brief term - daily)	Tables	Environmental sensors (producer) Data Analysis Unit (collector and processor)
Piedmont Territorial Geoportal and web map and feature services.	Basemaps, building location, geometries, restrictions, heights, territorial context.	Text, numbers, geometri es	Static	Shapefiles , geo- databases	Data Analysis Unit (collector and processor)

These are conducted after the collection phase led by the data analysis unit. As an example, the data pertaining to the geometric characteristics of buildings need to be processed via a Revit plugin for visual programming, namely Dynamo. In other instances, the data are entirely created and managed by the Data Analysis Unit, such as in the case of spatial data from online map services.

The data collection and processing and the maps creation for spatial analysis are conducted from scratch, as no area of the organisation is responsible for this task.

In the future, the AMS-App developed is expected to be managed and maintained by the university organisation, including the collection and updating of structured data according to appropriate guidelines and protocols. Such a task is planned to be performed by the Dana Anaysis Unit.

At the end of the collection, data have been stored in a cloud repository (Figure 1, section B) depending on whether referred to a specific building space, users and services, or the entire university assets. A further classification was made according to the static or dynamic nature of the data. Static data, such as for example geometric information, cartographic data, encoded names, and spaces main use, tend to remain unchanged over a long time, requiring little maintenance and updating. On the contrary, lecture schedules, students' numbers, offices assignments, and sensors measurements are highly dynamic data, requiring regular updates. The project as GIS-based maps and BIM models are supposed to directly host only static data, while the dynamic ones will be indirectly related to them exploiting the encoding system semantic association, as detailed in the 2.2 Section. Figure 3 shows the flow of information by level and type, and how they are exported to be imported within Microsoft PowerBI.

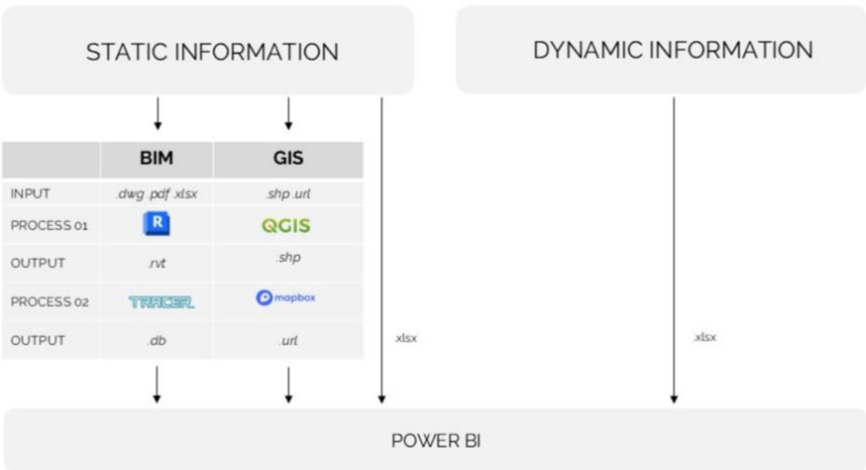

Figure 3: Example of information flow.

2.3.2 The GIS-based Maps creation

As presented in a previous step of the research (Gasbarri et al., 2024), there is great potential in the use of GIS in the UniTO asset management system, as it allows not only the creation of maps and the geo-localization of the assets, but also to perform spatial analyses. Thus, another important phase involved in the developed methodology concerned the expansion of GIS maps (Figure 1, section C) aimed at multiple purposes.

QGIS software enabled the creation of maps related to different topics, among which the UniTO building stock consistency identification. According to the related datasets, the buildings were firstly identified among the City of Turin, then over the Piedmont Region and the Aosta Valley maps, exploiting the open-source Web Map Services (WMS), Web Feature Services (WFS) and the download services, extracting information related to the building geometry and heigh. Buildings in use by the university in the year 2020-2022 have been identified and geolocated in separate shape files, reporting information such as building name, building code, address, municipality, main use, and administrative reference hub. Each year is related to its dataset and its shape file, also enabling the analysis of the evolution of the building stock consistency.

Additionally, following the same procedure, a list of maps showing which buildings host educational services or administrative functions have been created.

A further application of GIS in the UniTO AMS-App has been then exploited for the development of thematic maps related to building proximity, enabling to know the distance of buildings in terms of length and travel time, in particular identifying those within a time radius of a maximum 15-minute walk. The purpose is to propose the 15-minute city concept (Moreno, 2016), adapted to the UniTO context. This analysis and the relative maps were carried out exploiting a QGIS plug-in called pgRoutingLayer, which, from a road graph, allows the calculation of the shortest path between two points. The calculation has been carried out by defining a buffer zone of 1 km by each building, then operating the calculation adopting the average walking speed of a person of 5km/h (Caselli, 2021). Finally, calculation results were grouped according to the travel time into 4 ranges (0-5 minutes, 5-10 minutes, 10-15 minutes, +15 minutes).

As aforementioned, the GIS-based maps, host in this project only the static data, nonetheless thanks to the encoding system, further datasets can be related in the BI integration phase. Exploiting Mapbox tools, it was possible to customize the design of the maps, also enabling the 3D visualization, and sharing them through a URL link, then imported into Microsoft PowerBI. The 3D view gives a better understanding of the buildings distribution and consistency, giving a more detailed view of their location in the cities and enabling to query the buildings as they are displayed. However, for a clearer route visualization, a 2D view was preferred.

2.3.3 BIM Model development

While GIS was exploited for territorial analysis and map creation, BIM models have been developed to focus on a single building (Figure 1, section C). The geometrical models, developed in the Autodesk Revit environment, were then populated with the information of the selected dataset, exploiting the Visual Programming Language Dynamo, and developing a replicable and adaptable process.

The building datasets contain data such as the spaces area, use, and name. For each building were modelled the spaces as rooms, the stories as floors, and the building as masses, named according to the encoding system described in Section 2.2. Then, for all the elements, the Revit Element ID and the Name have been identified and extracted, enabling in this way the semantic association between the model and the datasets. Indeed, as the encoded name can be used to relate the elements to the dataset, the ID is used to reconnect the elements and the information associated with the 3D model.

Revit ID is exploited for this connection due to several reasons, for example, while the encodings may change over time or temporarily or be modified by error, the ID remains unique and unchanged over time avoiding information loss or redundancies. Once populated, the BIM model can be exported and integrated into Microsoft PowerBI. For this purpose, the Proving Ground Tracer software has been exploited, enabling the exportation of the BIM model into an SQL database. Such a database hosts both the 2D and 3D geometries information and the dataset values associated with the elements. Even if the BIM model, and consequently the SQL database, host a few pieces of information, once imported into Microsoft PowerBI and related to the additional dataset, they enable multiple analyses on different topics. Moreover, by importing only the data needed, lighter files can be handled in favor of system smoothness and file workability.

2.4 Data visualization, analytics, and dashboard structure definition

Literature highlights how BI tools have great potential in data processing, analysis, and visualization. Furthermore, the possibility of integrating different kinds of data and powerful information sharing made this tool the preferred choice for the AMS construction. Thus, a key phase of the methodology concerned the AMS structuring through different Microsoft PowerBI interactive dashboards, grouped into reports (Figure 1, section D) and accessible through a web-based AMS-App. As Figure 3 shows, the reports are organized according to different characteristics depending on the associated datasets:

- The topic: the five topics, highlighted in Figure 4 by different colors, give information about spaces, personnel, organizations, economics, and buildings. Additional sections are dedicated to health and safety topics, energy and sustainability. All the reports about the same topic are independent but related to each other according to a tree structure, and it's possible to start their single navigation from a Homepage;
- The subject: it refers to the object of the report analysis, which can be at the building level or at the territorial level. The former gives information only on a selected building and its occupants, the latter refers to the entire university asset. It is possible to visualize the building-level dashboard, selecting it from the main territorial level. According to the level, the dashboards enable the visualization of the BIM model, the GIS-based maps or both. BIM models, exported through the Proving Ground Tracer software, are included in the buildings' dashboard both with the 3D and 2D visualization for easier consultation also from non-expert users. Moreover, through the encoding system, the model elements are connected with the data previously excluded but collected into the spreadsheet datasets, such as the dynamic ones (i.e., environmental sensors measurements, timetables, personnel information). Additionally, GIS-based maps can be included in the territorial reports, and related to the datasets through the building encoding name. In general, the relations between datasets, BIM models and GIS-based maps are managed with Microsoft PowerBI, enabling to relate the different system components in one-to-one, one-to-many, and many-to- many relationships using to the encoding system;
- The information accessibility: it considers the dashboards end-user as the universities have to manage huge amounts of data, not all shareable with the entire community. Indeed, sensitive information visualization has to be controlled and limited, following a safety-oriented approach suggested also by ISO 19650:2018, part 5. In this way, some reports, such as the "Employees Information" and the "Economic Evaluation" ones, can be visualized only by authorized staff via authentication procedure.

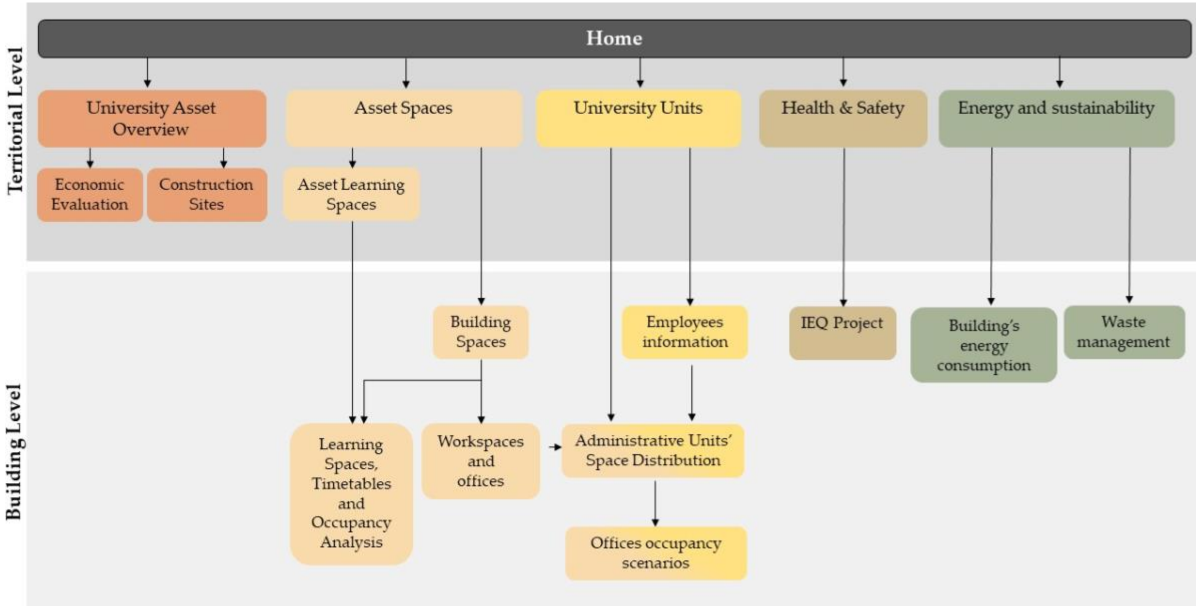

Figure 4: AMS-App structure. Each block is a Microsoft PowerBI report, connected to each other through URL link. The colors identify the different topics and how they relate to each other.

In addition to the aforementioned reasons, Microsoft PowerBI was selected due to its potential to organize such data and to the possibility of managing this characteristic.

2.5 AMS-App Updating and Maintenance

The last step of the developed methodology concerns the maintenance and updating of the AMS-App (Figure 1, section E). Although it is well structured and quite complete, it can be constantly improved by introducing new topics or updating existing reports. For introducing new topics, it's sufficient to retrace the methodology steps described so far, adapting the overall platform structure and connections. On the contrary, data updating can involve more or fewer steps, depending on the relevance of the updating. The datasets involved in the dashboard analysis are only connected and not imported, so a change in their values automatically updates the dashboard. Maps are related to the dashboard via a link, so once updated on the Mapbox publishing server it allows a real-time update in the dashboard. Instead, changes in the BIM models require a new exportation.

The AMS updating can be both scheduled or demanded by the areas as needed, enabling collaborative information exchanges between the university areas and the Data Analysis Unit. However, planning a dedicated meeting between these areas once a year, to revise and confirm AMS data correctness, is recommended. Hence, the system feeding with the last updated data maintains the optimal running of the platform and the quality of provided information.

The modelling guidelines and protocols under development as part of the "Organizational act" of UniTO, which will be evaluated and approved by its management bodies, the different updates to be considered according to the specific data and the information exchange or management process will be specified in detail.

Updates in the datasets and information exchange will be greater detailed, as the management process, under the development of guidelines and protocols. These documents are part of the "Organizational act" of UniTO, which will be submitted by its management bodies for approval.

3. CASE STUDY AND SELECTED DEMONSTRATOR

The UniTO large and widespread campus was selected as an emblematic case to test the replicable methodology developed and described in Section 2. It represents the average Italian mega-campus with a large and widespread building stock populated by approximately eighty thousand students with a vast catchment area involving a variety of users (e.g., professors, students, researchers, citizens, facility managers, technical and administrative staff) and services (e.g., courses, lecturers, seminars, master and so forth). As previously illustrated, the buildings under examination exhibit significant heterogeneity in terms of construction types and functions, often accommodating not only academic and administrative activities, but also spaces open to the public such as museums or performance venues. Indeed, many buildings are historic and built with various techniques, sometimes outdated but of great value and under historical-cultural constraints, leading to severe limitations or high costs in their modification to adapt them to current use. Other buildings, on the contrary, are very modern and recently built in response to the considerable development that UniTO undergone in recent decades. Furthermore, the variety of degree programmes and courses (counting 68 Bachelor and 83 Master science courses, 100 Master and 54 PhD courses in the 2023-2024 academic year) also provides diverse demands that a university should attempt to meet according to the specific study subject (e.g. chemistry or anatomy laboratories, language laboratories, spaces for botany, laboratories for virtual reality. etc.). In addition to its vast student population and assets, the administrative staff of UniTO counts around 2,000 users, plus approximately 2,100 professors and researchers. In total, the UniTO asset management deals with around 90,000 internal users, representing the population of the 50th Italian municipality, woven into the urban fabric of the city of Turin, which counts itself about 860,000 inhabitants, often involved in the activities offered by the university, academic or "extra-activities" such as museums, exhibitions, events, etc.

Situated in the northeastern region of Turin, the primary facility of CLE encompasses a total net area exceeding 36,000 square metres. It has a large catchment area and many activities involved, including a wide range of teaching schedules. Indeed, the facility houses the Department of Law, the Department of Political and Social Sciences, and the Department of Economics and Statistics "Cognetti de Martiis," which accommodates over 500 research fellows. Additionally, numerous administrative areas employ approximately 100 administrative staff members tasked with overseeing space management, personnel, contracts, and associated administrative affairs. Furthermore, the CLE has 47 lecture halls and hosts approximately 16,700 university users, rendering it a significant case study with extensive outreach and diverse activities. Indeed, considering the students and staff working in the CLE daily, it is possible to calculate that they represent approximately a quarter of the entire UniTO population. Due to its characteristics, the size, the numbers of users and the vast catchment area, the location and the availability of data coming from IoT devices installed for measuring the indoor environmental quality in the classrooms, it represents an ideal demonstrator, the most complete UniTO case study implemented so far, declined with respect to all topics currently manageable through the AMS-App and illustrated in the following sections.

Figure 5: The Campus Luigi Einaudi.

4. RESULTS AND DISCUSSION

As aforementioned, the proposed methodology and AMS-App were developed to be replicable and scalable through minor adaptations. Aiming at testing their validity and fine tuning, they were applied to the UniTO asset management as a pilot case. The following sections describe how they have been implemented, discussing the results accomplished so far.

4.1 Analysis of UniTO structure, management strategies and main objectives for information requirements formalization

Retracing the steps of the methodology developed to define and implement the AMS-App, the first step concerned the analysis of the UniTO organization structure and current management strategies, identificating the involved areas and data which should be collected and available through the AMS-app, as well as the existent databases and tools in use. This analysis revealed that, to date, there are ten areas operating under the control of the General Management, each responsible for specific functions (Figure 5; https://en.unito.it/about-unito/governance-and-organization/administrative-divisions).

The areas identified as those that will be directly responsible for producing the data to feed the AMS-app, are those highlighted in green in Figure 5, without excluding future expansions and involvements according to the future management needs and objectives. These four ares are as follow: the Building and Sustainability (BS) Area, the Security, Logistics and Maintenance (SLM) Area, the Education and Student Services (ESS) Area, and the Information Systems, Portal, e-learning (ICT). As shown in the results illustrated below, the main needs related to UniTO asset management have been met, providing an immediate perception of the consistency and distribution of the asset with integrated information regarding the geometry of the spaces and functional aspects for their correct occupation (e.g., allocation of resources in the offices and classes in the classrooms) with a focus on optimising the use of resources, avoiding waste and also considering internal comfort. All information made available through reports with different levels of detail, ranging from territorial level to the individual space, and accessibility, avoiding the universal availability of sensitive or private data. UniTO is organized in a hierarchical-functional structure with the General Management at the top and the other areas below, managing data concerning the real estate portfolio, its usage, maintenance and occupants, with internal sub-areas for specific functions (Figure 6).

Such organizational structure, typical of Italian universities, does not facilitate and encourage the information exchanges between the areas, leading to the vertical management of data in information silos separately handled by the different areas, preventing an effective collaborative approach. It has been observed that there is a lack of an integrated, complete and shared data source that allows information to be easily obtained and decisions optimised with respect to different aspects. Indeed, a strategic decision tipically has repercussions not only on the management topic handled by a specific area, but also on the topics handled by the other related areas. For optimal and effective decisions, all possible aspects and impacts (e.g., economic, environmental, social and operational) should be considered. For example, to assess the relocation of an office or a teching activity from one space to another, geometrical information about the spaces must be available, as well as data about plant and furniture, in addition to the information technologies equipment. Currently, such information are handled separately respectively by: the BS Area, the SLM Area and the ICT Area, thus the decision-maker has to track them from three different areas. Making this information available in an integrated and immediately comprehensible way thanks to the reports and dashboards of the AMS-app has high potential as the decisions concerning asset management and usage become more aware, easier to implement, and effective.

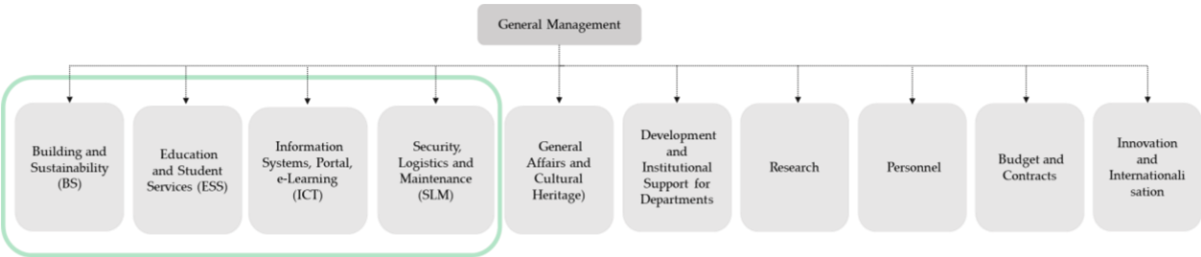

Figure 6: UniTO organization structure and areas.

Aiming at improving the management of its large and widespread asset, UniTO set several goals within its strategic plan 2020-2026, starting point of the research as the organization needed an integrated AMS-App enabling real-time data visualisation. This includes the provision of performance and asset utilisation information to promote cost savings and operational efficiency with the primary objective of improving space and resource management, reducing the overall environmental impact. The AMS-App enabled to track and monitor assets over time and make informed decisions on space allocation, occupancy and IEQ management. In parallel with the development of this tool, the entire inventory of UniTO buildings in going under digitalization, providing a comprehensive overview enriched with data on buildings distribution and use. This includes geo-localisation, structural consistency, geometric and financial information, building performance indicators, space capacity, available equipment and services, occupancy patterns and utilisation statistics. The improved visualisation of the building portfolio through a 3D map, incorporating data managed through BIM, GIS and BI systems, is bound to enhance several topics related to UniTO asset management such as:

- Managing university facilities at both territorial and building levels to generate multi-level data analysis and improve facilities operations;
- Rationalise university teaching schedules based on real-time classroom availability and capacity;
- Improving workplace management by implementing remote working strategies;
- Analyse and improve indoor environmental quality (IEQ) to enhance user comfort and safety through IoT monitoring.

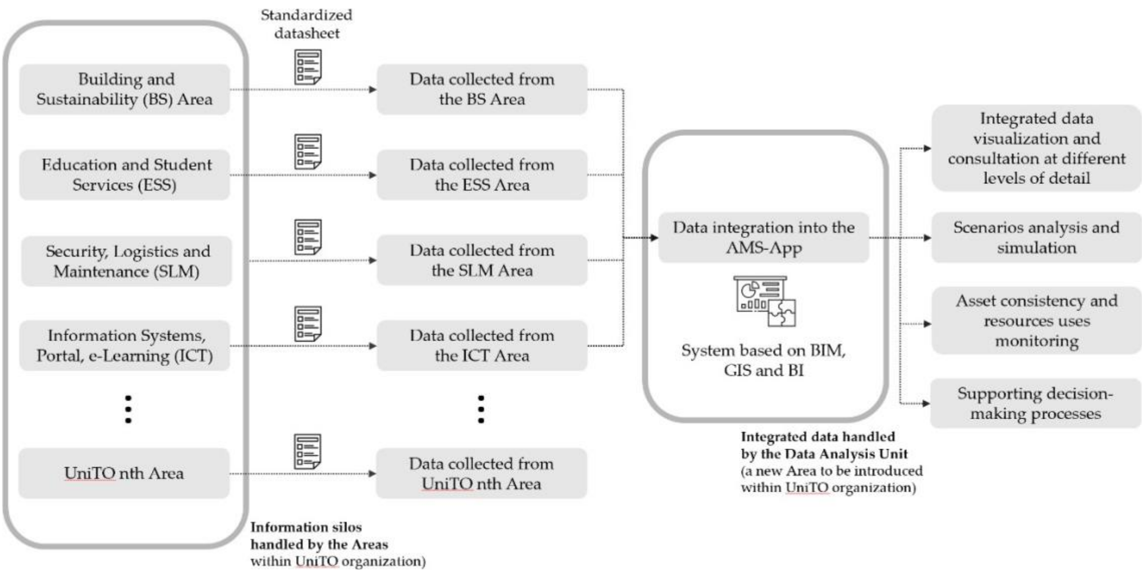

Figure 7: The transmission and processing of information and data within the UniTO organization.

Once identified the objectives, there was the crucial step concerning the identification and formalization of the IRs according to different management topics. As illustrated, the university technical areas, responsible for managing data and documentation related to facilities, spaces, equipment, performance, capacity, number of workstations and the definition of teaching schedules, currently rely on a document-based system characterised by segregated information, managed without a structured information organizational strategy with few formalised and traceable procedures. Information about rooms and their use are stored and exchanged in semi-structured formats such as .xls or .csv. Communication happens primarily through traditional means such as printed reports, emails, phone calls, and face-to-face or remote meetings, resulting in a lack of data sharing between stakeholders or administrative areas. As a result, comprehensive analysis of integrated data and information to support decision-making is difficult to provide. In order to address this issue, the data integration system presented aims at developing an updated tool that aggregates data from multiple sources, and it is accessible to the whole UniTO staff, providing a single and comprehensive source of knowledge This integration is facilitated by BI tools and the information management approaches applied for the AMS-App development, collecting and integrating data from the various IRs forms, generated by the technical areas. This approach allows to run the current processes for managing space, people, and usage data to be formalized and maintained without disruptions. This gradual and low-impact approach to integrating the AMS application and system increases the likelihood of practical adoption by UniTO staff (Mergel et al., 2019; Kraus et l., 2022). To this end, despite the proposal to introduce the transversal Data Analysis Unit collecting and managing the data of the different areas to feed and update the AMS-app, the areas preserve their management and operational autonomy, without disrupting normal practice but introducing small, gradual changes. For example, the area handling educational data is divided into sub-areas called "Schools" due to the large number of students and courses offered by UniTO. Each School manages the educational services of a limited number of departments, such as lecture timetables, exploiting different tools for their structuring (e.g., software, spreadsheet tables, classroom booking services, etc). Once the timetables for an academic year are defined, they are uploaded on a web portal for publishing and real-time classroom management (i.e., Cineca University Planner – UP), accessible by students through online timetables. The Schools' educational areas can download them in a spreadsheet table format. Aiming to settle this kind of information into the AMS-App, integrated with additional information, the IRs were defined starting from the UP output table, slightly modifying the existing one by adding data for AMS relations and analysis.

As suggested, a Data Analysis Unit should be introduced within the UniTO organization as a cross-functional team dealing with data handling and updating. Currently, such a unit is represented by is represented by the authors' research unit, counting seven individuals responsible for collecting data from various UniTO areas, structuring and integrating them through the proposed system (AMS-App), following the schema depicted in Figure 7.

Table 3: Standardised datashet for the collection of data related to the current use of UniTO buildings.

Building code	Building name	Main address	Municipality	Main use	Building type	Status
003_A	Cavallerizza Reale	Via Verdi 9	Turin	Classroom/ educational and research services	Portion of Building	In use
004_A	Palazzo Badini Confalonieri	Via Verdi 10	Turin	Classroom/ educational and research services/Departments	Building	In use
006_A	Accademia di Medicina	Via Po 18	Turin	Educational and research services/Departments	Portion of Building	In use
015_A	Palazzo Graneri	Via Bogino 9	Turin	Educational and research services	Portion of Building	In use
020_A	Palazzo Nuovo	Via Sant'Ottavi o 20	Turin	Educational and research services/Departments/Li braries	Building	In use
029_B	Campus Luigi Einaudi	Lungo Dora Siena 100	Turin	Classroom/ educational and research services/Departments/Libraries	No Type	In use
034_A	Orto Botanico	Viale Mattioli 25	Turin	Classrooms/Departmens	Building	In use
053_C	Palazzina Veterinaria	Via Leonardo da Vinci 44	Grugliasco	Classrooms/Departmens	Agglomera tion of Buildings	In use

As afore-illustrated in Section 2.3.1, the data handled by the technical areas of UniTO are gathered using standardised datasheets (Table 1). Table 3 reports an example of the datasheet used to collect data about the current use of UniTO buildings. They should be also used by the Data Analysis Unit to elaborate information regarding buildings, spaces, capacity, occupancy, and individuals using the spaces. This approach facilitates the efficient and structured data management, eliminating the need for initial data cleaning and processing. The integrated data, along with the resulting information and insights, are accessible and viewable through the platform, allowing for scenario-based analyses to assist UniTO asset management staff in decision-making processes.

The following sections illustrate specific applications of the proposed data integration system and AMS-App, eploiting the selected demonstrator for applications at the building level.

4.2 The management of real estate assets at the territorial level

The management of real estate assets at the territorial level require the collection and organisation of data about location, property ownership status (e.g., owned, rented from another institution or private entity, partially owned or rented), overall occupancy rates, presence of listed buildings, and other facility management information. Currently, such data about UniTO facilities are typically stored in isolated documents or .xls files, which hinders integrated analysis for informed decision-making processes. To address this challenge, comprehensive dashboards have been generated providing an overview of the whole UniTO's real estate portfolio. These dashboards enable simultaneous examination of multiple data, offering a visual representation of the geographical distribution of UniTO buildings. All the elements displayed through such a dashboards, including maps, charts, graphs, and cards, are dynamic and interactive. The selections in one view serve as filters for all other views within the page or the entire dashboard report, based on specific requirements. Territorial-level dashboards play a crucial role in supporting decision-making processes concerning overarching strategies for the university facilities. Figure 8 illustrates a territorial-level dashboard presenting general data regarding UniTO's real estate assets. Further territorial dashboards enable to display additional information such as facilities undergoing refurbishment with data related to specific interventions or buildings. This integrated approach to data analysis at territorial level, supports UniTO administrative areas in monitoring asset consistency, indentifying the buildings with related information about their pertinence and wether they are under refurbishment or not. From an accessibility standpoint, mostly of these dashboards are designed to be accessible only to individuals involved in strategic decisions (e.g., rector, deputy rectors, general managers, area managers, members of the academic senate, etc.) providing the unquestionable value of facilitating informed choices and broader assessments at the territorial level by consulting different information in a glance.

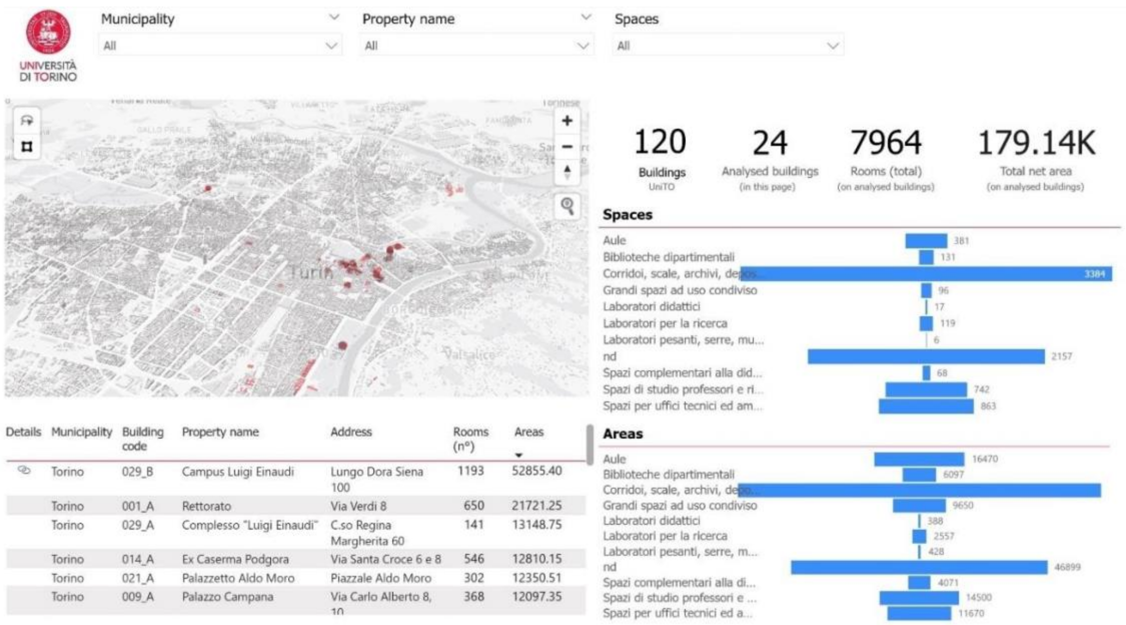

Figure 8: A territorial-level AMS-App dashboard displaying general data about UniTO real estate assets.

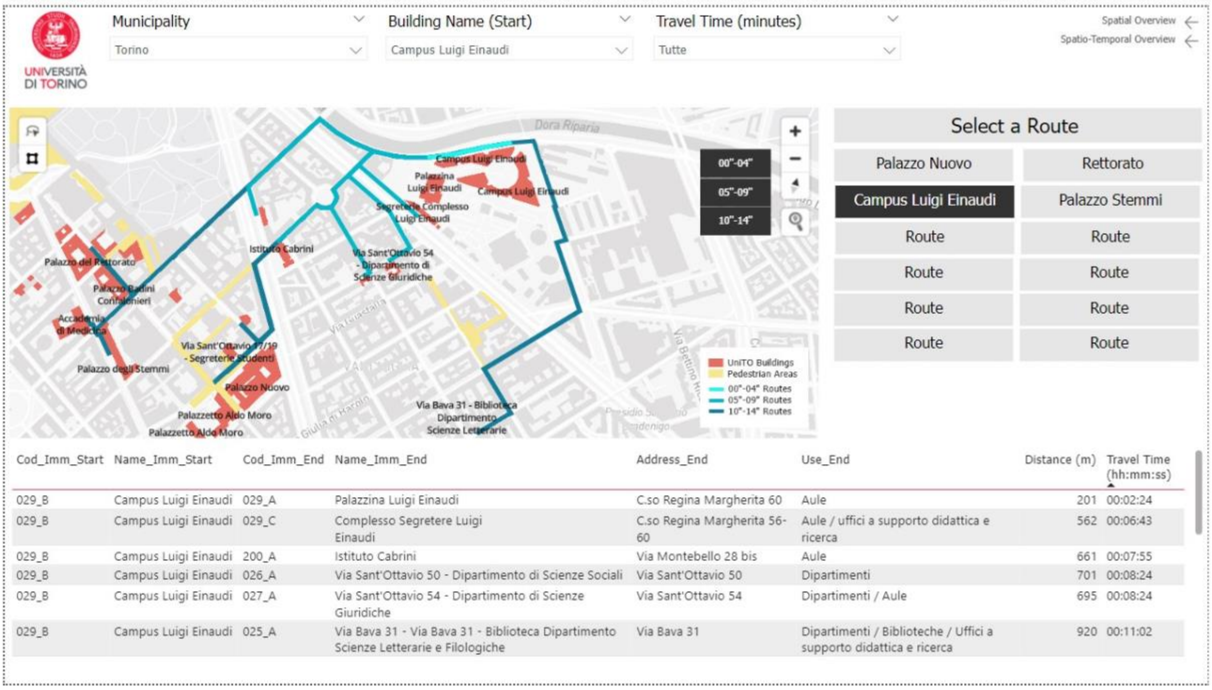

Figure 9: AMS-App dashboard about pedestrian routes.

Spatial analyses have been conducted on distances and proximity between university buildings. The results of these analyses can be visualised through informative dashboards, aligned with the logic adopted in the development of the AMS-App. The dashboard displays the analysis on the proximity between the different buildings considering their distance. This type of analysis is useful for both teaching timetable planning and managing emergency situations which require unexpected lesson relocation (e.g., in the event of flooding or collapse of a suspended ceiling and similar), facilitating students and staff in promptly reaching the new place. It is possible to filter the display of selected routes by distance range, including 0-5 minutes, 5-10 minutes, and over 15 minutes. An illustrative example of this analysis is presented in Figure 9, which shows how to exploit the dashboard to depicts the routes that can be navigated in a travel time of up to four minutes, starting from the CLE, setting such a query through filters. This can be a highly useful application, especially in the case of CLE, due to its high attendance of students and staff (i.e., about a quarter of the UniTO total), but also in special cases where full accessibility is compromised by social events or demonstrations. This type of dashboard can also be useful in the event of maintenance or renovation works that change the use and availability of spaces to optimize their reallocation. Thus, it can be exploited to better plan quick reorganizations, in a few hours, as well as in the long term, also considering the teaching assignments that UniTO staff may have in different buildings located in the Turin area, avoiding long distances that can cause delays, stress and a significant environmental impact overall.

4.2.1 Administration of lecture halls and coordination of teaching schedules

Managing teaching spaces and organizing lessons timetables presents a complex challenge due to the numerous variables to be considered, particularly within the CLE. Notably, the presence of various departments with different timetable allocation methods creates intricacy, and the wide range of teaching hours across different subjects and the diverse array of activities further necessitate diverse schedules, even within the same building. The current process for scheduling classes and assigning spaces follows a structured approach involving three distinct directorates/offices. Initially, the "Educational Services Directorate" provides information on course enrolments, course codes, and academic credits for each course. These data are then forwarded to the "Degree Programs Office," which operates under the school's guidance, serves the departments, and it is responsible for creating the teaching timetable. Finally, a local branch of the "Building Logistics and Sustainability Directorate" is responsible for space allocation based on the provided teaching timetables. The entire process is characterised by the fragmentation of data management, error prone manually implemented processes. Consequently, the primary aim has been to consolidate the data within a single analysis platform, ensuring a secure management and facilitating the evaluation of teaching space use. To achieve this objective, a dashboard was developed to provide a comprehensive overview of diverse data typically requiring their collection from the three separate offices. The unified dashboard enables users to access information regarding teaching spaces, including details such as classroom names, room codes, capacity, equipment availability, and net area. Furthermore, the dashboard offers insights into space utilisation and teaching hours, allowing for the estimation of the percentage of hours during which classrooms are booked, reserved, or available for use (Figures 10 and 11).

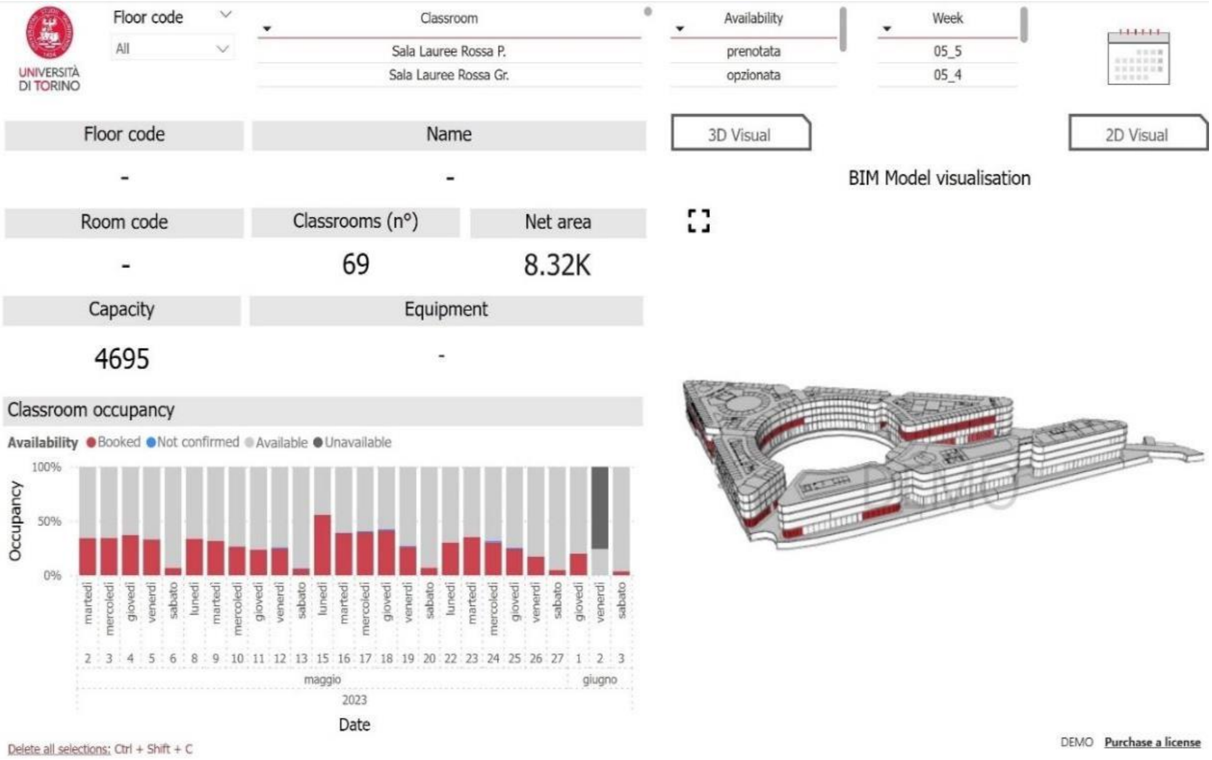

Figure 10: AMS-App dashboard facilitating the analysis of lecture hall spaces availability and occupancy at the building level with 3D visualization.

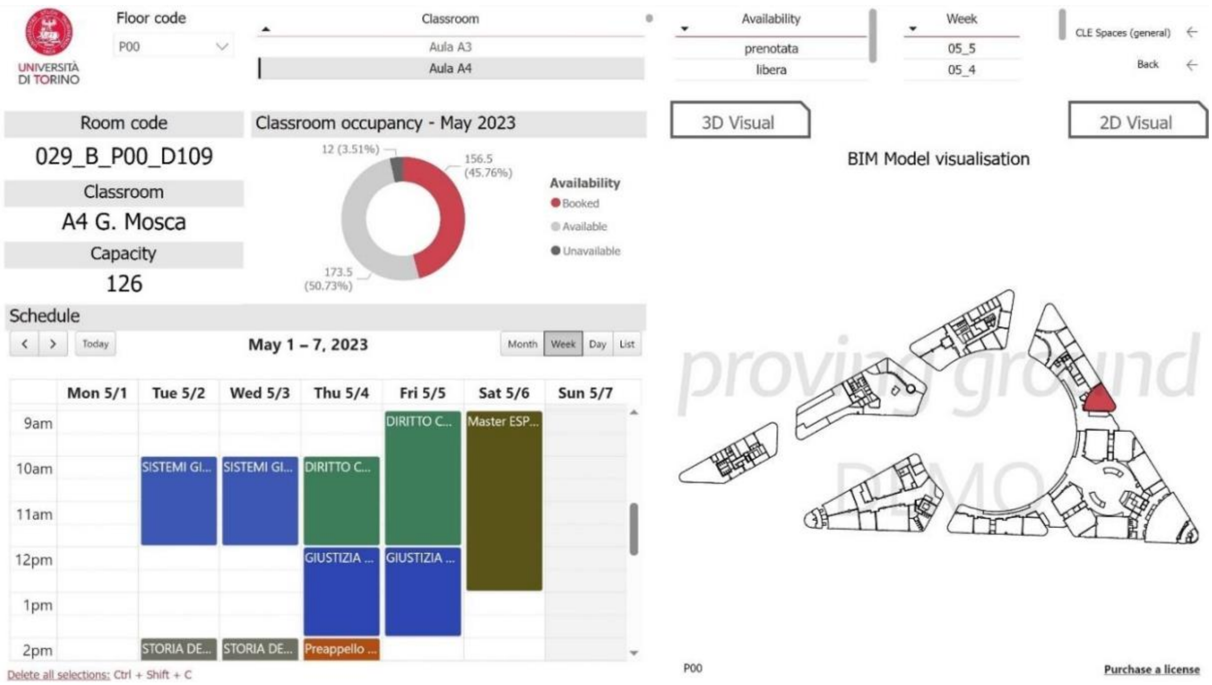

Figure 11: AMS-App dashboard at the room level, which enables the analysis of lecture hall spaces, occupancy, and timetables with 2D visualization.

This approach facilitates data access and analysis, enhancing overall efficiency and accuracy in managing teaching spaces by highlighting optimization potential through analytics. It must be reitraited that such data must be accessible according to different levels of privacy. The data facilitating the work of timetable creation are visible to the administrative staff working in the three offices mentioned above, while the data concerning the final timetable and the actual allocation of spaces are available to professors and students too. Figures 10 and 11 also illustrate the versatility of viewing rooms in both three-dimensional and two-dimensional formats. Regardless of the chosen view, users have the option to select specific rooms and access detailed data. The interactive line graph facilitates direct engagement with the data, while users can also apply filters based on the building's floors. At the room level, the scheduled time for each room throughout the week, month, or year can be displayed, as depicted in Figure 10. In this context, a future challenge is to cross-reference data on teaching planning and actual classroom utilisation. The evolution of this experimentation will involve automated attendance monitoring systems that will provide the most suitable spaces to be allocated based on the actual participation of students in the specific course, and other possibile tailored requirements considering equipment, location, etc. This digitalization is done with respect to any type of classroom, be it educational, administrative or of a more complex type, such as workers. The description of the equipment within each typology, can allow an important facilitation for asset management.

4.3 The management of real estate assets at the building level

The management of real estate assets at the building level encompasses a range of activities essential for an effective O&M phase. These include the management of staff, such as the administration of contracts and the allocation of space and equipment. Additionally, space management involves the allocation of space to departments and areas within each building.

Currently, building operations at UniTO are managed by the departments in charge or administrative staff located within each facility. Apart from space codes, which are standardised across all UniTO administration, the space management staff of each building locally manages all the other information.

There is no centralized structure overseeing all UniTO facilities at the space level. Thus, the primary objectives of this application consist in facilitating decision-making processes concerning UniTO facilities, gathering all the necessary information, and generating building-level dashboards to analyse spaces, occupancy, and people management through BIM, GIS and other data combined through BI technology. The data processed at this aim include the following:

- Location within the building, area size, and space type;
- Spaces allocation to departments or administrative areas;
- Spaces assignment to individuals within UniTO, including their role, contract type, and affiliation with a department or administrative area.

Figures 12 and 13 illustrate the AMS-App dashboard at the building level providing a comprehensive overview of all spaces within the CLE. It includes a detailed analysis of occupancy and staff allocation within offices facilitated through dynamic maps and charts presenting information on space types and room counts, as well as the allocation of spaces to departments or administrative areas. Individual data points regarding space net area and room counts are also provided.

This enables an overall analysis of the building, allowing users to access general space data, view the distribution of space types across the building floors, and review summaries of the total building net area and room count.

Figure 13 provides a comprehensive analysis of the offices within CLE case study, offering insights on the distribution of spaces and staff percentages across departments and administrative areas. The graphical representation enables the comparison between the number of employees and research fellows assigned to spaces and the maximum capacity of each room based on its net area.

This facilitates informed decision-making regarding the allocation of new staff members to departmental spaces. Moreover, the analyses support the impartial distribution of spaces among departments and areas.

Such a dashboard is fundamental as provides a comprehensive overview of both the building and the various floors exploitation at once.

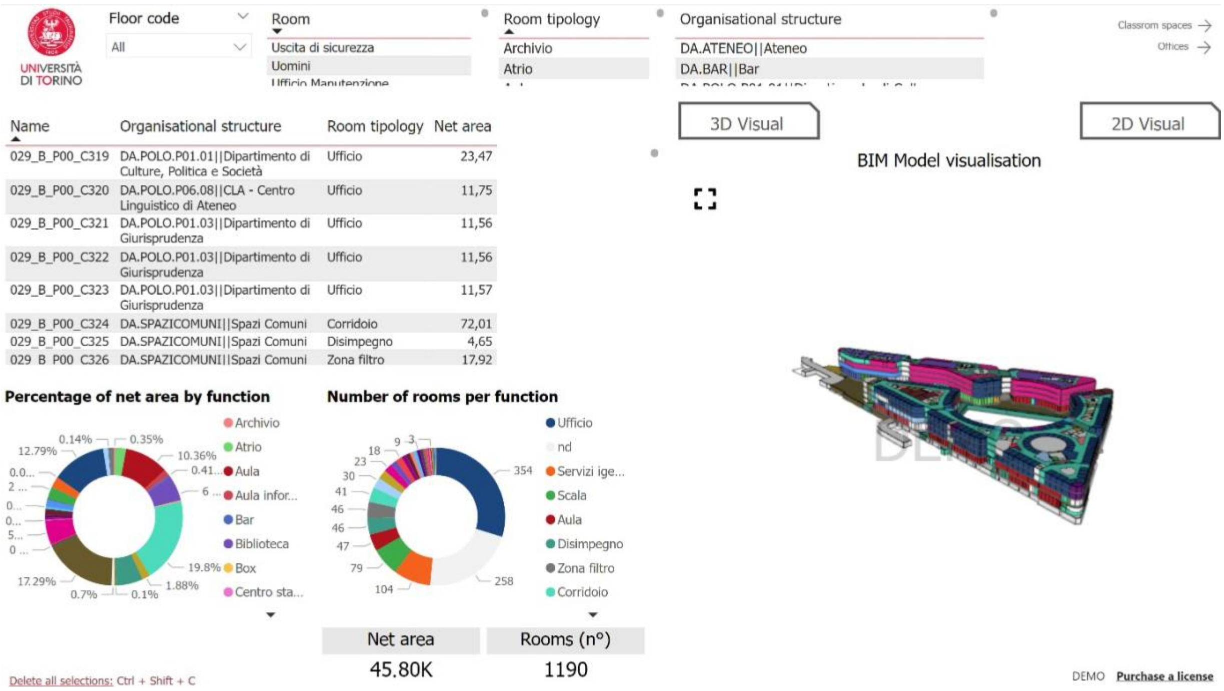

Figure 12: AMS-App dashboard at the building level enables the examination of space characteristics and allocation within CLE.

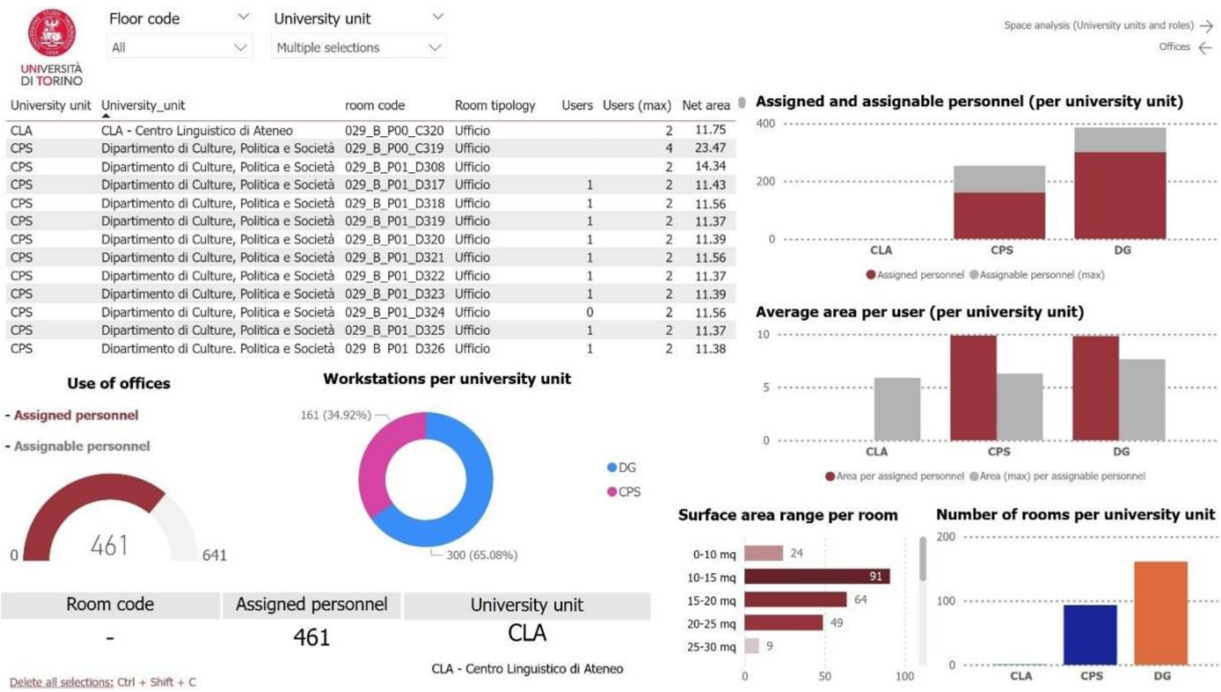

Figure 13: AMS-App dashboard at the building level offers a comprehensive analysis of office space and staff allocation within CLE.

Furthermore, the data can be filtered according to the selected department or area, enabling to display information about the allocated staff and the number of vacancies, the number of workstations divided by department or area, the average area for each user occupying the space, and the number of staff that can be accommodated further by selecting the individual room.

Currently, such dashboards are available to those responsible for space management, namely the school directors, the departmental directors, and the managers in charge of logistics and maintenance. In the future, when the management of the AMS-App will be fully entrusted to UniTO and the data will have to be accessible with different levels of privacy, the staff concerned will log in via username and password assigned for the report of interest.

4.3.1 Improving the use and management of work spaces

The objective of enhancing space management in the selected demonstrator led to the investigation of strategies to optimise the occupancy, allocation and utilisation of space through the implementation of work-from-home (WFH) practices. Currently, the contracts of professors, research fellows and PhD students offer flexibility in terms of working hours and locations, thus facilitating the organisation of WFH.

However, for administrative employees, WFH practices were initially introduced due to the COVID-19 pandemic and have since been maintained for two days per week. Despite the introduction of WFH practices, there have been no improvements in space management concerning flexible work scheduling.

The UniTO AMS-App aims to solve this problem by proposing an even distribution of WFH days among employees/researchers in the same office during the working week. This approach increases the maximum occupancy of individual offices, as not all occupants are in presence at the same time.

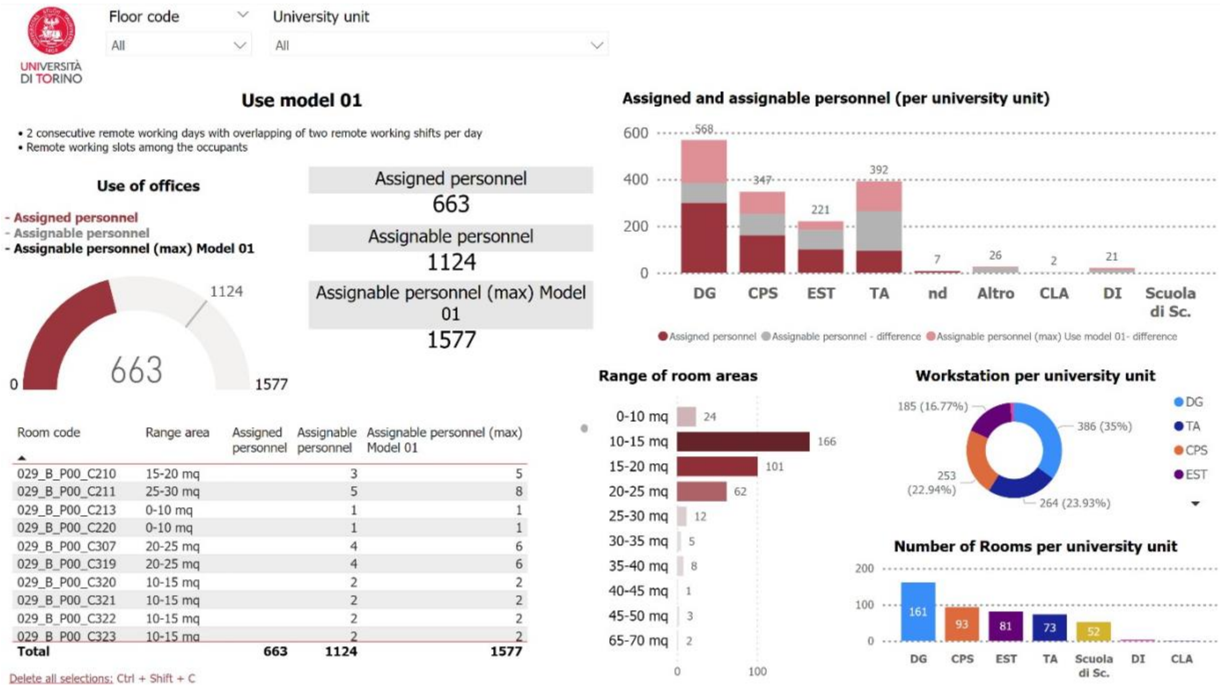

Figure 14: Analysis of space allocation and current occupancy levels, maximum capacity of each space, including the maximum occupancy when implementing work-from-home (WFH) practices.

WFH days are planned to ensure a certain number of occupants working remotely each day. Consequently, the overall occupancy of the building can be increased. If each worker has two WFH days in a five-day working week, the overall building occupancy increases by approximately 60 per cent (Figure 14).

This ensures that, in the event of recruitment, workstations are readily available within existing facilities, thus obviating the need to acquire or rent new space.

4.3.2 Monitoring and enhancing indoor environmental quality

Monitoring environmental quality data within educational spaces and offices is of paramount importance for two main reasons: firstly, to ensure a healthy environment enhance productivity and learning performance, secondly, for falut detection that may indicate the need for system adjustements and remodelling. Furthermore, this approach contributes to energy saving and the emissions reduction due to heating and cooling systems. Over the past two years, buildings at UniTO have been equipped with IoT devices for Indoor Environmental Quality (IEQ) monitoring. The CLE buildings serve as an excellent testing ground due to the high number of sensors and the presence of classrooms with different capacities and orientations. UniTO has selected IoT devices from Aircare® capable of capturing 15 types of measurements, including air quality, environmental comfort, and electrosmog indicators. Notably, the accuracy and reliability of these devices have been scientifically validated by the Italian Society of Environmental Medicine (SIMA) for PM2.5 and CO_2 measurements. A total of 39 IoT devices were strategically installed across 37 classrooms within the demonstrator, with a particular focus on the ground and first floors dedicated to teaching activities. The data generated by these devices are streamed directly to a cloud platform, facilitating data collection. Currently, the collected data are accessible through reports via an experimental platform managed by the ICT directorate, and they are not public or shared with other directorates. Designing a dedicated dashboard, the objective was to exploit the AMS-App's potential by linking the data to specific spaces and creating interactive charts to display real-time data from the continuously flowing information from the IoT devices. To maximise the advantages of measuring multiple types of data with a single IoT device, it was decided to associate viewable spaces with data related to CO_2, CO_2e, VOC, PM10, and PM2.5. The dashboard can merge the data with floor plans, thereby providing clear indications of the installed sensor locations within the respective classrooms. Users can easily access and visualize the recorded values throughout the week by selecting a specific classroom (Figure 15).

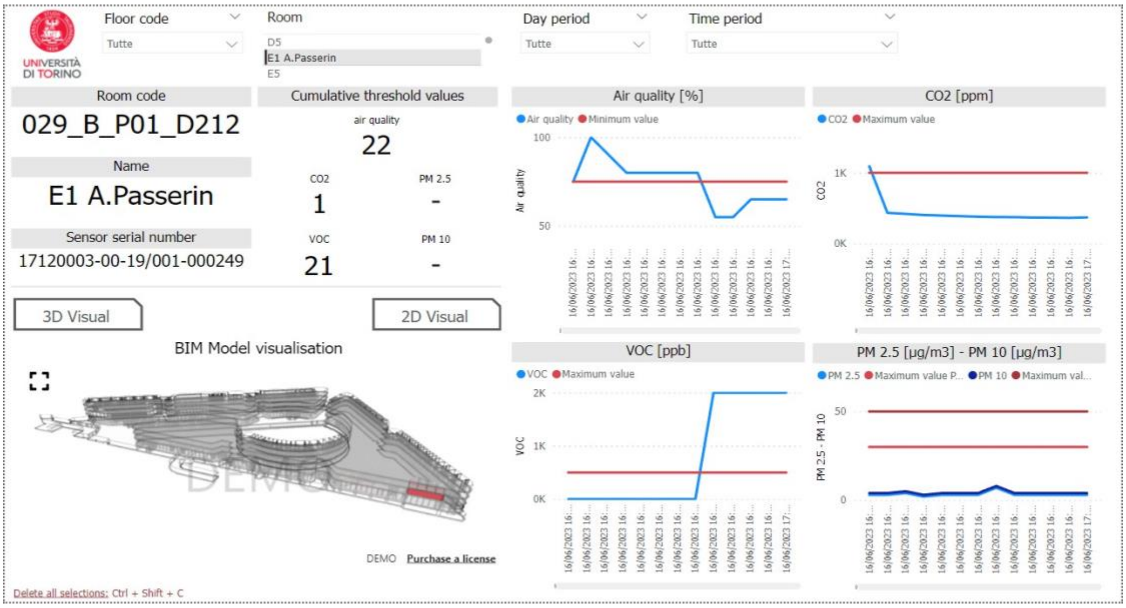

Figure 15: The AMS-App dashboard at the room level enables the visualisation of spaces and data provided by the sensors.

In order to serve as alert indicators, specific threshold values were established for the main parameters. In accordance with UNI 11300, during the heating season, temperature values ranging between 20 and 22 degrees Celsius were chosen, while for the cooling season, the range was set between 22 and 24 degrees Celsius. The threshold for CO_2 concentration was defined at 1000 parts per million (ppm). Concerning particulate matter, the recommended limits set forth by the World Health Organization were adopted: below 25 $\mu g/m^3$ for PM10 and below 50 $\mu g/m^3$ for PM2.5. Additionally, a limit of 550 parts per billion (ppb) was selected for volatile organic compounds (VOCs), by with the guidelines of the US Environmental Protection Agency (EPA). This approach offers several advantages. As first, it allows for the immediate visualisation of the data collected by IoT devices and their correlation with specific spaces. Then, it facilitates the analysis of recorded anomalies in occupancy and class schedules of those spaces. Overall, this comprehensive approach provides valuable insights for maintaining a healthy and optimised learning environment.

In the case of the indoor environmental quality dashboard, the information displayed is useful for various categories of users. Primarly, the university energy manager can monitor the trend of parameters and understand whether the systems are working properly. Additionally, students, professors, researchers and technical-administrative staff may also be interested in this type of data as they can monitor the environment in which they study and work and they can gain awarness while also possibly contributing to maintaining a healthier environment for all.

Potential future applications of this dashboard include the cross-referencing of environmental data with the operation of building systems. In this context, Internet of Things (IoT) devices can also function as actuators for systems and intervene to adapt environmental conditions. At a basic level, this mechanism could be triggered when a threshold is reached, while future developments could lead to more advanced triggers. Indeed, machine learning systems may support the implementation of predictive solutions that allow intervention on plants even before the threshold limit is reached.

5. CONCLUSIONS AND FURTHER DEVELOPMENTS

The paper presents the research developed under the umbrella of the UniTO strategic plan, aimed at developing an AMS-App that exploits the potential of the combined use of BIM, GIS, and BI tools in providing integrated data and analytics useful to support decision-making processes and optimize the management of one of the largest Italian university assets, proposing a replicable and scalable approach.

The research is contextualized in the ongoing digital transition of the AECO industry, revolutionizing management approaches through the adoption of data-driven and digital tools, aiming at improving efficiency and productivity. Indeed, implementing digital approaches coupled with information management strategies within organizations enables improved collaboration, structured information exchanges, and the availability of updated and shared information, effectively supporting decision-making throughout the asset lifespan. This can lead to significant impacts, especially during the operation and maintenance phase, which proved to be the most expensive and complicated to manage due to the lack of updated and comprehensive information, and formalized management processes with defined information requirements.

The motivations behind the choice of UniTO are explored with references to the current scientific background concerning digital transition and asset management. It is emphasized the importance of governmental actions for the effective and efficient implementation of BIM and digital technologies within organizations, especially public organizations that can lead and also have impacts on the private sector. The importance of the adoption of change management strategies to ensure the success of this transition is also highlighted. Indeed, disruptive and ineffective changes should be avoided, promoting the definition of modeling guidelines and protocols based on information management strategies and developed in agreement with the technical and administrative organizations' staff. In this way, the digital transition can be introduced more smoothly and effectively, thanks to the formalization of the information requirements and exchanges among stakeholders.

The replicable methodology developed for the creation of the AMS-App and its implementation in the organization's management system is illustrated. The results presented, show how the AMS-App enables the integration of data currently siloed and managed from the technical and administrative areas of UniTO, providing their visualization through BIM models and GIS maps, combined with other data through analytic and queryable dashboards, gathered in reports depending on the management scope. Some dashboards are useful to manage the asset at the territorial level, while others are designed to handle the information at building level. Furthermore, the reports and related dashboards are accessible with different levels of detail and privacy, according to the end-user and information sensitivity level.

The proposed methodology, with some minor adjustments, can be applied to other similar organizations and assets with significant impacts overall. Aiming at a smoother introduction of the AMS-App within UniTO management processes, the AMS-app has been developed exploiting software and tools compatible with the ones already used by the technical and administrative staff. Further improvements concern their complete or partial replacement with open-source solutions such as IFC standard or open-source BI and BIM modeling software, improving interoperability also towards external stakeholders as required by regulations. Anyhow, introducing such solutions is currently under evaluation concerning their stability and the staff competencies required, avoiding highly disruptive or expensive changes that can lead to the failure of the digital transition process and adoption of the AMS-App by the organization levels.

The results obtained so far with the gradual implementation of the AMS-App are discussed, illustrating several dashboards developed for different management purposes and levels. The whole UniTO campus is exploited to illustrate potential in supporting decisions at the territorial level. The analysis and potential for management processes at the building level are discussed through a demonstrator representing the most complete UniTO case study developed so far, the Campus Luigi Einaudi (CLE). It represents one of the biggest UniTO building, developed concerning all the topics managed through the app: (i) space management and use for multi-level data analysis and improved facilities operations; (ii) rationalization of teaching schedules based on real-time classroom availability and capacity; (iii) enhanced workplace management through the introduction of remote working strategies; (iv) IoT monitoring for analysis and improvement of indoor environmental quality and users' comfort.

Furthermore, the results show how the AMS-App can provide updated, integrated, and complete information, in the specified format and promptly available when required within the management process, effectively supporting decision-making procedures, and facilitating information exchanges. In future developments, a deeper analysis is needed to understand how automated data flow and analysis could be implemented through Artificial Intelligence (AI) and Machine Learning (ML). Indeed, the formalization of IRs and datsheets for the collection of data from the various areas allows for providing a single centralized repository such as a data lake, defining standardized queries to automatically extract needed data, feed and update the system, ensuring consistency over time.

When the AMS-app will be fully integrated into the UniTO management system, thanks to structured and formalized processes with related IRs, it will also be possible tasks automation. For example, the assignment of a space to a new resource will not neeed the request by the resource itself, the area or department directors. Similarly, when a resource leaves due to retirement, death or change of job, the space assigned will automatically be available and viewable through the application, without the need for time-consuming inspections and updates. Of course, protocols are under definition for the periodic management and updating of data to ensure maximum effectiveness throughout the asset lifecycle.

In conclusion, the introduction of the AMS-App enables overcoming various challenges posed by asset management practice and current siloed information management, providing structured information and the availability of comprehensive and updated data. The exploitation of BIM models, combined with GIS maps and other analytics enables to better understanding of the actual space exploitation and usage patterns, easily identifying potential for optimization and effectively supporting decision-making processes.

Of course, some challenges need to be faced. Such a change cannot be introduced without constant dialogue with stakeholders, otherwise, there is a risk of rejection, failure and inactivity. Rather, new digital approaches such as the one proposed should be gradually introduced, leaving to the different university areas management autonomy while sharing data. Changes are also necessary in the organizational structure, in the case of UniTO this concerns the introduction of a Data Analysis Unit across the different areas, which would be responsible for collecting, integrating, and updating data. Another issue to be considered is the periodicity of data updating, which is under definition based on the variability and type of data (i.e. static or dynamic data and data collected in the field). At the end of the implementation process, tailored guidelines and modeling protocols will be made available to managers and staff, defined for different project and managerial purposes, allowing IRs to be clear according to the objectives to be achieved, decreasing waste of spatial, financial, energy, and material resources.

Finally, the exploitation of optimal path analysis between buildings can lay the foundations for introducing real-time guided evacuation systems in case of emergency, providing actual Digital Twins of buildings. Indeed, having such a structured and comprehensive knowledge base available and the combined use of BIM and GIS , can enable the development of valuable DTs, enabling buildings to timely react to what occurs inside and outside them, both in standard conditions or emergency ones. At this aim, challenges will concern the correct installation of suitable IoT networks, the collection of nearly real-time data, the introduction of predictive and Artificial Intelligence tools, as well as the connection to the AMS-App. However, the system currently provides the structured, integrated, and constantly updated source of knowledge that is core for their development. The current possibility of displaying a BIM model, viewable on a GIS map and through analytical dashboards with insights from the sensors installed to detect IEQ conditions, is an excellent basis for developing and managing a DT driving actuators to optimize the building's environmental conditions based on both real-time sensing data and analysis of historical data, allowing predictions and corrections of deviations from expected behavior.

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