BIM-GIS integration and crowd simulation for fire emergency management in a large, diffused university

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Abstract

The integration of BIM (Building Information Modeling) and GIS (Geographic Information System) is promising to develop Asset Management Systems (AMS) for complex assets such as university building stocks. The potential lies in the ability to connect and contextualize data from several domains and at different scales, considering the relationship between buildings and surroundings, and paving the way towards the definition of Digital Twins (DTs) for proactive AMS. In a previous work, an AMS-app was developed through BIM-GIS integration in a web platform aimed at optimizing the Operational and Maintenance (O&M) phase of the large and diffused university of Turin's asset. The main objective was to provide an accessible and integrated database, supporting decision-making and improving user experience, enhancing resources use in both ordinary and emergencies scenarios. The paper presents the application of such a BIM-GIS platform and AMS-app for fire emergencies management through a case study. It illustrates the crowd simulation methodology developed, replicable to analyse the current fire safety level of the whole university asset and display it through the AMS-app and interactive dashboards. It describes how this is key to identify non-compliances and intervention priorities, in addition to the tailored data needed for each building. Furthermore, its importance for the long-term objective of developing DTs and active wayfinding systems useful for rescuers and users during fire emergencies is illustrated, identifying useful data which should be provided from on field sensors.

Keywords –
BIM, GIS, Asset Management, Operation and Maintenance, data integration, crowd simulation, fire emergency, Digital Twins

1 Introduction

The smart city concept recently was borrowed at campus scale to define digital AMS aimed at providing optimal resources use and a more satisfactory user experience during the low digitalized and investigated O&M phase [1-3].

BIM-GIS integration (i.e. GeoBIM) provides numerous advantages when applied together with Artificial Intelligence (AI) and Internet of Things (IoT), leading to buildings able to react to environmental changes autonomously and dynamically. Indeed, GeoBIM is promising to develop DTs and smart campuses [4], simulating buildings behaviour in the actual conditions of both the interior and surrounding, providing contextualized data and promptly decisions. At this aim, an accessible, well-structured, centralized, and scalable database is needed [5,6].

Thus, the first phase of the research, illustrated in a previous work [7], dealt with the definition of a holistic information management approach. It was core to provide an AMS-app, based on BIM-GIS integration, for the O&M phase of the University of Turin (i.e. UniTO) asset. UniTO has one of the largest and diffused Italian campuses with a vast catchment area. Nonetheless, its management system is still strongly document-based and fragmented, preventing awareness of its exact consistency and use. Over the past five years, enrolled students increased, amounting to approximately 83,000 in 2022. Together with teaching, administrative, and technical staff, it represents a quite complex system with a yearly expense of 1,3 million euros. Therefore, even a little improvement in the AM system can provide significant savings.

The research is part of a wider project, the short-term objective consisted in providing administrators with a digital AMS aimed at optimizing resources use and space occupancy [7]. The long-term objective concerns the development of a smart campus through interconnected DTs aimed at several purposes (e.g. management of energy use, mobility, emergency, facility and so forth) with buildings autonomously optimizing their performance based on real-time, historical, internal, and external contextualized data [8]. The first objective was provided through an AMS-app which enabled the asset visualization through an interactive 3D map, based on BIM-GIS integration [7]. Such an app collects all the data currently handled by several Directorates through a centralized database, key for the second long-term aim of developing future consistent DTs both for ordinary and emergency scenarios.

The most probable emergency in university campuses is fire emergency, still low investigated with respect to energy and facility management [9-10]. Thus, a crowd simulation methodology was developed and here presented through its implementation on a case study to check the current building fire risk level based on actual space occupancy and conditions. First results are presented, showing how this methodology could be replicated to cover the whole UniTO asset and provide a quick visualization of its current fire risk level through tailored analytics dashboards connected to the AMS-app. Required data which should be stored in the centralized database and gathered in real-time through future IoT systems were also identified. Providing administrators with such an AMS could enable to identify priority intervention, accordingly optimizing resources use and better programming of punctual enhancements. Finally, it’s discussed how future implementation of AI, IoT, DTs and Virtual Reality (VR) could enable active wayfinding systems useful for rescuers and users during fire emergencies, also identifying useful data which should be provided from on field sensors.

2 Background and motivation

2.1 BIM and GIS integration

The recent wide diffusion of IoT networks and digital technologies in construction industry is finally shaping the concept of smart buildings, and that of the smart city accordingly. BIM-GIS integration and DTs promise to facilitate their development and to provide cognitive buildings, autonomously reacting to environmental changes toward more resilient, proactive, and sustainable environments [6]. GeoBIM is a trend research topic, promising to reach data integration, strategic decision-making, and urban management with many advantages and applications [11]. Indeed, BIM enables to handle information at the scale of the building and its elements, while GIS at the macro-level of its surroundings [12]. Thus, the strength of such an integration consists in enabling digital AM from the micro-scale of the single component to the macro-scale of the territory. Nonetheless, BIM and GIS are not fully interoperable domains, and many issues must be overcome for their integration [13]. [14] identified three possible paths to convert and integrate data in a GeoBIM system, from BIM to GIS was recognised as the optimal one, with data extracted from BIM and imported into GIS. ESRI ArcGIS Pro® paired with Autodesk Revit® represents the most agreed and diffused authoring solution, easily providing BIM-GIS interoperability and data integration through a visualization platform. Numerous studies agree that the greatest benefits of BIM-GIS integration during the O&M phase can be found in AM and crowd simulation with a focus on risks, energy, facility, and security management [1, 3, 11, 14]. BIM improves route planning with its specific geometrical and semantic information about building interior and components. GIS provides spatial statistical methods for analysis, modelling data, in addition to localization data [27]. BIM-GIS provides the ability of creating a comprehensive scenario and enabling valuable simulations to identify optimal evacuation paths. One of the biggest issues in managing emergency scenarios.

Nevertheless, [3] illustrated how GeoBIM is still rarely investigated in the AM field, despite the great results in data collection, visualization, and analysis, providing enhanced decision-making. Mostly due to the challenges in collecting and storing a big amount of heterogeneous data with various granularity levels.

Finally, BIM-GIS integration is usually closely related to DTs and smart cities development and [1,3] highlighted how GeoBIM will be further improved to respond to the growing demand of DTs, significantly boosting the development of smart cities and smart campuses. [4]. GIS not only provides an immediate data contextualization, but it also enables data integration and DTs interconnection [15]. This is challenging but could results in great added value for university AM with a broader decision-making context in economic, social, and environmental perspectives. Indeed, it is needed the visualization of unknown and dynamic contextualized information for decentralized management based on a single source of truth. This is key in managing standard O&M scenarios but even more in emergency ones.

2.2 Smart campuses and university AM

Hardly accessible, and fragmented databases often struggle universities AM which is still strongly document based. This results in incomplete information leading to ineffective decisions. Particularly during the O&M phase which is already complicated [1] due to the need of comprehensive data exchanges among various stakeholders. A digital and dynamic AMS based on the principles of information management can support decision-making, providing a more comfortable environment, reduced costs, and resources waste [1, 3, 16]. A holistic information management system across several databases is still missing [1,3], even if could be particularly significant in smart campuses.

Several universities are borrowing the smart city concept at campus scale, mostly to provide more satisfactory user experiences and optimal resources use during the still low investigated O&M phase [1,2]. Indeed, university assets are characterized by a variety of services (e.g., courses, lecturers, and seminars) and users (e.g., professors, students, researchers, administrative staff, external people, and facility managers), resulting in a highly dynamic and changeable environment, complex to be managed [9, 17]. Ordinary management scenarios are characterized by a high level of unpredictability due to several heterogeneous users with different aims and schedules, representing a relevant causality source. During emergencies, panic stresses user behaviour and worsts unpredictability [9], especially in complex systems with crowded spaces such as smart campuses.

An agreed definition of smart campuses is still missing, even though many studies tackled their development with interesting results [10]. [18] identified six main features: context-aware, data-driven, forecasting, immersive, collaborative, and ubiquitous, highlighting the key role of data and their contextualization to provide consistent information and decision-making [1, 15]. The same key features are needed to develop valuable DTs for universities AM [1]. Thus, a switch from fragmented document-based approaches to digital collaborative ones is strongly needed [19]. Smart campuses with digital data-driven, user-friendly, analytical tools demonstrated to enable a holistic information management approach, needed to consider heterogeneous but interlinked data, influencing several ordinary AM activities (e.g., cleaning, maintenance, space optimization and occupancy monitoring). This enables to optimize information exchanges among several stakeholders throughout the complex university asset lifecycle, providing the best value and the optimal environment for users and owners.

Most cases developed so far started from a pilot building and its BIM model, only later georeferenced through BIM-GIS integration and then extending the procedure to the whole asset [12]. While this works for minor-sized assets, in the case of large and diffused ones would require years of development, preventing enhancement to the environmental footprint and to reach higher resilience and sustainability. Few examples exploited the reverse “macro to micro” approach [3], preferable to gain a quick overview of the asset in order to check its overall consistency, needed interventions and optimization opportunities. Indeed, there is not a unique and correct approach, the choice depends on the purpose. The “macro to micro” approach should be preferred when a strategic management tool for large assets is urgently needed and accordingly the analysis of its consistency and distribution [12]. Especially, when forecasting the development of smart campuses and future DTs.

One of the most interesting features unlocked by DTs consists in the ability to manage emergencies, that is complex scenarios due to their rapid evolution and variability [9, 20]. Particularly, in smart cities and smart campuses which requires crowd management due to many users carrying out various activities. DTs and VR can enhance quick decisions and crowd coordination through active wayfinding or alerting systems.

3 Methodology

The methodology is split in two parts: the first one, focused on the development of the web-based AMS-app with analytics dashboards using Business Intelligence (BI) tools. It dealt with the structuring of a centralized database, digitalization and georeferentiation of the whole UniTO asset through BIM-GIS integration [7]. The second part illustrates the significant potentials of such an AMS-app in one of its possible applications. The methodology defined for crowd simulation in fire emergencies is described and applied on a complex building, exploited as a demonstrator of its replicability to map the whole UniTO asset fire risk.

3.1 Data integration and AMS-app

The first step of the wider UniTO research project dealt with the definition of a methodology to develop the AMS-app, illustrated in [7] and following reported with a brief description of each step implemented.

1. Data acquisition and analysis of building stock and management processes: it dealt with the analysis of UniTO building stock and its management system to identify already available data, existing databases and platforms, in addition to the administrations involved in the AM. Useful missing data were unveiled and collected from the UniTO accessible communication channels or the several Directorates;
2. Data structuring to develop the integrated database: this was a key step concerning the identification and structuration of data previously collected, enriched with missing data about spaces and their functional attributes, providing a centralized, comprehensive relational database for the O&M phase. It was defined a tailored encoding system which uniquely identifies spaces and related data throughout the database, overcoming existent redundancies and duplicated codes, leading to multiple assignments. The data structure is flexible, enabling to insert additional fields whenever new data are needed;
3. BIM-based information modelling: BIM models

were developed and enriched with both spatial and functional semantic data. Buildings were modelled as masses, floors, and rooms to obtain an adequate level of information able to represent the whole diffused UniTO asset, without overburdening the AMS-app. Then, spatial and functional data previously acquired and collected in the centralized database were assigned to the related category of elements created (masses, plants, and environments) through Visual Programming Language (VPL).

4. Information models georeferentiation through the BIM-GIS web-based platform: the information models were implemented into the web-based BIM-GIS environment, providing UniTO asset and its attributed real-time visualization in an interactive 3D digital map (i.e., AMS-app). BIM-GIS interoperability was checked and achieved through the "BIM to GIS" approach exploiting ESRI ArcGIS Pro® and Autodesk Revit ®, currently representing the most suitable approach, as literature states. A tailored BIM-GIS integration workflow was used to model and georeferencing the whole UniTO asset, providing the AMS-app. The BIM models of the whole asset were imported in the GIS platform as georeferenced building masses, with geometric and semantic attributes;
5. Interactive analytics dashboards development: BI technology was exploited, enabling both the analysis of large amounts of data and interactive dashboard development aimed at facilitating information visualization and understanding. This is key to support AM and decision making, especially through future DTs. Several analytic dashboards were developed to provide information visualization at different scales, ranging from the macro level of the whole building or groups of buildings to the room micro level.

3.2 Crowd simulation for fire emergency

The steps afore-outlined involved information models integration in a web-based queryable AMS-app with their spatial and functional attributes. The further step concerned the definition of a replicable methodology for crowd simulations in case of fire (Figure 1), exploiting data stored in the centralized database.

The methodology aims at visualizing user reaction and movements in a fire emergency scenario, checking spaces and escape routes crowding levels, in addition to measuring and comparing the escape time with the regulatory reference one. It enables to analyse dangerous circumstances with high-density moving crowds at critical points of a building, such as stairs or fire exits. Crowding and emergency evacuations during hazardous events impeding to use one or more escape routes at a selected building floor can be assessed.

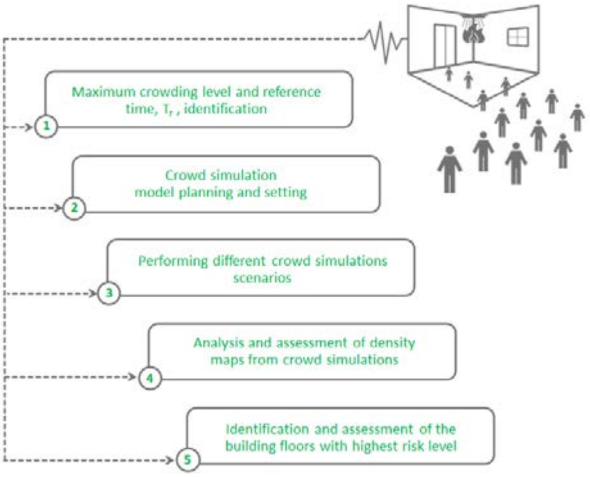

Figure 1. Methodology path for crowd simulation.

Previous studies identified the maximum crowding level, that is the maximum density of moving crowds over which high risk situations might arise, at five people per square meter (i.e., 5 p/smq) [21]. National prescriptive regulations (Italian M.D. 10/03/1998) define the reference escape time (T_R) as the effectiveness maximum time for the safety measures required. Thus, the actual safety of the building floors can be investigated considering high-risk levels of moving crowds and comparing the measured escape time with the prescriptive regulations' threshold.

The second step concerned crowd simulation model planning and setting (Figure 1). A microscopic approach [22] was applied to analyse the casual crowd [23] Literature identifies four factors influencing crowd simulations, among which space layout and users behaviour. The former can be considered by modelling the whole building or just a relevant portion, including all spaces and user flows exploiting the same safe place, escape routes and stairs, ensuring simulation reliability. Furthermore, the model should consider limitations on escape route or space access for predefined user groups. The users are represented as agents able to identify the best escape route according to crowd behaviours and the least effort principle thanks to an AI system. The model exploits a collision avoidance algorithm based on vision-based cognitive models [24], enabling agents to perceive their mutual position and movements and acting accordingly. Consequently, field of view (FoV) angle, user speed, avoidance preference direction, and avoidance range are defined. In order to simulate the worst possible evacuation scenario, agents are modelled considering the maximum building, building section, or occupancy capacity. Further scenarios are simulated introducing a hazardous event preventing the use of one or more escape routes on a selected building floor with agents able to use only free escape routes. The proposed crowd simulations aim to assess the safety of space distribution and occupancy besides the effectiveness of escape routes and exits.

The third methodology step (Figure 1) performed crowd simulation scenarios. The first scenario considered the whole building, or the section analysed as in the selected demonstrator. The agents are triggered to leave their personal spaces and evacuate through any possible escape routes and exits. Then, a hazardous event in one or more escape routes is introduced, preventing agents from their use during the evacuation.

The fourth step (Figure 1) involved the density map analysis resulting from performing crowd simulation. It is the maximum density of moving crowds reached during the whole simulation in each point of the building. As literature highlight, it is key to verify density values at critical points (i.e., fire exits, stairs access, and corridors), where different user flow intersections can provide overcrowding and accidents. In addition, scenario simulations enable the identification of the building floors with high risk levels of moving crowds, (i.e., density values greater 5 *p*/sqm) in non-safe areas, selected to be analysed in the next step. While safe areas are the protected and external stairs and the safe places identified by fire emergency plans, non-safe areas are spaces and corridors.

In the fifth step (Figure 1), the building floors which showed high-risk levels of moving crowds are further analysed, and for each selected floor, the escape time is measured ($T_1, T_2, \dots, T_n$). It starts when the first agent of the floor is triggered to leave the building and continues until the last agent has reached the safe place or the floor exit, which leads directly to the protected or external stairs. The measured escape time is then compared with the reference one. If $T_n < T_R$, the escape time is comparable or inferior to the one defined by prescriptive regulations, safety measures are defined based on it, and the check is satisfied. Otherwise, if $T_n > T_R$, the check is not satisfied, and the actual building layout, escape routes, exits, and other safety measures are not sufficient to ensure user safety during an emergency.

4 Case study

UniTO asset represents a large widespread campus, the third largest Italian university with a huge catchment area and users' number, resulting in a hard management and usability. It counts 112 buildings for an amount of almost 629,000 net square meters, mixed in style and destination, with a huge heterogeneity. UniTO's buildings host various activities, often open to the public such as seminars, exhibitions, and cinema; together with administrative, teaching, and technical staff, it represents the management of a small town with a high level of complexity and unpredictability. Nonetheless, the current UniTO AMS is fragmented and poorly digitized, preventing awareness of its consistency, use, and distribution over the territory. The prompt perception of these features is needed by administrators, as well as an AMS strongly connected with the urban space.

The selected demonstrator represents a significant case study, chosen due to its spatial and management complexity (Figure 2), worsened by the strong crowding. The building is Palazzo Nuovo and houses the school of humanities with five departments, 33 degree courses, and about 965 study courses, amounting to 22,641 students in the last academic year, that is the 27.7% of the total university population, showing a positive growing rate of 14.8%. It is composed by seven floors above ground and three basement floors, in addition to three huge classrooms separate from the main body with a net area of 6787 sqm (Figure 2). It counts 5000 seats between classrooms, study rooms and degrees spaces, in addition it holds places in other external buildings for a total availability of almost 7,475.

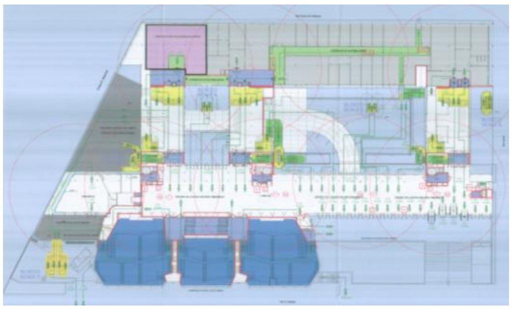

Figure 2. Standard floor plan showing the complex spatial articulation of Palazzo Nuovo.

Hence, current places can't cover Palazzo Nuovo demand and its complex management makes it a suitable case study to apply the crowd simulation methodology defined for fire emergency. Recently it undergone major renovations to minimize asbestos-related and to improve space and fire safety. All the staircases and escape routes were isolated to fulfil national standards and lead to a safe place according to the requested escape time.

5 Results and discussion

In the aim of testing the AMS-app and centralized database application potential, crowd simulations have been conducted on Palazzo Nuovo, investigating its actual level of safety in case of fire. The methodology defined enabled to simulate different evacuation scenarios compliant with fire and safety prescriptive standards. Traditional approach limitations were discussed, exploring improvements achievable through dynamic simulations and DTs during evacuations.

First and foremost, the reference escape time (T_R) for each floor was identified through the analysis of national fire regulations. T_R is defined as the maximum escape time from each single floor, enabling users to reach the nearest fire exit, leading either to fire protected or external stairs. Italian Government M. D. 10/03/1998 provides prescriptions and limitations both for existing and new buildings, identifying three buildings fire risk level: high, medium, or low. Palazzo Nuovo is classified as a university facility hosting more than 1,000 occupants with a high fire risk level, thus the simulation T_R is equal to 1 min for escape routes between 15 and 30 m long. According to the literature, the maximum moving crowds density to be considered is equal to 5 p/sqm. The crowd simulation model includes the six floors above the ground, counting a full capacity of 1,765 users using the same escape routes, stairs, and exits to reach the only two safe places at the ground floor. The six stairs represent the escape routes, placed two by two in the centre and on the two opposite sides of the building (Figure 3, top side). The basement floors were excluded as have dedicated exits and escape routes with less worrying crowd phenomena. The ground floor also was excluded as most of the exits lead directly to safe places. The simulation model involved the following parts:

- The ground floor with two safe places;
- The six floors above the ground and their spaces;
- The expected maximum occupants' number in each space from fire emergency plans, their walking speed, avoidance range, FoV angle, and avoidance preference. User speed is defined as a triangular distribution function of three speed values: low value of 0.8 m/s, medium value of 1.35 m/s, and high value of 1.75 m/s [25]. Avoidance range and FoV angle were set equal to 10 m and 75° as the default settings of the simulation software, and the avoidance preference was set on right;
- The six staircases representing the escape routes (i.e., three external and three protected).

Then, crowd simulations in two evacuation scenarios were performed. The first one considering the entire building section defined, while the second one with a hypothetic hazardous event on the first floor which hosts the greatest number of users. It was located in front of the two staircases on the left, preventing access to the two stairs for the first floor (Figure 3, top side). The next step tackled the density map analysis during the simulation for the two crowd scenarios (Figure 3, bottom side), at each floor of the building. Density above 5 p/sqm were considered dangerous when detected in non-safe areas, that is areas different from safe places and protected or external stairs.

In the first scenario (Figure 3), only the first floor shows high risk levels of moving crowds, becoming significantly more crowded in relation to other floors. The same results in the second scenario (Figure 3).

Figure 3. First floor with the hazardous event (Top side) and density maps from the first and second simulated scenario (Left and right bottom side respectively).

Comparing the two first-floor density maps, in the second scenario non-safe place area with density over 5 p/sqm is 14.23% greater than in the first one. Finally, each floor of the two scenarios with a detected density over 5 p/sqm has been analysed. Tn is defined for each floor as the time at which the first agent of the floor is triggered by the emergency alarm. It ends when the last agent of the floor reaches the fire exit, leading to a safe place or to the protected or external stairs. T_n was then compared to the previously defined T_R (1 min) in the two scenarios. The escape time of the first floor, in the first scenario, T1, and in the second scenario, T_2, is:

- T_1 = 12 min 52 s > T_R (1 min); 12.86 time greater than T_R
- T_2 = 15 min 48 s > T_R (1 min); 15.80 times greater than T_R
- The comparison shows $T_2 > T_1$ with T_2 22.79% greater than T_1.

The results pointed out the limits of prescriptive regulations to ensure building fire safety. Despite the escape routes maximum length, defined according to regulations (i.e., between 15 and 30 m with high fire-risk level, corresponding to a T_R of 1 min), should ensure the correct evacuation to all users, at all the building levels, the dynamic simulation highlighted criticalities due to user flows. This results in overcrowding and an escape time far superior to prescribed values, T_R, in both scenarios. Furthermore, the great negative impact that a hazardous event can have on the occurrence of dangerous phenomena and on the evacuation were pointed out.

The crowd simulations enabled also to define the set of significant data, which should be found in the database (e.g., T_R, T_n, density values, walking speed, FoV angle, avoidance range, expected occupants, and avoidance preference). It will be key both for future dynamic simulations aimed at mapping the current asset fire-risk level through the AMS-app and defining "fire emergency DTs". The actual occupation was individuated as the first, crucial data which should be provided in real-time through IoT networks. In the future, the current data set should be enriched and completed. Such as, all the possible crowd evacuation routes at each floor should be simulated and stored in the AMS-app. Thus, an AI algorithm could be integrated to analyse and optimize them as simulations progress, teaching the DTs better behaviours. They should also be loaded into a VR system connected to the AMS-app to provide active wayfinding [26]. Finally, a tailored dashboard was developed and connected to the AMS-app for fire safety analysis of each floor of the building, (Figure 4).

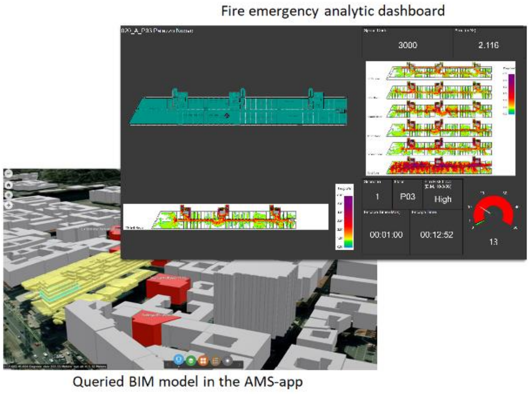

Figure 4. Example of queried BIM model in the AMS-app and related fire emergency dashboard.

It shows:

- the floor plan with occupancy levels,
- the floor plan with crowd simulation,
- the level of fire risk with respect to the regulations,
- the maximum escape time and the effective one deriving from the simulation.

6 Conclusion and future work

The paper is part of a wider research with the short-term objective of developing an AMS-app based on BIM-GIS integration to improve the O&M phase management of the large and diffused UniTO asset. This was accomplished in a previous work, briefly summarized, providing a centralized and flexible database. Then, the paper focused on the first steps toward the second long-term objective: the definition of the UniTO smart campus through DTs aimed at several purposes. This will enable to resolve or prevent deviations from expected behaviors in ordinary scenarios but especially in fire emergency. At this aim, a replicable crowd simulation methodology was presented and tested through a complex case study. The results highlighted the limitations posed by current prescriptive regulations and the need to integrate them with dynamic simulations based on updated data about the building and its occupancy. Required data which should be available from the centralized database and provided also through the IoT networks were identified.

In the future development, the crowd simulation methodology will be replicated throughout the whole UniTO asset, providing an overall “fire risk map” in the AMS-app, able to highlight interventions’ priorities. In the aim of providing a consistent smart campus, it will be also investigated how AI and VR systems could enable the cognitive features required by DTs. Thus, buildings will promptly react and adapt their behavior to environmental changes, improving performances simulation by simulation. Additionally, active wayfinding for fire scenarios could be provided and drive users evacuation through audio-based systems or lighting signals, according to data gathered from IoT networks and the actual occupancy. Users can be real-time guided through the safest and shortest evacuation routes, exploiting paths loaded in the AMS-app and displayed through digital devices. The app can be exploited also to alert rescuers and guide them with indications to reach life in danger or fire outbreak point in the shortest possible path and time.

The AMS presented could overcome current still document-based and fragmented management issues, providing a suitable database to develop consistent DTs. It could provide effective decisions and management based on complete, contextualized, and real-time data, stored in a centralized and flexible database. Through synthetic dashboards and BI tools linked to the AMS-app, useful strategic data and graphs could be displayed. Thus, a better management of UniTO’s financial and spatial resources will be enabled, with cost savings and waste reduction. There will be several challenges in IoT and AI implementation through the AMS-app, besides the development and interconnection of several DTs and overcoming stakeholders’ hesitance in adopting the new collaborative approaches.

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