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Enhancing Public Event Management through BIM–GIS Integration

A Case Study of Piazza San Carlo, Turin

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Abstract,

The integration of Geographic Information Systems (GIS) and Building Information Modelling (BIM) has become an important approach for better understanding complex urban environments. GIS provides spatial information at the urban scale, while BIM provides detailed information related to buildings and physical elements. In the context of event management, there is also a need to update the existing city map and bring information from different sources into a single environment, particularly when temporary event assets and other changing elements are involved. The integration of BIM and GIS can therefore contribute to creating a more up-to-date representation of the city. The present thesis investigates the potential of BIM–GIS integration for supporting decision-making in event management. A technological workflow was developed to collect, prepare, integrate, and visualize information obtained from different data sources. The workflow combines a fit-for-purpose building information model, urban spatial data, and event-related information and temporary assets in an integrated environment. GIS was used for spatial organization and analysis, while BIM-based information contributed detailed three-dimensional representation of relevant physical elements. The integrated information was presented via an interactive dashboard, offering an easier way to explore the updated event environment and access the information needed for management and planning. The results show that the proposed approach can improve the organization, visualization, and accessibility of heterogeneous information and can provide useful support for event-related decision-making. The developed dashboard also demonstrates the potential of integrated spatial visualization for innovative urban and event-management applications.

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CHAPTER 1. INTRODUCTION

1.1 Background

Urban public spaces play an essential role in shaping the urban texture, with their character emerging from a combination of historical, geographical, political, and cultural aspects. Beyond their everyday purposes, these spaces provide locations for a wide range of social and cultural activities, including temporary events that can significantly change their usual usage patterns. Festivals, public gatherings, performances, and other organized events can transform the way spaces are occupied, introducing temporary changes to circulation, accessibility, infrastructure, and interactions among different users. Nevertheless, as the frequency and size of such events increase, their organization and integration into the existing urban environment introduce growing challenges for planners and local authorities. This creates a need for more efficient planning and management approaches that can bring diverse and relevant information together at the same time, enabling a more comprehensive understanding of the situation and supporting more informed decision-making and effective event organization [33].

Urban events momentarily transform both the physical configuration and functional organization of public spaces. Temporary structures, pedestrian flows, access routes, public services, security actions, and other event-related installations must be integrated and coordinated within the existing urban setting. As the number and diversity of events taking place in cities continue to increase, this temporary transformation raises the question of how events can be arranged and designed to accommodate multiple, and sometimes conflicting, usages of public space. The challenge becomes particularly complex when events are held in central or historically important areas, where transient interventions must respond not only to the operational requirements of the event but also to the existing spatial, architectural, and heritage features of the site. In such contexts, effective event preparation and organization require a clear understanding of how temporary interventions interact with the existing characteristics of the urban space. Therefore, access to integrated and appropriately designed information can support stakeholders in estimating these conditions before and during event organization.

The complexity of temporary events also creates an information management challenge. Different aspects of an event, such as the physical attributes of the site, pedestrian circulation, temporary setups, accessibility, safety practices, and available services, are distributed and may be described through different types of information. Bringing these elements together is important for developing a comprehensive understanding of how an event affects its surrounding urban environment and for supporting the decisions required during event preparation and coordination.

The development of digital technologies has deeply changed the ways in which cities are represented, documented, and investigated. Traditionally, urban environments were described

through maps, drawings, and other graphical illustrations stemmed from observation, measurement, and the interpretation of urban form. As techniques for acquiring and organizing spatial information evolved, these representations gradually developed into structured digital models capable of supporting more complex methods of urban analysis and decision-making [29].

The emergence of Geographic Information Systems (GIS) expanded these capabilities further by enabling spatial data to be systematically managed, analyzed, and visualized within a common geographic framework. At a more detailed scale, Building Information Modelling (BIM) introduced digital representations of buildings and infrastructure that combine geometric information with data describing their physical and functional characteristics. While GIS primarily provides a demonstration of the wider spatial context, BIM allows the individual elements within that context to be described in greater detail. Therefore, the integration of these two approaches can provide a more thorough framework for managing spatial information across different urban scales [18].In the context of urban events, such an integrated representation could link the wider characteristics of an event site with detailed information about the physical and functional elements that are temporarily impacted or created during the event.

Piazza San Carlo in Turin provides a relevant case study for investigating these issues. As one of the city's most substantial historic public venues, the square combines distinctive architectural and heritage values with an active role in contemporary urban life. Its use for public events can briefly transform the square's spatial organization, requiring the coordination of temporary infrastructure, pedestrian movement, approachability, safety procedures, and public services within a built environment subject to specific locational and heritage constraints. The case study therefore provides an opportunity to investigate how the integration of BIM and GIS can support the organization, integration, and visualization of spatial, architectural, and event-related data through an interactive platform, ultimately facilitating more informed decision-making in the preparation, coordination, and management of public events.

1.2 Research Gap

The increasing adoption of digital technologies has enhanced the representation, analysis, and management of urban environments. Building Information Modelling (BIM) provides detailed information about buildings and infrastructure, while Geographic Information Systems (GIS) enables the management, analysis, and visualization of spatial information at the urban scale. Their complementary capabilities have led to an increasing interest in BIM–GIS integration for built environment planning, decision-making, and the development of digital twins [19]. However, existing research on this integration has largely concentrated on technical aspects such as data interoperability, information exchange, three-dimensional representation, and the development of

digital models for smart-city and digital-twin applications. Although these approaches have contributed considerably to the combination and representation of urban information, their application to the planning and preparation of temporary public gatherings remains relatively limited [27]. In particular, there is a need to investigate how integrated BIM–GIS environments can move beyond just the illustration of urban assets and support the organization, analysis, and communication of information required for event-related decision-making.

Public events in city centers require continuous coordination and decision-making among multiple stakeholders, while simultaneously dealing with heterogeneous datasets and changing spatial conditions. Event organizers and public authorities must consider a range of interconnected factors, including accessibility, safety, temporary structures, pedestrian traffic, public services, and the preservation of heritage values [35]. These requirements introduce a level of operational complexity that cannot be addressed through the representation of spatial or building information alone. Therefore, limited research has focused on developing integrated decision-support approaches specifically for the management of public events in heritage-sensitive urban spaces and there remains the necessity for an integrated approach capable of connecting these different types of information and supporting stakeholders in evaluating aerial configurations and making informed decisions throughout the event planning procedure.

A key gap therefore exists between the collection and integration of spatial and BIM-based data and their practical use in addressing the requirements of different stakeholders. Information concerning entrances and exits, barriers, surveillance cameras, temporary structures, pedestrian flows, safety conditions, and available services may be distributed across different datasets, models, or information systems. When these elements are not connected within a common decision-support environment, stakeholders may have difficulty obtaining a comprehensive view of the event configuration and understanding how changes to one element may affect others. This limits the potential of integrated digital models to support the practical coordination and management of events in dense urban environments.

Furthermore, stakeholder requirements are not always explicitly linked to the spatial and informational requirements of the digital environment. Different stakeholders may need different forms of information to support their decisions. For example, municipal authorities or event organizers may need to determine the appropriate location of temporary facilities, evaluate pedestrian circulation, identify potential safety risks, or assess how temporary interventions may affect existing heritage characteristics. However, much of the existing BIM–GIS research remains focused on the technical integration and interoperability of datasets, with less attention given to identifying the information required for specific decision-making tasks and determining how this information should be structured and presented to stakeholders.

The unresolved issue is therefore not simply how BIM and GIS can be technically integrated, but how their combined capabilities can be transformed into a practical decision-support environment that explicitly connects stakeholder requirements with spatial conditions, BIM information, and event-related data. Addressing this issue could enable integrated digital models to function not only as representations of the urban environment, but also as practical tools for supporting the planning, coordination, and management of temporary public events.

1.3 Aim and Objectives

The aim of this research is to develop a BIM–GIS-based decision-support framework for supporting the preparation, coordination, and management of public events in an important urban space. Rather than focusing solely on the development of a digital representation of the urban environment, the research seeks to establish a practical workflow through which relevant data can be collected, structured, integrated, and communicated according to the information requirements of the event manager and other stakeholders involved in event organization.

To achieve this aim, the research pursues the following objectives:

1- To identify the information and decision-making requirements of the event manager and other relevant stakeholders involved in the preparation, coordination, and management of public events.
2- To identify and structure the BIM, GIS, and event-related information required to address these requirements within the context of a historic urban space.
3- To establish a BIM–GIS workflow for integrating and organizing spatial, physical, and event-related information.
4- Displaying an interactive dashboard based on a temporary event scenario at Piazza San Carlo, utilizing dynamic synthetic data to visualize integrated information from diverse data sources within a unified environment.

These objectives are pursued through a sequential workflow that begins with identifying stakeholder requirements and information, proceeds with the preparation and integration of event-related, BIM, and GIS data, and using a event scenario and synthetic data demonstrates how an integrated information environment can support event preparation, coordination, and management.

1.4 Research Questions

Achieving the aim of this research requires an understanding of the needs of stakeholders involved in public event management, the information required to address those needs, and the ways in

which digital technologies can support related decision-making processes. Accordingly, the following research questions are investigated:

1- What information and requirements can be identified for the relevant stakeholders involved in the management of public events in an important urban space?
2- How can the identified stakeholder requirements be translated into a digital ecosystem and decision-support functionalities for public event management?
3- How can BIM–GIS integration support the connection of different types of information within a decision-support platform for public event management?

These research questions guide the process of developing and presenting the proposed framework.

CHAPTER 2. LITERATURE REVIEW

2.1 Evolution of Urban Representation for the Contemporary City

The representation of urban environments has evolved from selective visual depictions to increasingly structured and information-rich digital environments. This transformation reflects broader changes in the ways cities have been observed, measured, interpreted, and represented over time [29].

In the earliest forms of urban representation, maps and drawings were primarily produced to communicate particular aspects of the city according to the purposes for which they were created. Rather than attempting to provide a comprehensive representation of the entire urban environment, these documents often emphasized selected features considered relevant at a given time, such as important buildings, monuments, religious structures, streets, public spaces, or locations associated with political and civic power. Urban representations therefore initially functioned as selective interpretations of the city, reflecting specific spatial, cultural, and institutional priorities rather than providing a complete and systematic description of the urban environment[4].

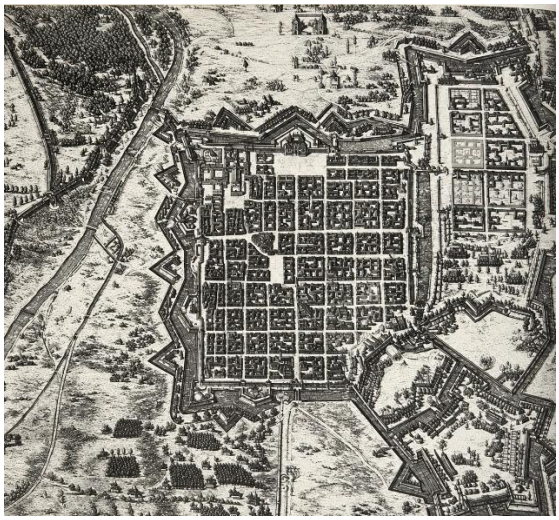


Figure 2.1 – Early selective urban representation emphasizing key urban features and spatial organization,[2]

Some early forms of urban depiction also sought to communicate a sense of three-dimensional space. Buildings were often portrayed in perspective, allowing their elevations, apparent height, and visual relationships with surrounding elements to be conveyed within a two-dimensional image. Nevertheless, such depictions remained fundamentally dependent on a particular viewpoint or vantage point. Although they could provide an impression of depth and spatial organization, they did not constitute fully measurable three-dimensional models in which geometric relationships could be examined independently of the observer's position.

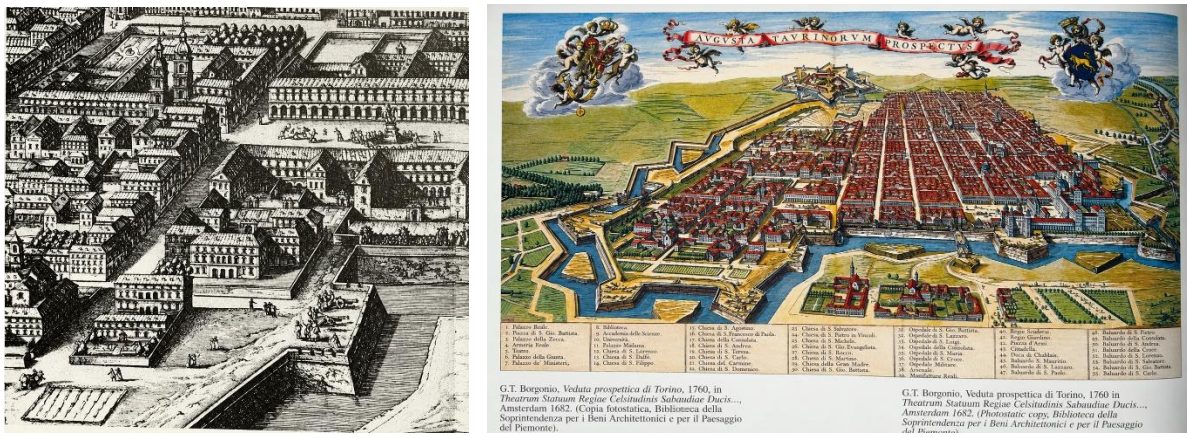


Fig.2.2. Early three-dimensional representation of Piazza San Carlo and its surrounding urban blocks, viewed from the Theatrum (1670),[5]

Fig. 2.3. Early three-dimensional visual representation of Turin by G. T. Borgonio, 1760, illustrating the city's urban form and spatial context,[2]

As surveying techniques advanced and methods for measuring and locating urban elements became more systematic, cartographic practices gradually achieved greater geometric precision and coverage. Urban features could be documented in terms of their position, scale, dimensions, and boundaries with increasing consistency, allowing the spatial relationships between different elements to be described more accurately. This development marked a shift from primarily visual depictions toward more structured representations in which the geometry and location of urban features could be measured, compared, and interpreted using a common spatial reference.



Figure 2.4 – Early urban representation of Turin, showing the geometric organization and spatial structure of the city, [4]

Alongside these developments, architectural standards and graphic conventions became important in forming consistent methods for describing buildings and urban spaces. The adoption of plans, elevations, sections, and other standardized forms of architectural drawing provided established systems for communicating geometric and spatial characteristics. These conventions

made it possible to describe architectural elements using consistent scales, projections, dimensions, and relationships, further strengthening the transition toward structured and measurable forms of urban and architectural documentation.

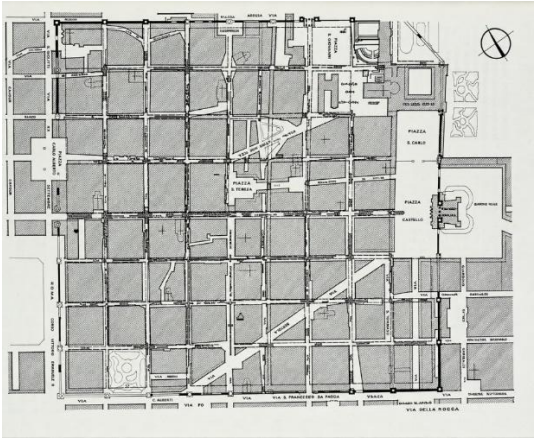


Fig. 5. Map of archaeological remains of urban interest in Turin, based on the documentation of the Archaeological Heritage of Piedmont and updated through 1984[4]

As methods of documenting the built environment became more developed, the focus of urban representation extended beyond the description of physical form and geometric properties to consider how places are used and experienced. Greater attention was given to land use, patterns of activity, and the functions performed within different parts of the city. For example, porticos and urban streets can be understood not only as architectural and spatial elements, but also as locations for commercial exchange, pedestrian activity, and everyday social interaction. This broader perspective contributed to an understanding of the city as an environment shaped by the interaction between its physical structure, patterns of use, and human experience.

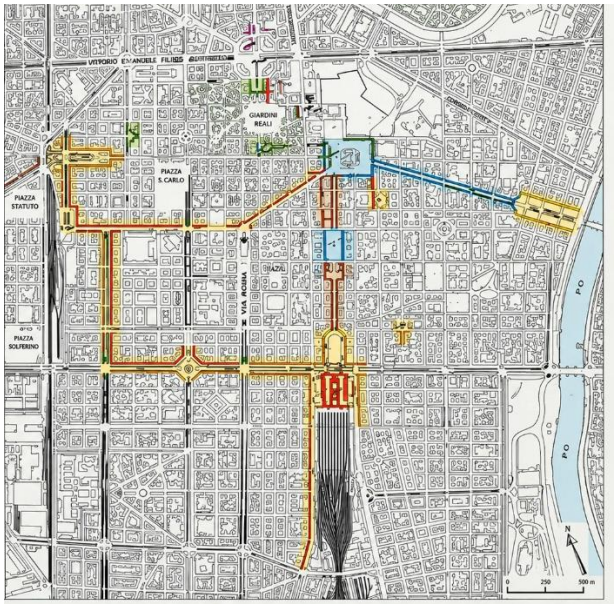


Fig. 2.6. Urban map of Turin showing the selection and classification of information for the representation of the city,[9]

Beyond physical configuration and geometric properties, the understanding of urban space is also closely related to human perception and the ways in which people interpret and assign meaning to their surroundings (Lynch, 1960). Kevin Lynch conceptualizes the public image of a city through five fundamental elements: paths, which structure movement through the urban environment; edges, which define boundaries or barriers; districts, which form identifiable areas with a distinct character; nodes, which act as focal points or strategic locations; and landmarks, which serve as external points of This framework illustrates that the organization of an urban environment cannot be understood solely through its geometric properties. The relationship between spatial configuration and human perception is also fundamental to readability and wayfinding, as people interpret and navigate places through recognizable spatial relationships and reference points. Consequently, an urban environment may be geometrically coherent while still being difficult to interpret if its paths, nodes, districts, landmarks, and boundaries do not form sufficiently clear relationships. Urban representation must therefore account, at least conceptually, for both the measurable characteristics of space and how those characteristics are perceived and interpreted by its users[12].

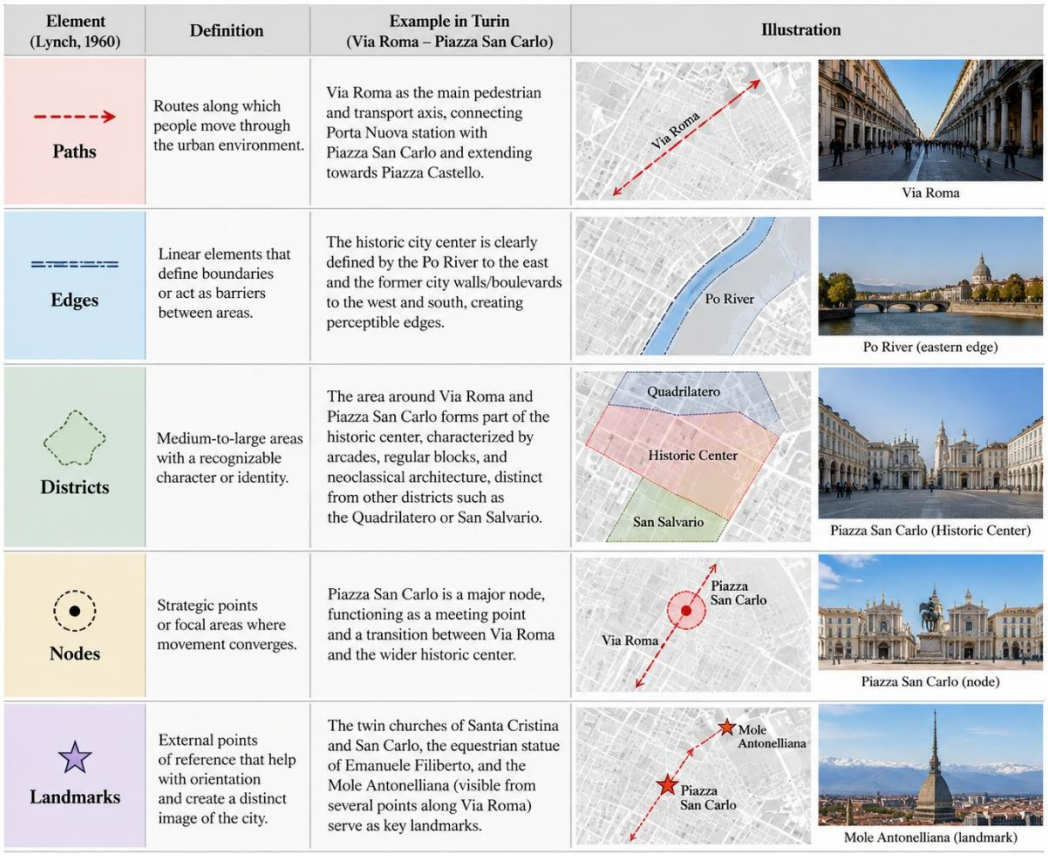


Figure 2.7– Urban map of Turin showing the classification and spatial representation of land use, movement, and urban activities, Author

With the emergence of computer-based technologies, the development of digital tools further transformed the documentation of the built environment. Computer-aided methods made it possible to produce plans, elevations, and other technical drawings with greater geometric precision, consistency, and efficiency. At the same time, digital workflows enabled a gradual shift from collections of separate two-dimensional drawings toward three-dimensional computer-

generated models. Buildings and other urban features could increasingly be constructed as digital volumes, allowing their height, form, and spatial relationships to be examined more directly and providing a more comprehensive understanding of their three-dimensional configuration.

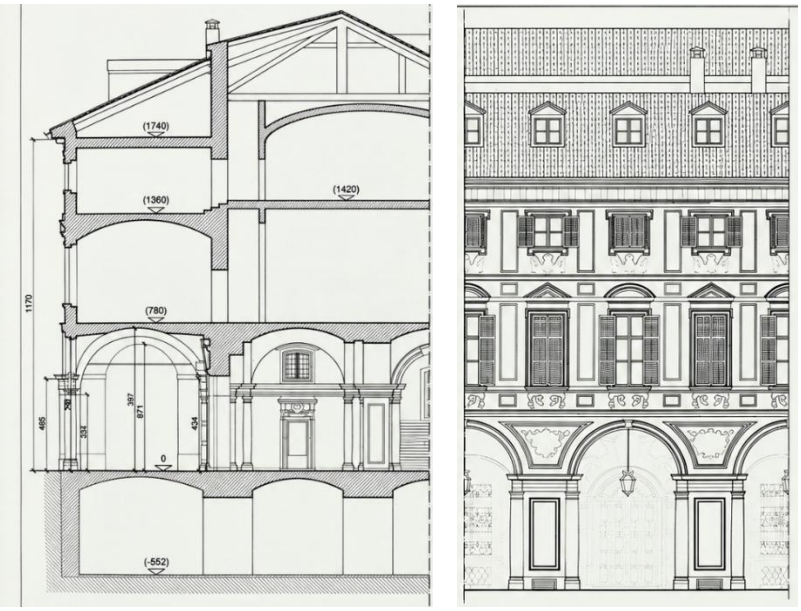


Figure 2.8. Digital architectural drawings representing building geometry and spatial configuration. [1]

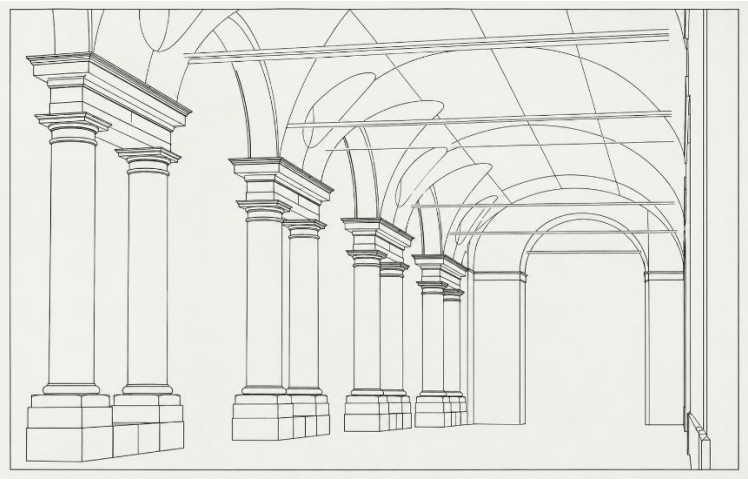


Figure2.9 . Three-dimensional digital representation of the porticoes of Piazza San Carlo, Turin[1]

However, a three-dimensional model based solely on geometry still primarily describes the physical form of an urban element. A further development was therefore the association of geometric models with additional information describing the characteristics, functions, properties, and relationships of the represented elements. Buildings and other urban features could consequently be understood not only through their shape and spatial configuration, but also through the information associated with them. The representation of the built environment thus began to move beyond visual and geometric description toward an information-based approach in

which spatial elements and their related attributes could be organized within the same digital environment. These developments demonstrated how different forms of information could be combined to provide a more thorough understanding of the environment built.

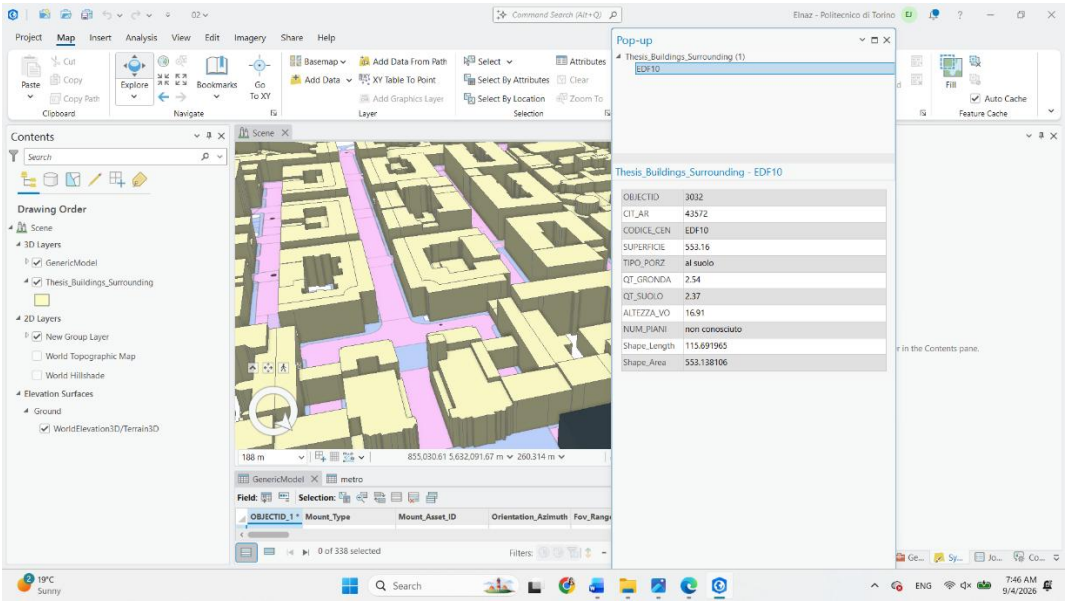


Figure 2.10 – Information-enriched 3D urban model integrating spatial geometry with attribute, Author

In conclusion, growing volume and variety of urban data require approaches that extend beyond static descriptions of physical and geometric form. This evolution has increased the importance of digital and information-rich environments capable of combining different types of spatial and descriptive information and presenting them through more interactive and integrated forms. Such approaches provide new possibilities for exploring, interpreting, analyzing, and navigating urban spaces, establishing the foundation for the digital technologies discussed in the following sections.

2.2 BIM–GIS Integration for Urban Information Management

With the evolution of urban representation from traditional maps to information-rich digital environments, the need to integrate diverse types of data regarding the built environment has become increasingly important. In this context, Building Information Modeling (BIM) and Geographic Information Systems (GIS) offer two complementary approaches to representing urban space. Both methods are widely employed and, while possessing distinct functions, compensate for each other's limitations; consequently, their complementary capabilities provide a foundation for integrating precise building data with broader spatial analyses at the urban scale.

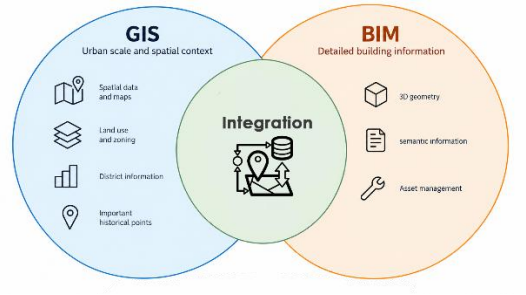


Figure 2.10 – conceptual integration fo GIS BIM Capabilities. Author

2.2.1 **Building Information Modeling** (BIM)

Building Information Modeling (BIM) is an advanced digital methodology for representing built assets through structured, information-rich three-dimensional models. It represents building elements as interconnected objects that integrate geometry, properties, attributes, and semantic relationships within a coherent digital environment. Also, BIM supports the organization and management of information throughout the entire building and asset lifecycle[48].

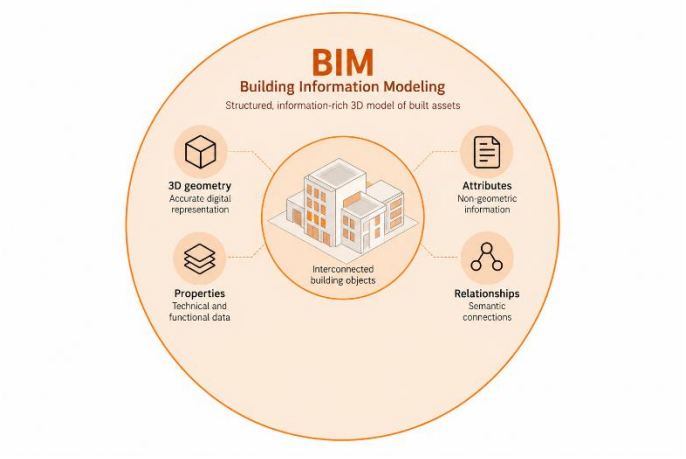


Figure 2.11 Key components and information dimensions of BIM, author

Level of Development (LOD) defines the degree to which a BIM element's geometry and associated data are reliable for decision-making The fit-to-purpose principle aligned with ISO 19650's concept of Level of Information Need dictates that models should contain only the geometric detail and data attributes required for a specific project use, avoiding unnecessary complexity [43].The primary benefit of this approach is enhanced model efficiency and performance, as stripping away superfluous geometry prevents file bloat, reduces software lag, and streamlines clash-detection bottlenecks (Succar, 2009). Additionally, it integrates lean construction principles by eliminating digital waste through the prevention of over-modeling, which saves authoring hours and lowers labor costs [46].Finally, establishing precise LOD requirements within the BIM Execution Plan provides critical contractual risk mitigation by clarifying design liability and managing stakeholder expectations regarding model reliability [42].

Benefit Category	Description
Enhanced Model Efficiency & Performance	Eliminates superfluous geometry to prevent file bloat, reduce software lag, and streamline clash-detection bottlenecks.
Lean Construction & Cost Savings	Eliminates digital waste by preventing over-modeling, which saves authoring hours and lowers labor costs.
Contractual Risk Mitigation	Clarifies design liability and manages stakeholder expectations regarding model reliability by establishing precise LOD requirements within the BIM Execution Plan.

Table 2.1 Benefits of the fit-to-purpose BIM approach ,author

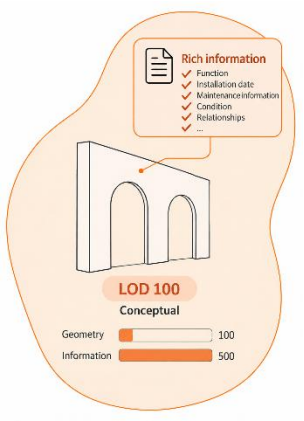


Figure 2.12 Level of Development Conceptual representation, author

2.2.2 Geographic Information Systems (GIS)

A Geographic Information System (GIS) is a geospatial information framework designed to support the collection, organization, management, analysis, and visualization of geographically referenced data. By integrating spatial and attribute information within a unified digital environment, GIS enables the representation of geographic features in various forms, including points, lines, polygons, and other spatial datasets. This capability allows users to identify spatial patterns, examine relationships between different elements, and analyze the distribution and characteristics of urban and regional phenomena. [48].

2.2.3 BIM–GIS Integration

Collecting and managing data across different spatial scales is essential for developing accurate and up-to-date representations of the urban environment. This can be supported by integrating Geographic Information Systems (GIS) with Building Information Modeling (BIM). Although these two systems operate at different scales and serve different purposes, they can effectively complement each other. BIM focuses on the detailed representation of building components and

assets, such as lamps, canopies, and other physical elements, while GIS provides their geographic location and places them within a broader urban and landscape context. By connecting these two perspectives, individual building assets can be related to their surrounding urban environment, creating a more continuous flow of information across different spatial scales.

Aspect	BIM (Building Information Modeling)	GIS (Geographic Information Systems)
Main focus	Building and its components (indoor and immediate surroundings)	Broader geographic environment (urban, regional and landscape scale)
Spatial scale	Detailed, object-level (e.g., building elements)	Large-scale, multi-layered (e.g., city, district, landscape)
Data type	Detailed geometric and non-geometric information (e.g., materials, performance, manufacturer data)	Geospatial data (e.g., land use, terrain, infrastructure, environmental and socio-economic data)
Coordinate system	Local coordinate system (project-based)	Global or national coordinate system (e.g., WGS84, UTM)
Level of detail	High level of detail (defined by LOD, e.g., geometry and attributes)	Variable level of detail (depending on data source and scale)
Typical applications	Design, construction, renovation, operation and maintenance, asset management	Urban planning, spatial analysis, infrastructure management, risk assessment, decision support
Main users	Architects, engineers, contractors, facility managers	Urban planners, GIS specialists, policy makers, asset managers
Common tools	Autodesk Revit, Archicad, Navisworks, IFC-based platforms	ArcGIS (Pro, Online), QGIS, other geospatial platforms
Role in integration	Provides detailed information about individual building assets	Provides spatial context and connects assets within the wider urban environment

Table 2.2 . Main Differences Between BIM and GIS author

The integration of BIM and GIS can also improve the way building assets are managed throughout their lifecycle. Different Levels of Development (LOD) within BIM allow the geometric and informational detail of building elements to be defined according to the requirements of a project. When combined with the broader spatial information provided by GIS, this detailed building-level information can support decisions related to site selection, spatial positioning, and asset management. For example, GIS can provide information about the spatial context and location of an asset, while the corresponding BIM model can provide more detailed information about its physical characteristics and associated data.

However, the value of BIM–GIS integration goes beyond simply combining two datasets. A key challenge is establishing a reliable connection between detailed building information and its wider geographic context. By linking BIM assets with their corresponding GIS features through consistent identifiers, such as Asset IDs, these two sources can be brought together within a shared spatial information environment. This connection allows detailed information associated with individual assets to be accessed in relation to their urban context, providing a stronger basis for informed decision-making and more effective asset management.

The table summarises the main previous studies reviewed in this research on BIM–GIS integration, highlighting their approaches, applications, advantages, and limitations. The reviewed studies cover a range of methods, including web-based integration frameworks, multi-scale spatial databases, IFC–CityGML semantic mapping, CIM and Business Intelligence applications, HBIM-based disaster recovery, and GIS-based dashboards for urban asset management. Collectively, these studies demonstrate the potential of BIM–GIS integration to connect detailed building information with broader geospatial contexts, support data sharing and querying, and improve information-based urban management. At the same time, several recurring limitations can be identified, including interoperability issues, geometric and semantic information loss during data conversion, dependence on proprietary software, and difficulties in georeferencing and spatial alignment.

Reference	Approach	Main advantages	Main limitations
Narindri et al. (2022) [18]	Web-based building management platform integrating BIM data into GIS using ArcGIS.	Supports data sharing and stakeholder collaboration; enables cloud-based model updates and reporting	Focuses mainly on architectural and structural BIM data; data quality is not deeply evaluated; depends on commercial software
Shirzad (2020) [13]	BIM–GIS workflow using FME and ArcGIS Pro to connect building-scale information with city-scale datasets and analyse energy consumption.	Supports schema-based BIM-to-CityGML translation and multi-LOD modelling; connects micro-scale building information with macro-scale urban GIS.	Translation can cause geometric and semantic data loss; coordination and coordinate-system mismatches remain significant obstacles.
Piras et al. (2024) [19]	Comparison of open-source QGIS and closed-source ArcGIS Pro strategies for BIM–GIS integration.	Highlights flexibility and customization of open-source workflows and advanced BIM visualization through ArcGIS Pro.	Open-source workflow can be technically complex; closed-source solutions require proprietary licences.
Zhou (2020)	Query-based dashboard integrating BIM and GIS data using multi-LOD building models and energy information for urban asset management.	Integrates heterogeneous datasets; provides interactive ArcGIS dashboards and multi-LOD visualization; evaluates different BIM-to-GIS conversion workflows.	Higher LODs require complex attribute mapping; direct Revit import has geometric limitations; accurate georeferencing is essential.
Scandurra et al. (2025) [31]	Integration of BIM, GIS and Business Intelligence tools for public heritage asset management within CIM systems.	Combines heterogeneous datasets; enables multi-scale queries, KPIs and dynamic dashboards.	Adoption barriers caused by traditional workflows and the absence of standardized operational procedures
Colucci et al. (2022)	Multi-scale spatial database integrating BIM and GIS using PostgreSQL and Dynamo for heritage maintenance.	Supports multiple Levels of Detail and establishes a bidirectional information bridge between modelling software and a spatial database.	Significant geometric and semantic incompatibilities remain; fragmented heritage data may require complex federated modelling.
Misilmani et al. (2024)	Integration of TLS, UAV photogrammetry, BIM and ArcGIS Pro for 3D heritage management and disaster assessment.	Combines accurate point clouds with HBIM and enables 3D spatial visualization through ArcGIS Online.	Legacy data processing is complex; accurate georeferencing and spatial alignment are required.

Table 2.3 comparative review of BIM-GIS integration approaches, author

Overall, BIM–GIS integration connects detailed asset information with the wider urban context, providing a foundation for more effective urban management and informed decision-making.

2.2.4 Connecting BIM–GIS with Urban Management

The integration of BIM and GIS becomes more valuable when the information is used to support the management of urban assets rather than simply combining datasets. Detailed BIM information can describe the physical characteristics and properties of an asset, while GIS connects the same asset to its geographic location and surrounding urban features. This allows assets to be

considered not as isolated building elements, but as spatially referenced components of the wider urban environment.

In this context, an integrated BIM–GIS environment can support urban managers in locating assets, accessing their associated information, and analysing them in relation to their surroundings. Such an approach provides a basis for interactive spatial visualisation and information-based decision-making, particularly when multiple assets need to be monitored or managed across public spaces. The integration therefore shifts BIM–GIS from a data-exchange concept towards a practical information-management framework for urban assets.

2.3 Decision-Support Interfaces for Public Space and Event Management

As urban environments generate increasing amounts of spatial and non-spatial information, decision-support interfaces help organize and present this information to support urban management. In public spaces and during events, they can integrate information such as asset locations, crowd distribution, capacity, accessibility, and warning areas.



Figure 2.13 Management decision -making by digital platform, Author

These interfaces may include interactive maps, KPIs, charts, filters, information panels, and warning elements, with different platforms supporting analytical, spatial, operational, or customized applications. Among them, Microsoft Power BI, ArcGIS Dashboards, and ArcGIS Experience Builder offer different approaches to interactive data visualization and management, as compared in Table [40].

Platform	Main orientation	Mapping	3D / BIM integration	Data analysis	Customisation
Power BI	Business / data analytics	Moderate	Limited / indirect	Strong	Strong
ArcGIS Dashboards	Spatial / operational monitoring	Strong	Strong within ArcGIS workflow	Moderate	Moderate
ArcGIS Experience Builder	Custom web applications	Strong	Strong within ArcGIS workflow	Strong	Very strong

Table 2.4 Comparison of Power BI, ArcGIS Dashboards, and ArcGIS Experience Builder, author

Based on this comparison, ArcGIS Dashboards was selected because the proposed system is primarily spatial and focuses on geographically referenced urban assets. Its map-centred interface enables spatial information to be combined with indicators, charts, filters, and asset information within the ArcGIS environment[41].

For this research, its main advantage is the ability to connect spatial context with operational information in a single interface. This makes it suitable for presenting BIM–GIS-derived asset information, event-related indicators, capacity conditions, and warnings to support public-space and event management.

CHAPTER 3. METHODOLOGY

3.1 Research Framework

The research aims to develop and evaluate a framework for integrating BIM and GIS to support event management in the urban public space of Piazza San Carlo, Turin. The research stages are categorized into input data, process, and output frameworks structures, that show a systematic definition of the relationships between user needs, required data, technical processes, and visualized research output.

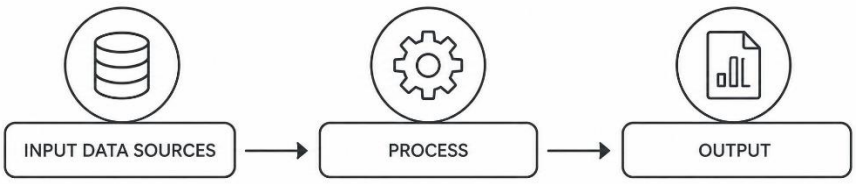


Figure 3.1 Research framework, author

User needs are considered a fundamental basis for defining the system. They are translated into functional and non-functional requirements which are determined for a decision-support system. Once user needs and platform requirements have been established, the system's primary use cases are identified. A use case illustrates how a specific system capability is employed in a scenario to address a particular issue.

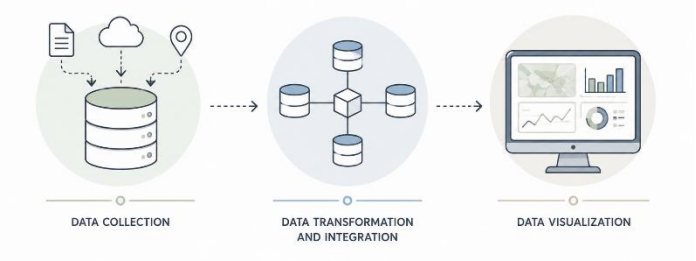


Figure 3.2. workflow steps from collection and preparation to integration and visualization. Author

To demonstrate process functionality in a real-world context, an event management scenario is considered in the case study environment. In this way, the role of BIM-GIS integration can be more clearly described and evaluated. Essentially, the scenario demonstrates how information derived from diverse sources can be utilized within an integrated process to address a specific operational requirement.

By considering a scenario, the input data stage represents the starting point and brings together different types of information which can be includes historical and morphological which representing the wider urban context, district data describing the spatial and geographical characteristics of the surrounding area, building data consisting of fit-for-purpose geometry and information related to relevant physical fixed or temporary assets, and event data describing temporary layouts, and operational requirements, and synthetic data based on the defined event scenario may be used to support the representation of dynamic conditions in the dashboard.



Figure3.3 - Input data categories, Author

For Processing, preparing collected data is the first stage, data are organized, and their quality and consistency are verified. Additionally, the spatial information, models, and layers required for subsequent stages are prepared. Within the BIM domain, the model is tailored to the research objective and the required level of detail. In the GIS domain, spatial data are organized for use within a spatial environment**.** The integration of BIM and GIS is the next step, establishing a link between diverse information. Combining these data enables the association of data from different domains within a shared environment, allowing them to achieve meaning and context within the framework of a specific problem. After integration, the data are further processed to transform them into usable information for decision-making. Depending on the use case, queries can be used to extract and relate the required information from the integrated dataset.



Figure3.4- Processing data steps, Author's elaboration

The final stage is output, which must demonstrate how the combination, integration, and processing of input data transform into information suitable for decision-making ecosystem like an interactive dashboard that presents processed information in a format that is simple, understandable for users. Where necessary, synthetic data derived from the defined event scenario are incorporated to represent dynamic conditions, enabling a more realistic and comprehensive visualization of information on the dashboard.



Figure 3.5. Dashboard-based approach to addressing users' needs, Author

Overall, the framework connects user needs, use cases, event scenarios, BIM–GIS integration, and decision-support outputs in a structured process. It provides the methodological basis for transforming diverse spatial and operational data into actionable information through an interactive dashboard for urban event management.

3.2 Case Study: Piazza San Carlo, Turin

Piazza San Carlo is one of the most important public spaces in the historic center of Turin, Italy. Located along the central axis of Via Roma and embedded within the city's historic urban fabric, it represents an important cultural and social landmark. Its architectural character is defined by the continuous facades and buildings surrounding the square, together with the churches of San Carlo Borromeo and Santa Cristina, which form its southern edge. Its central location and strong connections with the surrounding streets have contributed to its dual role as an everyday urban gathering space and a setting for organized temporary cultural and social activities. These characteristics make Piazza San Carlo a demonstrative example of Turin's historic public places and provide an appropriate context for examining the relationship between the permanent urban environment and its temporary event-related uses [1].





Figure 3.6 The square is located in the main axis of Via Roma, Figure 3.7. Urban View of city center of Turin, Italy (Google Earth Pro,2026)

The configuration of Piazza San Carlo reflects the historical development of Turin and the transformation of its central urban structure. The square forms part of the seventeenth-century expansion of the city and is associated with the urban projects undertaken during Turin's transformation into a capital city. Its layout is characterized by a strong geometric order, continuous porticoes, and a coherent relationship between the surrounding buildings and the open central space. At the southern end, the churches provide a distinctive architectural termination to the square, while the monument of Emanuele Filiberto occupies a prominent position at its center. Together, these elements contribute to a highly ordered spatial composition in which the architecture surrounding the open space and the elements within it are closely integrated [3].

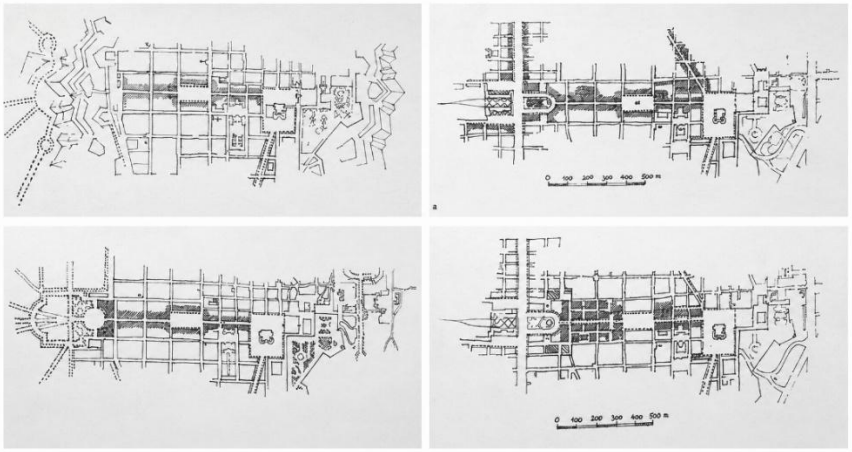


Figure 3.8. Historical evolution of Via Roma, Turin: Contrada Nuova, Porta Nuova, late 19th century, modern Via Roma (North: Right), Source [3]





Figure 3.9. The monument of Emanuele Filiberto, Piazza San Carlo, Turin. Source [2]

Figure right3.10 : portici of Piazza San Carlo., source [52]

Over time, Piazza San Carlo has undergone several transformations affecting circulation, paving, and the organization of its public space. In particular, the relationship between pedestrian areas and vehicular movement has changed considerably. Historical documentation of these transformations records the former circulation routes around the central monument, as well as the subsequent reorganization of the square following the redevelopment of Via Roma and the construction of the underground parking infrastructure [2]. These interventions resulted in a configuration that emphasizes the continuity between the surrounding porticoes and the pedestrianized central area while retaining elements of the square's historical spatial structure and paving pattern.




Figure 3..11 Square paving modifications,2006 Source: [54] - Figure 3.12 Vehicle thoroughfare until 2005., Source: [54]

The square functions as a multifunctional urban setting where everyday activities coexist with commercial, cultural, and temporary uses. The surrounding porticoes accommodate cafés, commercial establishments, and pedestrian circulation, while the open central area provides a flexible setting for gatherings and public events. The coexistence of permanent architectural elements and temporary uses makes the square particularly relevant to the study of public-space management, as event-related activities can modify how the existing environment is used without fundamentally altering its permanent structure. Its configuration can therefore be adapted to different types and scales of events, with temporary arrangements and facilities responding to their specific spatial and organizational requirements.

During temporary events, the existing status of the square can be supplemented or temporarily modified through the introduction of structures and other event-related elements. These may include event stands, barriers, checkpoints, cameras, temporary access points, emergency exits, and designated emergency routes. The presence, location, and arrangement of these elements can influence pedestrian circulation, accessibility, crowd distribution, and safety conditions. As a result, effective event preparation and coordination require the permanent features of the urban environment to be considered together with temporary event-related information. This creates a need for an integrated representation in which both the existing spatial context and the momentary configuration associated with an event can be organized and interpreted within the same environment.




Figure 3.13 CioccolaTò event at Piazza San Carlo,2022., Source [53]
Figure 3.14 Just the woman I am event at Piazza San Carlo,2022., Source [53]

For the purpose of this research, Piazza San Carlo is considered as a historic public space and dynamic urban environment in which different spatial configurations can be represented according

to specific event scenarios. The case study focuses on integrating the existing urban and architectural information of the square with event-related elements and associated data. The study area encompasses the main open space of Piazza San Carlo, the surrounding porticoed areas, relevant access and circulation points, and selected temporary elements introduced as part of the representative event scenario.

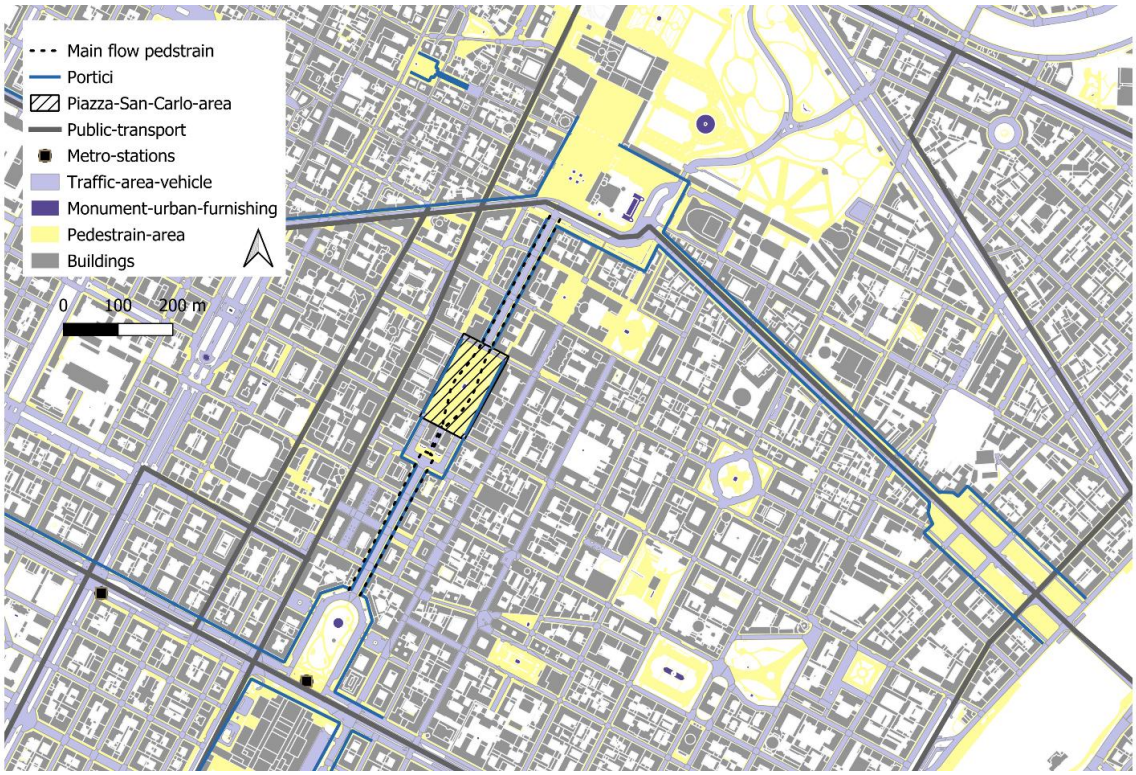


Figure 3.15 Urban context and spatial characteristics of Piazza San Carlo, developed in QGIS by author

The combination of detailed architectural features, pedestrian areas, access routes, temporary installations based on defined scenario, and event-related requirements makes the square a suitable context for demonstrating the proposed BIM–GIS workflow. Within the proposed approach, BIM is used to represent and organize detailed information associated with selected physical fixed or temporary elements, while GIS provides the spatial data for positioning these elements as well as their attribute table, analyzing their relationships, and relating them to the surrounding urban context all of which can be visualized and used to inform decision-making within the platform.

Event History and Requirements Analysis

Piazza San Carlo has hosted a wide range of public activities for centuries, including cultural events, celebrations, commercial festivals, public performances, and temporary installations. The diversity of these uses demonstrates the square's capacity to accommodate events of varying natures and scales, each requiring specific spatial and organizational arrangements. Factors such as fluctuations in visitor numbers, temporary infrastructure, circulation patterns, accessibility, and safety requirements can significantly influence how the space is organized and coordinated for a particular event.





Figure 3.16 Giovanni Michele Graneri, Piazza San Carlo in Turin, 1752, oil on canvas, Turin, Museo Civico. Source [2]

Figure 3.17- Tournament for the marriage of Vittorio Emanuele and Marie Adelaide, Drawing by G. Leoni 1842, Turin. Source [2]

Three prominent events previously held at Piazza San Carlo were examined to identify and analyze the conditions, inspiring scenarios, and possible challenges associated with developing the proposed integrated BIM-GIS system. The selected events represent different types and scales of contemporary public occupation of the square. These cases were selected because they illustrate different relationships between the square, temporary installations, pedestrian concentrations, cultural activities, safety requirements, and the heritage character of the surrounding built environment.

UEFA Champions League Final, 2017

One of the most significant events in the recent history of Piazza San Carlo took place in June 2017, when the UEFA Champions League Final between Juventus and Real Madrid was publicly screened in the square. The event attracted too large a crowd and subsequently became one of the most critical examples of crowd-safety challenges associated with the square.

During the screening, a sudden wave of panic spread among spectators, resulting in numerous injuries and fatalities. The incident was subsequently investigated by the City of Turin through a dedicated municipal commission. Beyond the specific circumstances of the incident, the event illustrates how a large-scale public gathering can substantially alter the conditions under which a historic urban space is used and managed. This case also illustrates how a situation initially perceived as an ordinary public gathering can rapidly escalate into a critical and extreme situation following an unexpected disruption [51].

Under normal circumstances, the open central area of Piazza San Carlo accommodates relatively distributed pedestrian movement. During a mass gathering, however, a large number of people may concentrate within a limited area, increasing the importance of the relationships between entrances, exits, surrounding streets, circulation routes, and potential escape paths. This event further demonstrates that population-related risk is not limited to physical density alone but can also manifest dynamically, as uncertainty and perceived threats influence crowd behavior[5]. Therefore, this example highlights the importance of understanding pedestrian concentration and circulation, access and egress, and safety-related spatial conditions when preparing for large-scale events in the square.





Figure 3.18 2017 Turin crowd crush, [51]

Figure 3.19 escape routes in Piazza San Carlo during the 2017 event. 2017. [51]

From the perspective of the present research, the 2017 event provides a significant precedent for examining crowd concentration, emergency movement, and the association between spatial configuration and public safety. The concentration of many spectators within a confined area can affect normal pedestrian circulation and increase the complexity of identifying and accessing available escape routes. The transition from normal event conditions to an emergency evacuation scenario also underscores the necessity of viewing risk as a dynamic process [5]. The event therefore highlights the importance of having clear information about the spatial conditions relevant to crowd movement and safety. These considerations make access and exit points, emergency routes, barriers, and other event-related elements particularly relevant when analyzing the spatial requirements associated with large-scale events in Piazza San Carlo.

CioccolaTò

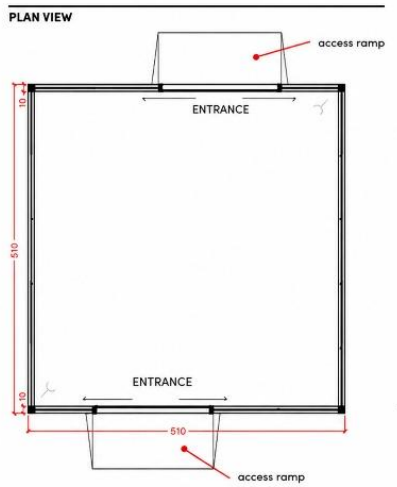
CioccolaTò is a recurring chocolate festival that has been held in Turin for several years, combining temporary exhibition stands, food-related activities, and cultural programs within the city center. In the editions considered in this study, particularly those of 2022 and 2023, Piazza San Carlo was among the main locations of the festival, with temporary stands and visitor activities occupying part of the square. The event provides a relevant example of how temporary installations can alter the spatial organization of Piazza San Carlo and influence pedestrian movement. The positioning and distribution of the stands create points of attraction where visitors stop, gather, and interact, potentially reducing the space available for continuous pedestrian circulation. From the perspective of the present research, this case is therefore useful for examining the relationship between the location of temporary installations, the distribution of pedestrian activity, and the continuity of circulation through the square.

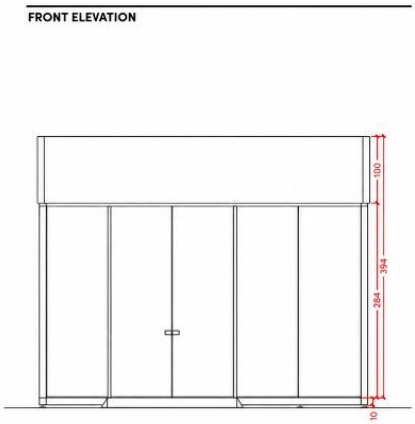


Figure 3.20, 3.21 CioccolaTò, event at Piazza San Carlo., 2022 Source [54]

Following a change in the event format announced in 2024, subsequent editions of CioccolaTò were relocated to Piazza Vittorio Veneto, where the exhibition area was organized around a huge number of temporary stands. Official documentation for the updated event format provides technical information on different stand types, dimensions, and configuration requirements, including standardized modules [25]. Although these specifications relate to a later edition of the event and to a different location, they provide a contemporary reference for understanding the scale and spatial requirements of the temporary installations associated with CioccolaTò. This information is therefore used as a reference in the development of the representative event scenario in the subsequent stages of the study, where dimensions for representative stands are defined based on the characteristics documented for the updated event format.

Exhibition Unit D
Stand_5x5m

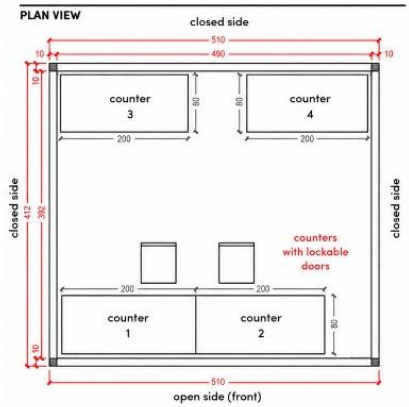


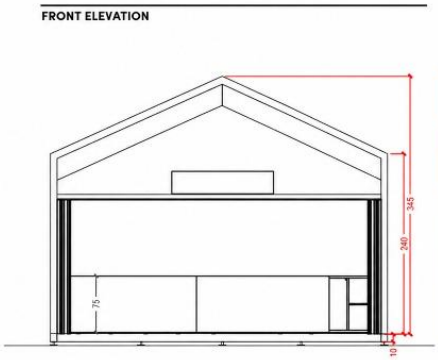




Electrical equipment
- 2 power sockets

Exhibition Unit C
Stand_5x4m



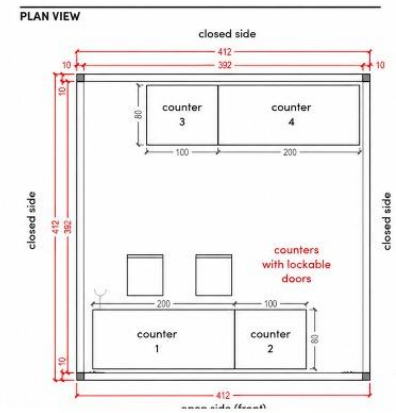




Furniture and fittings
- 2 chairs
- 4 counters 200x80x75 cm
- 1 wastepaper basket

Electrical equipment
- 5 spotlights
- 1 power socket

Exhibition Unit B1
Stand_4x4m



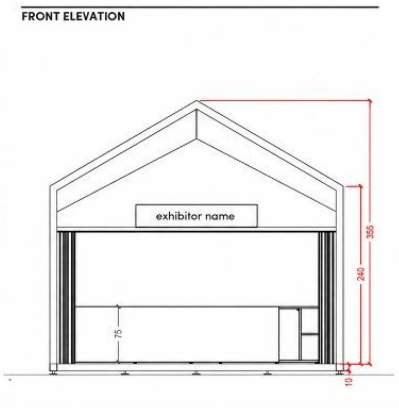




Figure 3.22 Technical data sheet of stands of CioccolaTò event [54]

Torino Città Dinamica, Light projections 2022–2023

In recent years, the use of architectural façades as surfaces for light projections, video mapping, and sound has become an increasingly relevant means of temporarily energizing public spaces in Turin, particularly Piazza San Carlo. Rather than relying primarily on additional physical structures, this type of intervention incorporates the existing buildings into the visual and spatial identity of the event. Light, images, and sound can attract attention, encourage people to gather in specific areas, and create a collective experience around a particular theme, occasion, or celebration. This approach is particularly relevant in historic urban environments, where existing architectural features can serve as active components of event communication while allowing the main pedestrian area to remain relatively unobstructed.

Torino Città Dinamica, held in Piazza San Carlo from December 2022 to January 2023, represents a significant recent example of this approach. The project used video mapping to project approximately 70 images from Turin's artistic and cultural collections onto the façades surrounding the square, temporarily transforming the historic architecture into a visual and cultural medium. The initiative demonstrates how light, visual content, and sound can function as non-physical event elements that influence how people perceive and experience an urban environment. In this context, the façades can be understood not only as permanent heritage features but also as potential surfaces for temporary communication and public engagement. From the perspective of the present research, this type of intervention provides an alternative to space-intensive installations: rather than occupying the ground with additional structures, an event can make use of the existing architectural environment to attract visitors and create a joint experience. This highlights the potential relevance of representing façades, projection areas, viewing zones, and event timing within an integrated spatial information environment, particularly when preparing and coordinating events in a historically sensitive public space.



Figure 3.23 3.24 3.25Using video mapping on the facades of Piazza San Carlo., Source [54]

An analysis of three selected events demonstrates that different types of events can give rise to distinct characteristics. The key requirements identified through the case studies are summarized in Table 3.1 and provide a basis for selecting the spatial and event-related information, as well as the inspiring scenario, to be considered in subsequent stages of the research.

Event	Type of Event	Main Characteristics	Key Spatial / Management Requirements
UEFA Champions League Final (2017)	Mass gathering / Public screening	• Very large number of people • Sudden panic and emergency situation • High crowd density in a limited area	Access & egress points Emergency routes and escape paths Crowd control and safety management
CioccolaTò (2022–2023)	Festival with temporary stands	• Temporary stands and installations • Points of attraction and gathering • Impact on pedestrian circulation and available space	Stand layout and distribution Pedestrian circulation and flow Event infrastructure (stands, services, barriers)
Torino Città Dinamica (2022–2023)	Light projections / Video mapping	• Use of building façades for projections • Attraction to specific viewing areas • Non-physical event elements	Façade / projection areas Viewing zones and spectator areas Event timing and program coordination

Table3.1 Summary of event characteristics and Key requirements for management in Piazza San Carlo., created by author

3.3 Stakeholders and User Needs

Organizing an event within an urban public space can be a complex undertaking, as it involves accommodating a diverse range of visitors, activities, temporary facilities, and operational requirements. The number of visitors and their movement patterns within the space can significantly influence the dynamics and quality of an event [38]. Therefore, effective event management requires an understanding of both the people using the event space and the conditions that affect their experience and behavior. Before designing and implementing a decision-support system, it is important to identify the main users of the event space, understand the factors that influence event quality, and determine which stakeholders are responsible for managing these conditions.

In this study, event visitors are considered the primary users of the event venue, as their presence, movement, behavior, and experience directly influence the quality and dynamics of the event. However, the proposed system is specifically designed to support event organizers and the event management team, who are responsible for managing the event space and responding to conditions that may affect visitors and the overall quality of the event. Consequently, event

organizers represent the specific user group investigated in this research. The distinction is therefore made between the people who primarily use the event space and the stakeholders who require decision-support information to manage it.

The relationship between these two groups is important for defining the system requirements. Visitors generate the spatial and operational conditions that need to be understood during an event, while event organizers are responsible for monitoring these conditions and taking appropriate management actions. For example, visitor movement may result in crowd concentration, while the organizer needs to identify such conditions and determine whether changes to circulation, access, safety measures, or temporary facilities are required. The needs and behavior of visitors therefore form an important basis for defining the information that event organizers need for effective decision-making.

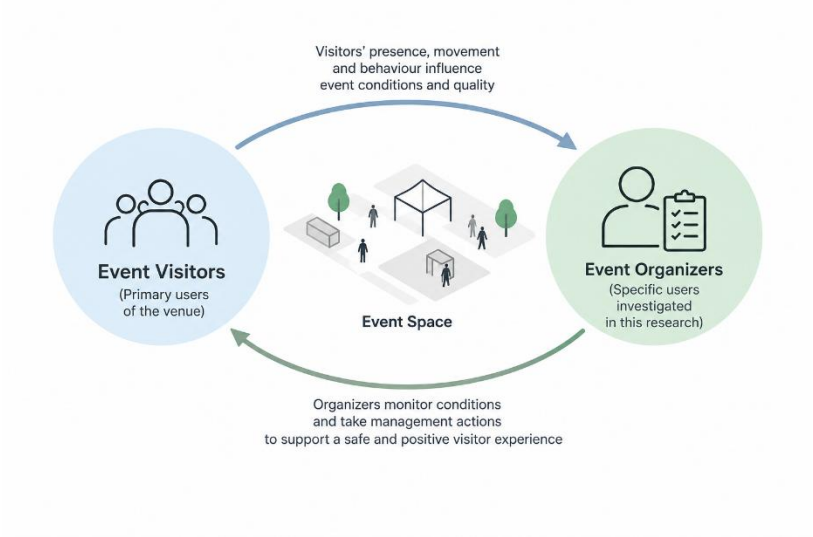


Figure 3.26. Connection between event visitors and event organizers.
Created by author.

There are various needs that could be considered when examining the relationship between event visitors and event organizers. However, this research focuses on needs that can be observed, measured, compared, or evaluated within the event space and that can be translated into operational information for event management. Based on the role of event organizers as the specific users investigated in this study, four main categories of operational needs are considered: spatial management, crowd management, safety management, and event and asset information management. These categories represent the main types of information required by event organizers to understand and manage the conditions of a temporary event within a public space.

Spatial Management

The first need concerns the spatial organization and configuration of the event space. A temporary event changes the use of an existing public space by introducing temporary structures, zones,

entrances, exits, barriers, and pedestrian routes. Event organizers therefore need to understand where different elements are located and how they are spatially organized in relation to one another. The objective is to provide a clear understanding of the overall event configuration and the relationships between its different elements [6]. Spatial awareness also provides the basic context for the other management needs, since crowd conditions, safety situations, and asset-related issues occur at specific locations within the event space.

Crowd Management

The second need concerns the distribution, concentration, and movement of visitors. During an event, visitors are not distributed evenly throughout the space. Certain areas may become more crowded due to entrances, stands, activities, checkpoints, or other attractions, and these conditions may change over time [33]. Event organizers therefore need to understand where visitors are concentrated and how crowded different areas of the event space are. Relevant information may include visitor count, occupancy, crowd density, busy zones, movement patterns, and queue length. These conditions can help identify areas that require management attention and support appropriate responses to changing visitor conditions.

Safety Management

The third need concerns the safety of visitors and the ability of event organizers to respond to safety-related situations. Safety is closely connected to both spatial organization and crowd conditions. A blocked route, high crowd concentration, unavailable exit, or other incident may affect the safe use of the event space. Event organizers therefore need to understand where safety-related problems occur and what resources are available to respond to them. Relevant information may include emergency exits, emergency routes, checkpoints, barriers, cameras, alerts, and incidents [35]. Providing this information in relation to its spatial context can support faster identification of potential risks and more informed management decisions.

Event and Asset Information

The fourth need concerns information about individual event assets and their operational status. Event organizers need to understand the nature, location, characteristics, and current status of the assets used within the event space. Temporary and permanent assets may include stands, cameras, gates, barriers, checkpoints, and other facilities. Each element serves a specific function and may have distinct characteristics and operational requirements. Relevant information may include asset ID, type, dimensions, capacity, properties, assigned location, and current status. While some characteristics remain relatively stable, others may change during the event. This need allows event organizers to move from an overall understanding of the event space to detailed information about a specific element when required for management or decision-making.

To further define these four user needs, the following table summarizes how they are addressed in previous studies and what aspects can be observed or measured within the event space.

User Needs / Article name (Article)	Spatial Management	Crowd Management	Safety Management	Event and Asset Information	What can be observed / measured
Ferrari & Guala (2015)	Urban regeneration of brownfield sites and waterfronts	Management of tourist flows and mitigation of congestion	Mitigation of resident fears regarding speculation and security	Evaluation of Genoa 2004, Turin 2006, and Milan 2015 mega-events	Tourist arrivals, overnight stays, and ticket sales
Hardiana & Iswati (2025)	Implementation of sustainable architecture and water management	Managing park user behaviors and nighttime interactions	Inclusive design for individuals with disabilities	Evaluation of parks as recreational and historical landmarks	Field surveys and environmental quality measurements
Behmanesh & Brown (2025)	Integration of urban design criteria via VR/MR tools	Addressing micro-urban challenges from temporary infrastructure	Assessing physical impact and human scale for safety	Evaluation of temporary structures using 3D context models	Protocol analysis and user feedback surveys
González-Villa et al. (2024)	Three-layer spatial model covering boundaries and risk grids	Evacuation routing and crowd density monitoring via Fruin scale	Counter-terrorism prediction models for arson, IEDs, and shootings	Decision-support tools integrated with smart city datasets	System performance latencies, casualties, and traffic volume
Gherardi (2017)	Disruption of urban public spaces during large screenings	Feast crowd transformation into panic and flight	Managing risks from virtual terrorism threats	Analysis of a major public event disrupted by panic	Injuries, emergency responses, and witness accounts

Table 3.2 . Selected User Needs for Event Management in Public Space., collected by author

These four categories establish the user-needs framework for the next stages of the research. They define what needs to be understood and managed, while the subsequent methodological stages determine how these requirements can be addressed and represented within the proposed decision-support system.

3.4 Scenario Definition

A food festival at Piazza San Carlo, Turin was selected as the representative scenario for this study. This selection was based on the four identified user needs and a review of previous real-world events held in public spaces, which helped define the main operational and spatial requirements of the scenario.

The scenario considers the temporary arrangement of food stands, pedestrian pathways, access points, barriers, emergency exits, and surveillance cameras. These elements provide a realistic

basis for testing the proposed BIM-GIS workflow and evaluating its ability to support the identified user needs in the management of a temporary public event.

3.5 Technological Process

The technological process defines the sequence of operations through which heterogeneous spatial, geometric, semantic, and event-based data are transformed into integrated information to support decision-making. While the research framework outlines the general relationship between input data, processing activities, and outputs, the technological process specifies how this relationship is implemented using BIM and GIS technologies. Consequently, this process is viewed as a continuous workflow that ultimately culminates in presentation via an interactive, decision-support interface.

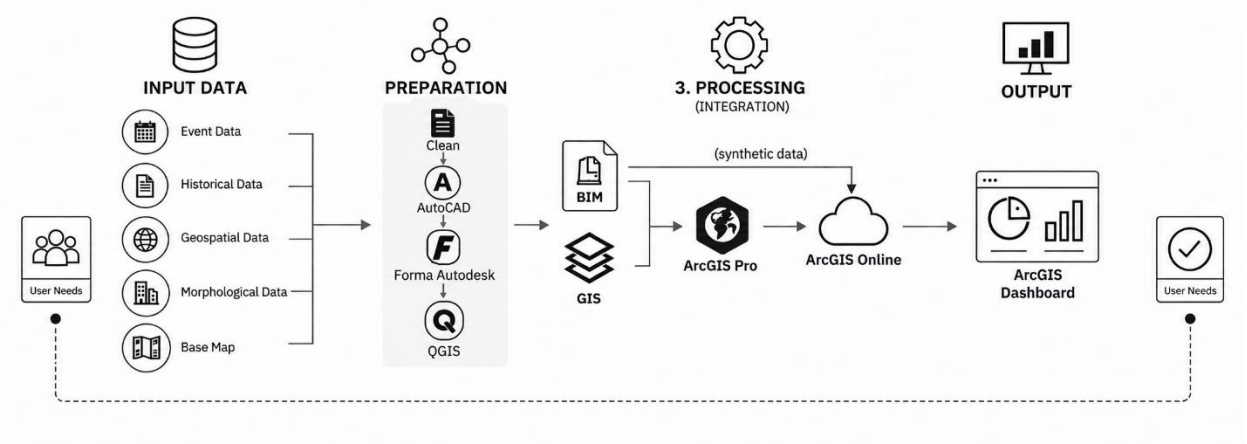


Figure 3.27 Technological Pipeline for BIM–GIS integration, Author

The proposed workflow is developed according to the specific requirements of event management in an urban public space. In this context, the objective is not to produce a detailed representation of the entire city, but to establish a fit-for-purpose digital environment capable of connecting the urban context of Piazza San Carlo with the temporary elements and operational conditions associated with an event. BIM and GIS are therefore used according to their complementary capabilities. GIS provides the spatial and geographic framework for representing the square and its surrounding urban context, while BIM provides structured geometric and semantic information for relevant physical and temporary assets. The integration of these two domains creates a common information environment in which urban-scale and asset-level information can be combined for analysis and visualization.

Data Input and Preparation.

The workflow begins with the collection of the datasets required to represent both the physical context and the event conditions of Piazza San Carlo. The input data are organized into five main

categories: event data, historical data, geospatial data, morphological data, and base-map data. These datasets provide the information required to describe the existing urban context as well as the conditions relevant to event management. Before integration, the required spatial information is prepared using AutoCAD and Autodesk Forma. AutoCAD is used to clean and organize the relevant geometric information, while Autodesk Forma supports the preparation of the urban and morphological context. In parallel, the BIM model provides structured geometric and semantic information for the selected physical assets.

Data Processing and Integration.

The prepared BIM and GIS datasets are brought together in ArcGIS Pro, which constitutes the main processing environment of the workflow. At this stage, the building- and asset-level information provided by BIM is combined with the geographic and morphological information provided by GIS, establishing a common spatial context for the case study. Synthetic data are also incorporated to represent event-related conditions and temporary information that are required for the scenario but are not available as permanent datasets. The integrated information is then prepared for publication and further use within the web-based GIS environment. ArcGIS Online serves as the platform through which the resulting datasets are made available for web-based access and visualization.

Data Visualization and Decision Support.

The final stage presents the integrated information through ArcGIS Dashboards. The dashboard connects the processed spatial, BIM-related, and event information in an interactive interface, allowing the selected information to be visualized according to the defined user needs. The final output therefore does not represent a separate dataset, but an accessible decision-support environment in which the results of the previous stages can be explored and interpreted for event management. The complete implementation of these stages is described step by step in the following sections.

3.6 Input Data

The implementation begins with the identification and collection of the input datasets required to represent the physical, spatial, and operational characteristics of Piazza San Carlo and its event context. These datasets include event data, historical data, geospatial data, morphological data, and base-map data, each providing a specific type of information required by the proposed workflow. Together, they establish the initial information base for the subsequent preparation, integration, analysis, and visualization stages.

Historical maps provide a temporal perspective on Piazza San Carlo, showing how its spatial structure and role as a central place for gathering and public activity have been maintained over time.



3.28, existing urban fabric and building morphology along Via Roma., Source [5]

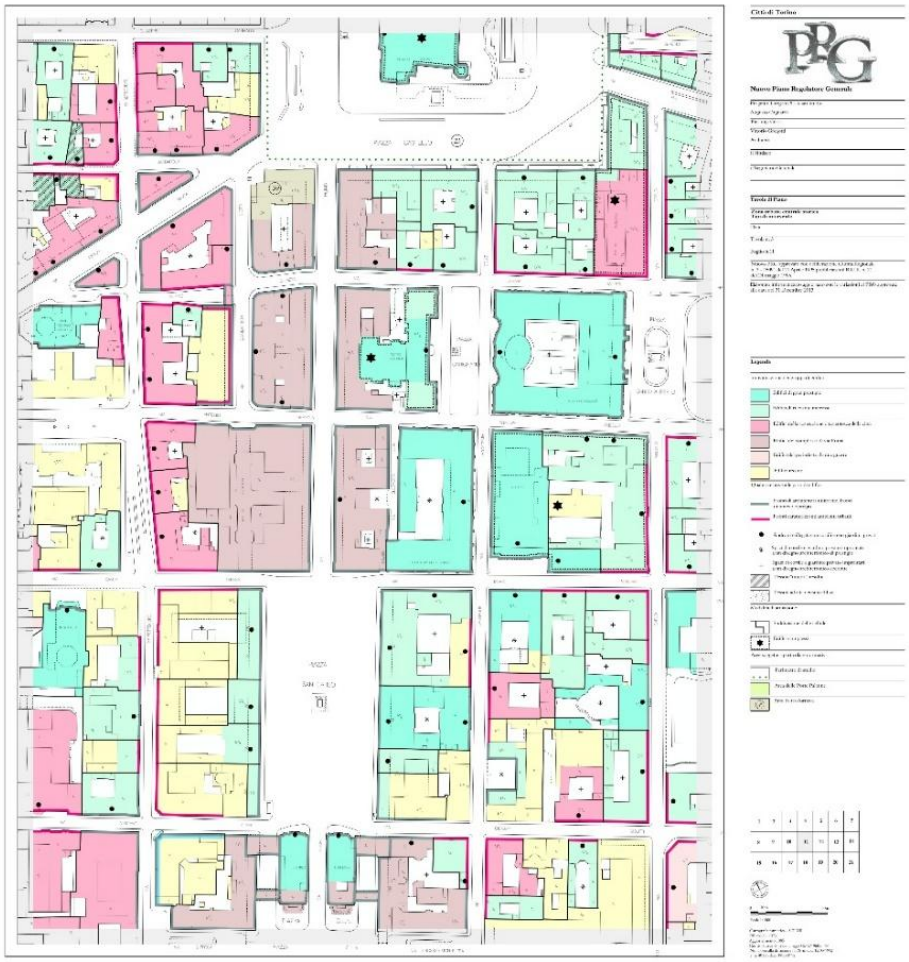
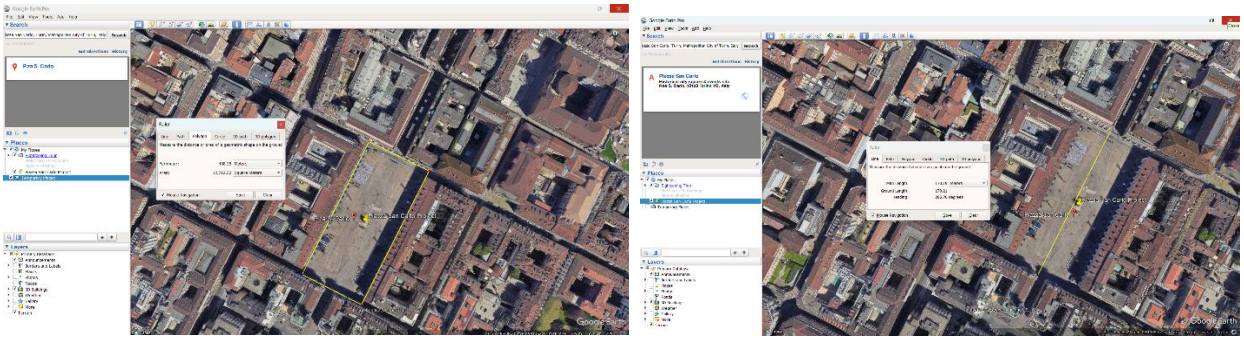
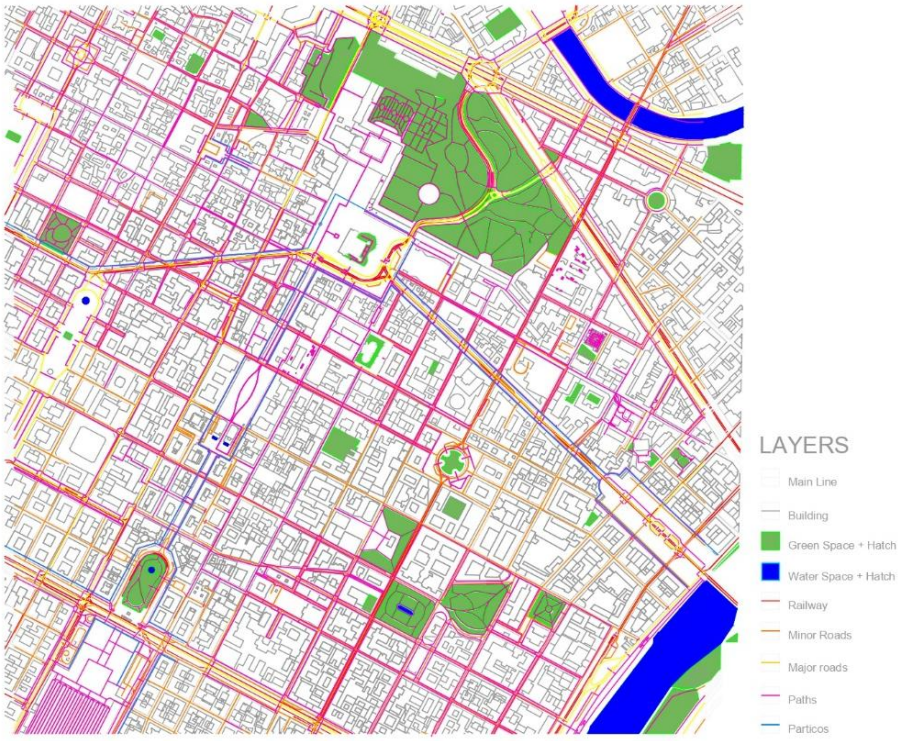


Figure.3.29 Geopotrale map for knowing context of city [60]

In addition, Google Earth and Autocad used to verify the dimensions, spatial relationships, and locations of elements for which reliable or sufficiently clear information was not available from the collected sources. This provided an additional reference for checking the size, position, and configuration of existing elements within the square before their integration into the digital environment.



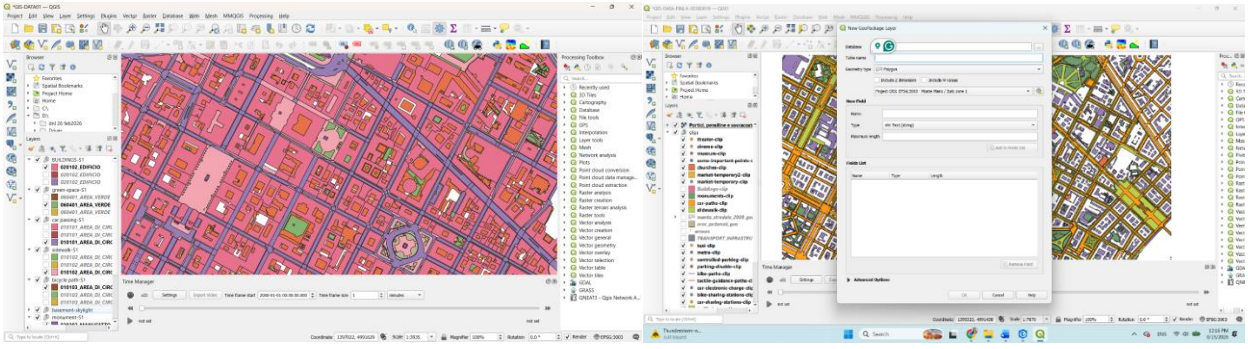
3.30 Google Earth pro dimention double check,[56]



3.31 AutoCAD drawing map author

3.7 Data Preparation: BIM and GIS domains

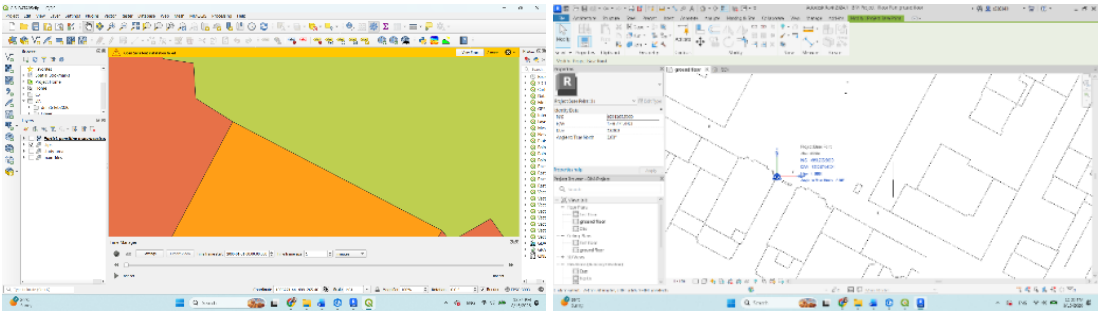
At this stage, the focus was on cleaning, organizing, and preparing the spatial data for integration. The available urban maps were cleaned and refined to remove unnecessary or inconsistent information, and the relevant spatial data were exported from QGIS as a GeoPackage.



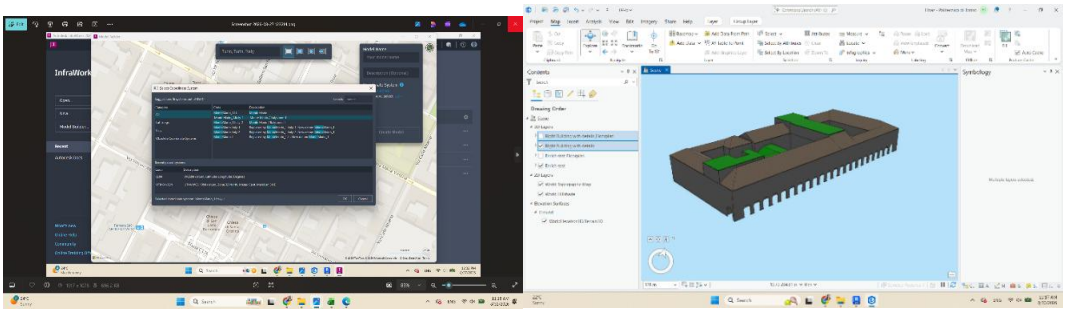
3.32 preparing and clip GIS data for geopackage author

In parallel, different approaches were examined for defining an appropriate coordinate system and positioning the Revit model, with the associated limitations of each approach identified. Based on these checks, the final preparation resulted in a clean Forma file containing the

surrounding buildings and a consistent spatial reference, providing a reliable basis for the subsequent BIM–GIS integration.

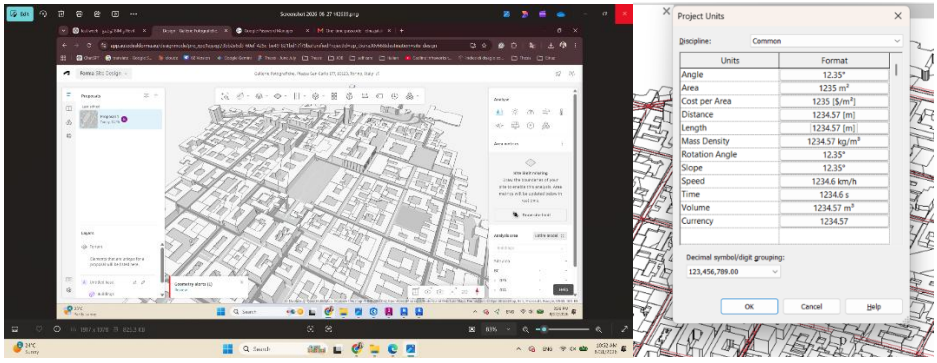


3.33 test for coordination ftom QGIS to Revit



3.34 test for coordination ftom infrawork to Revit

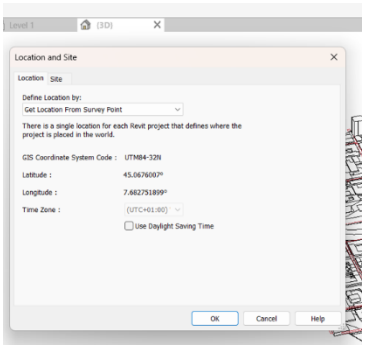
Following the initial tests, an alternative method was adopted to establish the BIM model within the correct spatial context. The urban model was exported from Forma Web together with its real-world geographic coordinates and then imported into Revit. This approach successfully preserved the spatial position of the urban context and provided a reliable coordinate reference for the subsequent BIM modelling process.



3.35 approved test for coordination ftom forma web to Revit

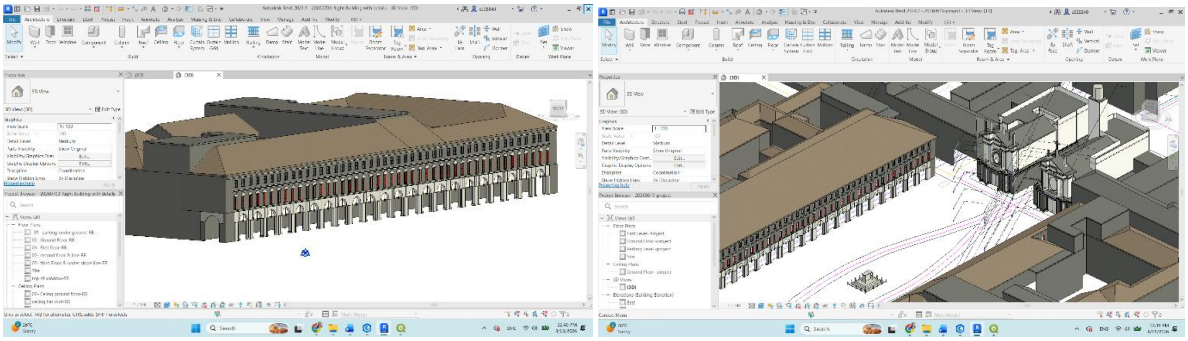
3.8 Data Processing: BIM–GIS Integration

The BIM–GIS integration process begins with the BIM model, which is developed within a correctly georeferenced environment. The prepared Forma file is first brought into Revit using the appropriate plugin, providing the surrounding urban context as a spatial reference for the BIM model. Before modelling, the position of the imported context is checked in ArcGIS Pro to verify that it corresponds to the correct geographic location. Once the position is confirmed, the BIM modelling process is carried out within this established coordinate context.

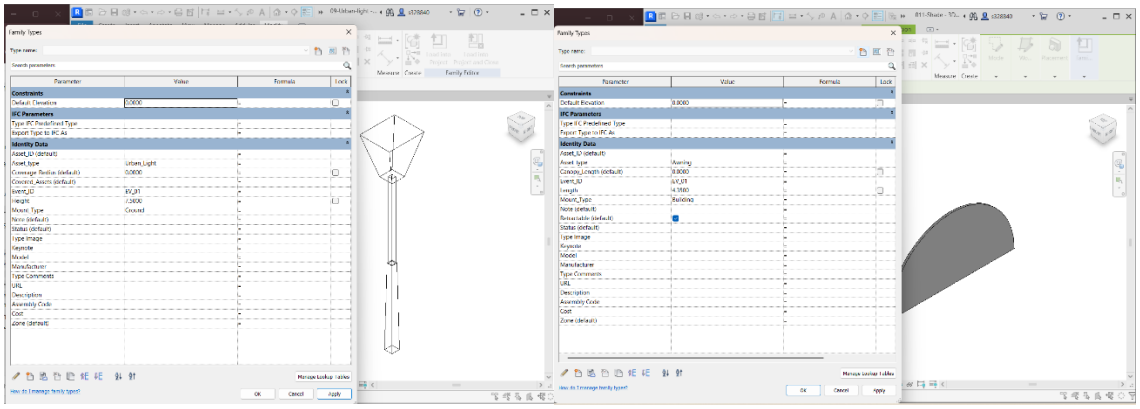


3.35 Approved coordinate

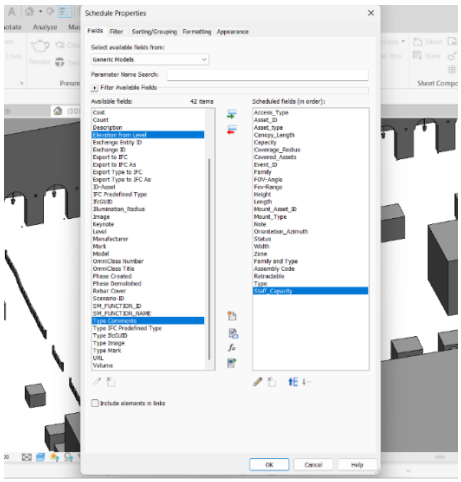
Two modelling approaches were considered. The first approach focused on high geometric detail with limited semantic information. Although this approach could produce visually detailed elements, it increased the file size and did not provide the information required for the intended GIS integration and decision-support outputs. The second approach therefore focused on LOD 100 geometry combined with rich semantic information. Instead of increasing geometric complexity, relevant information was embedded through custom parameters assigned to the Generic Models. This approach maintains a lightweight BIM model while enriching the elements with the attributes required for their identification, classification, and subsequent integration with GIS.



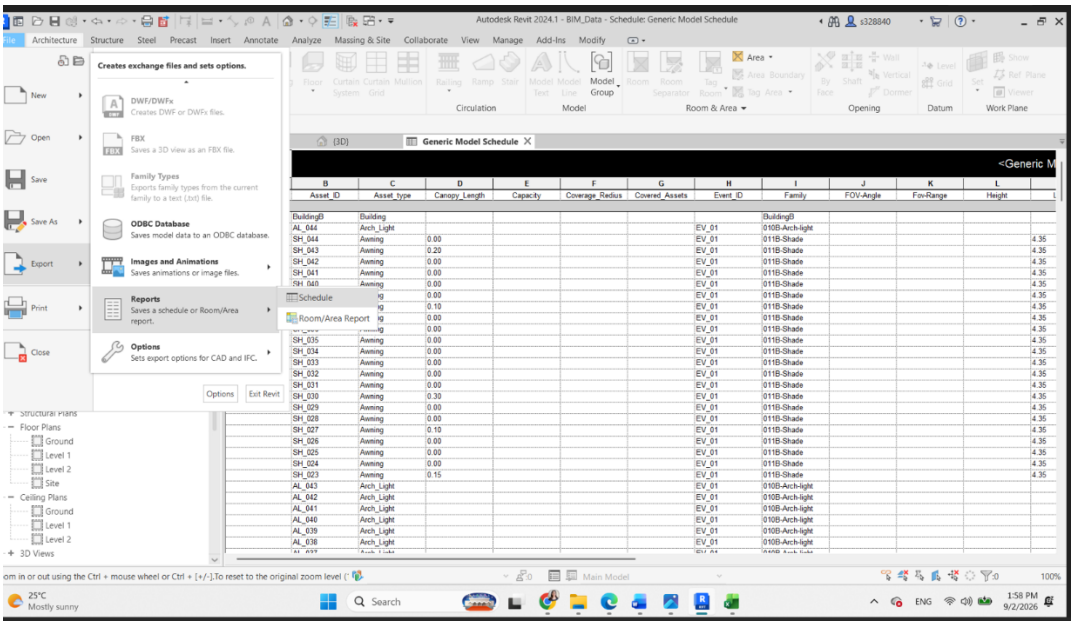
3.36 test for LOD drawing



3.37 enrich model with customize parameters

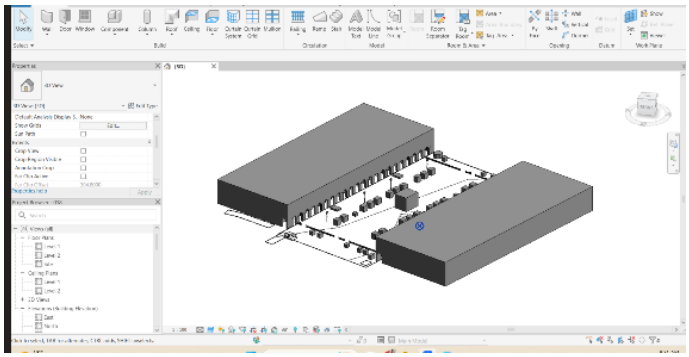


3.38 customize parameters at shared parameters



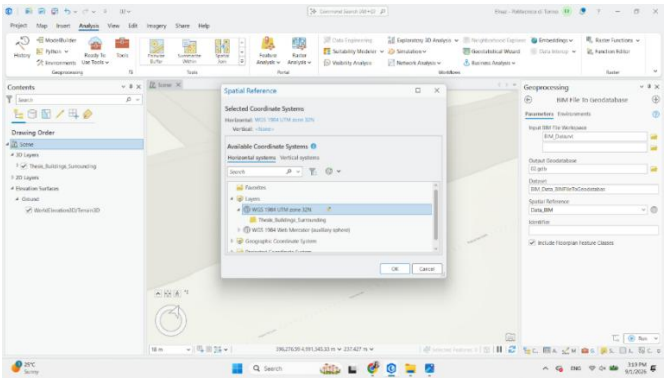
3.39 schedule table of generic models

Finally, a Revit Schedule is generated to document and verify the modelled elements and their associated parameters. This schedule provides a structured overview of the modelling results and demonstrates the extent to which the required semantic information has been incorporated into the BIM model before proceeding to the GIS integration stage.

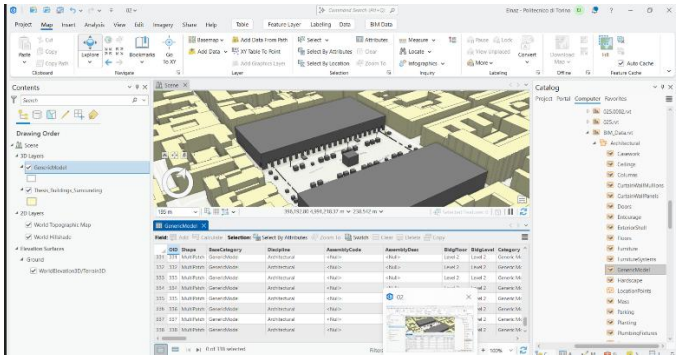


3.40 enrich model in Revit environment

Once the BIM model was completed, the Revit (.rvt) file was transferred directly to ArcGIS Pro without changing its original format for the integration stage. The same coordinate system defined during the Forma preparation was selected in ArcGIS Pro, and the BIM model was correctly positioned within its geographic context. However, despite the correct spatial placement, the semantic and attribute information of the BIM model was not read by ArcGIS Pro. The file was therefore interpreted primarily as a geometric volume rather than as a structured BIM dataset, resulting in the loss of the information embedded within the model elements.

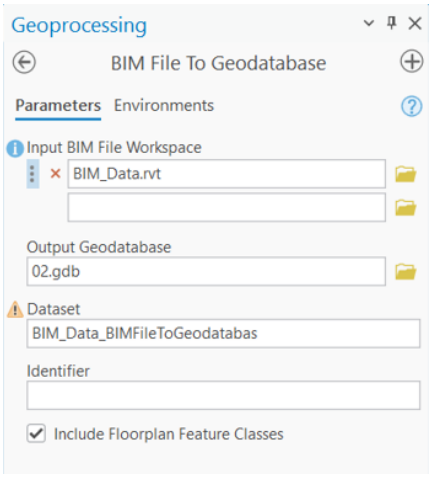


3.41 suitable coordinate system

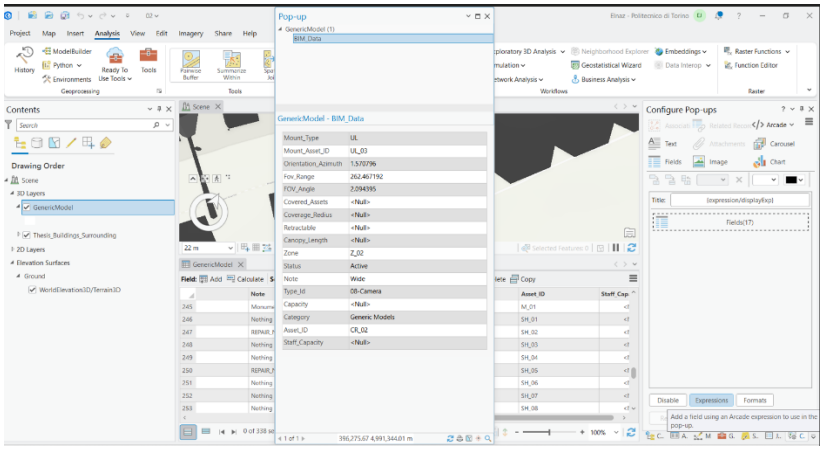


3.42 test to know limits of direct insert

As the direct import of the RVT file did not preserve the BIM semantic information, a BIM-to-Geodatabase conversion was subsequently performed. This additional step converted the BIM elements into structured GIS layers within a geodatabase, allowing their geometric and attribute information to be retained. The process was successful, and the individual BIM layers were transferred into the GIS environment with their associated information, providing the required basis for the subsequent BIM–GIS integration and analysis.



3.43 BIM file convert to Geodatabase



3.44 appropriate model insert

However, some of the unit conversions were affected by the new spatial environment in ArcGIS Pro. Therefore, the relevant units had to be converted again and standardized with those used for the surrounding urban elements. This ensured consistency across the integrated dataset and made the resulting information more familiar, understandable, and practical for event managers when interpreting the final outputs.

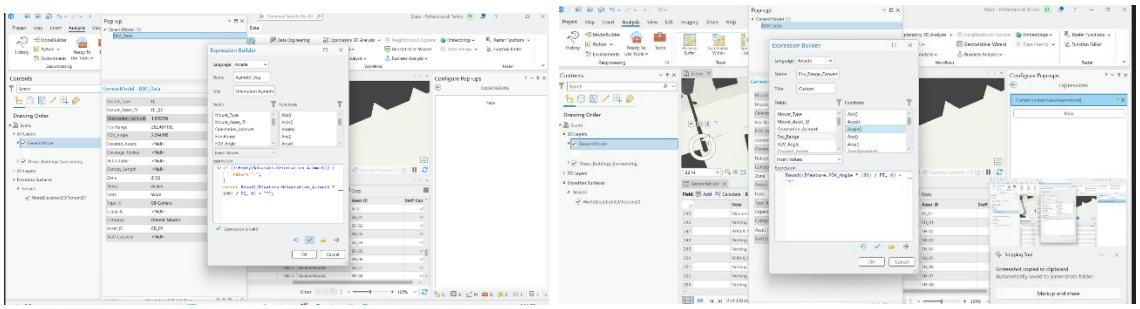


Figure 3.45 BIM data cleaning and parameter organization

Finally, the required BIM layers were cleaned and organized within the GIS environment. The BIM elements were then classified and separated according to their type and Generic Model categories, allowing the different asset types to be distinguished clearly. This organization established a structured GIS representation of the BIM elements and prepared the dataset for the subsequent integration with the other urban and event-related layers.

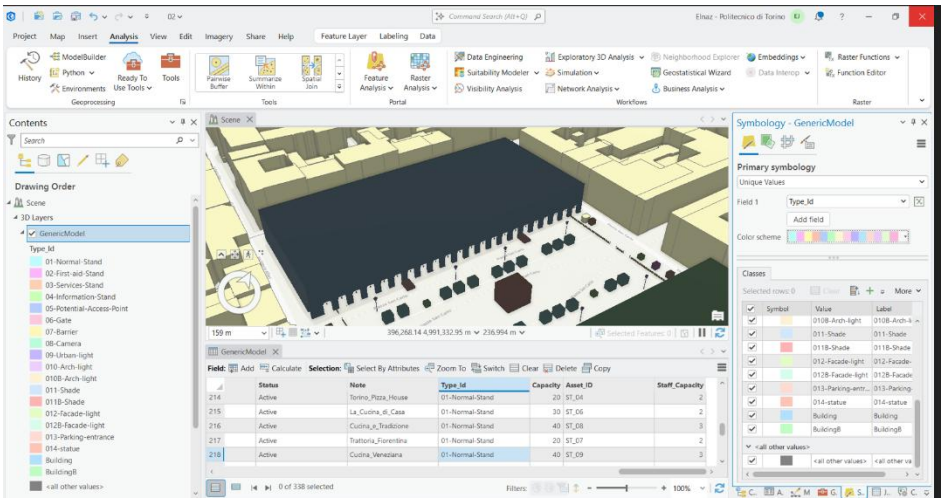


Figure 3.46 Classification data by type

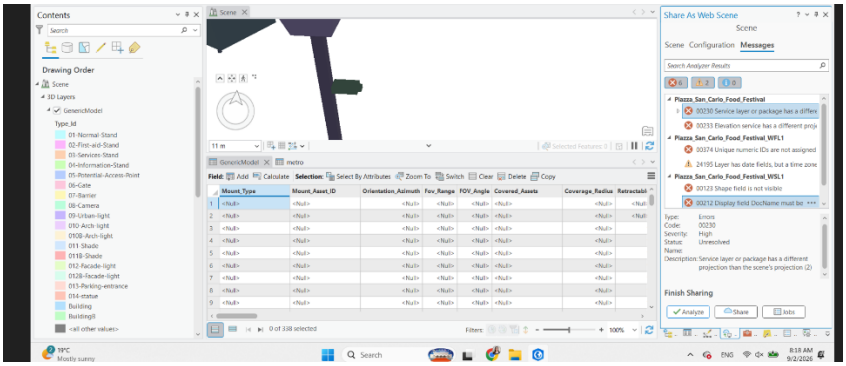


Figure 3.47 analyzing before publishing on ArcGIS Online

At this stage, the main work in ArcGIS Pro was nearly complete, and the required datasets had been successfully organized within the same spatial environment. The next step was to perform the required analysis and quality checks before publishing the results to ArcGIS Online. However, an issue was identified with the GeoPackage layers obtained from the urban GeoPortal. Although these layers appeared to be correctly positioned visually, their coordinate reference was not fully consistent with the BIM-derived layers, causing the datasets to be interpreted as being in different spatial environments and preventing the analysis from being completed without errors. Therefore, the coordinate reference of these layers was adjusted to match that of the BIM layers. After this correction, the analysis was completed without spatial inconsistencies, and the resulting layers were successfully published to ArcGIS Online for the next stage of the workflow.

However, the BIM data were not correctly visible in ArcGIS Online after publication. Therefore, the BIM layers were further reviewed and corrected in ArcGIS Pro, where the required settings and layer structure were adjusted to ensure that the BIM information could be properly represented in the web environment. After this correction, the updated BIM data were republished to ArcGIS Online.

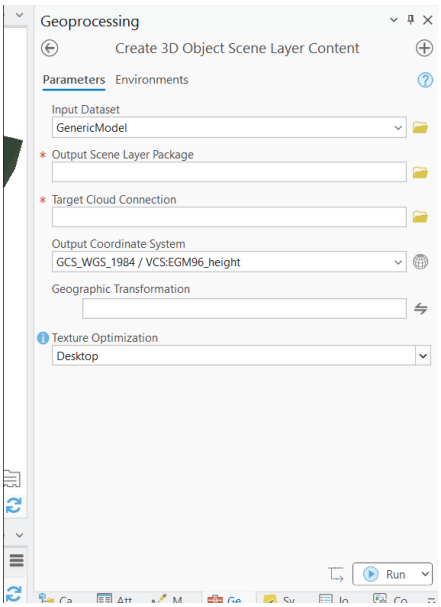


Figure 3.48 Creation of a 3D Object Scene Layer from BIM data in ArcGIS Pro.

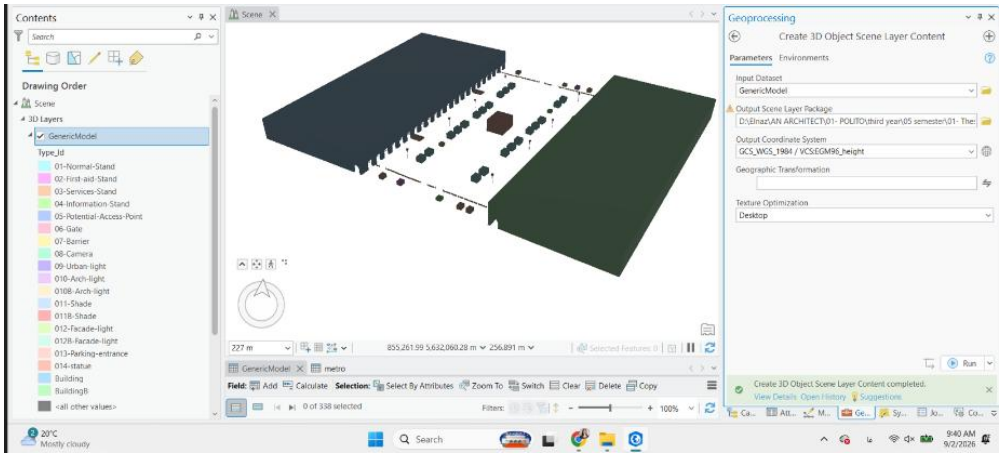
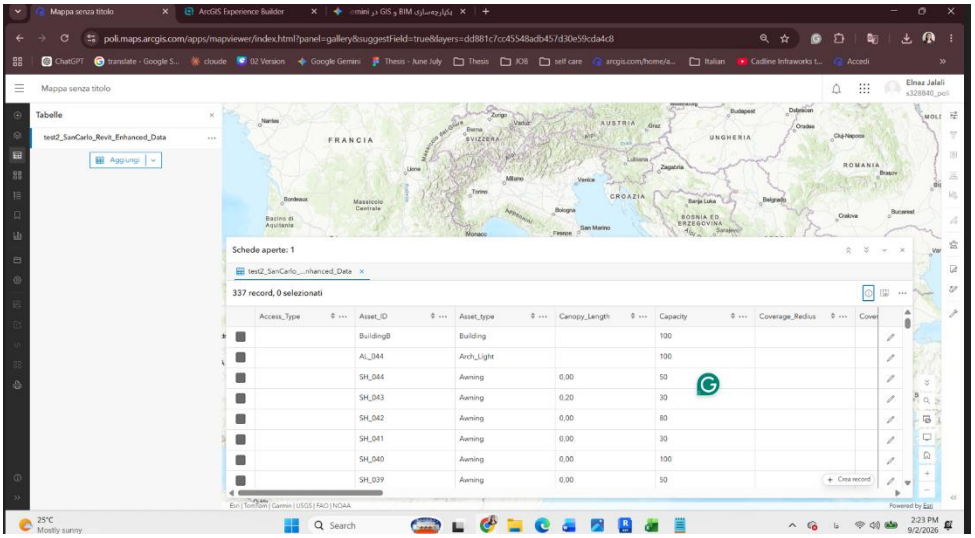


Figure 3.49 Valid model publishing

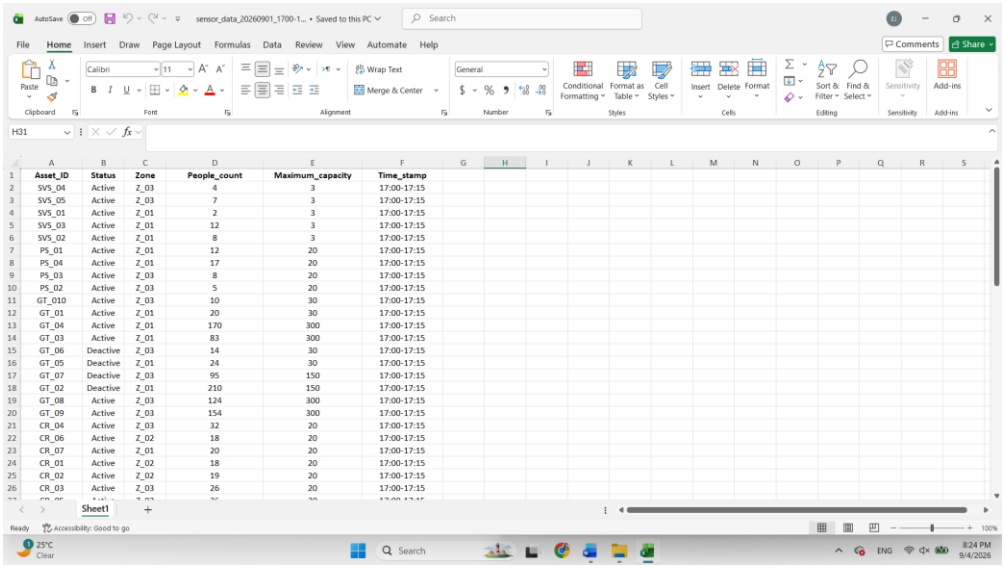
3.9 Decision-Support Interface

Following the corrections in ArcGIS Pro, the BIM data were successfully prepared for web publication and became properly visible in ArcGIS Online. The final configuration preserved the spatial position of the BIM elements while maintaining their structured layer representation, allowing them to be viewed together with the surrounding urban datasets. This successful transfer confirmed that the coordinate system, layer structure, and BIM-to-GIS conversion were correctly established. At this point, the integrated spatial environment was ready to incorporate the remaining event-related information and proceed toward the final visualization and decision-support stage.



3.50 read data in online environment

At this stage, a synthetic data layer was added to represent event-related information that would typically be received from sensors during an event. The required fields were first defined by modifying the Revit Schedule, and random values were then assigned to these fields to simulate reported sensor observations. The resulting dataset was structured as a spatial layer and added to the ArcGIS Online environment, allowing the simulated event conditions to be associated with the corresponding spatial elements and used in the subsequent visualization and decision-support stage.



Asset_ID	Status	Zone	People_count	Maximum_capacity	Time_stamp
SVS_04	Active	Z_03	4	3	17:00-17:15
SVS_05	Active	Z_03	7	3	17:00-17:15
SVS_01	Active	Z_01	2	3	17:00-17:15
SVS_03	Active	Z_01	12	3	17:00-17:15
SVS_02	Active	Z_01	8	3	17:00-17:15
PS_01	Active	Z_01	12	20	17:00-17:15
PS_04	Active	Z_01	17	20	17:00-17:15
PS_03	Active	Z_03	8	20	17:00-17:15
PS_02	Active	Z_03	5	20	17:00-17:15
GT_010	Active	Z_03	10	30	17:00-17:15
GT_01	Active	Z_01	20	30	17:00-17:15
GT_04	Active	Z_01	170	300	17:00-17:15
GT_03	Active	Z_01	83	300	17:00-17:15
GT_06	Deactive	Z_03	14	30	17:00-17:15
GT_05	Deactive	Z_01	24	30	17:00-17:15
GT_07	Deactive	Z_03	95	150	17:00-17:15
GT_02	Deactive	Z_01	210	150	17:00-17:15
GT_08	Active	Z_03	124	300	17:00-17:15
GT_09	Active	Z_03	154	300	17:00-17:15
CR_04	Active	Z_03	32	20	17:00-17:15
CR_06	Active	Z_02	18	20	17:00-17:15
CR_07	Active	Z_01	20	20	17:00-17:15
CR_01	Active	Z_02	18	20	17:00-17:15
CR_02	Active	Z_02	19	20	17:00-17:15
CR_03	Active	Z_03	26	20	17:00-17:15

3.51 synthetic data

The final stage focused on developing an interactive interface capable of presenting the information generated throughout the workflow in a form suitable for event management. After the spatial and BIM datasets were prepared, integrated, and validated, the relevant layers were published to ArcGIS Online. In addition to the physical and spatial information, a synthetic data layer was incorporated to simulate event-related observations that could be generated by sensors. These

data were connected to the relevant spatial elements, allowing both asset information and changing event conditions to be represented within the same environment.

Based on this integrated dataset, ArcGIS Dashboard was used to organize the information into an accessible decision-support interface. The dashboard combines spatial visualization with selected indicators, charts, and attribute information, enabling users to examine the site and access the information associated with its elements without directly working with the underlying datasets. The interface was structured according to the previously identified user needs, so that the final presentation focuses on information relevant to event management rather than simply displaying the available data.



3.52 Preparing Data in ArcGIS Online for Use in a Dashboard

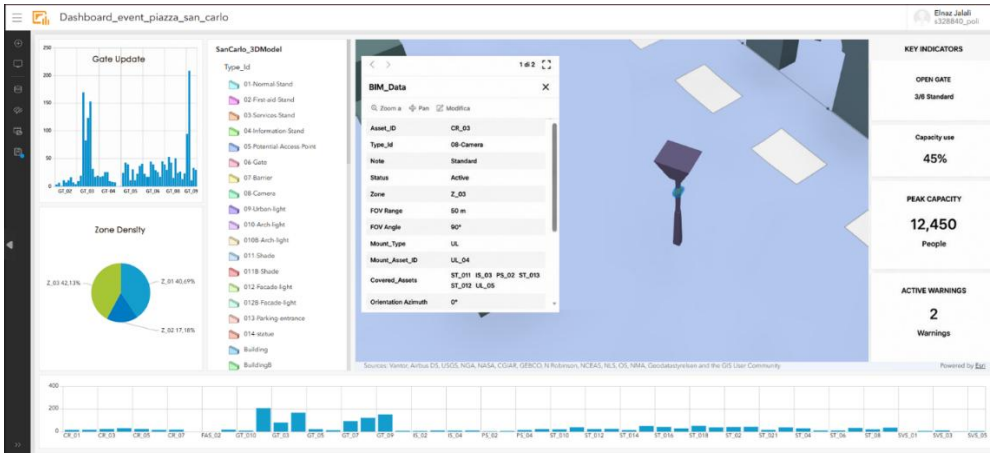


Figure 3.53 Interactive Dashboard

The final result demonstrates the complete transition from raw and heterogeneous input data to an organized, spatially referenced, and interactive information environment. The dashboard provides a practical representation of the proposed BIM–GIS workflow and demonstrates how structured asset information can be combined with simulated event data to support the interpretation of conditions within an urban public space.

CHAPTER 4. RESULTS

4.1 General Workflow consideration

The implemented workflow successfully established a continuous process from data preparation to the final decision-support interface. The main result was the creation of a common spatial environment in which BIM, GIS, and event-related information could be combined and used for visualization and analysis. During implementation, several interoperability issues related to coordinates, data structure, units, and BIM information were identified and resolved through the preparation and integration stages.

Aspect	Result
Data preparation	Required datasets cleaned and organized
Coordinate consistency	BIM and GIS datasets successfully aligned
BIM–GIS integration	BIM information converted into structured GIS layers
Semantic information	Relevant BIM parameters preserved
Synthetic data	Event-related sensor-like data successfully added
Web publication	Integrated layers successfully published in ArcGIS Online
Decision support	Final information presented through ArcGIS Dashboard

Table 4.1. Summary of the main workflow results

4.2 BIM–GIS Interoperability

The interoperability process resulted in the successful integration of the BIM model with the surrounding GIS context. The initial tests showed that direct coordinate-transfer approaches were not sufficient. The final solution used the Forma Web model with real-world coordinates as the spatial reference for the Revit model. For BIM–GIS integration, the BIM model was subsequently converted to a geodatabase, allowing its elements and associated information to be represented as GIS layers. Coordinate and unit adjustments were then applied to achieve consistency with the surrounding urban data.

A key result of this process was the shift from a purely geometric BIM representation to a structured GIS representation of BIM elements. The initial direct import of the RVT file into ArcGIS Pro

positioned the model correctly, but its semantic information was not available in the expected form. The BIM-to-geodatabase conversion resolved this issue by separating the model into usable GIS layers and retaining the relevant element information. The layers were subsequently cleaned and organized according to the different BIM element types and Generic Model categories, making the information easier to manage and analyze within the GIS environment.

The interoperability process also demonstrated that spatial alignment alone was not sufficient for successful integration. The urban GeoPackage layers appeared visually aligned with the BIM model, but differences in their spatial reference prevented them from being treated consistently during analysis. Their coordinates were therefore adjusted to match the BIM layers. Similarly, unit representations were standardized after transfer to ArcGIS Pro. These steps resulted in a consistent dataset in which the BIM-derived elements and the surrounding urban layers could be analyzed together and subsequently prepared for web publication.

Approach	Result
High geometric detail + limited information	NO
LOD 100 + rich semantic information	YES

Table 4.2. BIM model correctly positioned within the urban context

4.3 Event Management Dashboard

The integrated BIM and GIS layers were published through ArcGIS Online and complemented with a synthetic data layer representing event-related sensor observations. The required attributes were prepared and populated with simulated values, allowing dynamic event information to be associated with the spatial elements. The final ArcGIS Dashboard combines the spatial context, asset information, and event-related indicators within an interactive interface structured around the identified user needs.

CHAPTER 5. CONCLUSIONS AND FUTURE DEVELOPMENTS

5.1 Conclusions

This research developed and implemented a BIM–GIS workflow for urban event management at Piazza San Carlo. The results demonstrated the feasibility of integrating urban, BIM, and event-related information within a common spatial environment. Through iterative testing, a lightweight LOD 100 BIM model with enriched semantic information was successfully integrated into GIS and combined with synthetic event data. The final integration in ArcGIS Online and ArcGIS Dashboard provided an interactive environment for organizing and communicating information relevant to event-management decision-making.

5.2 Future Developments

Future developments should focus on testing the workflow with real-world and more extensive datasets to further evaluate its performance under actual event conditions. In particular, the synthetic event layer could be replaced or complemented by real-time data from sensors and monitoring systems, including crowd movement, environmental conditions, mobility, and other operational information. This would allow the system to move from a primarily descriptive decision-support environment toward a more dynamic platform capable of reflecting changing event conditions. Further development could also explore the use of AI-based methods for prediction, anomaly detection, and more advanced decision support.

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