A FREE AND OPEN-ACCESS GIS FOR THE DOCUMENTATION AND MONITORING OF URBAN TRANSFORMATIONS IN THE AREA OF THE EXPO 2015 EXHIBITION IN MILAN

M. Gentile [1], F. Gaspari [1] *, V. Tornatore [1], F. Migliaccio [1]

[1] Dept. of Civil and Environmental Engineering (DICA), Politecnico di Milano, Milan, Italy – marco.gentile@mail.polimi.it, (federica.gaspari, vincenza.tornatore, federica.migliaccio)@polimi.it

KEY WORDS: Free and open-source GIS, QGIS, GeoNode, Urban landscape, Expo 2015.

ABSTRACT:

Mega-events imply several city transformations at different scales that could be challenging to be identified and documented. The impacts of such events like Universal Exhibitions are difficult to be identified and tracked in space and over a long period of time. This paper discusses the use of open-source geospatial technologies as innovative tools in support of urban planning and management of digital cities, analysing in particular the case of an international exhibition in the urban landscape. A GIS-based approach is used to design a spatially enabled database, which is essential for implementing advanced analytics in modern smart cities. The pilot project proposes the design and implementation of such georeferenced database for monitoring the urban transformations of the area used for Expo 2015 Milano (Italy). The potential of GIS environment in the consultation process, which allows to obtain different interactive views and to make selections and queries of the data, is explored. The paper also discusses the possibility of publishing such prototype on a shared platform, allowing a larger non-technical audience to follow the urban evolution of the area in a diachronic perspective.

1. INTRODUCTION

Currently, representative 2D models of digital cities are based on geospatial data derived from a Geographic Information System (GIS), which can be considered an indispensable tool for spatial development and, in general, for territorial governance (Grimaldi et al., 2022). Urban planning is one of the main applications of GIS, used both as a spatial database (DB) and as an analysis and modelling tool to support the design of strategies and policies for urban mobility and emergency management (Souza and Bueno, 2022). Indeed, the design of a spatially enabled database is an essential starting point for the implementation of advanced analytics for modern smart cities (Monteiro et al., 2018), not only to document the conditions of buildings, services, and roads, but also to track their evolution over time. Such approach supports multidisciplinary studies of the city, involving different skills and professionals in the urban development process, as amply demonstrated by case studies that combine urban planning with the study of historical and cultural heritage (Baratin et al., 2015), the analysis of the accessibility of neighbourhoods and green areas (Lahoti et al, 2019), and the management and design of underground services (Cazzaniga et al., 2013). In this context, Free and Open-Source Software (FOSS) are becoming key components of the urban planning process (Lovelace, 2021), providing multi-scale and customizable alternatives to commercial tools (Yap et al., 2022). Their dynamic communities and application-oriented point of view could indeed represent important elements for the analysis of a particular case of the whole urban ecosystem of some metropolitan areas: the fair district. Such portions of cities usually consist in large zones that undergo substantial renovation and transformation interventions in a relatively short period of time (Roche, 2017). In particular, mega-events like Universal Exhibitions organised by the Bureau International des Expositions present challenges that are considered futuristic for the transformation of an area and the communities that live and experience it daily, promising the change of one or more neighbourhoods with the installation of new services and infrastructures (Kaya and Erbaş, 2022). However, in most cases, the long-term effects of this type of large events are not investigated, implying controversial social impacts on the urban communities affected by the transformations (Minner et al., 2022). Geospatial technologies and open-source tools could answer these needs, not only by computing statistics on the short term (Migliaccio et al., 2019), but also supporting complex urban transformation analysis over a longer period, also implying the possibility to engage citizens in the governance process through web and interactive tools (Alicandro et al., 2022).

The work proposed in this paper regards the design and implementation of a georeferenced database, for the development of a GIS and its publication on the web through open-source technologies. The aim of the case study is to test the design of a prototype platform for monitoring the urban transformations of the area used for Expo 2015 Milano (Italy) designing a shared DB containing cartographic and thematic information about the Expo area, including both geo-referenced data and non-georeferenced data. For these reasons, opportunities and challenges of structuring the existing data archives according to the model of a relational DB for an optimal management are presented. Moreover, the potential of GIS environment in the consultation process, which allows to obtain different interactive views and to make selections and queries of the data, is explored together with the possibility to publish such prototype on a shared platform, allowing a larger

* Corresponding author

non-technical audience to follow the urban evolution of the area in a diachronic perspective.

2. METHODOLOGY

Given the need to understand the effects and the transformations due to the event over a long period, the work first consisted in the reconstruction of the timeline history of the exhibition site, starting from the first announcement of the venue to the current situation (as of 2022). This preliminary step is essential for identifying the dimensions of the site, the stakeholders involved in the urban planning process and in the technical data documentation and the timeline from the period before the event, during the event and after its conclusion.

Then, having a more detailed understanding of the site and of the urban and territorial elements affected by the transformation process, it is possible to start designing the relational DB schema. The structure of the DB for the case study has been defined by following the rules stated by the theory of database designing, extensively proposed and commented in the literature (Chen, 1976, Carrion et al., 2009), and the standard methodology defined by the ANSI (American National Standards Institute) SPARC Committee (Standards Planning And Requirements Committee). In designing the Expo spatial database, four steps identify the different levels of information modelling in a database: the external model is used to describe the relevant information to be archived; the conceptual model presents a concise, schematic, and univocal description of the organization of the data; the logical model is used to define the structure of the “relations” (i.e., the tables) which will contain the data; the internal (or physical) model contains the description of information in terms of computer storage unit. In this case study, MySQL Workbench Community Edition has been used for the development of the database logical model.

The database implementation has been performed in a GIS environment using QGIS. The adoption of this software for the geodatabase implementation was driven by the fact that the QGIS project is extensively documented by its community. Moreover, thanks to its simplified and user-friendly interface, the software is now commonly adopted by public administrations’ employees, as reported in (Rosas-Chavoya et al., 2022). In this phase, particular attention has been given to: (i) the self-consistency of cartographic data in the UTM WGS84 reference system (which has been defined as a standard in Italy); (ii) the integration in a unique database of information of different types and origins, such as cartographic data and data provided by administrative and cadastral services; (iii) the interoperability with other GIS platforms, meaning the capability of different systems to share data for different applications.

Once the GIS system is defined according to the DB schema, the data entry step consists first in the collection of information in different formats from websites and other official channels linked to the actors involved in the urban transformation process for the area under analysis. Then, the consistency of such data and their compatibility with a GIS system is evaluated, implying the adoption of basic data manipulation procedures when needed (e.g., georeferencing, vectorisation, reprojection).

The efficiency of the database is then evaluated and tested through basic queries that could be executed in the QGIS environment, highlighting possible routine operation related to land use evolution in time, building footprint changes and network analysis.

Finally, the ordered and structured data and their metadata are shared on a web-based GIS platform, enabling citizens to explore the evolution of the territory through maps and analytic widgets. For the implementation of the WebGIS prototype, GeoNode has been chosen thanks to the possibility to customise the project also with quantitative narrative and geo-storytelling tools such as geo-stories and dashboard (Corti et al., 2019). The design choices had the purpose the help keep track of the most relevant urban planning steps, from site analysis to monitoring and evaluation of its transformation with the QGIS and GeoNode integrated geospatial tools. Moreover, this pilot approach could also support future scenario planning, by: (i) storing and managing the spatio-temporal documentation in a coherent format, (ii) providing the citizen community with the possibility to interact with it dynamically, fostering a better knowledge of the transformations to which the territory is subjected and an improved public participation in the decision-making process.

3. THE CASE STUDY

The case study investigates the planning and development of the exhibition area that hosted the World Expo 2015 and its post-event redevelopment as the so-called Milan Innovation District (MIND). The study area is an urban sector located in the municipality of Milan, in the North of Italy (in the Lombardy Region). The study area approximately covers 100 hectares (= 10^6 m^2) and is geographically located between the Municipalities of Rho and Milan. The study is based on GIS techniques to map the urban transformations in the Expo area. In order to test the potential of open-source GIS for DB implementation and urban analysis, the study examines a ten-year time span (2012 - 2022). This period is necessary to determine the trends of local transformations in the Expo area between the time before it acquired the status of being an Exhibition area and after the event occurrence. The choice of the Expo area is motivated by four main reasons:

1. the proximity with respect to Milan (bordering the MIND area in the north-east side) which has influenced the development of this district of the metropolitan area;
2. the extension and its own physical-functional characteristics, making it a highly complex urban area and the engagement of local authorities in promoting and implementing urban transformation interventions which aim to an improved sustainability and integration of the site;
3. the lack of a complete digital database documenting the urban transformations in the Expo 2015 area, at the time when this study was performed;
4. the availability of high-quality cartographic production that allows to conduct multi-temporal studies and analysis on landscape changes, especially in terms of landscape coverage and network analyses, for the purpose of supporting landscape planning and management both in the present and in the future.

Along the process, particular attention has been paid to procedures for the collection, documentation, integration, and digitisation of cartographic data for the construction of the spatial database, unifying a large variety of data and integrating them into a unique GIS environment.

3.1 Defining timeline analysis steps for the case study

Considering the planning process, six different phases can be identified (Gaeta and Vita, 2021): three occurring before the Expo opening and the other three after the Expo closing.

The first phase (2006-2008) corresponded to the successful candidacy of the city of Milan, which submitted its candidature in 2006, in a context of an international competition. The selected area was a privately-owned greenfield (around 100 hectares, or (= 10^6 m^2),) located on the north-western edge of the urban core, between Milan and Rho municipalities. The Expo site, designated by the so-called Bidding Dossier, was enclosed within a densely built infrastructural network near the fairground complex.

After the event awarding in 2008, the masterplan for the exhibition area was revised as the “planetary garden”, an innovative design concept aimed to gather the diversity of food production around the World with very minimal built structures. This masterplan divided the longitudinal and irregularly shaped area by two orthogonal axes called *cardus* and *decumanus*, according to Roman surveyors’ ancient practice of measuring and dividing agricultural land. However, the planetary garden was not realised because of the organisers’ requests to build national pavilions instead of light temporary structures.

The second phase (2008-2011) coincided with a period of economic crisis and uncertainty regarding the mega-event governance characterised by long delays in both the mega-event and post-event planning and development.

After more than three years of inaction, in the third phase (2011-2015) the necessary works were started and completed. The specific planning agreement for the Expo site was signed, providing a change in land use from agricultural to non-agricultural uses and enabling the final layout design.

In the fourth phase (2015-2017), the Expo effect was obscured by difficulties encountered in planning and designing the post-event transformation of the exhibition site. These difficulties can be considered as consequences of the Expo site location in a peri-urban enclave accessible by supra-local road and rail infrastructures, though not functional to urban development (Figure 1).

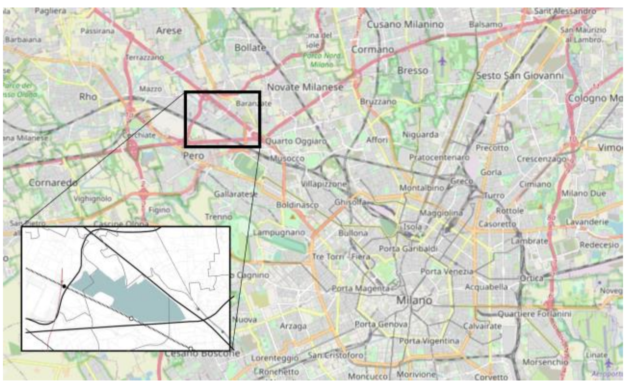


Figure 1. Location of the study area.

The site was left in a state of semi-abandonment with most pavilions to be dismantled.

During the fifth phase (2017-2019) the post-event transformation of the Expo site were finally started thanks to the national government contribution to the reconstitution of the Arexpo company and the catalysation of new interests through the selection of public functions working as drivers: the Human Technopole research centre, the new Galeazzi Hospital, and the new campus of the University of Milano.

Due to this new approach, the project is now called Milan Innovation District (MIND). MIND is the legacy project of Expo 2015 dedicated to nutrition and human wellbeing, and originates from the idea to regenerate the area that hosted the Expo 2015 and transform it into an innovation district that promotes inclusion, wellbeing and environmental sustainability as drivers for a new way of being together. The project will be completed and fully operational by 2031, becoming a physical place that will host offices, co-working spaces and shared laboratories, residential towers as well as entertainment places.

In the last phase (2020-2023), the construction of the Galeazzi Hospital has been completed in August 2022, the construction of the Human Technopole is now ongoing, and the construction of private buildings has gradually started in summer 2021, with the demolition and renovation of the Expo remaining buildings being completed.

3.2 Current planning guidelines for the area

The development of the masterplan is continuing without repercussions from the Covid-19 pandemic. The public-private cooperation had enabled multiple public and private actors to share their interests around this intervention. However, in 2017, when Arexpo company launched an international auction to lease the land and select a developer for the post-event redevelopment of the site, the guidelines specified that the expected masterplan would preserve the axes together with other morphological elements: the perimetral canal and the hill, as well as an old farmstead (Cascina Triulza, then transformed into Arexpo headquarters), the Italian pavilion and the “tree of life” iconic sculpture (Figure 2).

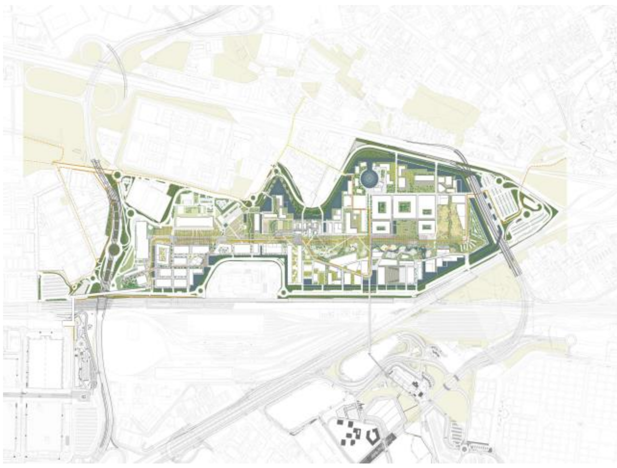


Figure 2. Post-event masterplan of the Expo site (now MIND). Source: Arexpo in cooperation with Comune di Milano, Lendlease, Systematica and Carlo Ratti Associati.

According to the new masterplan, the area retains its insular character, which is determined by existing transport infrastructures (providing supra-local accessibility but separating the site from its local context) and is reinforced by the perimetral canal. Also, the axes changed meaning because they are now used to separate the private functions, located south of the *decumanus*, from the public functions to the north. The masterplan is characterised by high building ratios with generous public spaces where the ground level under the private buildings is fully open to pedestrians and public use. That is the so-called "common ground" concept. Green areas are not envisioned as a unified park, but smaller and specialised gardens flank the main buildings and partly cover the orthogonal axes.

3.3 Relational database design

Following the strategy described in the methodology Section, the external model was defined on what were assumed to be the future users' needs in terms of data storage, consultation, and queries on the data. The conceptual model, a concise, schematic, and univocal description of the data structure, was designed in the form of a well-known model, namely the Entity Relationship Model (ERM), which represents the database content, data types, and relationships (connections) between data. Two different types of entities were included in the ERM: non-geometric and geometric entities, both with attributes. In the latter case, elements can have point, polyline and polygon geometry. Aiming at documenting also the timeline of the urban transformations of the area, the Entity Relationship Diagram (ERD) was designed integrating in a unique conceptual scheme the temporal dimension of the transformations, going from the pre-Expo to the Expo and finally post-Expo layout of the area. Relationships were defined between couples of entities (cadastral parcels; buildings; stakeholders involved in the urban transformations; land regulations; open spaces; land cover; functional lots; public transport stops; roads and underground utility lines). Figure 3 shows the ERD for the relational database, with the relationship mappings between entities.
Then, the logical model, describing the structure and content of the tables in which the data will be archived, was implemented based on the previous steps. In Figure 4, the logical model of the integrated database is reported, according to a formalism that helps to understand in a schematic and intuitive way the connections between the entities contained in the information system and where also the primary keys are reported. Moreover, it is important to underline that while designing the GIS of the area, it was considered fundamental to adhere to standard procedures and formats when collecting data to obtain a consistent digital archive and GIS. In this way, a unique integrated database was obtained, and thus a unique GIS.

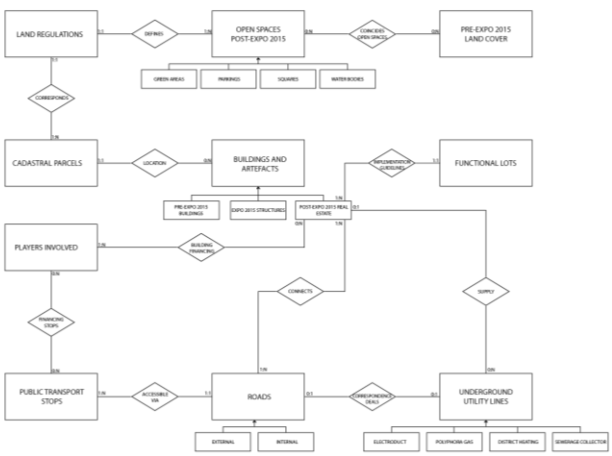


Figure 3. ERD (conceptual model) for the Expo area DB; mapping values of the relationships are reported.

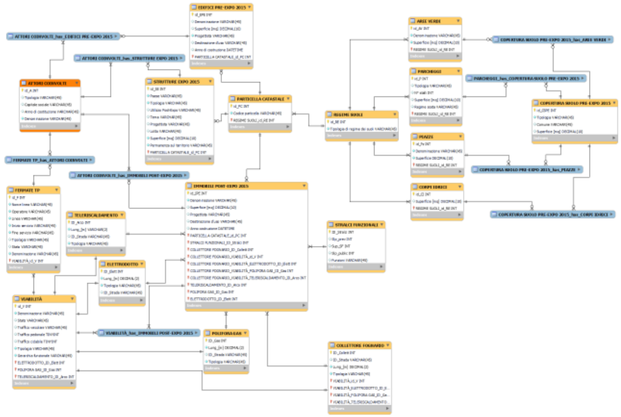


Figure 4. Logical model for the MIND GIS database; for each entity the primary key is reported.

3.4 Data sources

The input to the process was the initially available information: all the data which were needed to implement the GIS. This information is represented by maps in digital non-georeferenced format of development projects and by cartographic products attached to city plans, which show all the elements that make up the Expo area and the adjacent areas both regarding urban fabric and territorial characteristics. The acquisition and systematization of all the information deriving from the land-planning instruments about the study area required to research a large number of sources, which were mainly represented by images of maps available online on websites maintained by the different stakeholders, ranging from the archives of the public administration channels, OpenStreetMap crowdsourced contributed geodata, to official Expo 2015 communication platforms. Usually, the Technical Departments of Italian towns have cartographic data available in digital format, which means that at least a part of their digital information archives are geographically referenced. Hence, the study was mainly based on secondary sources of data: the geodatabase was extracted from digital online archives in which the projects are stored as digital images, which are publicly accessible both by emplyees and private users, but in different formats not mutually compatible. After checking the compatibility of the process with the original licenses, the maps had been made openly accessible to the public after being scanned, so they had to be geo-referenced and vectorized in order to be entered in the spatial database designed for this study.
The input data resulted in a very diverse collection, originally not organized as a DB, but only represented by graphic layers without attributes. As a result, the above-described operations of data acquisition produced a conspicuous archive of digital data, with many files in PDF format, which were then converted in raster format. Moreover, every company involved in the urban transformation process independently chose the formats which they considered best fitted for their aims (usually CAD files). In particular, data concerning the design phases of the urban transformations were developed and made available online in CAD environment and exported in PDF format. So, this large set of digital data was not natively structured according to a DB model but the data (both spatial and non-spatial) of the area were simply stored and accumulated in time, and as a result

only simple selections or visualizations could be made. No relationships had been defined between data, making up a stratified archive which failed to satisfy complex queries of the users. On the contrary, the availability of a system working with an organized DB structure allows to set up elaborate queries, involving many layers. For all these reasons, the database implementation in a GIS environment required to prepare and convert the Land Planning Office data to GIS format.

3.5 Data processing and GIS implementation

Data preparation required all the map images to be georeferenced, vectorized and compared in a GIS environment.
The information represented by PDF files were stored according to the proposed DB model, archiving the geometric elements of each file. As a first step, the digital maps in PDF format were converted to raster files in JPG format in order to be managed with georeferencing tool in QGIS. The design phase was carried on using GIS software and afterwards the information was structured as required by the ERM at the design level; the lines and points of the area were converted and stored into separate shapefile format.
Later, the existing digital data archive had to be re-organized by designing a database according to the rules of the relational model of data, for which vector entities were defined. They are cadastral parcels, buildings, players involved in the urban transformations, land regulations, open spaces, land cover, functional lots, public transport stops, roads and underground utility lines.
Then, the raster datasets were imported into QGIS for the georeferencing process, which was the result of a coordinate transformation algorithm, for which a first order polynomial was used. The algorithm links the digital maps to the current projection system assigning coordinates in the Universal Transverse Mercator projection in the World Geodetic System 1984 (UTM WGS 84, zone 32N - EPSG 32632).
In order to associate the maps with a common geo-referencing system, the ground control points (GCPs) method was used (QGIS georeferencer tool). The number of GCPs used was high enough to achieve a satisfactory level of transformation accuracy, trying to overcome the difficulty of individuation of known points on which to define the GCPs. Once the data were imported and georeferenced in the GIS environment, a fundamental operation was the evaluation of their quality. In particular, the assessment of spatial accuracy made it possible to determine the deviation of the georeferencing component of the data from reference values that can be assumed to be "correct". The OpenStreetMap dataset, which is considered accurate and up to date for this purpose, was selected as a term of comparison. It was decided to evaluate the spatial accuracy (Table 1) of a layer of polygons (layer "Land Regulations") by considering 20 pairs of homologous points, corresponding to the vertices of the polygons themselves.

	East	North	Overall
Sample size	20	20	20
Average distances [m]	1.32	0.98	1.74
Maximum distance [m]	5.18	6.86	8.60
Minimum distance [m]	0	0.12	0.12
RMS value [m]	1.15	1.45	1.76

Table 1. Calculation the distance between homologous points.

The error associated with the transformation was calculated as the RMS sum of all the residuals of points and showed a good assessment of the transformation accuracy.
By considering that most of the data were georeferenced using the project maps of the area, and that it was often impossible to locate the exact point corresponding to a specific element represented on the map, we concluded that the result obtained could be considered of good enough quality, as the average of the distances between homologous points is 1.74 m, a value considered sufficient for the uses of this database.
Finally, all the raster images were interpreted and then digitized in QGIS in the form of vector features (polygons and lines) by using on-screen digitizing as a manual method to extract geometric entities. The manual vectorization procedure was preferred, because it does not require specific software and, if performed accurately, it can guarantee considerable precision in terms of the interpretation of map contents.

3.6 WebGIS prototype

The WebGIS prototype aims to support the authorities of the Municipalities of Rho and Milan and other professionals and technicians involved in the urban transformation process during their whole administrative process. It is also a valuable opportunity to share the data with citizens. For this purpose, and in compliance with the strategic objectives of the European Commission (Open-Source Software Strategy 2020-2023) to use FOSS inside public administrations, an open-source Web-GIS prototype was proposed and developed. The proposed solution was realised through a user-friendly application, GeoNode, for developing the Web platform and for the testing the publication of the designed system on the Internet (Figure 5).

Figure 5. Prototype WebGIS interface.

The combination of QGIS and GeoNode provides an easy way to implement a free and open-source Web-GIS and it represents an opportunity to push the Public Administration toward the use of FOSS as required by the European Commission. The choice of the web platform was driven by the possibility to make the project as accessible as possible also through expandable tools in support of storytelling as well as easy to understand dashboards for visualizing quantitative analysis results. The possibility of having interactive tools, which allow company employees to work directly on the shared WebGIS platform, has the great advantage of having databases that are constantly updated and shared in real-time. Moreover, this approach helps to involve external users (as citizens) in the urban transformation process, accessing a simplified interface for interacting with the DB, making simple computations and comparisons between data (Figure 6). In this way, front-end users could create maps, graphs and reports that highlight

portions of interests, and export relevant information in different formats.
The demo version of the WebGIS is accessible at the following link: https://stable.demo.geonode.org/catalogue/#/map/5993.

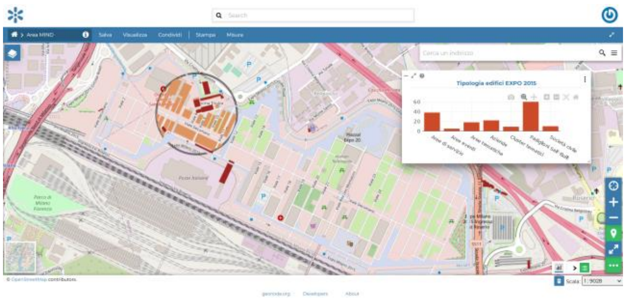


Figure 6. Example of a pre - during Expo 2015 comparison using GeoNode native widgets.

4. RESULTS AND DISCUSSIONS

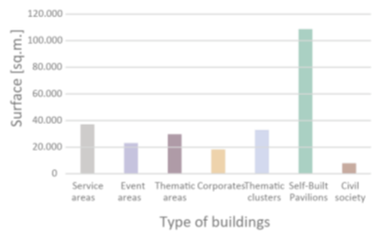
To validate the designed DB model, it was decided to test its compliance with some sample queries. In fact, the database of the MIND GIS can now be queried and used in an integrated way, allowing to perform queries involving different layers for obtaining relevant urban transformation statistics.

4.1 Analysing urban change

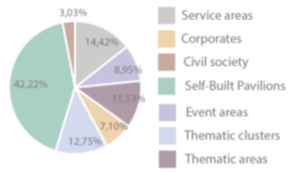
The use of the GIS has allowed to obtain maps that facilitate the understanding of the modifications of the urbanisation over time, defining them both qualitatively and quantitatively and processing histograms (Figure 7, 8, 9) to make them more understandable and directly connect them to the maps. This approach provided insights on the surface covered by buildings in the different periods and on the change of destination or decommissioning of exhibition pavilions in the post-Expo environment. The trend and pattern of urban expansion was calculated, and the building footprint was quantified and mapped at the different time thresholds. The feature class created in the geodatabase already provides in the attributes table the areal dimensions of each record. The main characteristics which emerge by comparing the three time periods are outlined in Figure 7. The analysis highlighted that in the MIND area there has been a decrease of approximately 25% in the amount of built-up area from the Expo situation to the post-Expo project scenario. Moreover, by grouping the Expo pavilions by use type and category in a single comparison, it is possible to carry out calculations and statistical evaluations. The cartographic representation through different symbologies by categories allows an immediate visual effect of the size of the modifications (Figure 9). Such operations, as shown in Figure 6, could also be replicated in the GeoNode prototype environment, enhancing the transparency of the data and the open accessibility to user-friendly and simplified tools for understanding how the territory has changed.

Figure 7. Comparison of the built environment along the three-time thresholds.

Figure 8. Map of the Expo 2015 area during the exhibition with buildings classified by their type of use.



Surface area covered by buildings according to their type



Surface area covered by buildings, expressed as a percentage of the total covered area

Figure 9. Statistics on building types during Expo 2015.

4.2 Query in support of maintenance operations

The database implemented in this study also allows users to query the data to identify underground services as well as buildings that may be affected by future works on roads or buildings located in the area of interest. In fact, the topological models of the streets and of the underground network of the district heating were implemented, in the latter case also connecting each building with the corresponding segment of the network. Finally, the topological consistency and coherence of such network and its components were validated. All the example of analyses listed above can be performed through queries, which the system can answer thanks to the presence of the foreign keys in the relational tables, as it is shown in the logical model (Figure 4). The mapping of underground utility lines is of benefit in planning excavation works, since it is possible to know the location of underground lines and their volumetric dimensions, hence better "targeted" excavations can be carried out in safer conditions, avoiding interference or damage to existing artifacts and reducing the risk of accidents for workers and residents. A simple example of data analysis of the district heating network is the calculation of the length of each section of the network.

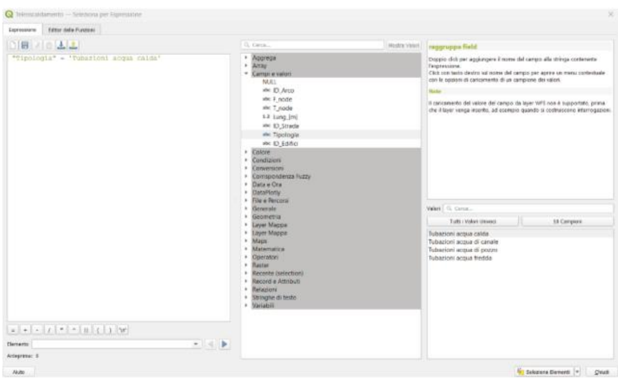


Figure 10. Example of hot water pipe selection on underground lines data.

It is also possible to select only certain types of pipe sections using the "Select elements using an expression" command, thanks to the presence of a field specifying the heat transfer fluid present in that section (see Figure 10). The syntax of the expression, assuming the selection of a specific pipeline according to the type of service provided, is as follows: Select "Tipologia" = 'Tubazioni acqua calda'.

5. CONCLUSIONS

The work presented in this paper regards the implementation of a geographical DB for the storage of data of a relevant urban transformation located in Milano (Italy), where the rules of database modelling have been applied to the design of a GIS for urban data management. This study looks at the role which geoinformation is playing and could still play in the urban expansion, by enhancing the possibility of the correct management of urban decisions in the framework of planning, monitoring and intervention.
An important condition to build a system working on a heterogeneous archive of data (where geographic data have a fundamental role), is to have data which are correctly structured according to the rules of database design and implementation, in particular the rules which apply to relational databases. Applying the rules for relational database design to the reorganization of the MIND data archive allowed to obtain an integrated GIS database, containing consistent data which can be used in an automatic and efficient way to perform selections and answer queries on data representing both spatial and alphanumeric thematic information.
An additional problem which was tackled and solved is the integration and unification of the existing maps (in digital non georeferenced format) in a unique GIS environment: the result was a unique structure, in which all the entities can coexist thanks to the use of primary and foreign keys which implement the relationships between entities. The chosen solution regarding the GIS environment was to use QGIS to realize the database. To share the data on the Web, the GeoNode software was selected since it gives the possibility to directly share the QGIS project and, in the future, to update and manage the database inside QGIS. All these methods, together with the creation of increasingly articulated and shared databases, could become important when it comes to supporting decision-makers and sharing and transferring information among stakeholders. The method applied in this study allows to gather knowledge about the urban landscape, whose result, once shared with decision-makers, will contribute to transparent planning process. In addition, the combination of FOSS tool has the purpose of ensuring maximum transparency to users who, although not directly involved as employees, could access the WebGIS to see how the urban transformations have been performed and if the promised sustainability goals have really been taken into account through strategies and interventions on the area.

6. FUTURE DEVELOPMENTS

The integration of different data formats is the next challenge for the project, identifying possible additional data that could enrich the database and the analysis of the site. A research field where interoperability is fundamental is the integration of Building Information Modeling (BIM) with geospatial data. The large amount of data and the possibility of managing multiple information contained in a BIM model can, indeed, be usefully integrated and declined at higher scales than the single building, since they can be extended from the scope of pure architectural design to the planning sector. Besides, 3D georeferenced products coming from specific field surveys based on the use of drones and laser scanning technologies could also provide a comprehensive picture of the site, unleashing the potential of 2D and 3D integration with open-source tools. Indeed, this enrichment with heterogeneous data sources and formats could support immersive experiences to support not only the narration of the urban transformations but also the management of maintenance operations (Carneiro et al., 2018). Moreover, a future development of this research could be the integration of the already collected data with other topological data not yet stored. In future, it would be useful to have the data of the Spatial Planning Office of both Municipalities of Rho and Milan directly acquired in a DB format or in a format easily convertible in DB. Due to the long construction phase, it will be also necessary to constantly update the data in a consistent way with the construction schedule. Finally, by implementing further improvements, the prototype of WebGIS could lead to a decision support system, to be used as a tool to understand the area for the benefit of all actors involved with different expertise and background in the urban transformations.

REFERENCES

Alicandro, M., Zollini, S., Oxoli, D., Pascucci, N., Dominici, D., Brescia, D., 2022. Design and Implementation of AN Open-Source Web-Gis to Manage the Public Works of Abruzzo Region: AN Example Towards the Digitalization of the Management Process of Public Administrations. *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, 48, 21-26.

Baratin, L., Bertozzi, S., Moretti, E., 2015. The geomorphological transformations of the city of Urbino: the design of the city analysed with GIS tools. *SCIRES-IT*, 5, 41-60.

Carneiro, J., Rossetti, R. J., Silva, D. C., Oliveira, E. C., 2018. BIM, GIS, IoT, and AR/VR integration for smart maintenance and management of road networks: a review. In *2018 IEEE international smart cities conference* (ISC2) (pp. 1-7). IEEE.

Carrion, D., Maffeis, A., Migliaccio, F., 2009. A database-oriented approach to GIS designing. *Applied Geomatics*, 1, 75-84.

Cazzaniga, N. E., Carrion, D., Migliaccio, F., Barzaghi, R., 2013. A shared database of underground utility lines for 3D mapping and GIS applications. *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, 1, 105-108.

Chen, P. P. S., 1976. The entity-relationship model—toward a unified view of data. *ACM transactions on database systems* (TODS), 1(1), 9-36.

Corti, P., Bartoli, F., Fabiani, A., Giovando, C., Kralidis, A. T., Tzotsos, A., 2019. GeoNode: an open source framework to build spatial data infrastructures (No. e27534v1). *PeerJ Preprints*.

Kaya, B. E., Erbaş, İ., 2022. Effects of Expo Fairs on Urban Development as the Event Legacy and Their Sustainability: Comparison of Expo Lisbon and Expo Antalya Cases. ICONARP *International Journal of Architecture and Planning*, 10(1), 01-20.

Gaeta, L., Vita, S. D., 2021. Planning disaster, successful event, and uncertain future: the twin cases of the World Expo 2015 and Innovation District in Milan. *Les Cahiers de la recherche architecturale urbaine et paysagère*, (12).

Grimaldi, M., Giordano, C., Graziuso, G., Barba, S., Fasolino, I., 2022. A GIS-BIM approach for the evaluation of urban transformations. A methodological proposal. *WSEAS Trans. Environ. Dev*, 18, 247-254.

Lahoti, S., Kefi, M., Lahoti, A., Saito, O., 2019. Mapping methodology of public urban green spaces using GIS: An example of Nagpur City, India. *Sustainability*, 11(7), 2166

Lovelace, R., 2021. Open source tools for geographic analysis in transport planning. *Journal of Geographical Systems*, 1-32.

Minner, J. S., Zhou, G. Y., Toy, B., 2022. Global city patterns in the wake of World Expos: A typology and framework for equitable urban development post mega-event. *Land Use Policy*, 119, 106163.

Migliaccio, F., Carrion, D., Ferrario, F., 2019. Semantic validation of social media geographic information: A case study on Instagram data for expo Milano 2015. *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, 42(2), 1321-1326.

Monteiro, C. S., Costa, C., Pina, A., Santos, M. Y., Ferrão, P., 2018. An urban building database (UBD) supporting a smart city information system. *Energy and Buildings*, 158, 244-260.

Roche, M., 2017. Mega-events and social change: Spectacle, legacy and public culture. In *Mega-events and social change*. Manchester University Press.

Rosas-Chavoya, M., Gallardo-Salazar, J. L., López-Serrano, P. M., Alcántara-Concepción, P. C., & León-Miranda, A. K., 2022. QGIS a constantly growing free and open-source geospatial software contributing to scientific development. *Cuadernos de Investigación Geográfica*, 48(1), 197-213.

Souza, L., Bueno, C., 2022. City Information Modelling as a support decision tool for planning and management of cities: A systematic literature review and bibliometric analysis. *Building and Environment*, 207, 108403.

Yap, W., Janssen, P., Biljecki, F., 2022. Free and open source urbanism: Software for urban planning practice. *Computers, Environment and Urban Systems*, 96, 101825.