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Typological GIS for knowledge and conservation of built heritage: a case study in Southern Italy

Sistema de Información Geográfica tipológico para el conocimiento y la conservación del patrimonio construido: un caso de estudio en el sur de Italia

Luigi Mollo (*), Rosa Agliata (**), Luis Palmero Iglesias (***), Marco Vigliotti (****)

ABSTRACT

A typological GIS is a system designed to store, analyse, manage and visualize geo-referred data about the built environment. It allows interactive queries to explore spatial relationships between buildings, improving the knowledge of the built heritage at different scales. For example, by running space-typological analysis, it is possible to extract information about the most used typologies in the existing buildings at different levels, from the urban scale to the construction detail. This knowledge shows a great potential in building design applications and may provide support for a correct design in urban renovation projects aimed to keep the character of the considered area unchanged and preserve its cultural and historical value. This work presents the first phase implementation of the typological GIS of an historical city centre set north of Naples and shows some examples of possible GIS queries for typological investigation of built environment at different detail levels.

Keywords: GIS, building typologies, heritage, typological GIS, built environment.

RESUMEN

Un SIG (Sistema de Información Geográfica) tipológico, es un sistema diseñado para almacenar, analizar, gestionar y visualizar datos geo-referenciados sobre el entorno construido. Permite consultas interactivas para explorar las relaciones espaciales entre edificios mejorarando el conocimiento del patrimonio construido a diferentes escalas. Realizando un análisis espacio-tipológico, es posible extraer información de los edificios existentes sobre las tipologías más utilizadas a diferentes niveles, desde la escala urbana hasta el detalle constructivo. Este conocimiento, podría servir de apoyo para un correcto diseño en los proyectos de renovación urbana destinados a mantener inalterado el carácter de la zona considerada y preservar su valor cultural e histórico. Este trabajo presenta la primera fase de implementación del SIG tipológico de un centro histórico situado al norte de Nápoles, y muestra algunos ejemplos de posibles consultas del SIG para la investigación tipológica del entorno construido a diferentes niveles de detalle.

Palabras clave: *GIS, tipologías constructivas, patrimonio, GIS tipológico, ambiente construido.*

(*) PhD. Associate Professor. University of Campania "L. Vanvitelli", Aversa (Italy).
(**) PhD. Research Fellow. University of Campania "L. Vanvitelli", Aversa (Italy).
(***) PhD. Associate Professor. Universitat Politècnica de València (Spain).
(****) PhD. GIS expert. University of Campania "L. Vanvitelli", Aversa (Italy).
Persona de contacto/*Corresponding author*: luigi.mollo@unicampania.it (L. Mollo)
ORCID: https://orcid.org/0000-0002-1067-0142 (L. Mollo); https://orcid.org/0000-0001-7341-3840 (R. Agliata); https://orcid.org/0000-0003-0046-5134 (L. Palmero Iglesias); http://orcid.org/0000-0002-1709-4424 (M. Vigliotti).

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1. INTRODUCTION

Between the end of the XX century and the beginning of the XXI century, GIS had established as a support for urban planning, also in a participatory way (1). Later on, thanks to its mapping features that allow the storage of spatial (physical) and immaterial data, it has also started to be considered as an auxiliary tool for heritage conservation (2, 3). GIS, being devoted to modelling real world with a geographic approach, enables to acquire and store information about the shape and elements of the built environment. This characteristic makes it particularly suitable for exploring, by carrying out geospatial analysis with appropriate queries, the relationships between buildings (4) and building components, picturing the built environment at different levels, from land scale to construction detail (5). A GIS containing this kind of information is called "Typological GIS" (6).

To fully exploit a typological GIS potential, analogously to what has been done in the field of energy consumption reduction with the Energy GIS (E-GIS), it is necessary to consider a building in its own context and analyse, also for the latter, the same characteristics to be investigated for the construction (e.g. sustainability for E-GIS) (7, 8, 9). Recent works (6, 10, 11, 12) examining the relationship between building typology and urban space, highlighted how a typological GIS may provide data on the identity and character of built areas. In order to know one city's character, it is necessary to identify the typological invariants that, at different scales, characterize a specific built environment and constitute the guiding elements for urban regeneration and building retrofit projects (13, 14). By typological invariants are meant, at different scales, the characteristics of the built environment, e.g. at the district scale the invariant typological element is the building layout (15). It is well known (16, 17) that typological elements are relatively few but, with those, it is possible to create many different buildings, which specify the city's character. Therefore, a typological GIS is meant to digitalise the modelling-guides for the design of urban areas and buildings, shaping up to be the simplest and most effective tool in managing the complexity of the built environment, also for urban and architectural regeneration projects (2, 3, 4, 5, 7, 18).

However, GIS environment does not allow a detailed 3D representation of the architectural object and it is not suitable to the storage of historical documentation and data, and remote decentralized planning and management of heritage recovery projects, for which Heritage Building Information Modeling (HBIM) is more appropriate (19, 20, 21). HBIM procedures start with a survey of the existing building (e.g. laser scanner acquisitions), then the information retrieved can be used for geometric modeling (e.g. points clouds (22)) and compared to libraries of software objects until a satisfactory similarity is reached. In this perspective, a typological GIS could also be a valuable support to record and classify elements to be included into the HBIM libraries the way to properly describe the built heritage to be modeled. The interaction between the two systems (23) would be extremely useful for building design (24), restoration and managing of cultural heritage sites (25, 26, 27) and facility management (28) especially in urban environment (29).

This work shows the results obtained by moving one step forward in an ongoing research on typological analysis matched with topological data, conducted on the historical centre of the city of Aversa (Campania region, Italy) (6). The aim of the study is to construct the typological GIS of the chosen case study (named from now on "Tp-GIS") and verify its potential (e.g. the possibility of exploiting it it in building regeneration operations) by carrying out typological analysis on the surveyed buildings.

2. METHODOLOGY

The case-study area is the historical city centre of Aversa, a 53000 inhabitants city set north of Naples, characterized by a rich time stratification that has yielded to the coexistence of several typological and technological solutions together. First step of the research is the field survey, aimed to collect pictures and data (geographical, historical, socio-economic, technological, typological, etc.) about the buildings in the studied area. A census of 735 buildings is taken following a consolidated methodological procedure for data collection and subsequent analysis (30, 31) consisting in filling in datasheets specifically prepared. Each surveyed building is univocally identified in the sheet by assigning it a unique identification code (ID) and geographic coordinates, the latter by means of a GPS app installed on portable devices. Other fillable fields in the form include information about building typological scheme (e.g. courtyard building, multi-storey building, etc.), components (e.g. windows, gates, roofing system, etc.), materials, state of conservation and date of construction. For the latter, the date of the urban settlement is considered, not the one of the single building, identifying five main historical periods (32), each of them corresponding to a district: *Sancti Pauli* (XI cent.), *I Surrounding Walls* (XI-XII cent.), *II Surrounding Walls* (XII cent.), *Medieval City* (XIII-XV cent.) and *Lemitone* (XVI-XVIII cent.).

Acquired data are also integrated with literature/archive documents and aerophotogrammetric data and then arranged in .xls spreadsheets to be further processed. Several topographic maps, already georeferenced, together with multi-time series of aerial pictures of the city, are collected for the study, as reported in Table 1. The multi-precision Topographic Data Base, 2004/2005 edition, concerning the studied area and derived from Campania's CTRN[1] (1:5000) is also used in personal geodatabase format (.mdb).

A GIS interface software is used to organise the pictures, .xls spreadsheets (bearing the gathered data) and cartographic materials to create a buildings catalogue. All locational errors, typical of historical centres with narrow streets and tall buildings ("city canyons") are also corrected in this phase by referring to the exact address of the building affected by the error. This way, the typological GIS is built, classifying, at different scales, the typological elements of each building according to main typological features.

The procedure followed for the Tp-GIS creation and query is sketched in Figure 1.

[1] *Carta Tecnica Regionale Numerica.*

Table 1. Materials acquired for the study and related characteristics.

Scale	Name	Year	Format	Geographic projection	Resolution
1:50.000	446-447 Napoli	1993	Raster	Gauss Boaga Zone 2 Roma 40	6,4×6,4
1:25.000	184 IV NE Trentola-Ducenta	1957	Raster	Gauss Boaga Zone 2 Roma 40	2,5×2,5
1:25.000	184 I NO Aversa	1957	Raster	Gauss Boaga Zone 2 Roma 40	2,5×2,5
1:25.000	Tav. 22 Lago Patria	1987	Raster	Gauss Boaga Zone 2 Roma 40	1,6×1,6
1:25.000	Tav. 23 Napoli	1987	Raster	Gauss Boaga Zone 2 Roma 40	1,6×1,6
1:5.000	447 031 Teverola	2004-2005	Raster	UTM33 WGS84	0,2×0,2
1:5.000	447032 Cesa	2004-2005	Raster	UTM33 WGS84	0,2×0,2
1:5.000	447033 Lusciano	2004-2005	Raster	UTM33 WGS84	0,2×0,2
1:5.000	447034 Aversa	2004-2005	Raster	UTM33 WGS84	0,2×0,2
1:5.000	447 031 Teverola	2004-2005	Vector	Gauss Boaga Zone 2 Roma 40	
1:5.000	447032 Cesa	2004-2005	Vector	Gauss Boaga Zone 2 Roma 40	
1:5.000	447033 Lusciano	2004-2005	Vector	Gauss Boaga Zone 2 Roma 40	
1:5.000	447034 Aversa	2004-2005	Vector	Gauss Boaga Zone 2 Roma 40	
	Ortophoto	1991	Raster	Gauss Boaga Zone 2 Roma 40	10×10
	Ortophoto	1998	Raster	Gauss Boaga Zone 2 Roma 40	2,5×2,5
	Ortophoto	2011	Raster	UTM33 WGS84	0,5×0,5

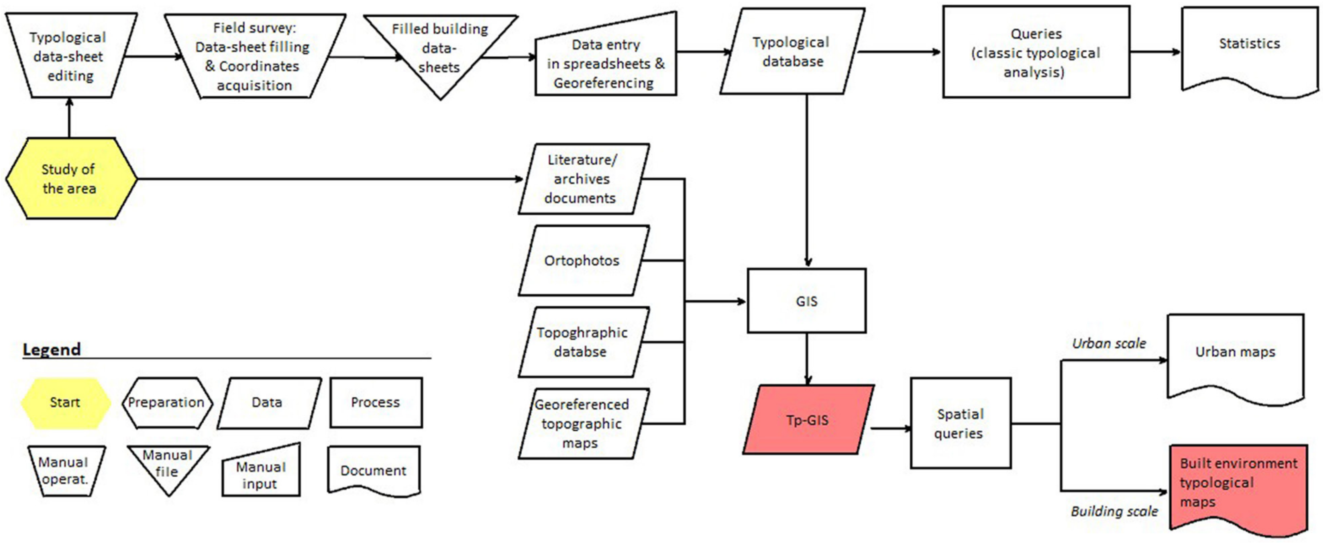

Figure 1. Flowchart of the used methodology.

3. RESULTS AND DISCUSSION

The statistical analysis of typological aspects of the built environment allows reading the character of the city and identifying the typological invariants characterizing historically homogeneous areas at various scales. Below are some examples showing what kind of results is possible to retrieve from Tp-GIS. Although GIS allows displaying all results on the map generating "thematic maps" (4), here only results of the first query are represented on the map for the sake of clarity (9).

First analysis examines the number of buildings in each district of the historical centre, as shown in Figure 2. Sorting buildings by construction date is probably the most common type of analysis and it is used as preliminary categorization in many GIS-based studies, e.g. within the scope of energy assessment (7, 9). As many Norman cities founded in the Middle Age, Aversa has developed radially around two key elements, which are cathedral and castle but, conversely to the typical European Norman settlements sprang up along the hillsides, this city had been constructed on a flat land, which makes it unique. Thus, for the first three districts, which are concentric circles, the more the area is far from the central nucleus, the bigger is the district and the higher is the number of buildings in it. The district showing the highest number of buildings is Medieval city, which also has the biggest surface; the second most populated area is Lemitone, which is smaller than II Surrounding Walls district but appears to have a high population density. This is because Lemitone was constructed as a property speculation district by the Real Casa dell'Annunziata to finance its charitable activities. This speculative will is also confirmed by other characteristics, as the "chessboard" urban layout with minimum public spaces, the development in height, the higher building density compared to the neighboring areas and the lack of noble buildings. Then, the distribution of services in the area, and the surface occupied by them, is considered (Figure 3). Services include schools, churches and administrative buildings (city hall, courthouse, etc.). The response to the query highlights that public buildings are in all districts in maximum number of 10, but Lemitone, where the lack of services (100% of constructions are used as houses or

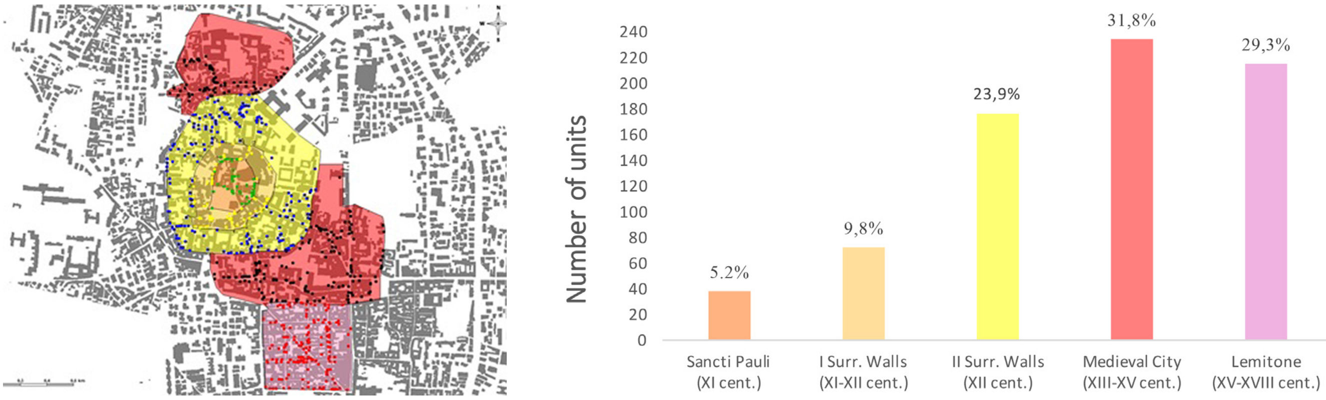

Figure 2. Historical evolution of the city. In panel a) each district (historical period) is marked in a different colour; in panel b) total number of building for each district is reported.

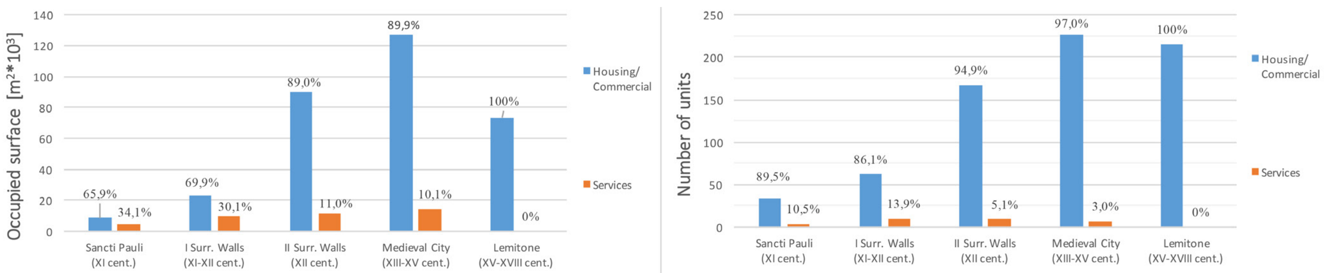

Figure 3. Distribution of services. Blue bars indicate housing and commercial purposes; orange bars indicate services. Percentages are calculated per district.

for commercial purposes) is a consequence of the speculative nature of the district. In a similar study conducted on a 55000 inhabitants city in Greece (2), the authors found that majority of the services buildings are located in the most ancient part of the city. Analogously, in Aversa the surface occupied by services is around 30% of the built area for the two districts close to the nucleus and 10% for the other two. Remaining at the district scale, the state of conservation of the buildings is also examined. The results of the query, reported in Figure 4, show that in all considered areas most of the buildings are kept in overall good condition. It is worth highlighting that in newer districts, with marginal heritage value, the percentage of buildings in poor conditions is lower. A probable explanation may be the fewer legal and architectural constraints, permitting an easier restoration and reconversion, in addition to the younger age of the buildings, of course. Similar results were obtained by the study (2), which found that the most well-kept construction are concentrated in the newly-built areas.

Moving from the urban scale, to the building scale, results concerning the end use of ground floors are shown in Figure 5. In all districts dwellings are less than 50% of the total ground floors of the area and low-income people, such as

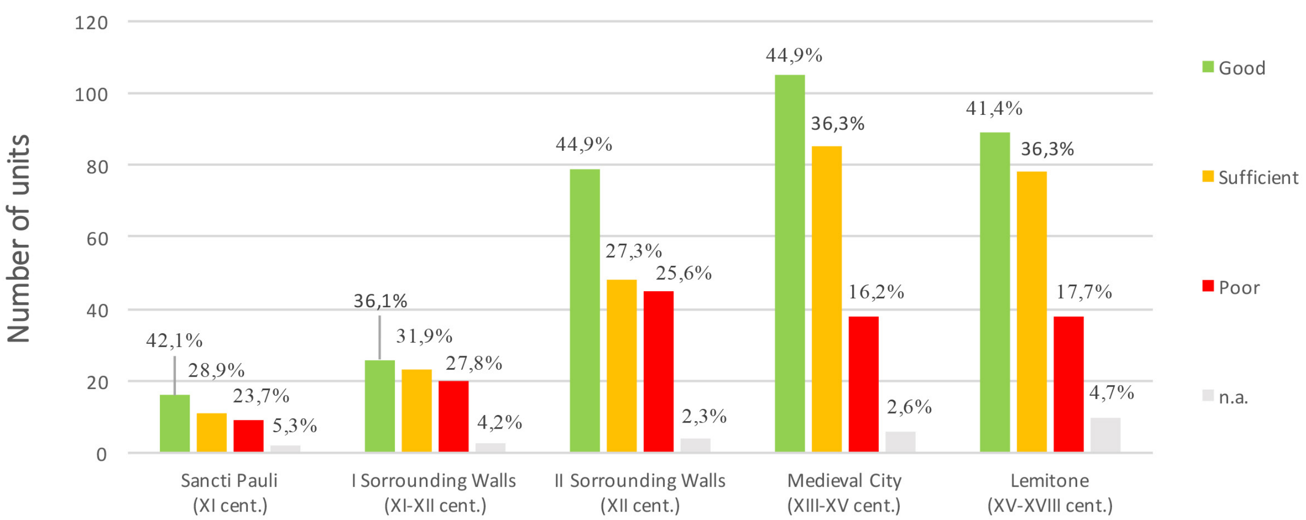

Figure 4. State of conservation of buildings. Percentages are calculated per district. “n.a.” indicates buildings condemned or under construction/renovation at the time of the survey.

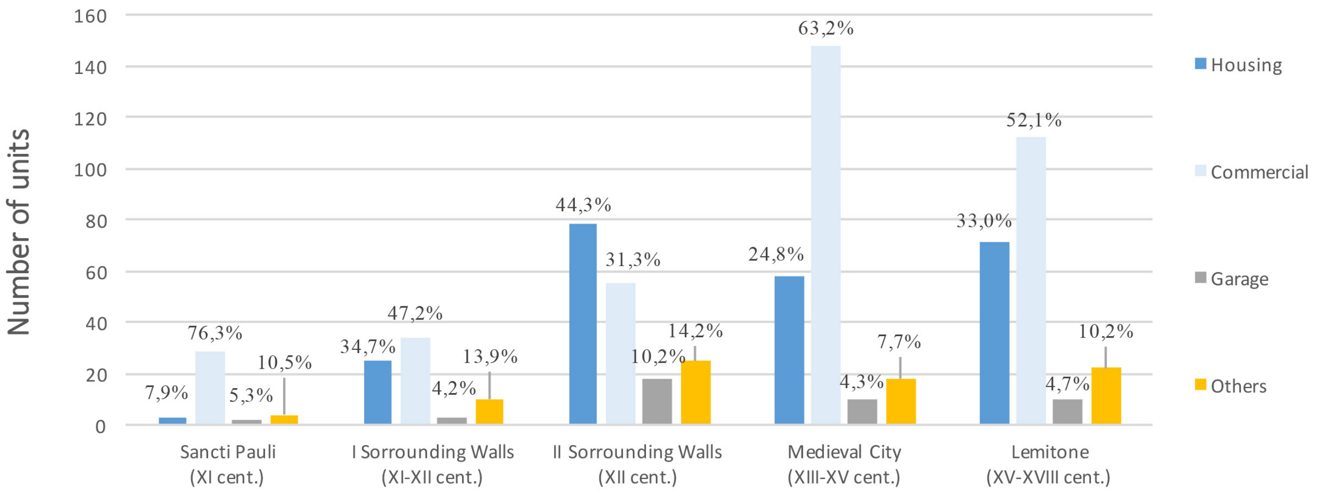

Figure 5. End use of the ground floors. Percentages are calculated per district.

elderly or immigrants, generally occupy them. Only in one district, the third annulus, housing is the prevailing end-use (45%). Sancti Pauli district, the most ancient one, has the lowest housing percentage (8%) as the lively nightlife of the district has driven the birth of many entertainment venues that have occupied more than 75% of the available ground floor spaces. In other districts, the incidence of commercial activities varies from 30% to 63%. The distribution rate of garages and other kinds of end uses is almost constant in all districts (the variation concerns a few percentage points) and guarantees a certain diversification. The study conducted in Greece (2) obtained completely different results, registering the almost exclusive residential use of ground floors in most of the Old Town area. This is probably due to different customs and traditions in the two Mediterranean countries and the different vocation of the cities.

Lowering the scale it is possible to examine technological elements; next query reports the results concerning the roofing system. Figure 6 shows that the pitched roof is preferred in over 60% of the buildings. The attic has become a characteristic element of the area probably because, in a purely agricultural economy, developed in a wet and humid area, there was a strong need to have a place with good conservation conditions to stock foodstuff. Although in most cases the attic has lost its traditional stocking function (still testified to by typical arched windows alive in some buildings), it has remained in the construction tradition and it constitutes now (at the building scale) one of the typological invariants characterizing the city.

The spatial analysis carried out highlight how Aversa historical centre has kept the role of economic city centre as the majority of ground floors have a commercial end use. The overall good state of maintenance of buildings testifies the high attractiveness of the area for both residential and commercial purposes, as also underlined by the fact that the majority of constructions have residential and commercial functions. This mixed use indicates a good quality of the built environment, which is one of the pre-requisite for a good quality of life (33).

4. CONCLUSIONS

This paper shows the methodology used to construct a Typological GIS and some examples of the analysis that is possible to run when data are imported in the GIS database. It appears clear that Tp-GIS may be an important support tool for the

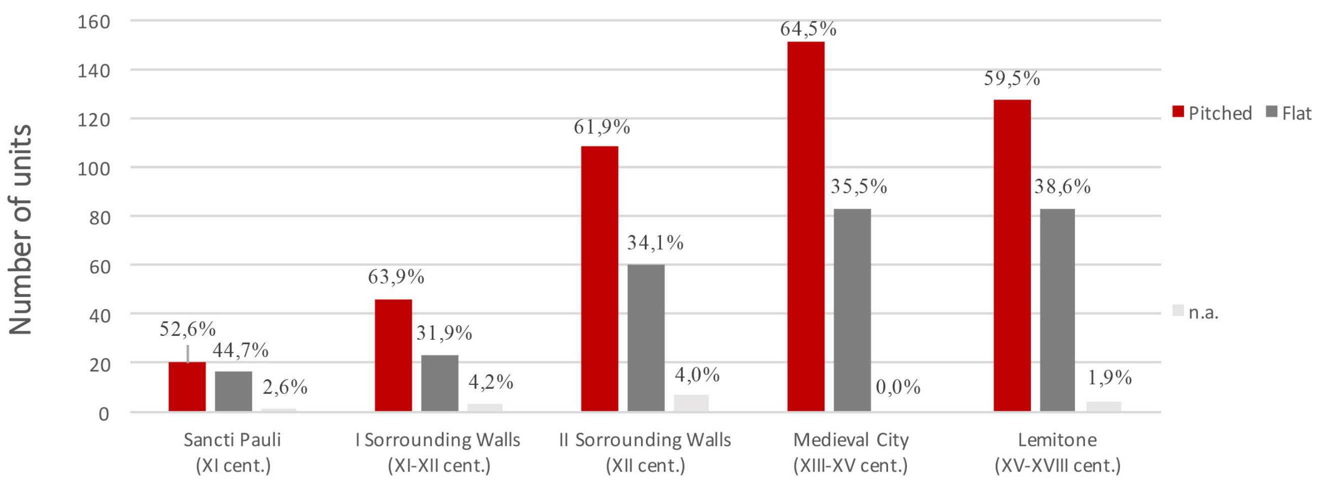

Figure 6. Roofing system. Percentages are calculated per district. "n.a." indicates buildings with no roof (condemned or under construction/renovation) at the time of the survey.

recovery and enhancement of built heritage. The construction of a Tp-GIS, with georeferenced typological information on the built environment at different levels of detail, from the urban scale to the constructive details, is laborious, complex and time-consuming. However, the time invested in the construction of detailed Tp-GIS pays off with the possibility of carrying out short-time analyses for a better understanding of the district and building fabric, useful, for example, in building regeneration projects.

Further work is aimed at extending the number of metadata in the Tp-GIS, such as more historical data and technological details, environmental parameters, risks for materials, etc. With the goal of conceptual integration and automatic data acquisition between Tp-GIS and HBIM, the work will continue by defining, based on the identified typological invariants characterizing the existing built environment, the constructive elements to be introduced in BIM libraries of objects, for HBIM applications.

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