

## THE GEOMORPHOLOGICAL TRANSFORMATIONS OF THE CITY OF URBINO: THE DESIGN OF THE CITY ANALYSED WITH GIS TOOLS

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### Abstract

The study covers the geomorphological transformations of the area in which the city of Urbino rises, starting from the first Roman settlement, until reaching the nineteenth-century nucleus and the current situation. The design of the walled city and its immediate surroundings is analysed with GIS tools, that allow one to manage data in a georeferenced way, to evaluate the changes of urban expansions in the various historical periods and to represent them not only from a qualitative point of view but also a quantitative one. The representations of the analysis make use of all the 2D and 3D devices available for a greater understanding of the data analysed

### Keywords

Urban transformations, historic centre, GIS, virtual reconstruction, 3D representation

### 1. Introduction

The origin of *Urvinum Matuarense* and the successive phases of development of the city in the middle ages and modern era must be put in close connection with the morphology of the territory on which it is located. The current shape of the city of Urbino is the result of various transformations that start from very ancient origins: although some clues seem to prove the existence of a protohistoric settlement, the first important evidence dates back to Roman times. In this period the city was developed on one of the two hills upon which it currently extends. Successively, one witnesses a gradual expansion in two building phases that took place respectively in medieval and Renaissance eras up to the current configuration of the historical centre. Each of these phases coincides with the building of many city walls, two of which, the Roman and medieval walls, were built by leveraging the morphology of the site as a natural defensive element.

The strategic site on which the ancient town of Urbino arose, referred to as "Poggio", is geologically constituted of land belonging to the Umbro-Marchean stratigraphic succession. The many formations that compose it are essentially made up of limestone, limestone with flint and to

a lesser degree of marly limestone or marl. The Miocene part also has lithologies with composition that is more terrigenous or composed of turbidite (Centamore & Deiana, 1986). The area in which Urbino rises has in outcrop three overlapping formations that are stratigraphically layered, called from the bottom upwards *Bisciario*, *Schlier* and *Marnoso-arenacea Formation*. The *Bisciario Formation* consists of strata of grayish marly limestone and gray argillaceous marl that are variously alternating and emerge, in a discontinuous way, in the south-east side of the Renaissance city walls. Although not directly affecting the historical centre, from this formation came blocks of stone used for the foundation structures of many masonry works in several important historical buildings. The *Schlier Formation* is comprised of an alternation of marl, calcareous marl, gray argillaceous marl and whitish marly limestone and it constitutes the substrate portion of the southernmost of the historical centre, in particular, it affects the portion of the sixteenth-century city walls which runs from Borgo Mercatale to the former Prison. It is possible to observe that the walls stand on this formation in the stretch between the bastion of S. Caterina and Porta S. Maria. The *Marnoso-arenacea Formation* is represented by a rhythmic alternation of marly and sandstone of yellow-

ochre colour, from fine to coarse, with thicknesses of the strata ranging from a few decimetres to several metres. To these, there are alternated strata of gray-blue marl or marly siltstone of hazel colour with thicknesses ranging from a few centimetres to several metres. It constitutes the stony substrate part of the central and north-western part of the historical centre of the city and is visible downstream of Alborno Fortress and the section of the wall that flanks Porta San Bartolo. The lithotypes of the *Schlier Formation* and of the *Marnoso-arenacea Formation* pose problems especially in that they are the foundation soils of the Renaissance wall. The state of intense decay of the layers and surface degradation, in fact, make precarious the stability of some portions of the slopes on which the walls rest.

The study covers the geomorphological transformations of the area in which the city of Urbino rises, starting from the first Roman settlement, until reaching the nineteenth-century nucleus and the current situation. Some attempts of geomorphological reconstruction in other contexts have already been addressed, as for example in Amato et al. (2009) and in Baubinién et al. (2014). The design of the walled city and its immediate surroundings is analysed with GIS tools, that allow one to manage data in a georeferenced way, to evaluate the changes of urban expansions in the various historical periods and to represent them not only from a qualitative point of view but also a quantitative one. The representations of the analysis made use of all the 2D and 3D devices available for a greater understanding of the data analysed.

## 2. Urbino in the Roman period

Developing a GIS project that allows one to combine the data that is present in order to obtain the information necessary for evolutionary and historical analysis requires a careful planning phase. The conceptual diagram shown in Fig. 1 defines the steps that lead from the acquisition of input, raster and vector data, to their georeferencing and processing in order to be able to proceed to the phase of editing of the depth contour lines, which constitute the geomorphological reconstruction of the territory, and to process the relative TINs. In addition, there are statistical analysis of the evolutionary phases of the urbanised area that has grown in close connection with the geological and morphological

conformation upon which it rose, highlighted three-dimensionally, together with the situation of the current built environment, modelled and managed between plans and perspectives. The GIS-based project has been developed in the 10.2 release of ArcGIS by ESRI and georeferenced in the national geodetic system called Monte Mario Italy 2 (EPSG 3004), analogously to the one used by the Municipal Administration in its own geographical information system. The cartographic data in the \*.dwg format and diverse rasters were acquired as starting input. In particular, cartography provided by the Municipality and produced by the Government Authority was used. It shows all the elements that make up the centre of Urbino and the adjacent areas, both regarding urban fabric (buildings, roads, walls, etc.) and territorial characteristics (depth contour lines outside of the urban centre, quoted points, boundaries of wooded areas, etc.). These maps describe the shape of the buildings at the ground and at the eaves. At their integration, the CTR, (Regional Technical Map), at the scale 1:10,000, and thematic geological and geomorphological maps, acquired by the CARG project, always at the scale 1:10,000 in raster format, were the basis for the classification of the main focus points to start the geomorphological reconstruction.

For the historical description the DWGs were imported and georeferenced with the diverse evolutions of the urban apparatus in the different historical periods and reconstruction maps in raster format.

The polylines of the various layers of the DWGs were transformed into shapefiles, the depth contour lines and all points containing information on the quota were extracted, which are especially useful in the absence of altimetric information. Particular attention was paid to altimetric control by means of the attributes table where the Editor of ArcMap has allowed the elimination of some of the records that did not have a quota or ones that had incorrect quotas. This check must always be carried out and, if necessary, reliefs must also be executed on the ground by means of the GPS altimeter, or other methods as already highlighted in Limoncelli and Scardozzi (2013). All the objects have been eliminated that are not necessary for obtaining correct altimetric information such as power lines, buildings, woods, etc. The quoted base data have made it possible to generate the TIN of the

current morphological conformation of the historical centre of Urbino and depth contour lines with fixed distance equal to 1 metre, which is consistent with the original equidistance of the depth contour lines. The lowest quota measures 318 metres. and the highest measures 484 metres.

The representation of the built environment instead occurs through files of polygons, for both the current situation and for the archaeological reconstructions (Fig. 2). Where there were only the layers of polylines derived from the DWGs present, these were transformed into polygons by means of a specific conversion tool (Feature to polygon), after having checked, if necessary, the geometry and topology used. The DWGs that are not georeferenced were first exported then georeferenced using the Spatial Adjustment extension (it was chosen to georeference the shapes instead of the DWGs in order to be able to insert more Control Points and have a more accurate yield).

Various types of rasters were acquired from thematic maps, to historical, archaeological and orthophoto ones both general and detailed, indispensable as a basis. All of the rasters were

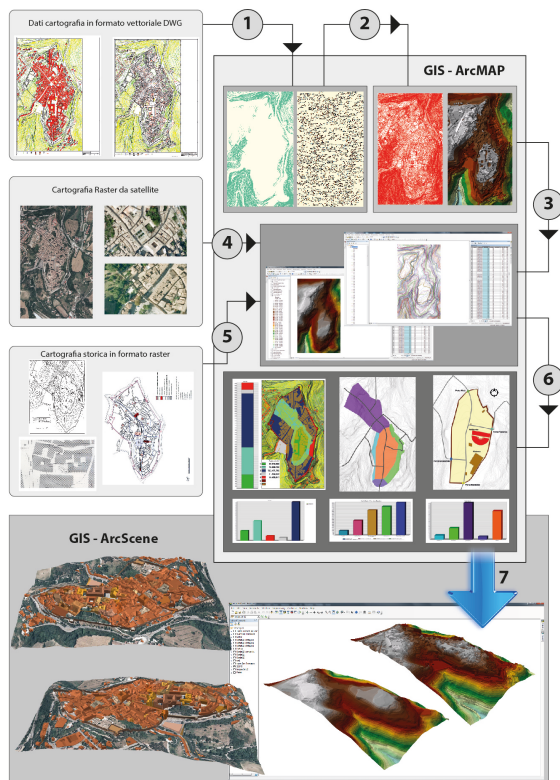


Fig. 1: Conceptual diagram of the development of the GIS project



Fig. 2: Cartographic elements used for the reconstruction of the geomorphological historical centre: (top) the depth contour lines extracted from the quotas of the aero-photogrammetric cartography, (bottom) the urbanised part

georeferenced using Georeferencing, trying to overcome the difficulty of individuation of known points on which to define the GCPs.

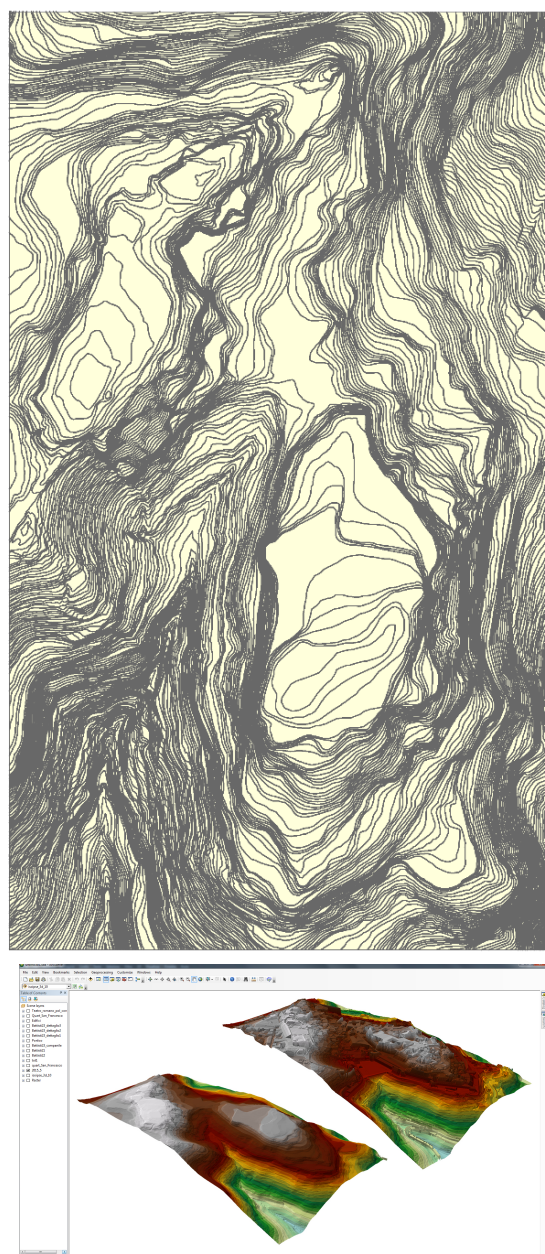
Other data that had positioning only by means of a more or less accurate description were taken into consideration at the moment in which manual digitisation was undertaken through the Editor for the final reconstruction of the contouring of the depth contour lines.

All this basic cartographic apparatus, all the information of quotas, that were able to cover almost the entire area of analysis, and the knowledge of an expert geologist of the territory have allowed us to move forward with the reconstruction of the depth contour lines in the missing areas, such as in the historical centre or in areas that have undergone profound changes due to urbanisation and covering over, such as at the Mercatale. This phase is completed manually in Editor, in ArcMap, and then in the 2D environment, by fixing the positioning of each vertex and attributing the correct reconstruction quota and arriving at the restitution of the depth contour lines with an equidistance of one metre.

The digital model was generated from the depth contour lines, in this case a TIN, which clearly defines the morphological evolution of the ground before the human interventions that it had undergone throughout the centuries. The display and management of three-dimensional data takes place in ArcScene, from which it is possible to note in particular the flat summit of the hill, where the first settlement of the Roman urban nucleus would be located. (Fig. 3).

The entire project was transformed and assembled bit by bit in Geodatabase environment in order to be able to take advantage of the potential benefits offered, including the ability to create rules for insertion.

The geomorphological analysis was developed in a manner closely interconnected with the reconstruction of the walled city through four periods that were selected: Roman, Medieval, Signoria 1 and Signoria 2. The use of the GIS has allowed one to obtain maps in this phase that facilitate the understanding of the modifications of the urbanisation over time, defining it both qualitatively and quantitatively and processing histograms to make them more understandable and connect them directly to the maps. In this context a further element of focus has been the city walls, whose reconstruction becomes crucial to highlighting the urban development in the



**Fig. 3:** Reconstruction of the depth contour lines on the hill on which the first settlement of Urbino in the Roman era was located and comparison with the TINs created

different historical periods and to reach quantification. There were reconstructions of the walls of the diverse periods or from vector elements, if present in DWG, or through digitisation of historical maps of archaeological reconstructions, opportunely georeferenced, creating and editing a specific feature class. It will then be possible to highlight these elements in a three-dimensional visualisation through an extrusion on the heights that are hypothesised or identified with respect to the base (the TIN used as Base Height).

The diachronic analysis of the city is mainly based on the development of the walls and when possible, on the individual monuments within the urban perimeter, today bounded by nineteenth-century walls. Procopius of Caesarea described the particular position of Urbino already in the 6th century, as situated on a rather steep hill with a single access from the north. Bernardino Baldi, in the sixteenth century, locates the Roman city walls positioned in such a way as to take advantage of the geomorphological course along the curves that are level with the Roman city situated on a single hill. As regards the urban fabric of the current historical centre, the persistence of the general lines of the Roman urban plan are still recognisable, characterised by two major roadways that, however, show some anomalies with respect to the typical Roman organisation in a perpendicular pattern. In fact, the *cardo* road runs along the back of the hill, from Porta Mondelce (medieval name) up to Porta Maia, rotated slightly to the west. Porta Posterula to the east and the western gate are not symmetrical and give rise to two different decuman roads. The area of the forum was probably the area of the today's cathedral, the widest and flattest part, close to the access to the city and to the amphitheatre. The existing ruins along via Budassi prove that it dates back to the 3rd - 2th centuries. The building technique is that the blocks of stone laid dry.

In the current urban nucleus three different phases of development are clearly recognisable. In addition to the Roman city,<sup>1</sup> one recognises a medieval and Renaissance city wall, clearly highlighted by the GIS reconstructions by means of the class feature. Even if the period of the Signoria can be broken down into a first period that corresponds to the major architectural

<sup>1</sup> On the argument there has been an immense bibliography by Mario Luni, archaeologist of the University of Urbino which has developed much research in the area in particular: M. Luni, A. L. Ermeti (2011), *Le mura di Urbino tra tardo antico e medioevo*, Edizioni all'insegna del Giglio; M. Luni (1985), *Urvinum Mataurense. Dall'insediamento romano alla città medievale*, in M.L. Polichetti, *Il Palazzo di Federico da Montefeltro*, Urbino, pp. 11-49; M. Luni (1982), *Per la topografia storica di Urvinum Mataurense. Not. Scavi*, XXXVI, pp. 400-407; M. Luni (1993), *Le origini di Urvinum Mataurense. Dall'insediamento protostorico all'oppidum romano*, in R. Varese (a cura), *Studi per P. Zampetti*, Ancona, pp. 27-31; M. Luni, A.L. Ermeti, W. Monacchi (1989), *La Data nel contesto di Urbino romana e medievale*, in M. Bruscia (a cura), *La Data di Francesco di Giorgio Martini*, Urbino, pp. 105-124.

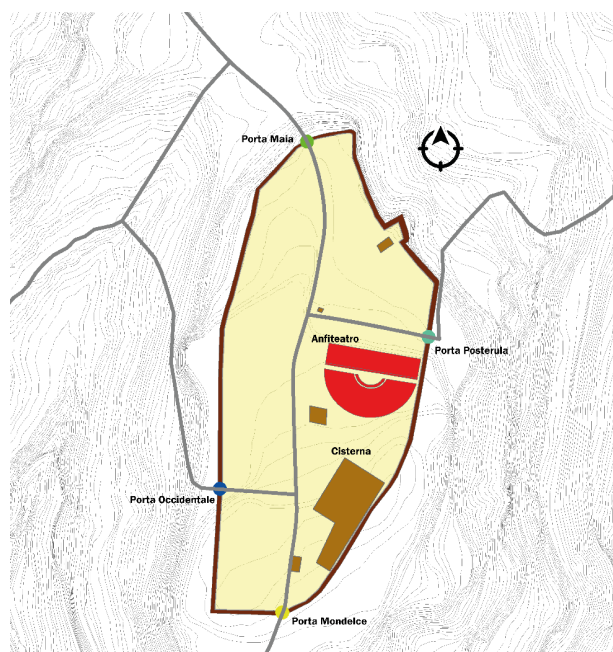


Fig. 4: Extension of the urban nucleus of Urbino in the Roman period

modifications of the city, with the construction of Palazzo Ducale and with the cutting off of the Valbona trench and the construction of the filling up of the Mercatale. The second period of the Signoria brings other modifications to the wall, above all for reasons of defence, with the construction of the Albornoz Fortress and the completion of the ramparts. After the completion of these works, one may affirm that the plan of the walls corresponds practically to its present conformation.

To include the reasons that are at the base of the foundation of inhabited Roman Urbino, it is necessary to bear in mind the morphology of the area on which the antique city was located. The presence of sources of water on the summit of the "Poggio" was a crucial element for the installation of the primitive settlement. This has been favoured also due to the special strategic position of the promontory: it occupied, in fact, the summit of a steep hill, surrounded by deep valleys and isolated from the neighbouring hills. The entryways into the city were very difficult to use, because the roads started from below and the last segment was very steep; only towards the North it was in the form of an arm of land in a slight slope joined to an adjacent hill.

The morphology of this "plateau" is not very regular, as is demonstrated also by the reconstruction carried out in Fig. 3, but it has a roughly elliptical shape and it is developed on an

extension of about 40,000 square metres. The "Poggio" in the highest point is estimated at reaching 460 metres above sea level and constitutes the watershed between the nearby valleys of the Foglia (Pisaurus), towards the north, and of the Metauro (Metaurus) to the south; besides, the peculiarity of the site is given also from its arrangement in an intermediate position between the Appennine mountain passes and the Adriatic coast.

The presence of man seems to be attested by some historical studies since the protohistoric age and it has been extended with continuity through the centuries until our days, partially modifying the structure of the hill. The historians affirm that the Senones of Gallia occupied the territory and subjugated the Celts in the 4th century B.C. and that in 285 B.C. the Romans succeeded them and thus begins the Romanisation of Urbino (Urvinum Metaurense).

One can definitely say that the defensive structure of the original urban village is directly dependent on the physical characteristics of the site. The name of the city itself seems to be derived from the geomorphology of the place: it is, in fact, a long "urvus" (a term which literally means the curved handle of a plow).

The second part of the name, in reference to the river Metaurus, served to distinguish this antique centre from the internal city of Umbria called Urvinum Hortense. On the margin of the entire natural plateau was built, between the 3rd and the 2nd century B.C., the city walls, which follow the line on the "tactical roadside" of the escarpment below. The fortified wall therefore surrounds a plateau that is particularly important from a strategic point of view, as is confirmed in the description of the site made by Procopius in 538 A.D., about the war events between Goths and Byzantines. The wall, in opus quadratum, consists of parallelepiped blocks of local limestone very similar to travertine marble, which has a mineralogical composition consisting of 95% calcite (CaCO<sub>3</sub>) and a very high porosity. The choice of a similar material is due to its easy extractability and workability as the rock in the quarry is very "soft"; upon exposure to air and consequent drying, it hardens and acquires better physical-mechanical characteristics. Such type of stone is assumed to have its origin from the

nearby area of Canovaccio-Fossombrone<sup>2</sup>. The blocks are about 59 cm high (2 feet), in many cases they are 74 cm long (2 and a half feet) and are laid dry, arranged in regular rows.

The construction technique has analogies in other Roman cities of the middle Adriatic and interior areas of Umbria. Within the walls were identified the remains of two large buildings, the amphitheatre and a tank, in addition to isolated structures of a thermal building, some homes and other dispersed archaeological material. The reconstruction of the perimeter of the Roman walls was carried out on the basis of an archaeological type study, in the portions where there are archaeological finds, and on assumptions derived from the historical-archaeological and iconographic documentation in the missing sections. The remains of certain dating are unfortunately scarce and in some cases, the material of the Roman period had been reused in later times, making their placement not very reliable. The GIS potential allows one to manage in a single "container" all the information about the close inter-connection between the development of the urbanisation of the city and the consequent modification of the territory, clearly viewable from modifications of depth contour lines and from the consequent Digital Terrain Models - Triangulated Irregular Network (TIN). All the different evolutionary phases are developed in the overlay feature, which were subsequently combined into a single one for a quantification of changes due to urban expansion during the various historical periods. The surface of the Roman nucleus, using the maps and the reconstructions that were processed, is estimated at 39,914 square metres. The ability to manage all the qualitative and quantitative information of the morphological and human development evolution of the city at the same time with a clear display of the progress and the entity of the various phenomena, provides an immediate comprehensive picture of the historical reconstruction.

### 3. Urbino in the medieval period

The archaeological documentation confirms that, in late-Roman and Byzantine periods, the

<sup>2</sup> See the studies of P. Busdraghi, F. Veneri (1994), in *Le tre cinte murarie di Urbino. Aspetti stratigrafici e morfologici del "poggio" e caratterizzazione petrografica dei materiali da costruzione*. Tema, Fascicolo 3, Milano.

city has gone beyond the limits of the walls and it extended externally, following the plan of the road that went out from the northern gate, the only one that had a fairly level area beyond it.

The rugged slope of the land has prevented the rise of neighbourhoods outside of the other three city gates. The northern gate was the most important of the city and the road that ran along it led to a site mentioned in the Middle Ages as "Pian di Mercato" (Market Plane) (today's Piazza della Repubblica) and from here then branched out into three distinct paths following the natural progression of the terrain.

Although the general framework is still in a fragmentary in appearance, it can be stated that even at the end of the first century B.C., the Roman city had undergone an extension toward the north running along the road that climbed up the northern hill (today's via Raffaello) and to a lesser extent along the two roads that ran along the valleys, toward the west (today's via Mazzini) and toward the east (today's via Battisti). The archaeological remains recently found in connection with these roads leave no doubt that the Roman road network has been used with continuity up to our days.

In this period, the prevailing defensive needs still rendered decisive the use of the strong city walls of the oppidum that, even if reinforced, remained however practically unchanged. The city, in the medieval era was perched on the "hillock", the heritage of the pre-existing Roman nucleus, which fell out of use during the barbarian invasions. The transformations of this period can be divided into two phases: the first, which is linked to the birth of the Municipality in the early years of the Thirteenth Century; the second, which is linked to the investiture of the Montefeltro dynasty, in 1234, to the takeover of power by Antonio da Montefeltro in 1375, after the failed attempt of restoration of the papal dominion. The city was maintained within the Roman walls up to the 11th century and the external development, up to this date, had to be sparse and rather random.

As for what concerns the early stages of development, it is likely that the medieval walls had an almost concentric path, with respect to the Roman plan, and that in various parts the fortified wall from the Roman era was partly reused in the

medieval era<sup>3</sup>. In fact, it is not by accident that the iconography of the views of Urbino maintains the point of view from the east until the end of the Fifteenth Century, that is, until the city of Federico da Montefeltro changes its typical connotation of the western perspective of the Palace, connected to the function of the Mercatale and if the Gate Valbona.

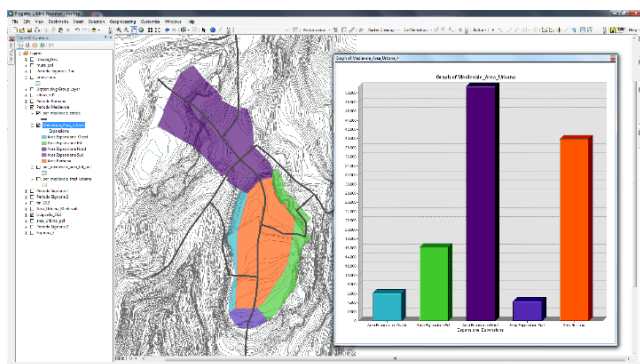
But already at the beginning of the Thirteenth century, with the dominion of the Montefeltro family, Urbino ratcheted up its role as regards both political and strategic spheres; the city was still exposed and therefore had to provide itself with a defensive system of protection. In fact, the rapid urbanisation had allowed the urban nucleus to extend itself especially toward the north, along the path which, leaving port Maja, rose towards the second hill, setting itself on the ridge that leads toward Pesaro, Rimini and Montefeltro. This route became the axis of support of the new part of the city; the shape of the ground, in fact, was for a long stretch almost flat and allowed a natural enlargement that easily connected with the old city.

There were understandable military reasons for the fortification of the north side of the area, in fact since the Roman period, this was the most vulnerable point and in addition, this second hill, standing over the first by a few dozen, allowed greater defence. Therefore, this area was included in the new perimeter, so as to not allow such a strategically important ridge to be unguarded. The new round of walls redesigned the shape of the city that now it extended in length up to the top of the second hill, connecting the Roman city with the northern ridge. In this way, the centre of the city came to identify itself in the crossroads of the Pian di Mercato, stretched out in the manner of a saddle between the two hills. The new perimeter of the walls modified the accesses to the city: the expansion had included the routes that prior to then were external and that, intersecting the new city walls, generated new points of entry (Fig. 5).

To the north was the opening of the Del Monte Gate on the ridge and the S. Lucia Gate located at a lower point, which became the easiest access to the city. On the Valbona-Lavagine axis were opened the two gates of the same name; S. Bartolo

<sup>3</sup> See M. Luni (1985), *Urvinum Mataurense. Dall'insediamento romano alla città medievale*, in M.L. Polichetti, *Il Palazzo di Federico da Montefeltro*, Urbino, pp. 11-49.

Gate was born on the drift toward the valley of the antique Roman Gate of Posterula. On the western side was opened the Nova Gate, located on steep slope that from the "hillock" descended toward Valbona, formed by transfer of the Roman gate along the path. At the southern tip, due to the limited development of the city, the new gate was found a few dozen metres further downstream of the former one (Porta S. Paolo).



**Fig. 5:** Extension of the urban nucleus of Urbino in the medieval period (in purple) starting from the Roman nucleus (in orange) with the diagram of the areas of expansion to the south, east and west

As defined, the GIS analysis of the urban development allows one to quantitatively evaluate the extension of each zone. The feature class created in geodatabase already provides in the attributes table the areal dimensions of each record. By grouping them together in a single comparison feature it is possible to carry out calculations and statistical evaluations and the views through different symbologies by categories allow an immediate visual effect of the entity of the modifications. For the sake of convenience, the four development areas were divided as shown in Fig. 5. The diagram at the right shows us how the extension toward the north, equal to 51,401 square metres, by itself more than doubles the area in which the Roman city rose, which we note has been estimated at a measurement of 39,914 square metres. Also not very extensive are the developments in the eastbound direction (16,145 square metres) or in the westbound one (6,034 square metres), absolutely modest are those to the south (4,304 square metres). Overall, the extension of the medieval town walls can be estimated to measure about 117,698 square metres. The tools of statistical and geostatistical analysis of ArcMap allow one to instantly view these differences in specific diagrams created directly from the

attributes table (with functions of Summarize, Statistics, Create Graph, etc.) or through the specific extension of geospatial analysis. In this case, being that they are simple modifications, to highlight only quantitatively it is sufficient to create bar graphs.

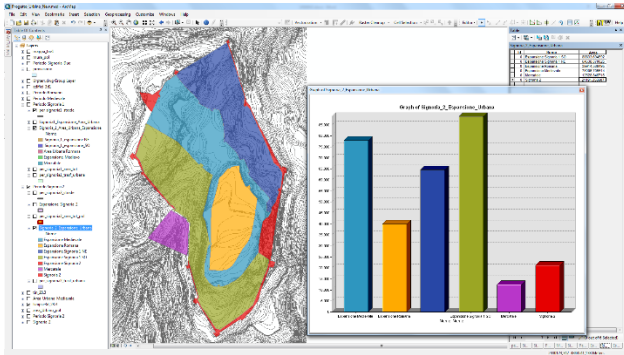
#### 4. Urbino in the period of the Signoria

Toward the middle of the Fifteenth Century, the new political role that the Duchy of Montefeltro assumed led to a new transformation of the city, to become seat of a major Renaissance court. The city, though having developed on a now well defined planimetry and by now strongly anchored to its territory, was however modified by Federico da Montefeltro. The Duke was responsible for the emergence of monumental complexes that substantially changed the face of the Roman-medieval city. Most of the primitive nucleus that stood on the "hillock" was disrupted by the construction of the Cathedral, by the Archbishopric and by Palazzo Ducale, buildings which project a part of their structures outside the medieval curtain.

An important variation to the Fourteenth-century walls took place in the tract where the Duke had the large structure of the stables built (Data or Orto dell'Abbondanza), work of Francesco di Giorgio Martini, incorporating the ancient tower, and laid against the existing perimeter wall. The tower was completely modified and perhaps expanded so as to obtain within it a wide spiral ramp that, in addition to the function of direct connection between Palazzo Ducale and the Mercatale, also had a defensive purpose for the firing positions distributed at the various levels. This complex was begun in 1480 and completed after the death of Federico da Montefeltro. Also in the survey of the city walls drawn in 1502 by Leonardo da Vinci is evident that the stable was part of the existing defensive border at the time.

The walls, which surrounded the city until the early years of the Sixteenth century, therefore, were only in part the medieval ones, while the new city walls had brought together into a single enclosure the expansion of the suburbs. They were walls designed to withstand warlike actions of the traditional type, in which the operations of attack and defence took place along the entire curtain. The areal extension had to be very similar to the current one (Fig. 6).





**Fig. 6:** Extension of the urban nucleus of Urbino in the first period of the Signoria with the diagram of the areas of expansion

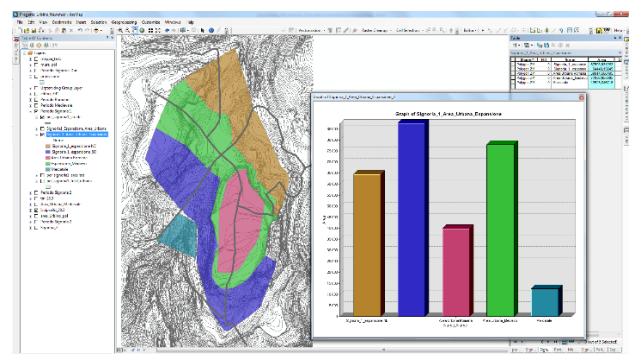
At the end of the Sixteenth century in fact, with the restructuring of the urban area desired by Federico da Montefeltro completed, the city is composed of the two old areas, the Roman, now deeply modified, of 39,914 square metres and one measuring 77,886 square metres, which represents the overall expansion that occurred at the end of the middle ages. These two areas are integrated with an area of expansion to the NE of approximately 67,593 square metres and a more consistent SW one measuring 87,593 square metres and the area that from this point will take the name of "Mercatale" located outside Porta Valbona, even if not particularly relevant by extension, which covers only 12,528 square metres. The area is the fruit of the modifications brought to the Roman area of the city, in fact, to obtain the depth of the mighty foundations of Palazzo Ducale, it became necessary to undertake vast excavations of soil; a large amount of land was conveyed downstream, beyond the walls, to fill the wide trench that was then obstructed with the construction of the great wall with arches and buttresses of Risciolo. The Mercatale thus began its secular history as major meeting point of the city and theatre of historical-political events, but also important seat of markets, livestock fairs and conferences.

With the introduction of gunpowder and modern methods of warfare, the perimeter of the walls soon proved to be obsolete and the construction technique of the masonry structure inadequate to ensure defence.

In 1507, Duke Francesco Maria Della Rovere brought about the start of the construction of the new perimeter wall, designed according to the new defensive techniques. The new principle, used for the first time by Francesco di Giorgio Martini in the construction of fortresses,

concentrated the defence, namely the artillery pieces, in points particularly adapted at overlooking the enemy camp. Heart-shaped ramparts were built that protruded from the alignment of the walls at the points where it bent, forming obtuse angles, so that the cannons, placed on them, could have the maximum field of action. The new perimeter followed, roughly, the evolution of the previous walls, running externally, so as to obtain upstream a mighty embankment that increased the resistance of the walled structure. The two plans differed only in two parts, on the eastern side: in the stretch from the gate of Lavagine it rises toward the northern tip, where the previous bulge, that followed the outline of the terrain was corrected; and from the gate of S. Bartolo to the Torrione di S. Chiara, where the new perimeter included a vast area that previously had been excluded.

In the area of Mercatale, it was not necessary to amend the existing city walls, because the intervention by Francesco di Giorgio Martini was conceived according to the modern art of war, placing the mouths of fire within the tower, equipped for diagonal shooting, in the direction of the two roads of access to the esplanade and in line with the gate of Valbona.



**Fig. 7:** Extension of the urban nucleus of Urbino in the first period of the Signoria with the diagram of the areas of expansion

The materials that compose the Renaissance walls are, for the most part, made of bricks. This third belt, despite being the most well-preserved, is difficult to analyse, since it had undergone, during the subsequent centuries, numerous conservation and restoration interventions that have brought about changes, not only in the typology of the bricks but also in the masonry structure. The transformations of this new structure in the walls have an overall

measurement of the extension of the walled area of 21191 square metres as shown in red in Fig. 7.

##### 5. *A new entrance to the city: Porta Nuova*

Since the beginning of its history man has had to liaise directly with the territory that surrounded him; the geographical position, the morphology of the terrain, the geological characteristics, the proximity to sea, river or lagoon coasts, has greatly influenced his activities and determined characteristic aspects of the societies that derived from them and also of the urban areas that set them apart. In the course of history, the clash between the engineering expertise of man and the territorial characteristics has produced works that are excellent and one-of-a-kind, generated not only by the artistry of the period but also influenced by the local context in which they were created. Urbino, has been and still is famous as the supreme example of the Renaissance city. As we have seen thanks to an exemplary compromise between geomorphology and the needs of urban development that could not be postponed, together with functional modifications. It sits on the territory while respecting its forms and maintains an elevated degree of environmental safety.

On the urban structure of the Sixteenth-century, Urbino continued relatively to develop itself and innovate for about three centuries, but always remaining within the traditional perimeter which is in fact that of the current historical centre. The only substantial modification of the Fifteenth-Sixteenth Century urban structure started when, in the Nineteenth Century, a new road network was designed to interrupt the isolation of Urbino. The steep slope of the urban street from Lavagine Gate to Pian di Mercato, in fact, prevented easy access to the city and so it had been established to avoid it, initially, by means of a tortuous path within the walls through the streets of the city. Around the 1930s, the idea took hold to circumvent Urbino from the south with a path in part outside the walls and in part within them, which brought the carriages to Pian di Mercato with ease. The road, today's Corso Garibaldi, was begun in 1831 and it directly joined the centre (today's Piazza della Repubblica) with the roads for Pesaro, Fano and the Via Flaminia, passing under the Cathedral, the façade of the Torricini and in front of the Stable of Palazzo Ducale.

From the road to Pesaro, the new segment branched off, running along the eastern side of the city, from the bastion of S. Bartolo up to that of Belisario, toward the southern tip, where there was the insertion into the Sixteenth-century walls by means of an oblique cut that connected the fortified wall to the profile of the road. Between the two parallel wall stretches a gate was built (Porta Nuova) formed by two massive pillars which supported a large metal gate. The operation produced vast movements of the land to level a terrain in steep slopes, and it was necessary to construct a massive curtain containment wall upstream. The large amount of soil excavated was partly thrown inside what was the volume of the Ducal stables (the large windows toward the Mercatale were in fact walled up) and in part was used to fill the bastion of S. Polo, rebuilt in the same years.

Another element of great interest is the development that took place to the Mercatale, already in 1621 it was enhanced by the construction of the Valbona Gate on the occasion of the wedding procession of the last of the Della Rovere family. Subsequently, at the fall of the Duchy of Montefeltro under Papal rule, the large square had not interrupted its function as a centre for access and aggregation of the entire city, it also maintained the habit of hosting major markets, popular events and games, in particular that of the "Bullfight" documented by an engraving of the year 1837. The livestock fairs that were held at Mercatale since the beginning of the 1900s are still famous, as they occupied the entire square. In these occasions it became a kind of suburban "gateway" in which the people of the neighbouring towns flocked to en masse, and then they left as soon as they concluded their business deals, without even crossing the gate of Valbona to enter into the city. During the Second World War, with the increase of private and public motorisation, it immediately transformed itself into a desolate paved car park. It was later modernised in the 1970s with the construction of a multi-level underground garage.

Porta Valbona was the subject of further studies and analysis in its individual architectural elements by means of GIS, such as material characteristics and deterioration, within the entire project of 3D development of the built urban environment and integration between plans and perspectives.

If the architectural landscape of Urbino from the Sixteenth Century to the present day has not changed much, one thing that has undergone considerable change over the last few centuries has been the presence and characteristics of the vegetation, in the green areas of the urban area or in the immediate environs. By performing a diachronic analysis through different views of Urbino, one can observe that until the middle of the 1600s the development of the vegetation of the valley of Risciolo and of part of the hill Colle del Monte was almost absent. From approximately 1700 until the first years of the 1900s we witness an increase of agricultural use that extends even to the inaccessible and rather steep areas of the territory surrounding the historic centre, while in urban areas there are some trees and green areas starting to have a presence. From the mid-1900s until our day the landscape has been characterised by a progressive increase in green areas both within the city and in peripheral areas of the city walls, observing the almost definitive disappearance of the large zones dedicated to agriculture, which had been replaced with vast zones of vegetation and rows of trees with a large foliage.

Currently the region downstream of the Mercatale has luxuriant vegetation that reaches almost halfway to the height of the arches of the retaining wall, creating a pristine landscape, immersed in nature. The Municipality of Urbino intervened by integrally protecting the valley of Risciolo, considering this as one of the areas of greatest naturalistic and environmental interest in which norms should prevent any activity of building or urban transformation, incompatible with the natural environment and the landscape. In these areas will instead be promoted the activities of correct tourist fruition, study and research, requalification and restoration of the natural environment and the conservation of important and unique characters of human presence in this environment, where this integrates in with the natural characteristics of the places to form a semi-natural environment of great aesthetic and landscape interest.

As already mentioned, the city of Urbino is situated at the summit of an almost isolated hill which is also the watershed between the basins of the rivers Foglia and Metauro. At the end of the 1800s, there was the need to connect the city with the national railway network. The orographic conditions did not allow a railway to arrive to the

urban nucleus, for which a decision was made to place the train station 100 meters below, in the valley of the trench of the Risciolo. Works for its construction began, albeit slowly, and as the inauguration neared, the city was presented with the need of a road that connected the station with the town centre. The work for the construction of the road began in the summer of 1898, but only a month later, they were interrupted and then abandoned. Therefore, the railway was inaugurated, without the connecting road, on 20 September, 1898 with the railroad trunk Fabriano-Pergola-Urbino (the remaining section, which was to bring travellers from Urbino to Sant'Arcangelo di Romagna, was never realised). The same fortune awaited the railway line Fano-Urbino of 43,164 Km, which opened to the exercise by the Ferrovie Padane of Milan the First of May 1915. The Fano-Urbino line was discontinued in 1933 due to the closing of the activity of the Ferrovie Padane company due to serious financial difficulties and restored again by Ferrovie dello Stato (the Italian State Railways) in 1941, only to be itself destroyed during the Second World War. At war's end, there was the start of the plan to reconstruct and nine years after the reactivation of the Fabriano-Pergola line, also the Fano-Urbino line was reopened in 1956.

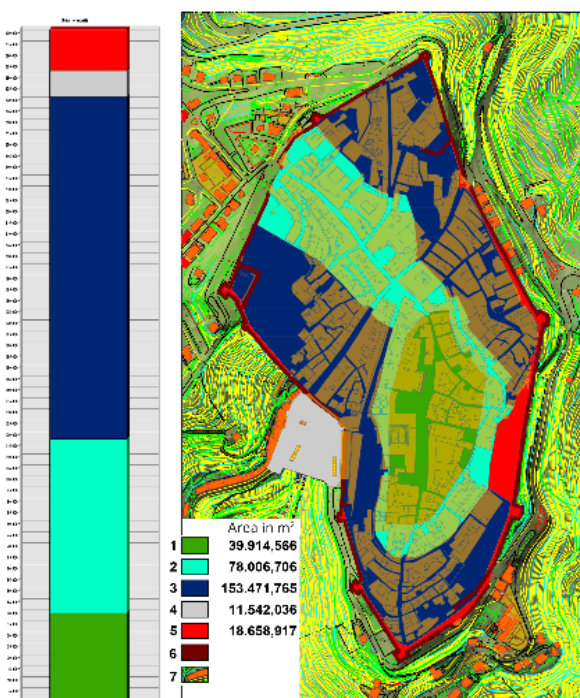


Fig. 8: The transformations of Urbino in recent centuries

Year after year, however, the boom of mass motorisation, joined by the progressive disinterest in the management of the line by the State Railway (state of abandonment of the line, inadequate timetables...) users were increasingly discouraged to use it, so that it ended up being classified as a "dry branch" and it was closed with the Decree of the then Minister of Transport Claudio Signorile on 31 January, 1987.

The railroad, in reality, has never ceased to live in the memory of those who had the luck of taking advantage of its service, and it is thanks to the interest of the inhabitants of some areas crossed by former railroad, together with the great passion of a group of people that, in 2000, the founding of the Associazione Ferrovia Val Metauro was made possible, having as its aim the recovery, conservation and reuse of the Fano-Urbino segment (Fig. 8).

#### 6. *The transformations of the city in their three-dimensional component*

The reconstruction of the transformation of the geomorphological territory of Urbino, strictly connected to the urban evolution of the city, has allowed us to develop a complete representation of the urban reality of Urbino during its different phases.

A project has been developed that represents the constituent elements of the urban fabric in their geometric, geographical and altitude connotations, using geomorphology as base ground on which to drape the elements. The polygons of the buildings have been redefined and correlated to a comprehensive database to indicate the names of the various palaces and the intended use and the historical period to allow searches and statistical analysis. (Fig. 9)

The three-dimensional component of the buildings is defined by an extrusion process that determines the volume of each of them based on maximum heights and placing them physically at the height of the ground, thanks to the TIN built by geomorphology that is used as the Base Height. The models of some of the buildings were then imported and managed as multipatch in ArcScene.

The urban elements in the map can then be managed, even in their three-dimensional representation, and searched according to their characteristics according to the interests that have emerged by the various users. . One proceeds to a relatively simple modelling, which varies from LOD1 to LOD2 on the basis of the

interest of the different areas, as defined by Kolbe et al. (2005) and Königer and Bartel (1998). The management of the views, through these tools, allows the possibility of representing and searching the built environment both in planimetry and in altimetry. All the perspectives are processed in the two-dimensional environment, in Arcmap, without georeferencing but by defining the correct spatial dimensions, constructing a database with the different attributes of the materials, the state of conservation, interventions carried out, etc., all information useful to the study of the transformations of the city. All of the information has been obtained from the maps of the PRG (Municipal Urban Planning Regulations) and inserted into the attributes table thanks to a specific drop down menu created with the domains of the Geodatabase. To complete the database, images taken from Google Street view have been inserted to identify the individual buildings. Each elevation is placed at a height corresponding to the real one on sea level and it undergoes a process of splitting at the vertices, attributing in the table of attributes the relative heights as if they were defined along the y axis instead of along the z-axis. These heights will serve for a transformation of the feature in 3D, then passing to a definitive georeferencing. The concept is that of thinking of the wall of a building as if it were seen from above, taking therefore the four points of the corners of the façade and placing them very close to one another, two by two, almost to form a straight line. The feature thus treated, once opened in the three-dimensional environment, will be placed in the correct position, resting on the model of the buildings already present.

By connecting information to the Geodatabase it will be possible to associate sample images to the different records in the table, being able to manage, analyse, and search all the elements in a map and in perspective, together with models, rasters, TIN, geomorphological reconstructions, historical data in a single project that is fully three-dimensional (Fig. 10 and 11).

#### 7. *Conclusions*

The research on GIS applications in an urban environment has allowed us to highlight the extreme usefulness of an extremely flexible tool that allows the grouping of the entire mass of geometrical-graphic-spatial information as well

as information on the components of the urban fabric of a city, by enhancing the possibility of their correct management in the framework of planning, monitoring and intervention. The territorial scope in which the urban structure is inserted will coexist and define characteristics connected to the same geometric arrangement of the buildings, which are managed in various three-dimensional aspects, providing tools for search and analysis. The use of new technologies applied to cultural heritage increasingly highlights the importance of interoperability and integration between systems so as to take advantage of the potential offered by each of them in a truly multidisciplinary approach.

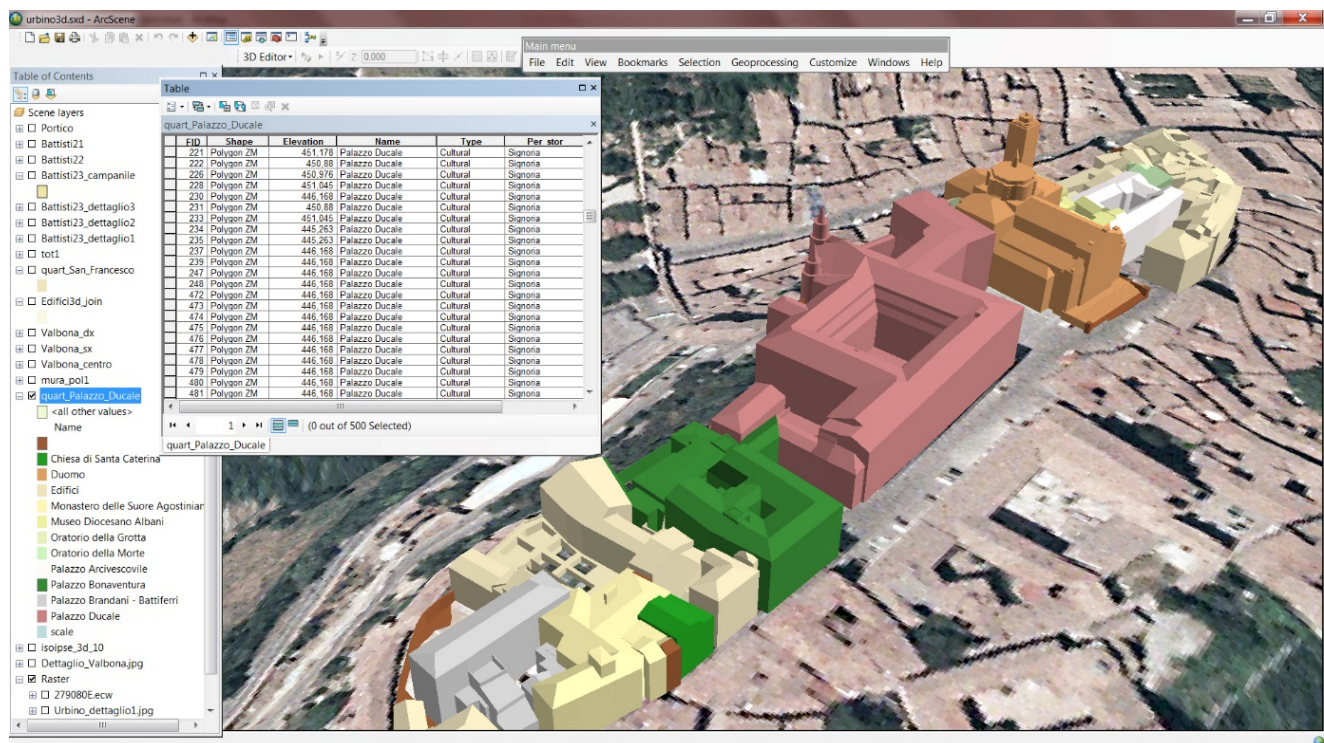
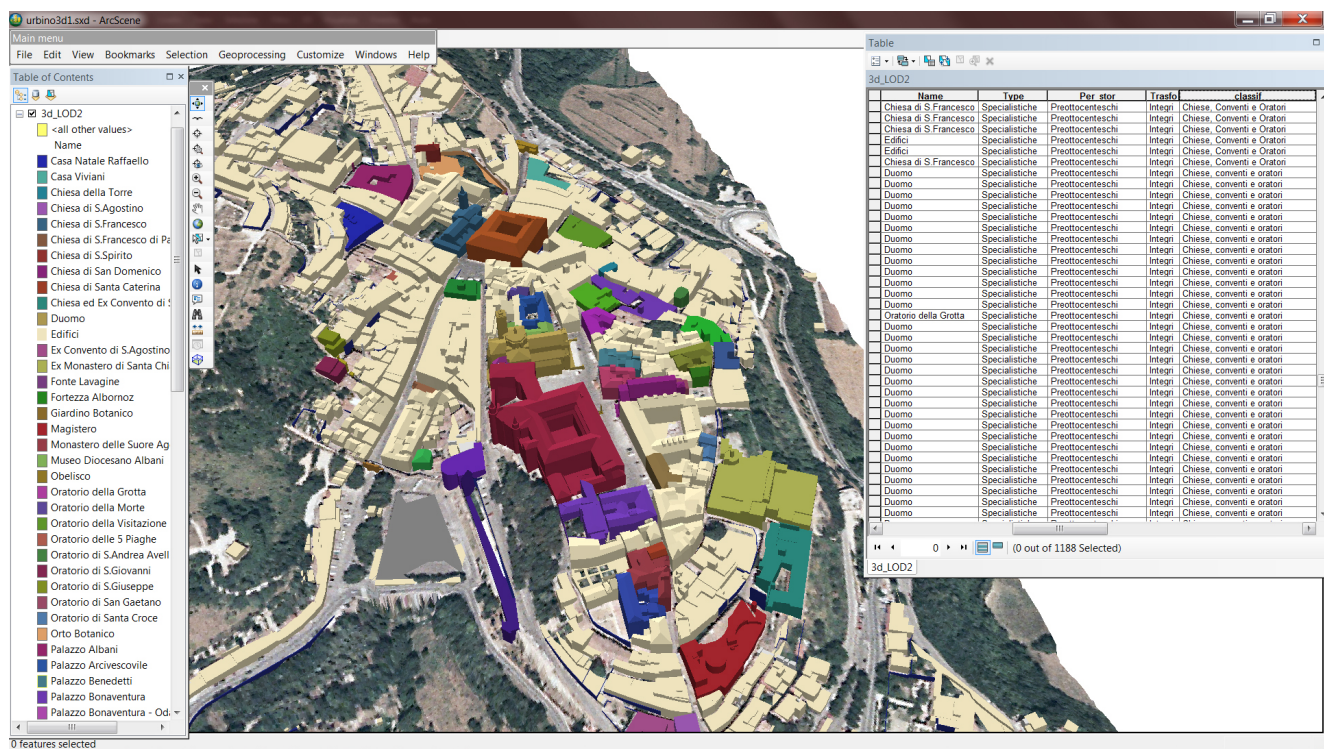
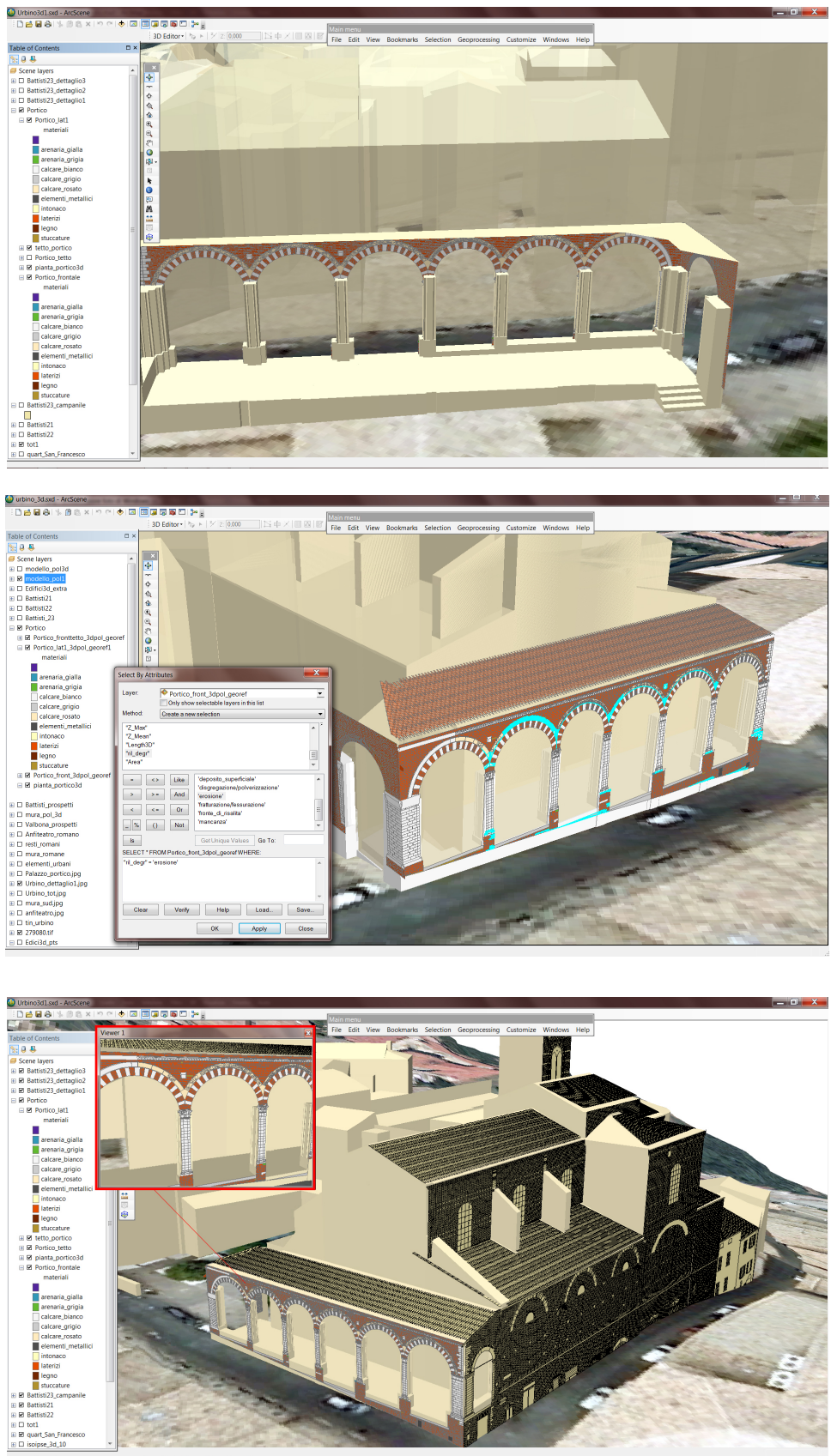


Fig. 9: Buildings in the historic centre of Urbino, the volume of which is determined by an extrusion based on the height of the individual elements drape over the TIN which is used as the Base Height for all vector and raster elements (orthophotos, thematic maps, historical maps etc.)



**Fig. 10:** Portico of the Church of San Francesco, example of a correctly georeferenced model in overlay starting from the orthophoto of the city and the geomorphology of the terrain. The model is presented in its three-dimensional rendering and is accompanied by a complete database that can be searched on the state of conservation of the building

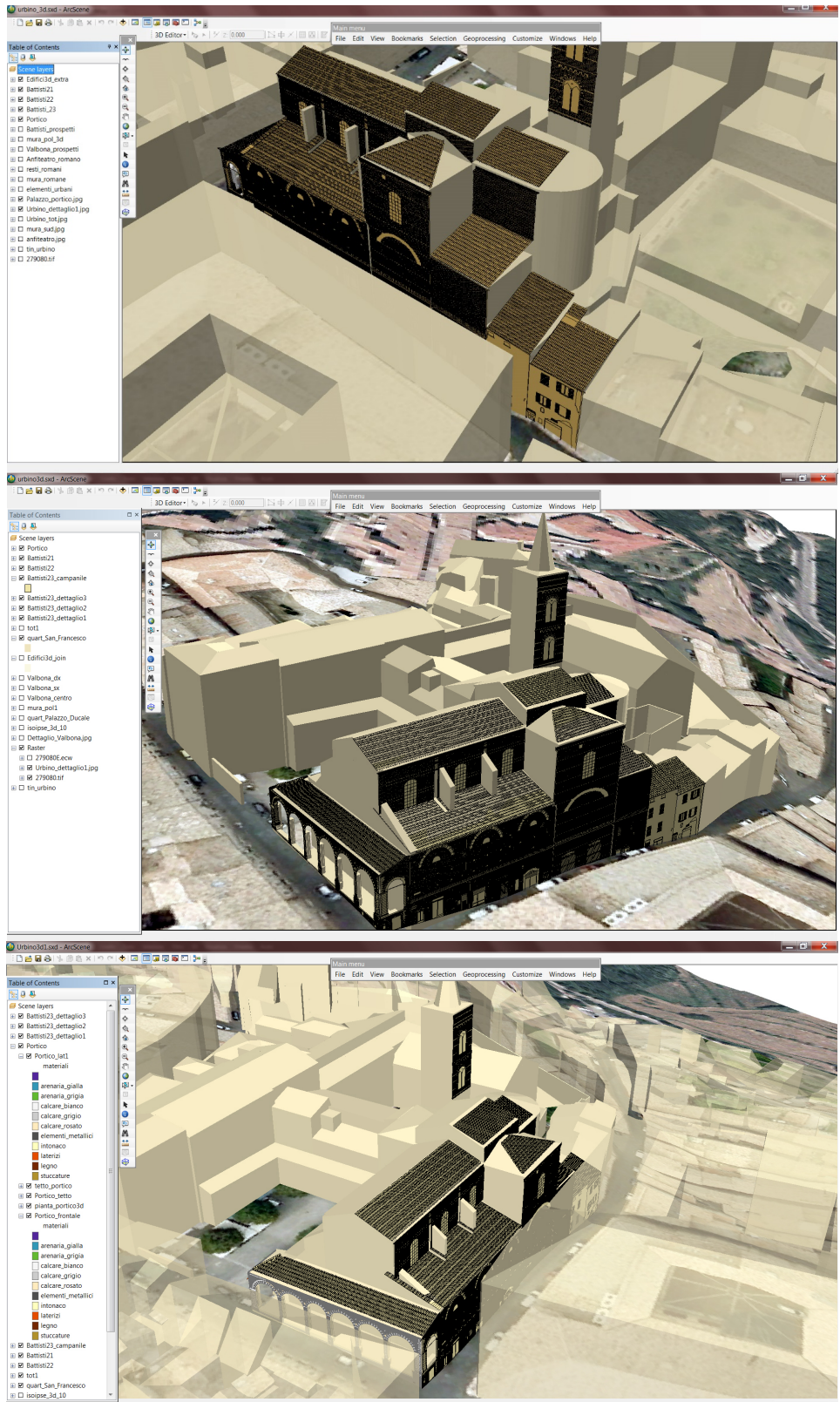


Fig. 11: Urbino: models of the perspectives extended to the whole of the southern part of the Church of San Francesco and the buildings of Via Mazzini



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