



Le Vie dei  
Mercanti

XV FORUM INTERNAZIONALE

WORLD HERITAGE and DISASTER

Knowledge, Culture and Representation

Naples 15 - Capri 16, 17 June 2017

## Restitution of Barcelona at the end of the third century. Models and diffusion of the Colonia Iulia Augusta Faventia Paterna Barcino

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### Abstract

Barcino 3D is a project that seeks to unify archaeological knowledge, allowing the formal definition of Barcelona at the end of the third century, designed for the dissemination of archaeological heritage to all types of public, through a set of interactive applications for web, smartphones and tablets (IOS and Android).

This article defines the methodologies used for the virtual construction of Barcino and its territory, based on a procedural construction and Geographic Information Systems (GIS), allowing to propose different approaches of the city. In this process, archaeological information is organized based on rule-base modeling and database management, with multiple levels of information, at different scales: territorial, urban and architectural. These models are optimized to the different platforms, to transmit knowledge and direct visualization between the present Barcelona and the colony of Barcino at the end of the III century.

**Keywords:** Heritage, Barcino 3D, archeology, Geographic Information Systems, WEB app, iOS app, Android app

### 1. Introduction

*Barcino3D* is a project that seeks to unify archaeological knowledge, which allows the formal definition of Barcelona at the end of the third century, and transmits the knowledge of roman archeology through a Web application [1], designed for the dissemination of Archaeological heritage to all types of Public, and a set of applications for smartphones and tablets (IOS and Android, which can be downloaded for free from their platforms), to expand this spread. This task is part of the initiative of the Barcelona City Council with the *Pla Barcino*, launched in 2012, whose purpose is the recovery and enhancement of the heritage of the Roman city.

This project focuses on Barcelona with origin in *Colonia Iulia Augusta Faventia Paterna Barcino*, founded between 15 and 10 BC, placed where today we locate Ciudad Vella. Part of studies carried out by archaeologists, historians, epigraphists, documents generated after Archaeological excavations and patrimonial studies, all of them documented in the archeological Letter [2]. This base has been supplemented with data obtained by comparison, referencing to roman cities that were contemporary of *Barcino*, as well as knowledge of treatises and studies of urbanism at this time. All this has allowed to generate a series of multi-scale models, creating a hypothesis about unknown roman city aspects.

The chronological framework in which the project takes place, is Barcelona at the end of the third century when a transformation of the city took place, such as the construction of a second walled enclosure, the beginning of the remodeling of the great *domus* (Archeological studies are currently underway), the incorporation of privately owned thermal springs, and the growth of the city through occupation of the streets.

We start from the idea that the users can approach the city through three scales: a territorial model that reaches up to 80km, another one that is based on a model of Barcino at city scale taking into account

its context, and the last one, architectural models of unique buildings and first-person tours through the streets.

These scales require different levels of detail of the models, generating for each scale a level of representation that confronts archaeological information, both on a scale of detail, and the ideal of city and territory. Therefore, the process of generating them is divided in two parts: the construction of the territorial model and the construction of the urban procedural one.

For the construction of the territorial model, we start with *Barcino's* landscape studies in the territorial and urban context of *Barcino* scale, integrating different geo-referenced information on the same base, such as studies of Roman roads, tributaries, archaeological studies, the coastline, aqueduct path studies, DTM (Digital Terrain Models) and crop studies. All this to achieve an integral vision of both the context close to the city and the landscape that surrounds this urban nucleus, which is connected to the vast network of Roman cities.

In order to address the construction of the urban procedural model in a massive way, making a parametric model has been required. This effort has been combined with the design of unique elements (aqueduct, *domus*, temple, towers, basilica). Parametric modeling allows the reconstruction of the elements of the city thanks to the application of rules that establish a range of plausible randomness to the elements where there is no archaeological evidence. In this process, what is known will influence the most on the program's decision making, creating hypotheses about the part of the city that is unknown to us.

These models are integrated in applications that start from the approximation of archaeological characteristics in the different scales developed, that allow to relate in each section of the applications the colony and the territory of *Barcino* with the territory and city of Barcelona. This is achieved not only relating information but doing it in a way that is easy to understand and locate it in the space of the current city.

## 1.1 Antecedent

The main reference of restitution and diffusion in multiple scales is the project *Roma Reborn*, is an international project that illustrates the urban development of the ancient city of Rome, of the first settlements of the Late Bronze Age (about 1000 BC) until the depopulation of the city in the Middle Ages. This project has had several stages of development, reaching the *Roma Reborn* version 2.1 in 2010 [3].

To make *Barcino's* different models, data with the vestiges of the Roman Colony, that can be visited today, was collected in different layers of information. The base documentation [Fig. 1] are pathways and centurion [4] studies, documentation of the Villas found [5] and topography. The urban structure is based on studies of "*Planta de la ciutat romana als segles*" [6]; the construction of the urban model of *Barcino* takes into account the developments in the publication "*Presència i lligams territorials de Barcelona*" [7]; the context of the urban scale, part of the *Institut Català d'Arqueologia Clàssica* ICAC map [8]; all of them being modified based on archaeological sites "*Guías de historia urbana Barcino/BCN*" [9].



Fig. 1: Examples of base documentation used

## 1.2 Georeferenciation

Thanks to the documentation provided by the Archeology Service of Barcelona (*Institut de cultura de Barcelona ICUB*), 15 files in *shape* format and a digital model of the DTM terrain were identified in the ED50 - UTM 31N projection, which served for the reconstruction Virtual of *Barcino* late 3rd century.

All the base information has been transformed into the UTM 31N projection, with the ETRS89 reference ellipsoid, to be able to superimpose it to the current cartography. Even so, to be able to work with the

different programs, and not to have problems between the different formats, a transformation of all the bases has had to be realized.

A four-parameter translation has been performed to bring the center of the urban model (XUTM = 431210.0m, YUTM = 4581570.0m) to the coordinate origin. Thus, by the territorial model the characteristics are the following:

Coordinates center: X = -1450.0m; Y = 1855.0m

Range Heights: Min = 0m; Max = 516m

Dimensions: X = 20000m; Y = 20000m

## 2. Construction of scientific and diffusion models

### 2.1 Territorial scale

We have worked on a digital model of the terrain with contours to highlight the adaptation to the city's terrain and especially the two hills that make up the original site of the colony: the one known as Mons Taber, and the one that would be in the Sant Just square.

#### 2.1.1 Definition of the territory and coastline

*Barcino* has been worked on three different scales: the territorial, the urban and the architectural; each with its corresponding DTM. The territorial scale is based on the current topography, which has been removed from the digital terrain model of large infrastructures [Fig. 2]. Next, two images are shown scaled to 8bits, since the base worked is a float16bits and the changes are not perceptible to the naked eye. The left image has drawn the current road structure, and the other one without it, is the one used in the territory of *Barcino*.

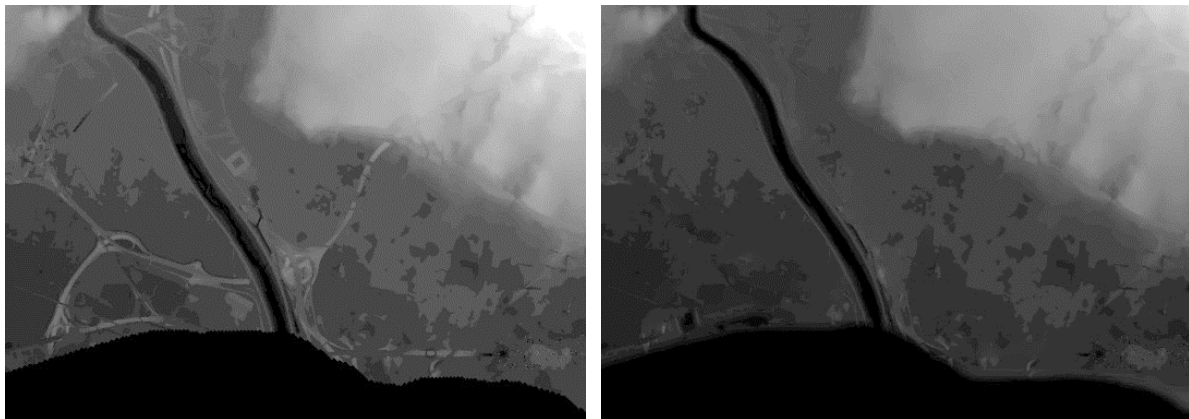


Fig. 2: Terrain current urban scale and *Barcino* late 3rd century (MDT)

For the urban scale has been used the DTM provided by the Servei d'Arqueologia of Barcelona, which recognizes the existence of a second hill, apart from Mons Taber, in the vicinity of the square of Sant Just.

As far as the coastline is concerned, the different existing hypotheses have been superimposed [Fig. 3] to different scales and chronology to finish establishing a reference distance from the sea gate.



Fig. 3: Images 20km. (Left): Superposition of the different layers. (Right): Resultant images used at territorial scale

### 2.1.2 Territorial structure. Routes, centurion, villas and the aqueduct

The context where *Barcino* is located is mostly rural, on which villas for agricultural production are distributed. The archaeological remains, that have been found, mark their link between the villages, the layout of the road network and the plot of the centurion.

**Roads of *Barcino*:** The road axes used are based on Palet's studies [4], which integrate archaeomorphological analysis to a single plane, through the implementation of Geographic Information Systems.

The necropolises, which had to be outside the city, normally near the entrance of the city, were distributed on the roads for hygienic, symbolic and traditional reasons, as well as being contemplated in Roman legislation, generating what is now considered as the Roman tombways. In *Barcino*, several Roman necropolises have been located, emphasizing the sepulchral way of the plaza of the *Vila de Madrid*, from centuries I to III and a necropolis of the centuries I to V, that is placed in the present *Atarazanas Reales* of Barcelona.

**Criteria for delimiting the centurion and structure of the *Ager*:** The centuriation was the division in which the territory that surrounded the Roman cities was divided. It was an ideal, regular grid, usually linked to the road network that connected the cities with the Empire.

The restitution in the publication "*Centuriació i estructuració de l'ager de la Colònia Barcino*" [4] confirms the existence of a centuriated grid in the central sector of the flat area of Barcelona.

**Delimitation:** The limits of the centurion are between the river *Besòs* and *Llobregat*, from the first slopes of the coastal mountain range to the coastline. It is bounded to the south and north by the branches of the *Via Augusta*, which go from *Barcino* to the valley of the *Llobregat* and the Strait of *Montcada*.

**Territorial modulation:** The basic modulation is 15 by 20 *actus*, visible in the central zone near the urban center, along with islands modulated to 15 *actus*, present in the central sector - south of the center of Barcelona (*Sarrià*, *les Corts*, *I' Hospitalet*, *Esplugues*).

**Orientation:** The northeast / southwest orientation of the centurion seeks parallelism with the coastline and mountain range, accommodating the grid to the natural slope, favoring the circulation and drainage of the waters. The orientation of the plot is 49° 30' sexagesimal, conditioned by the terrain.

**Roman Villa:** The roads connect the agricultural production, and the exploitation of fertile lands of the *ager* was distributed in the territory villas.

**Aqueduct:** Aqueducts were essential to bring the best quality water to cities [12], to satisfy basic needs and leisure. To such an extent that, public works were carried out to guarantee civil and political rights, around the concept *civilitas* (civility). *Barcino* fed from the sources of *Montcada* and brought the water through an aqueduct of eleven kilometers, mostly buried, that was adapted to the topography of the terrain [Fig. 4].



Fig. 4: Georeferencing of databases, in relation to the layout of the aqueduct

### 2.1.3 Landscape. Crops and orography

For each of the scales worked, three textures had to be made: 21st century, late third century and a mixture of both. The basic documentation has been extracted from the Institut Cartogràfic and Geològic de Catalunya (ICGC).

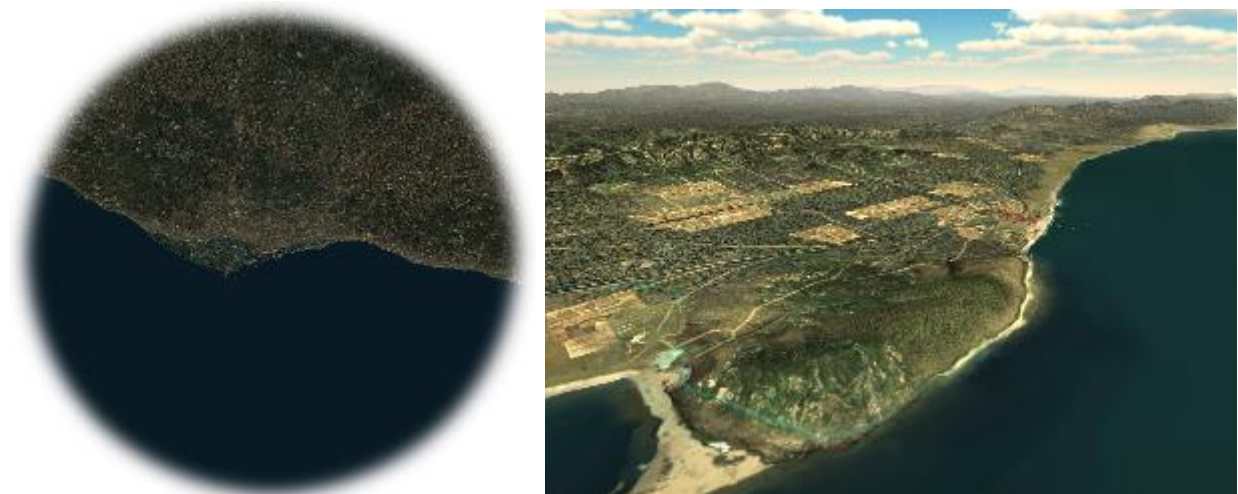


**GENERAL CONTEXT:** A circumference of 80km in diameter. From the DTM of 15 meters resolution of the ICGC, it has been optimized to get a mesh of about 30,000 polygons. Due to the texture of the late third century, the appearance of Baétulo had to be taken into account [Fig. 5].

**TERRITORIAL:** A square of 20km each side. From the MDT of 5 meters of resolution of the ICGC, the great infrastructures of the city of Barcelona had to be softened [Fig. 2], such as the *Rondes* or access roads to the city, and the land, lowered to mark the coastline of the late third century. Later it has been optimized until obtaining a mesh of about 19,000 polygons. As for the texture, up to six different layers have been superimposed to obtain the resulting image.

Premises for the definition of crops in the landscape [4]:

- Some studies based on the analysis of pollen determine that in *Barcino*, grains and vine were grown, and that there was little olive cultivation.
- These studies also determine that landscape modifications are more typical of natural evolution than of an impact of human action, hence the predominance of wooded areas called *Silva*.
- Among these wooded areas there are areas for crops, which were a kind of mosaic in the landscape.
- Studies indicate that a specialized, intensive and small-scale type of agriculture was practiced, which had an impact on the transformation of space.
- The largest areas of cultivation are in the Llobregat, as there is evidence of extensive agricultural activity, dominated by the cultivation of vine and cereals.
- Another area of cultivation is the southern slope of Montjuïc, with forests populated by perennial oaks, pine trees and deciduous trees lived with the cultivation of the vine and, later, of the cereals.



**Fig. 5:** Mix between the current image and the late III century (Left image), and perspective with the horizon view at 80km (Right image)

**BÁRCINO:** A square of 1km each side. From the MDT facilitated by the ICUB, it has been optimized to a mesh of about 11,000 polygons. In addition, a mesh of about 4,000 polygons has been made to make the moat around the wall. In this case, apart from the three textures (current, 3rd century BC [Fig. 6] and mixtures), a specific texture had to be made by trench of the wall.



**Fig. 6:** Superposition of the different layers (left image) and images resulting from the texture used in the Barcino environment (right image)

## 2.2 Barcino on the urban scale

The vestiges of the Roman Barcelona appear in a very punctual form and generally of partial form. Even so, they have allowed archeology to reconstruct certain elements with a high historical rigor. In addition, especially in the case of the wall, archaeologists have discovered whole sections of wall, which have allowed the obtaining standard parameters for the realization of the procedural model.

The reconstruction has taken place in two parts. On the one hand, rigid models of some elements and buildings have been made: the most documented (known *domus*), and the ones that have needed a more detailed definition because of its relevance (temple, basilica, curia). On the other hand, the elements (wall, domus, thermal, aqueduct) of which only a part of them has been recorded, have been reconstructed through parametric modeling.

The procedural modeling has allowed to reconstruct elements of the city, of which no information is available, applying the same parameters as the elements that we know, setting the actual value of the known elements and leaving a random range for unknowns. In addition, the fact of working with all the georeferenced elements allows to compare in real time the reconstructed model of the end of the third century with the present.

### 2.2.1 Roman wall, towers and gates

The founding wall of *Barcino* was aimed at demonstrating imperial power. It was the wall of the third century, with its 76 towers, that made *Barcino* an impregnable fortified enclosure [10].

For the parametric modeling of the fortification, [Fig. 7] it has been established 4 types of walls (foundational, imperial low, both mixed and both with access stairs), 3 tower typologies (rectangular, semicircular and polygonal) and 3 types of doors (the two doors to the *cardo maximus* are modeled with The same rule).

**The first wall:** The perimeter of the founding wall of *Barcino* was established following the strict principles that the Romans applied when choosing the locations for their cities: the situation on a high ground, the climate, the existence of water resources and the fertility of the territory. According to these criteria, the first fortified enclosure of the city was erected in the 1st century BC around Mount Tabor. The construction was carried out in a context of peace and because of that, it did not respond as much to the defensive logic as to the symbolic will of prestige and visibility of the new political institutions dictated by the emperor Augustus.

The perimeter of the *vallum* (Roman wall) was eminently rectangular, but had the lateral angles chamfered, because it had to adapt to the topography. It covered a course of about 1,315 meters, was eight meters high and two meters thick, and was built with Montjuïc's sandstone. Four monumental gates embellished and further enhanced the sense of representation of the Empire.

**The second Roman Wall:** In the low empire period, at the end of the third century, the founding perimeter of Barcino was transformed with the construction of a new wall: the previous one was reinforced with *two* meters of width of the wall, that gained to the *suburbium*, and was embellished with

seventy-six towers. Thus, the founding wall became the interior wall of the new fortified enclosure: *Barcino* became an impassable fortified enclosure.

The real importance of the *Barcino* wall lies in this transformation, since, thanks to its impregnability, the city was able to overcome the crisis derived from the end of the imperial dominion and did not die out, as it happened with many other Roman cities. For this same reason, was chosen as capital of the Visigothic kingdom, after Roman Empire, and from year 1931 forms part of the municipal patrimony, because of its historical significance.

**The entrance doors to the city:** Of the four gates that gave access to the city, there are only vestiges of those that connected with the *decumanus maximus*. Even so, it has been considered that the four doors are composed of a large central arch flanked by two smaller arches.



**Fig. 7:** Comparative perspective of the procedural model generated on the current orthophotography of the city

### 2.2.2 Urban structure, roads and subdivision of the domus

The urban structure forms part of the perimeter of the city, on which the interior was structured, dividing the interior into four parts, intersecting two axes, the main streets: the *cardo maximus* (orientated from north to south) and *decumanus maximus* (West to east). All the secondary streets are structured from that intersection and the knowledge of the Roman standard cities, designed on parallel and perpendicular streets, marking a grid. From these new intersections emerged each *insula* (block of houses).

Other factors that influenced the Urban structure are the topographical characteristics, which came to alter the orientation as the delimitation of the city. The colony is erected on two hills, the Mount Táber and another small hill, forcing to adapt the usual regular square or rectangular form of the Roman cities. For this reason, the *cardo maximus* does not exactly have a north-south orientation.

For the realization of the procedural model it is necessary to have the base documentation in vector format [Fig. 8], so we had to vectorize the raster information that was available converting all the elements into lines or polygons.



**Fig. 8:** Documentation base Barcino. (Left): Vector information base provided by the ICUB. (Center): Example raster base information provided by ICUB (Right): Base vector information made by LMVC



### 2.2.3 Aqueduct in the city

In the Roman world, water also became one of the most visible expressions of *dignitas* (dignity), because it determined the level of Romanity, that is, the level of civilization of the city. The *dignitas* demanded strict sanitation measures, linked to both clean and dirty water. As for the clean water, the best water had to reach all the public fountains and the spaces of corporal hygiene and leisure, that is to say, the baths. As for the dirty ones, it was necessary to guarantee the evacuation of the waste water through an interconnected sewer system [11].

**Exterior of Barcino:** The arrival of the aqueduct in the city has been made from the foundations found in the excavations at Plaça Nova, the remains of the *Casa del Arcediano* and the section seen from the Plaça del Vuit de Març [Fig. 9].

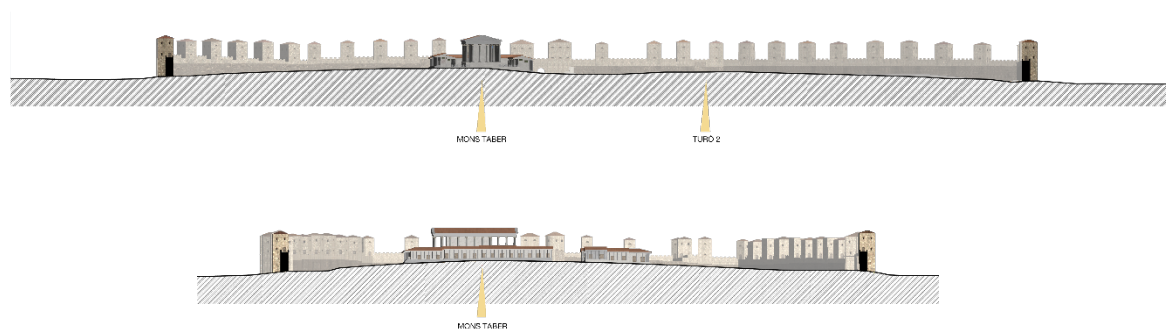


**Fig. 9:** Evidence aqueduct. Left: Excavation Plaça Nova. Center: *Casa del Arcediano*. Right: Place Vuit de Maig

Although it is observed the arrival of two aqueducts to the door of the Plaça Nova, there is no evidence of the existence of these. So it has been chosen to represent a single aqueduct that comes to the surface near the Plaza de Sant Pere, and forks in a *castellum aquae* before entering the city.

**Interior of Barcino:** The urban distribution of water required infrastructures called *castellum aquae*, which constituted urban water reservoirs. According to Vitruvius, they were divided into three sub-sites (the *triplex immisarium*), which distributed water unevenly between public fountains, thermal baths and some private houses.

In *Barcino*, there is evidence of the existence of two of these infrastructures. A *castellum aquae* (in Latin "water castle") is a water reservoir located in the highest part of the city, it was located in the highest area of Mount *Táber*, near the present square of Sant Jaume, some seventeen meters above sea level, on one side of the forum touching the *decumanus maximus*. This elevation was the most appropriate for downward sloping water circulation. In addition, it is very likely that the arrival of water in such an emblematic space of the city would be monumentalized with a fountain. The other water distributor in the city was located on the other elevation of the land, in the present square of Sant Just, where it has also been represented with a fountain.



**Fig. 11:** Sección longitudinal y tangencial del terreno con la muralla y el *Forum*

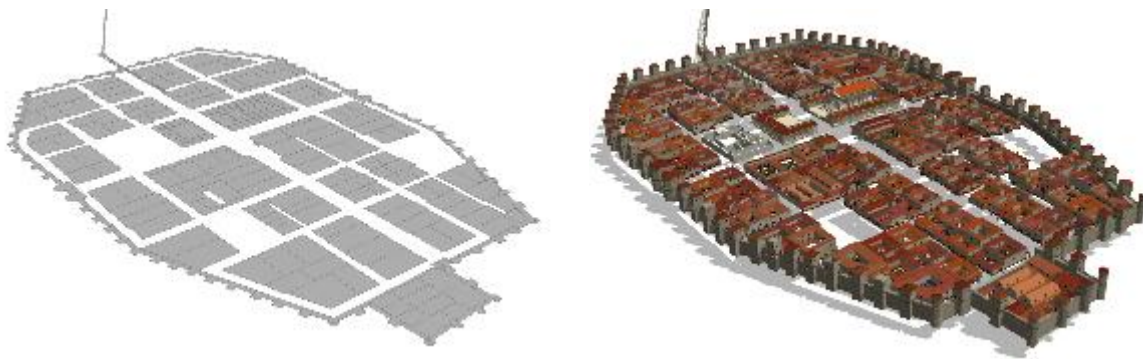
**Documented Domus:** At present, a total of seven *domuses* have been documented within the walled enclosure of *Barcino* [12], but the archeology service of Barcelona has for the time being only been able to reconstruct a total of four: *Domus de Sant Iu*, *Domus de Sant Honorat*, *Domus de Sant Miquel* [Fig. 12] and *Domus de Bisbe Caçador*. These models had to be optimized to be able to be added to the models at different representation scale.



**Domus models based on procedural rules:** The procedural model [Fig. 9] was carried out with the support of the Barcelona Archeology Service. In the parametric model only the Barcino in the interior of the wall was made, in the context of the completion of the construction of the low-imperial wall, towards the end of the third century.

The procedural method consists in projecting polygons in vector format to the ground and then applying to them programming rules (a series of functions in Python programming language) that constructs the model in function of the pre-established parameters.

For the construction of the model, a total of 22 different standards have been made to model the different elements, as have been more than 50 different textures, that combined with the different colors provide the materials used for the texturing of the model.



**Fig. 9:** Procedural model. (Left): Base vector information, on which the different programming rules have been applied. (Right): Perspective of the procedural model generated



**Fig. 13:** Perspective of the procedural model and its relationship with the environment

### 3. Conclusions

This work has been useful to unify archaeological bases, which had not previously been confronted, through its georeferencing, through the use of Geographic Information Systems (GIS), both vector and raster information. This allowed an integral view of Barcino.

In this process it was indispensable to establish an exact chronology to which the model refers, Barcino at the end of the third century, being the date in which the construction of the second wall was completed.

In addition, in the 3D model, only the inner city of the walls was developed, understanding that there were already buildings outside of them.

The constructions of the procedural models have allowed to confront the different data bases and to generate different versions of the Roman colony, which were analyzed with a group of experts of the service of archeology of Barcelona. This methodology has allowed to generate more than 10 proposals of urban models, being these models the point of understanding between disciplines. Modeling through code has allowed the urban model to be modified quickly and systematically, allowing a great flexibility in decision making.

This parametric model allows the 3D and territorial models to be edited, based on the new knowledge and reflections that are acquired from the colony of Barcino at the end of the III century AC and will be updated as new evidence appears. As it is a geo-referenced model that combines traditional and parametric modeling, this updating process can be performed in a simple way. Allowing for a dialogue between disciplines, in the search for greater knowledge of Barcino, being a model that can evolve.

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