X-Minutes Cities Before Modernity: The Case of Roman Foundation Cities

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Abstract. The 15-minute city has been establishing itself in recent years as a model of both urban planning and urban design and is centered on some basic elements that define its basic characteristics. The elements that more than others define the concept of the 15-minute city are the proximity of a series of essential amenities (both public and private), walkability, the close relationship with at least one access point to fast and direct connections with other parts of the city, the presence of a lively life framework supported by medium or high density residence, a certain compactness of the settlement (which makes proximity to services possible), a certain diversification in the services supply. What we want to suggest in this contribution is whether it was possible to trace in the history of the city some period in which this concept of proximity, high density and diversification of amenities has established itself with a certain clarity in terms of urban planning. To this end, three cities of Roman foundation (Pompeii, Leptis Magna and Timgad) are analyzed with the aim of evaluating whether they can be considered X-minute cities: the lack of rapid means of transport, in fact, had forced Roman planners to think of urban models that could concentrate within a relatively limited space residence, amenities, efficient road infrastructure. In conclusion, some reflections are proposed on the effectiveness and performance of these city models and whether they can represent some useful reference for the urban design of contemporary cities and neighborhoods.

Keywords: X-minutes Cities · Roman City · Urban Planning

1 Introduction: The Emergence of 15-Min City Model

1.1 The Model of 15-Min City

The 15-min city has established itself in recent years as a model of both spatial planning and urban design and is centered on some fundamental elements that define its fundamental characteristics. In the history of modern urban planning [1] the idea of proximity and accessibility to basic services for social and family life has a long and consolidated tradition of studies and applications. If some fundamental references can already be traced in the seminal intuition of C. Perry who through what he first defined as "neighborhood units", further references (even if less explicit) can be found in the expansion plan of

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Barcelona, where I. Cerdà had imagined a subdivision of the urban grid into districts and sectors, linking a specific provision of services and amenities to each level of the urban space. From those initial ideas, passing above all through the Northern European and Anglo-Saxon concept of garden city (following Howard's example), we have arrived at recent applications in the cities of Portland, Paris and Barcelona [2–4]. The idea of a 15-min city (or even 10 or 30-min city) is based on the observation of the excessive use of the cars in the contemporary city. An intensive use of private vehicles leads to high rates of pollution, congestion, the need for structures specifically intended for parking that fit problematically into cities with a historical tradition (therefore especially, but not only, in European cities) that were not originally conceived as urban spaces suitable for vehicular traffic [5]. The promotion of a pedestrian and walkable city is linked, however, not only to the objective of limiting the use of the private automobile in travel (both systematic commuter-type travel and episodic travel linked to other life needs) but also has to do with the concept of accessibility [6] and therefore, ultimately, with the concept of spatial equity [7]. Reflecting on the issues of accessibility means dealing with the question of the relationship between needs (social demand) and ways to satisfy these needs. From the spatial point of view, this means proposing city models that guarantee a facilitated and easy relationship between places of residence and the location of services and amenities (points of interest). Or even, if we look at it from another point of view, what is the best distribution in space of the points of supply of services: this involves returning to the concept of "urban grain" that K. Lynch had already proposed when he was reflecting on the themes of the good ruban form [8]. Referring to these intuitions, the elements that most define the concept of a 15-min city are proximity to a series of essential services (both public and private), walkability, a close relationship with at least one access point to rapid and direct connections with other parts of the city (on the model of Perry's neighborhood unit and subsequent urban models based on the Transit Oriented Development criterion [9], the presence of a vibrant urban fabric supported by a medium or high residential density, a certain compactness of the settlement (which makes it possible to reach the main basic services within a radius that can be reasonably covered on foot [10]), and finally a certain diversification in the supply of services. The temporal duration (usually 15 min) in the definition of a x-minute city indicates a clear tendency to create settlement environments that can be covered on foot within a rather limited radius of travel, between 1000–1500 m.

The x-minute city can be considered an approach to promoting a form of settlement in which active personal transport (walkable) is contained within a temporal "radius" of 10, 15 or 20 min that defines the boundaries of the optimal neighborhood [2, 4]. It is in fact interesting to note how the concept of 15-min city is strictly superimposable to that of neighborhood, and specifically to that of unitary neighborhood. There has been a great deal of internal reflection on this theme within Modernism and the proposals of urban planners that have matured in Europe and the USA since the 1920s. Le Corbusier himself can be said to have been a promoter of the idea of an autonomous and self-sufficient neighborhood, intended as an urban-building unit that contains both the residence and basic services for families. And, after all, the Unitè d'Habitation, an idea that matured and then implemented in the 1950s, is exactly this: a neighborhood in the form of a building, where inside or on the roof there are various services for families

(grocery stores, nursery, spaces for moving around, gym, etc.). Today the concept, in which "residents are able to satisfy most of their needs a few steps from home" is promoted by the C40 Cities, the global network of cities that are committed to addressing the climate crisis with shared strategies, has partly distanced itself from those initial ideas, renouncing the idea of the super-block, but maintaining other principles, such as the integration of residence – services, or underlining the importance of green areas. The same separation of traffic flows where vehicular traffic for medium and long-distance travel is separated from the minute network of local residential routes, does nothing but resume, in only slightly different forms, those of many modernist urban planners. The concept of the 20-min city evolved from the Portland City Plan's 20-min neighborhood concept (2008), which envisioned a set of neighborhoods where residents could access daily activities within twenty minutes, ideally on foot, but alternatively by bicycle, public transportation, or even by car [11, 12]. A 20-min city can be defined as a city that allows its residents to access most activities necessary for a good quality of life within 20 min, on foot, by bicycle, or by public transportation from their residence [13]. More recently, after the Portland experience, much discussed within the New Urbanism movement [14], the 20-min city has also been adopted in Tempe, where accessibility has taken into particular consideration non-work travels. Typically, in modern spatial planning methods, accessibility measures the relationships between residences and workplaces per unit of time as an indicator of the overall performance of the urban mobility system. However, this model is based on a concept of the city that has now entered into crisis. Only in the "typical" industrial city was there a rather clear distinction between residential neighborhoods (often monofunctional) and productive areas, where jobs were concentrated (whether they were cut from the manufacturing or tertiary sphere, such as business centers or CBDs). Today, in a metropolitan context, most trips are no longer commuting. The 15-min city is part of this change in urban paradigm: many urban planning programs today aim to increase the use of sustainable modes by reducing the use of the car in discretionary trips (which have become the largely majority ones), especially those for daily needs.

Specific morphological conditions, such as urban development in flat areas, or places that due to their geographical position enjoy a good climate for most of the year, undoubtedly favor outdoor activities and in these cases promoting pedestrianization or intensive and massive use of bicycles is easier. Another aspect that is linked to the promotion of 15-min cities is that relating to density. In fact, a dense city or neighborhood concentrates a significant portion of the population, reducing the space to be dedicated to road networks and in general to spaces dedicated to movement. The 15-min city finds it difficult to be a feasible idea where the city is not very dense: in large areas of urban sprawl; in fact, it is very complicated to organize a public transportation system that can adequately serve a dispersed population and, at the same time, the settlement model based on isolated single-family buildings greatly expands the space of the city and therefore tends to exponentially increase the infrastructure networks intended for physical movement. A related concept to density, the superblock or urban spaces built without cars, was first introduced in some eco-neighborhoods (Fribourg) [15], and then extended and finally incorporated into the concept of the eco-city [16, 17].

The urban design concept, which we call here "x-minute city", includes numerous other benefits in addition to reduced emissions and easier accessibility to services. Among them, the improvement of social cohesion, environmental justice and public health. Increasing the shares of time spent walking within one's neighborhood increases social interactions and cohesion, as J. Jacobs had already noted [18, 19]. Pedestrian neighborhoods, synonymous with densified cities, also better promote social capital, as individuals tend to have greater trust in their neighbors and have been shown to improve the quality of life of young and elderly residents [18, 20].

1.2 A Brief History of 15-Min City Concept

The 15-min model was recently revived in 2016 by scientist and economics professor Carlos Moreno [2]. Today, it is being practiced by many urban planners in cities around the world.

But the 15-minute concept is an extension of existing urban planning models. The concept behind Ebenezer Howard's "Gardens Cities of Tomorrow," published in 1902 (and later attempted through the work of urban planner R. Unwin), developed through the idea of neighborhood units, introduced by urban planner Clarence Perry in the 1920s in an attempt to design autonomous neighborhoods as cities began to industrialize. It is also comparable to the compact city, a similar urban planning model that emerged in the 1970s. The idea of a compact city, characterized by short commutes and wide accessibility to services, characterizes many theories, designs, and sometimes even realizations of many modern urban planning and architecture projects. Many post-war architects studied solutions around the concept of dense neighborhoods, or "super-locks" or compact cities. The Dutch school (thinking of the expansion districts of Amsterdam built after 1945 or the Pampus project by architect Bakema) provided numerous contributions in this sense, as made the Swiss or German ones (including some neighborhoods by Gropius). Another relevant example is the project for the new city of Toulouse (Toulose – Le Mirail). Even the super blocks designed by Le Corbusier for Chandigarh or the "super quadras" of Brasilia (Costa and Nyemaier) can be considered an anticipation of the 15-minute city. In these great neighborhoods, the residence (generally organized according to medium-high density models) was strongly integrated with services directly accessible within the space of the block itself, which did not exceed 3–400 m per side. Even the experience of the English new towns that developed from Abercrombie's Greater London plan in the post-war period (as well as the neighborhoods recognized within the city), refers to the concept of neighborhood, where residence and services are integrated and developed in compact settlement models. What can perhaps be considered the last of the new towns, Milton Keynes (GB), was organized by urban planners precisely as a grid within which the life of the blocks was organized in a semi-autonomous way with respect to a series of essential services for daily life and where each cell was connected to a stop of fast local public transport.

Compact, mixed-use, pedestrian-centric neighborhoods with optimal building density in areas adjacent to public transportation stops are also founding principles of New Urbanism [14, 21] and transit-oriented development (TOD) paradigms [9, 22]. In addition, similar criteria inform the neotraditionalist, small-town-revival (urban hamlet, village city) design developed by Duany and Plater-Zyberk [23] and are central factors of

urbanity. The idea of the city underlying these urban theories recognizes the importance of compact urban structures, multifunctional public spaces based on the integration of pedestrian circulation. It becomes crucial, in this way, to use urban density, pedestrian movement, diversification of service offerings to ensure and improve urban vitality [24].

As a final outcome of this long process of reflection on the character of the "vital" and accessible city has led to the latest and most recent initiatives, such as the case of Barcelona in 2016 and Shanghai, which introduced the 15-minute community life circle in the same year [7].

In Paris, Carlos Moreno's hometown, 50 fifteen-minute cities are already active. Melbourne, Australia's fastest growing city, is incorporating this planning framework to ensure it continues to meet the needs of its communities and secure the future of its services and facilities. Shanghai has become the first Chinese city to adopt this urban planning approach, in an effort to combat urban sprawl. By 2035, the city plans to reach 99% of public services within a 15-minute walk and 90% of green spaces within five minutes. Milan is often cited as a reference for the implementation of this planning model, along with Paris and Barcelona.

1.3 The 15-min City Main Characteristics

The 15-minute city emerges as a powerful urban concept not only for the construction of new cities but especially for the adaptation of existing cities [25]. It is based on the concept of chrono-urbanism to envision an urban model in which the five basic life functions (work, education, healthcare, entertainment and commerce) are located within a reasonable distance from each residential building, in order to encourage active mobility and reduce travel times to 15 min.

The concept of chrono-urbanism emphasizes the spatio-temporal aspects of urban organization, promoting a distribution of urban functions aimed at optimizing individuals' time budgets. This paradigm minimizes travel times related to essential activities, thus increasing the potential for leisure and social engagement. Furthermore, the reduction of travel times aims to reduce car dependence, improve access to services of general interest and promote active mobility. The time-centric perspective offers multiple benefits: equitable access to urban services, reduction of energy consumption, noise and air pollution, strengthening social engagement and improving the quality of life [25].

The 15-minute city concept involves the optimization of urban structures, land use and services to encourage public transport and active mobility options and reduce travel times to reach basic services to 15 min. More precisely, the 15-minute city model is based on four criteria: density, diversity, proximity and digitalization [26]. Diversity refers to the optimal number of residents that supports the plurality and diversity of services. Density is the factor that ensures greater access to services and urban vitality, active mobility and reduced dependence on the car. Consequently, compact and dense urban structures can lead to the reduction of pollution and energy consumption and the optimization of infrastructure provision [27].

Proximity refers to the spatial proximity of facilities related to the basic aspects of life, work, health care, education, entertainment and commerce. This concept integrates spatial and temporal dimensions, implies decentralization and redistribution of services of general interest at the district level and versatile use of basic urban infrastructure. More

precisely, proximity is positively related to increased active mobility, independence of vulnerable users and reduced dependence on automobiles [28].

From this perspective, density is not the only relevant variable. It is also necessary to consider the organization and the presence or absence of a hierarchy of urban services. Many scholars identify this hierarchy through the concept of rarity of use (of a service) which is determined by the frequency of use and the share of the population interested in the use of specific amenities. The combination of these considerations brings the reflection on the hierarchical structure of services (organized as a pyramid based on the priorities of use) and, consequently, to the hierarchy of urban centers within a regional space or service centers within a city [28].

As already intuited by Jacobs [18], the concentrated plurality of services and comforts is the basis of urban vitality. This is a concept taken up more recently by Gehl [29, 30] in his studies on the pedestrian city, where compactness, density and diversity in the offer of services are essential to create a vibrant city. These concepts had already been expressed in a more formalized way by C. Alexander [31], since his fundamental study on the network form of the real city (in contrast to the simplifications of the tree city that are the basis of many modernist and reductionist theories) [32]. From Alexander's formal mathematical and topological studies, it is quite logical the development of these ideas that leads to the concepts of the city as a complex network or the city as a multifractal reality. The polycentric configuration, the continuity of the ecological infrastructure, the access to essential urban functions and the optimization of density emerge as criteria of models based on the conceptualization of cities as multifractal structures [33].

2 Space Syntax as a Tool for Modeling Pedestrian Cities

2.1 The Role of Configurational Analysis

In recent research, diversity, proximity and density are considered as conditions determined by the urban form and are also identified as factors that favor vitality. Vitality (according to the fundamental studies in this field by K Lynh [8], in fact, is defined as a social process resulting from the concentration, intensity and diversity of individual and social activities activated by the combination of urban functions and the complexity of the urban form. The urban form, in turn, refers to the structural components of the built environment, including the configuration of lots and buildings, the configuration of streets and urban spaces and the organization of land use [34, 35]. More precisely, vitality is related to the diversity of functions and uses of the land [36], to the density of Points of Interest (POI) related to distinct categories of services [37] and to the density of population and buildings [Kim]. Furthermore, several factors related to the configuration of built areas and urban spaces emerge as predictors of vitality, including the permeability of the urban structure, defined by the distribution and topology of road intersections [38], and the density and compactness of buildings, defined by the ratio between floor area and surface area of the ground floor, which can be summarized, for example, in the SpaceMatrix diagram [39]. Furthermore, the theory of the economy of movement confirms the interdependence between the configuration of spaces, the intensity of pedestrian activities and the location of services, intrinsic to the concept of urban vitality. The latter maintains that the location of urban functions, including private services of general

interest, depends on the intensity of pedestrian activities, which in turn are facilitated or hindered by the configuration of convex urban spaces. As had been highlighted in its time by the well-known studies on the topological-configurational properties of urban spaces by Hillier and other scholars [40, 41]. All these studies, developed in recent years, converge in the identification of relationships between the physical space of the built city and the flows of people moving in the city. The relationships between flows and built space, in turn, generate new interpretations on the location, within the urban fabric, of functions, uses and activities. Location depends significantly on the topology of spaces open to pedestrian circulation and there are quite clear correlations between the centrality of elements of the road network and the location of activities. This relationship often follows a similar correlation between topological centrality and quality/rarity of points of interest. Configurational analysis conceives the city as a unique system of nodes and arcs [42], where centrality (or peripherality, on the contrary) acquires a determining role. The most central areas (streets or squares) in the urban grid have a decisive role in conditioning the choices of location of activities. In Hillier's conceptualization, not only do human societies use spatial configurations to give spatial form to social structures, but spatial configuration also influences social practices by restricting or generating fields of encounter, or co-presence, between individuals.

The economy of movement that is generated from the configuration of urban spaces (essentially: the road network) determines the intensity of crossing flows and these, with a feedback action, generate more or less central, more or less frequented and crossed places. The intensity of crossing conditions the location of activities, which will tend to concentrate where the flows are greater, generating a real competition for the use of space. Only when there is a strong central power, with great investment and conditioning capacity on land use, do situations arise in which the location of some functions can separate from the utility deriving from the connection with the most central places of the network. These are those functions that in the vision of Space Syntax are defined as "monopolistic" [43]. The spatial configuration, therefore, determines an initial concentration of pedestrian movement along specific spaces that emerge as suitable places for economic activities, for exchange or even just for simple meetings. The location of economic activities increases pedestrian movement rates and may lead to the location of more functions and the intensification of the urban network. Intensification, in turn a self-perpetuating process, refers to an adaptation of the urban structure aimed at increasing its permeability and the number of spaces suitable for the location of activities. Measuring configurational properties at distinct scales allows estimating the relationship between the built environment and flows [44].

2.2 Space Syntax Metrics

In highlighting the configuration, Space Syntax does not take into account the nature and function of places, but analyzes space using a topological perspective that considers spatial geometry and the relationships between spatial units [42, 43].

The technique can be applied through different types of analysis, specifically designed. These differ from each other depending on the geometric spatial unit used to segment the space. The most common Space Syntax analyses used for the study of urban road networks are:

- Axial analysis. The spatial unit is the axial line, defined as the longest straight line that represents the maximum extension of a point in space and mainly used to analyze urban road networks. In orthogonal grids each road corresponds to an axial line from start to finish, while along irregular routes the axial lines are interrupted in case of a change of direction if this is greater than a certain angle preliminarily defined [45];
- Segment Analysis. Like axial analysis, this is also a form of linear analysis and follows the same principles, although in this case the axial lines are segmented at each intersection point between the road axes and the values are calculated based on each segment;
- Visibility Graph Analysis, or VGA, investigates the visual properties of space through its visibility graph. Here the basic element is the isovist, understood as the set of all the points visible from a given point in space and whose size and shape can vary according to the position [46].

Each type of analysis allows to calculate different parameters, which in turn describe different spatial relationships analyzing the urban network as a unitary system (i.e. as a system). The main indicators that can be measured through Space Syntax and that we take into account here are:

- Connectivity, which indicates the number of connections of each spatial unit. This can show to what extent a road is connected to others and what are the probabilities that it is part of internal urban routes [47];
- Integration, which indicates to what extent locations within a system can be central or peripheral on a topological scale (and therefore how easily a spatial unit can be identified and reached);
- Choice, which indicates how much a spatial unit is included in all the shortest paths calculated within a spatial system (i.e. how often a spatial unit is chosen in all possible paths within a configuration).

2.3 Space Syntax for Studying Archeological Sites

In the last two decades, the use of Space Syntax in the field of archaeological studies, and more specifically in urban sites, has seen a remarkable increase [48, 49]. It has also increased the possibilities of understanding more deeply the built environment of ancient cities and their intrinsic characteristics, highlighting aspects that would otherwise escape a non-computational, but simply geometric, approach, related to the dimensions of excavations and finds. From these seminal studies, many other applications have recently developed to different case studies, covering areas ranging from ancient Mesopotamia and Syria, to archaeological sites in Mesoamerica. It must also be considered that it is not always useful or simply possible to use the methods and metrics of Space Syntax: everything depends on the conditions of the archaeological excavations, on the historical, anthropological and ethnographic research developed, on the quality of the geographical data related to the sites.

According to Morrow [50], to obtain a correct application of Space Syntax the following premises should be necessary:

- a clear geophysical map of the buried structures;
- an extensive survey (in terms of surface covered during the survey);

- a sufficient corpus of archaeological data from field excavations;
- a good knowledge of the cultural context.

However, following Morrow's experience, the technique has been successfully applied in contexts such as Ostia [51], Ammaia [52] and Dionisia [53], sites belonging to the Roman era and therefore able to provide better cultural support points. All these applications have reaffirmed the ability of Space Syntax to integrate the study of ancient cities with the dynamics of pedestrian movement (or at most with carts pulled by animal power), the central and peripheral urban areas and the strategic position of buildings, using quantitative data to also reconstruct the social life of these ancient cities. The most obvious limitation in these cases was the uncertain information base, consisting of a largely incomplete ground survey of the site of buildings and roads. In fact, analyses have always been conducted on incomplete urban layouts, whose boundaries had only been hypothesized, since field investigations left many uncertainties about the actual boundaries of cities. When one intends to analyze an ancient archaeological site, as may be the case with ancient Greco-Roman cities, one must not forget that once a notable percentage of the houses were built with poor materials, which the passing of time has almost completely erased. Constructions by bricklayers using stones or bricks (more durable over time) were often not the norm. And, in any case, even if the "central" areas of the most important cities had a monumental dimension that had seen the use of durable materials, there are many uncertainties about the urban suburbs, the outer neighborhoods, and the houses located in the rural context. This may represent a limitation for the application of Space Syntax and the interpretation of the site as a whole, since the technique, based on the reconstruction of the urban framework defined by the street grid and the buildings that delimit it, offers better results when the spatial configuration can be exactly defined by the internal and external physical boundaries of the settlement and by the knowledge of the social customs of the population that inhabited it (and which explains, for example, the preference for the construction of theaters, squares, thermal facilities, triumphal arches, etc.). Of course, the construction of the city walls to defend the city was often built with durable materials and therefore sometimes more evident traces of it remain, but many internal elements of the city are not entirely knowable with precision, except in the presence of very well-preserved archaeological remains. Consequently, the use of Space Syntax when the configuration of the urban space cannot be defined with certainty may compromise the results, especially in the case of small urban contexts such as those of the ancient world. In fact, as in any ecological or eco-social system, Space Syntax starts from the assumption of considering the city as a unitary whole and therefore if from the starting data it has not been possible to reconstruct with sufficient precision all the elements of the urban space, the results may appear misleading. For this reason, as well as to further test the potential of the technique, in this research we have selected sites characterized by clearly defined boundaries and a relatively known road network, documented by previous sufficiently accurate geophysical surveys.

3 Three Foundation Roman Cities as a Case of "Natural" 15-min Cities

3.1 Case Studies

The aim of this study was to analyze the spatial configuration of some Roman cities of foundation (therefore we excluded both the cases of cities originating from spontaneous processes or urban synoecism, and the cases of cities rebuilt on the remains of pre-existing settlements) to capture some elements that could constitute useful tools of analysis and design also for contemporary cities, if we want to adopt the principle of the city of x min. The starting hypothesis is that ancient cities (up to the threshold of modernity, that is, up to the 19th century, initially only in some areas of the planet starting from England and then progressively expanding to the rest of the planet) were all, to a certain extent, cities of 15 min. This is mainly due to obvious reasons related to technology (absence of mechanized transport - both horizontal and vertical - with artificial driving force, starting from the internal combustion engine). The relative slowness of transport "forced" urban centres to necessarily limited dimensions, beyond which the settlement lost in terms of performance (i.e. in responding to the social needs for which it arose and developed) and there was a decline in its spatial (and therefore also "social") performance. This is true for most cities, since there have always been large and very populous cities (Imperial Rome is an example), but which have constantly evaded, for economic, political and social reasons, the rule of optimal size, which necessarily had to be contained. If we look at the rank-size rule of ancient urban systems, we can see that often dominions, empires, civilizations were dominated by primatial cities (the capitals) that escaped the dimensional rules of the rest of the urban system (where instead the urban system, as a whole, rather faithfully followed Zipf's law, reaching the smallest settlements and inhabited nuclei [54, 55]. The size of "ordinary" settlements depended on factors related to the agricultural productivity of the surrounding urban regions and precisely on the internal configurational efficiency, which did not allow large dimensions. The limits imposed by technology and socio-economic conditions (the economies of antiquity were characterized by very slow growth over time), determined a sort of "implicit project" of the settlements, of their shape and size and, above all, of their configurational characteristics. Precisely the slowness of travel, the difficulty of moving with wheeled vehicles, the need to create, however, at the same time, lively and functioning urban environments, led the "builders" to choose the right size for their settlements to provide themselves with implicit rules that would allow a city, forced to be pedestrian, to function optimally. In this way, techniques and systems were refined that have allowed, over the centuries, to improve the performance, efficiency and yield of settlements.

In recent years there has been a growing interest in the urban planning of the Greek and Roman world [57, 58]. This has led to a kind of consensus on some of their vital statistics, such as the population size of the major settlements and the size of the overall urban population, the rate of urbanization (i.e. the share of individuals living in urban, rather than rural, settings) and the total population [59]. Following the study of W. Scheidel in the Cambridge Economic History of the Graeco-Roman World. It is thought that around 1.5 million people probably lived in the five largest cities of the Greco-Roman world by the 2nd century AD. These included Rome, which had a population

of around 1 million; Alexandria, which may have numbered around 500,000; Antioch, which may have numbered at least 150,000; and Carthage and Ephesus (Scheidel does not give explicit figures for these centers). Although there may have been a few more cities of the same size, most of the remainder were reasonably small, averaging no more than a few thousand inhabitants [60, 61].

There has been intense debate among classical archaeologists and ancient historians about the nature of Greek and Roman cities. These debates revolve around the question of whether urban centers were designed or remodeled according to a standard model centered on public spaces such as forums and agoras, with a common set of monuments articulated by regular street grids on a quadrangular mesh [62, 63].

Recent studies of ancient Roman urban planning show that not only was there considerable variation in the design of cities and the provision of services, but also that cities responded to the advent of imperial rule in different ways [60]. Although some were originally laid out on grids, most expanded organically. Furthermore, although some cities had specific structures from the beginning, most acquired these more structured forms over time, depending on their social, political and economic position in the geography of the Empire. In this study we consider three cities of Roman foundation, which satisfy the requirements of completeness of archaeological data proposed by Morrow and which, at the same time, constitute exemplary cases of coordinated and centralized urban planning.

Although many Roman cities are the result of an "organic" urban development, the grid plan, the regularity in the spatial distribution of the main functions and urban poles, the overall size of the settlement are characteristic elements of the mature phase of the Roman Empire and for this reason can be considered interesting case studies.

We have considered the three Roman cities of Pompeii, Timgad and Leptis Magna. These three settlements have some fundamental elements in common, which in our opinion allow a fruitful application of the metrics of space syntax (Fig. 1):

- these are settlements for which archaeological excavations have brought to light a large part of the ancient settlement, in its most mature and consolidated form;
- these are settlements for which there is adequate literature not only regarding their physical structure, but also information about their intended use, lifestyles and the architecture of public spaces;
- these are three settlements whose demographic size can be reconstructed with good approximation.

3.2 Measures of Configurational Centrality

Using the DepthmapX software, we have elaborate three configurational analyses, one for each of the cities case studies: the axial analysis using isovists, the angular analysis (which, almost in theory, improves the performance of the axial analysis) and the visibility map applied to the convex spaces of the cities (streets, forums, theaters, squares, open spaces).

We've adopted DepthMap X (Space Syntax Laboratory, The Bartlett, UCL), that is a software designed to evaluate the design efficiency of urban spaces and road circulation



Fig. 1. The three cities of Roman foundation analysed (same scale): Timgad, Leptis Magna and Pompeii: planimetric scheme of the insulae and convex spaces (streets, forums, etc.).

networks. It is built following the principles of visibility and movement established by the Space Syntax theory.

The centrality measures that are most significant are those regarding integration and choice. They are effective in representing the general dynamics of the flows that can be assumed to animate these cities. Integration provides a representation of the urban areas where the road segments most connected with the rest of the urban fabric are concentrated. The integration highlights a typical equivalence of the regular road network, that characterizes, in different ways, of all the cities considered. This characteristic of spatial equivalence must have been particularly effective, as it allowed for essentially equal spatial conditions in all urban areas, avoiding the formation of centripetal systems and central-peripheral dynamics. The regular network combined with the forcedly limited size guaranteed a regular spatial diffusion of constant positional values and this was well suited to a very dense and mixed urban fabric, as evidenced by the Roman cities excavations. In fact, within the blocks of these cities, mixed activities and functions coexisted, since residence (the most frequent function) was always associated with fine-grained service functions for the population (in fact in Pompeii, for example, bakeries, commercial businesses related to food and basic services, taverns, etc. were extremely widespread everywhere). The spatial grid with this configuration guaranteed a constant balance. A type of balance that did not change nature in the case of any expansions of the city, where these expansions were characterized by reproducing the same morphological principles. The measures relating to the choice provide further elements of understanding the space of the Roman city. A "natural" 15-minute city (the size of the cities rarely exceeded the radius of 1000–1500 m, precisely because it had to be covered on foot). From the parameter of "choice" it is clear that the large "monopolistic" elements of the city are often found in non-central positions. It cannot be thought that this was accidental: we are led to believe that it was instead a precise choice of urban planning. Theaters, amphitheaters, baths, gymnasiums and even the forum itself were in topologically semi-central positions: evidently it was believed that such urban structures were capable of independently attracting large flows of people and it was therefore preferable not to place them near the topological center of the settlement. This first reflection may appear counter-intuitive and certainly deserves to be explored in more depth, by expanding the number of cases to be analyzed, but we believe it expresses a precise and deliberate urban strategy. It should not be forgotten, in this regard, that in many Roman cities it was customary to

locate large structures (especially amphitheaters) not only outside the (geometric) center of the settlement, but also very decentralized. Evidently, a spatial planning practice was established over time that spread to all the geographical areas of the empire, a testimony to its good performance.

The segment angular analysis shows a further significant element: through this analysis, in fact, the main axes of the urban grid are highlighted, which rarely coincide with the classic cardo-decumanic intersection. In the three cities, the main axes tend to be rather peripheral with respect to the regular grid and this is believed to be another element resulting from a design choice, since it depends on the overall shape of the grid. The centrality of some axes is linked to the evolution of the urban structure and conditions (and in turn is conditioned) by the added urban areas, by the suburbs outside the urban perimeter, by the presence or absence of large "monopolistic" buildings (Figs. 2, 3, 4 and 5).

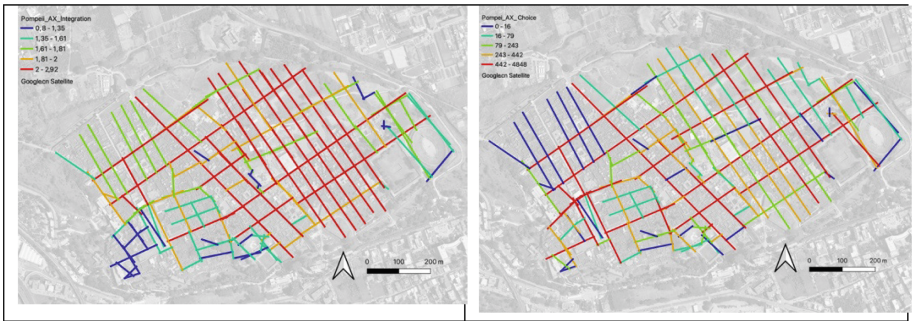

Fig. 2. Pompeii: Axial analysis with the results of the integration (left) and choice (right) metrics.

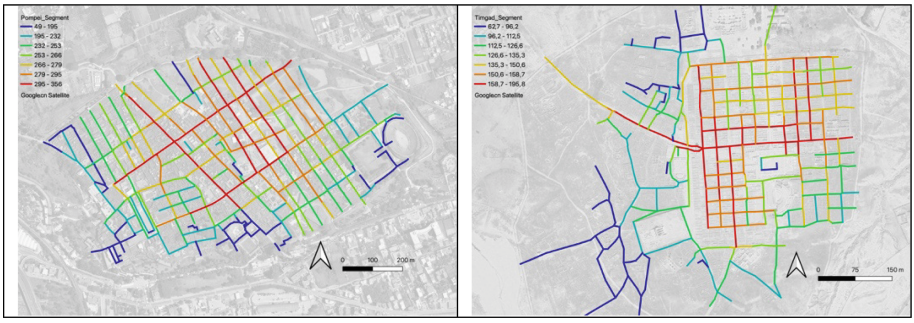

Fig. 3. Pompeii and Timgad (Timugadi): Segment angular analysis (integration)

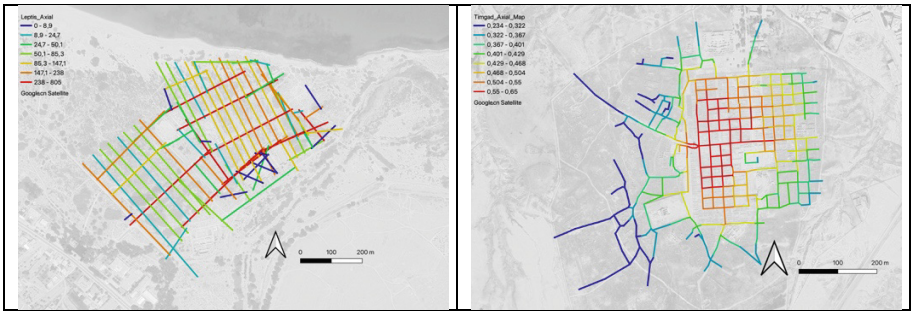

Fig. 4. Leptis Magna and Timgad (Timugadi): Axial analysis (integration).

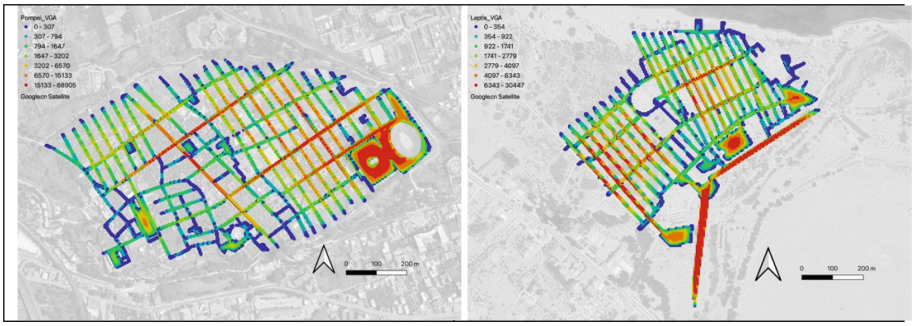

Fig. 5. Pompei and Leptis Magna: Visibility analysis (VGA).

4 Conclusion

The configuration analysis of the three Roman foundation cities examined led to the calculation of some topological indicators of centrality, mainly linked to integration and choice. In the case of visibility graph analysis, the calculation of through visions was of particular interest, as it provides a picture of the places where the view was most open and this gives a first idea of what was considered "central" for the planners of the time.

What emerges from the first results concerns first of all the use of the regular grid set on a right angle, which Roman planners used very often in newly founded cities or in the expansions of already existing centers. Rarer were the cases in which the urban intervention was limited to modest and limited updates to the layout of already existing cities.

Wherever possible, the use of the quadrangular street grid was one of the principles adopted in the construction of the grid. An example of this is the case of Paestum (Italy) where an urban addition was built to the ancient Greek settlement in Roman times which, while leaving part of the pre-existing settlement unchanged, intervened with an addition set on a regular grid. Timgad and Leptis Magna were two cities founded by the Romans with the aim of controlling important communication routes, promoting commercial traffic and providing a valid military garrison in areas of high socio-political turbulence.

The regular grid, if analyzed with the configurational metrics of space syntax, presents a strong homogeneity: all segments tend to have the same role in terms of integration, while in terms of choice indices, the central sections of the grid, i.e. the most internal ones, will be advantaged. In the realistic case of the Roman cities studied, this is not exactly the case. In the case of Pompeii, for example, the grid created is configured in such a way that the east-west axes have a clear prevalence (these are the two decumani maximi to the north and south.

The cases of Timgad and Leptis Magna are different, where the intentional and conscious aspect of centralized planning is more evident. While in Pompeii (and, in fact, in many other cities founded by the Romans) the forum is not very central (perhaps due to an urban growth that occurred gradually and not through a single act of foundation), in Timgad and Leptis Magna the fora show a high degree of centrality and the regular street grid enhances this centrality.

In all three cities we then note the peripheral location of the large public buildings (the theater, the amphitheater, the thermal complexes, the gymnasium): although they are sometimes close (in the Euclidean sense) or close to the physical center of gravity of the city, they are, from a configurational point of view, peripheral and segregated. We can then hypothesize that such large public buildings were the equivalent of today's "monopolistic" settlements. Where the central power has the strength to intervene with large investments and growth is not driven by the maximization of flows (and by the relationship between the most central road segments and the location of service activities), then the Roman planner preferred more peripheral places.

It is also interesting to note how the size of the blocks (in all three cases) was proportionate not only to the homes (domus) but also to the average size for the time of the buildings used to provide amenities, such as ovens, shops, small public baths, which normally stood along the routes of greatest flow. In this sense, the Roman city acquired a great capacity for adaptation, reaching high standards of spatial optimization.

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