BABESCH 87 (2012), 1-27. doi: 10.2143/BAB.87.0.2160690.

Social Network Analysis and the Emergence of Central Places
A Case Study from Central Italy (Latium Vetus)

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Abstract

*The last decade has witnessed a growing interest in the network model, both as a metaphor and as an analytical tool, within a wide range of disciplines, and recently archaeology. This article aims to assess the potential of the social network analysis model for the study of emergent complex polities, using a case study from central Italy (*Latium vetus*). In particular the emergence of known proto-urban and urban centres in this area, from the Final Bronze Age (1175/1150-950/925 BC ca), during the Early Iron Age (950/925-750 BC ca) up to the Orientalizing Age (750-580 BC ca) and Archaic Age (580-509 BC ca), will be examined by using social network analysis (SNA) centrality indexes and tools. Thus, the potential of this approach will be assessed, and its associated theoretical and methodological issues discussed.**

Introduction

During the last few decades a number of traditional disciplines among the humanities, such as history, art history, ancient history, archaeology and historical archaeology have witnessed a significant growth of interest in social network analysis, which had previously principally confined to the fields of anthropology, sociology and social geography. In particular, within archaeology various applications have shown that social network analysis can provide a useful set of theoretical and technical tools to answer a variety of spatial as well as social questions and more importantly a combination of the two. While a number of case studies with practical examples have concerned pre-historical or fully historical societies, the potential of social network analysis for the study of the emergence of complex polities has only been used as a metaphor for interpretation rather than an analytical tool.

This article aims to fill this gap by applying a number of social network centrality indexes to predict proto-urban and urban settlements formation in *Latium Vetus* (*fig.1*) from the Final Bronze Age (1175/1150-950/925 BC ca) up to the Archaic Age (580-509 BC ca.).[1] This will be done by comparing the grades of centrality generated by social network analysis indexes, with their centrality ranks, based on existing, recognised, historical and archaeological knowledge; thus it will be possible to evaluate these indexes and their capacity of predicting the emergence of central places.

Traditional locational analyses, which have proved successful in investigating settlement hierarchy and centralization, such as the central-place theory and the rank-size rule, present a limit which is the adoption of a basically static view. In the majority of those analyses the importance of a site has only been measured in relation to a local distribution: the size of the settlement itself and the distance from the immediate neighbouring settlements. In this way only first order relationships (neighbours) are considered, while higher orders are disregarded. Seeing the distribution not as a set of points on a plane, but rather a set of points, which are related and connected, leads to the idea of the network.[2]

In this study, Latial settlements from the Final Bronze Age (1175/1150-950/925 BC ca) to the Archaic Age (580-509 BC ca) will be connected via rivers and road[3] networks, as a means of social communication and a number of centrality indexes, commonly used in social network analysis, will be calculated. The results of the analysis will then be collated, and also compared against what is independently known from the historical reconstruction, based on archaeological and historical sources. In this way the potential and also the theoretical and practical issues of social network analysis for the study of the emergence of complex polities will be assessed and discussed. Finally some suggestions will be advanced for

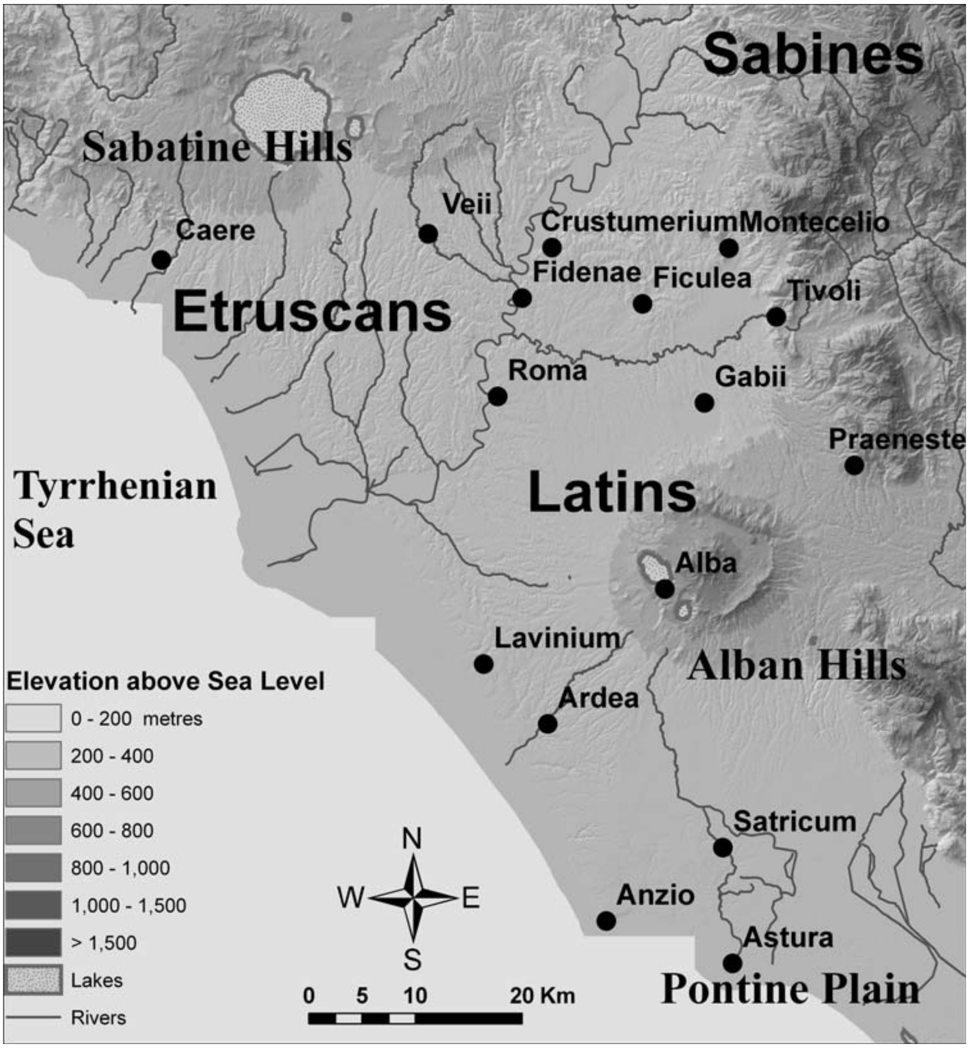


Fig. 1. Geographical context: Latium Vetus with major Early Iron Age settlements.

further developments of this project and for the more general application of social network analysis in archaeology.

The Social Network Analysis 'Paradigm' and Archaeology

It is commonly agreed that the last three decades have seen an exponential growth of interest in social network analysis from within a wide variety of academic fields as well as in the public sphere. A number of books[4] have popularised and diffused many of the social network analysis principles such as, for example, the small world idea,[5] first elaborated by social psychologist Stanley Milgrom, according to which strangers can be connected via a short chain of acquaintances.[6]

At the same time, as noticed by Knoke and Yang,[7] a similar proliferation of network research applications to natural phenomena as well as to complex social systems occurred in mathematical and physical disciplines.[8] But an even greater contributory factor to the diffusion of this model has been the proliferation of a number of software-tools[9] and manuals[10] that are intelligible to non-specialists, who lack a background in mathematics and physics.

As a consequence of this diffusion, social network analysis can now be rightly considered as an institutionalized transdisciplinary and interdisciplinary perspective or paradigm.[11] In fact its basic concepts and indexes[12] are widely used in a variety of diverse disciplines, ranging from sociology and anthropology,[13] classic areas for social network analysis studies, to ethnology,[14] economics, business management and organization studies,[15] geography,[16] economic geography,[17] biology,[18] medicine, etc.[19]

More recently the model/technique of social network analysis has been introduced into more traditionally humanistic disciplines, such as classics,[20] ancient history,[21] history,[22] art history,[23] cultural history,[24] archaeology (see below) and historical archaeology.[25] This widespread diffusion of social network analysis among so many varied and different disciplines is an interesting research topic in itself.[26]

The underlying principle of social network analysis is 'structural relations'. According to this perspective actors' behaviour is not only based on their attributes (sex, age, mentality, belief etc.) but is interdependent on and influenced by the behaviour of other actors.[27] The first pioneering study in this direction was Jacob Moreno's sociometric work,[28] which elaborated a *sociogram* or a two-dimensional diagram for representing 'the relations among actors in a bounded social system, for example, an elementary classroom'.[29]

This study, which introduced concepts and theories from graph theory[30] to social studies, is universally considered the starting point of social network analysis.[31] In sociograms and graphs, actors are represented by a set of points (the nodes or vertices), while lines drawn between pairs of points indicate a relation or tie between two actors that can be directed (arcs, generally represented by arrows) or undirected/bidirectional (edges, normally represented by simple lines), and un-valued or valued, depending on various degrees of intensity.

Actors can be individuals and links among them might represent friendship, animosity, family relationships etc.; but actors can also be microscopic entities such as neurons or macroscopic entities such as communities, cities or even nation states and their relationships can be measured in terms of neuronal connections (in the first case), alliances, trade etc. (in the others). The scope of social network analysis is to represent actors and their relations and to measure them accurately in order to explain why they occurred and what the consequences are.[32]

While social network analysis is a relatively new method and tool in archaeological research, a couple of articles have already appeared which discuss general concepts and methods in relation to the discipline and review a number of studies. In particular, Gary Lock and John Pouncett, in their introduction to a session on social network analysis in archaeology, organised at the 2006 conference on *Computer and Quantitative Methods in Archaeology*, provided a concise but effective overview.[33]

These scholars correctly identified the roots of archaeological social network analysis in quantitative geography[34] and described the fragmented interest in this technique since the early 1990s up to the end of the last Millennium. At the turn of the 3rd Millennium, as emphasised by the same authors and by Ulrich Müller, the use of social network analysis in archaeology seems to have grown exponentially.[35]

A number of pioneering applications, developed during the 1970s and 1980s, and generally overlooked by recent literature, have used social network analysis to study rivers and road networks and predict the emergence of central places such as 12th and 13th centuries Moscow[36] or Roman London;[37] or discussed the utility of graph theory in the interpretation of regional survey data[38] and of social network analysis in the study of prehistoric trade.[39]

More recently social network analysis, as an analytical tool, has been used to study communications, transport and trade, social and economic structures within fully historical communities;[40] or to investigate socio-political and economic relationships or belief systems within pre-historical communities,[41] where fixed ordered hierarchies were not yet fully established.

The potential of social network analysis in the study of the emergence of complex polities, ancient states and empires has also been emphasised[42] but rarely investigated,[43] and, recently published studies,[44] mainly adopted the concept as an interpretative metaphor[45] rather than a tool for analysis, or used social network analysis concepts to build agent-based simulation models.[46] Finally what is generally lacking is a discussion of issues and problems either in the application of the model or on a more general theoretical level.[47]

This article aims to present a concrete application of the social network principles as an analytical tool; the method will be tested on a specific historical and geographical context and the results will be assessed by comparing them with independent historical knowledge and will hopefully provide the ground for further discussion and studies.

Social Network Analysis and Proto-Urban/Urban Centres in Central Italy: Methodology

A long tradition of studies has accumulated a great deal of information and knowledge on the emergence of complex polities and urbanization processes in middle Tyrrhenian Italy during the Final Bronze Age and the Early Iron Age. Although finer details and local variations continue to be discussed and debated, the main picture is commonly agreed both from historical perspectives, based on ancient authors,[48] and from an archaeological point of view.[49]

The Roman school of pre and proto-historic studies,[50] founded in Rome by Renato Peroni, who sadly has recently died, made great strides in this field; and while the roots of the process are still being discussed, and a long-standing debate has been engaged in the identification and weight of internal impulses versus external *stimuli*, it is generally agreed that by the end of the Final Bronze Age (1050/950-950/925 ca) and during the Early Iron Age (900-750 BC ca), a number of centralized settlements, the so-called proto-urban centres, appeared in middle Tyrrhenian Italy,[51] with sligthly different modalities and timing.[52]

While recent research has shown a greater internal variability and a more nuanced picture than previously thought,[53] it is generally agreed that the process of centralization and nucleation was more rapid, revolutionary and earlier in southern Etruria, and it was more gradual and slightly later in *Latium Vetus*. In particular, in the course of the Final Bronze Age, in southern Etruria, it is possible to identify the sudden abandonment of a large number of hilltops and open Bronze Age sites in coincidence with the (novel) widespread occupation of a few larger plateaux (such as Veii, Tarquinia, Caere and Vulci), which previously had not been settled or at least not so extensively.[54] In *Latium Vetus* the process of agglomeration can be generally seen as more gradual and often the first order settlements developed from already occupied small hilltops or *arces* (generally defined *acropoleis*, with Greek term), which were enlarged, by including the connected plateaux within the inhabited area.[55]

Common features have also been identified for these nucleated centres such as: *1.* proximity to the sea or rivers, which allow regional and long-distance connections; *2.* availability of good arable land; *3.* defensibility; and *4.* size which differentiates these settlements from the minor settlements within the same region.[56] With reference to this last point a marked difference has again been observed between southern Etruria and *Latium Vetus*: in the former region primary order centres are normally noticeably large, ranging from 150 to 200 ha, while in the latter primary order centres measure normally between 20-30 and 80-90 ha with the sole exception of Rome (100-200 ha ca), which was more comparable to Etruscan centres.[57]

Building on this earlier knowledge, this study considers Early Iron Age Latial sites larger than 20-25 ha as primary centres or 'central places'. This classification is based both on the observation of settlements size frequencies (*fig. 2* shows as an example the graph for the Early Iron Age 2, about 850/825-750 BC), and previous studies. For example the work by Marco Pacciarelli on proto-urban developments in middle Tyrrhenian Italy has identified three main orders of magnitude for primary proto-urban centres in *Latium Vetus*.[58]

Pacciarelli distinguished Latial centres A, between 100 and 200 ha (only Rome falls within this category); centres B, between 50 and 100 (for example *Gabii*), and centres C between 20 and 50 ha (the most common range for primary centres in *Latium Vetus*), while centres D between 1 and 15 ha are considered subordinates to all other centres.[59] In addition my previous work has confirmed these definitions by the application of a number of different locational models.[60]

When considering the Final Bronze Age, Latial centres larger than 4-6 ha, have also been considered to have had some sort of central role. This size limit has been chosen on the basis of Final Bronze Age settlements size frequencies (*fig. 3* shows as an example the graph of the Final Bronze Age 3, about 1050/950-950/925 BC), and on a number of studies conducted on southern Etruria, which have chosen a similar size threshold to distinguish between first order and secondary order villages.[61]

Primary Bronze Age and Early Iron Age centres, identified on the basis of their size and contextual archaeological knowledge will provide a checklist to compare centres predicted to be central by social network analysis indexes. In particular a number of different types of networks will be modelled on the basis of *1.* proximity analysis, *2.* rivers and *3.* road connections. Then a number of centrality indexes, commonly used in social network analysis (Degree Centrality, Betweenness Centrality and Closeness Centrality) will be calculated for each type of network. Finally the results from these analyses will also be compared among themselves and against the above mentioned checklists.

As already mentioned, a number of software-tools are available for social network analysis. For this study the Pajek software has been used because it is available as a free source and is provided with an excellent and accessible manual.[62] Wouter de Nooy, one of the developers of this software and the authors of the book, has provided precious advice from a very early stage of the project and has developed a script used with

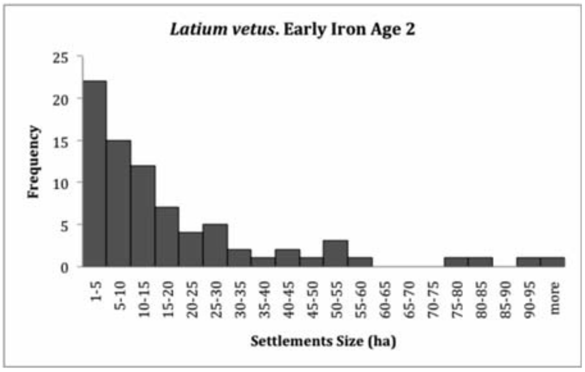


Fig. 2. Size frequencies of Early Iron Age 2 Latial settlements.

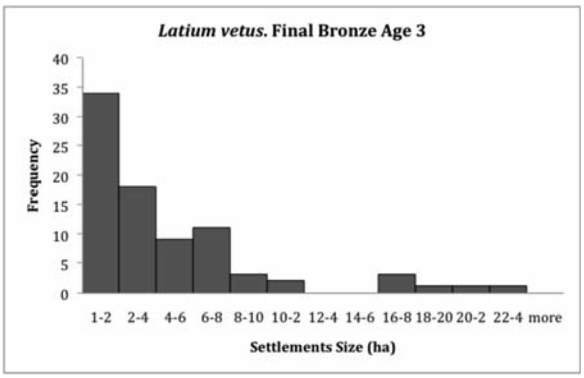


Fig. 3. Size frequencies of Final Bronze Age 3 Latial settlements.

the statistical software R to model the ideal network based on proximity analysis, performed with the Delaunay triangulation, as shown below.

The river and road networks have been modelled by connecting two sites directly and reciprocally reachable via a river or a road. The river network has been based on digital data provided by Regione Lazio, while the road network has been modelled on routes reconstructed by Marcello Guaitoli for the Final Bronze Age[63] and Lorenzo Quilici and Stefania Quilici Gigli for the Early Iron Age.[64] Both will be defined and discussed in more detail in the section which illustrates and discuss the analyses.

The present study has been limited to Latial settlements from the Final Bronze Age to the Archaic Age, due to it representing a coherent group with common material culture and roughly defined geographical limits. Previous phases have been omitted because the Grotta Nuova and Apennine culture would have implied a larger geographical delimitation. Settlement data collected during previous research has been checked against the recent publication of all pre- and proto-historic sites of Lazio edited by Clarissa Belardelli and other authors.[65] A number of sites only known from literary sources such as *Pedum*-Gallicano or *Bola*-Labici have also been included (for a complete list of sites included in this study see Appendix 1).

When considering the representativeness and completeness of the data sample, issues of an imbalanced intensity of research within the region cannot be denied. In addition it has been observed that missing data in social network analysis might affect smaller networks.[66] However, as will be shown in the subsequent sections, positive results from the analyses, partially validated by statistical tests, seem to imply that the sample has a good representativeness and that even the missing data does not significantly affect the model.

When full coverage surveys of settlements size measurements were lacking, their estimations have been based on specific theoretical assumptions, formulated by the Roman school of pre- and proto-history and generally accepted by scholars studying settlement patterns in Bronze Age and Early Iron Age central Italy. These assumptions have been illustrated and discussed in a contribution by Alessandro Vanzetti, according to whom:

1. in the case of a well defined morphological unit such as a hilltop or a small plateau, the unity of the settlement is implied, even though the material is scarce (particularly in the Bronze Age);
2. when Bronze Age material (even scarce material) is found along the ridges and slopes of well defined morphological units such as hilltops or small plateaux, it is assumed that they have been displaced from the top (due to post-depositional processes such soil erosion and/or alluvial deposits) and a unitarian settlement is implied.[67]

In addition, when considering Early Iron Age settlements and, in particular, large proto-urban settlements located on the plateaux later occupied by Archaic cities, the localization of formal burial areas has provided additional topographical elements, which have helped to establish the hypothetical extent of the inhabited area. In fact, it is generally agreed that by the end of the Final Bronze Age and the beginning of the Early Iron Age, a formal distinction between the living and the dead was sanctioned, and funerary areas were confined to the outside of the inhabited area, and normally formed a sort of annular ring around it.[68] However, the plurality of these funerary areas has been differently interpreted, against or in favour of the assumption of the unity of the settlement.[69]

Social Network Analysis Centrality Indexes

As mentioned earlier a number of centrality indexes, commonly used in social network analysis, such as Degree Centrality, Betweenness Centrality and Closeness Centrality have been calculated for different types of networks modelled for Final Bronze Age and Early Iron Age Latial centres on the basis of *1*. proximity analysis, *2*. rivers and *3*. road connections. This procedure is based on the assumption that natural or human geographical connections such as rivers or roads equate to encounters and exchanges not only of goods and objects but also of ideas and information.

The *Degree Centrality* 'measures the extent to which a node connects to all other nodes in a social network'[70] and indicates how easily information can reach a node. It is based on the assumption that the more links and neighbours a node has, the higher the probability for that node to receive information, and is given by the following equation:

$$C_D(N_i) = \sum_{j=1}^{g} x_{ij}(i \neq j)$$

This means that, in a simple and undirected network with g actors (where g is the total number of nodes or actors), the Degree Centrality (C_D) of an actor or node i (N_i) is given by the sum of the number of its direct links to the g–1 other j nodes of the network ($\sum_{j=1}^{g} x_{ij}$), that is, in simple terms, the number of its neighbours.[71]

However, actor degree centrality may vary with the size of the network (g or the number of nodes/actors). In fact the larger the network, or the number of its nodes/actors, the higher the potential of each single actor/node to be directly linked to other actors. For example, an absolute actor degree centrality of 3 (which means direct link to three other actors), might represent a very high value in a network of 5 actors but would be a low value in a network of 50 actors or more. Therefore, Wasserman and Faust, in order to eliminate the effect of variation in degree centrality caused by the size of the network (g), suggest normalizing it according the following formula:[72]

$$C'_D(N_i) = \frac{C_D(N_i)}{g-1}$$

Then the normalized degree centrality (C'_D) of a node i (N_i), is given by its Degree Centrality, $C_D(N_i)$) divided by the maximum number of possible connections with the other actors, that is the total number of nodes (g) minus one, the node itself (g–*1*). In this way it is possible to yield 'the proportion of the network members with direct ties to actor *i*. Proportions vary between 0.0, indicating no connections with any actors (i.e. an isolate), and 1.0, reflecting direct ties to every one. Normalized actor degree centrality measures the extent to which an actor is involved in numerous relationships. Actors with high scores are the most visible participants in a network.'[73]

The *Betweenness Centrality* indicates the degree to which an actor controls or mediates 'the relations between other pairs or dyads of actors that are not directly connected. Actor betweenness centrality measures the extent to which other actors lie on the geodesic path, or the (shortest distance), between pairs of actors in the network.'[74] At this point it ought to be noted that distance in a network is the number of links which connects two nodes, not a geographical distance. In other words the betweenness centrality index measures the extent to which a node or actor lies on the shortest route connecting each pair of other nodes/actors in the network. Therefore, it is clearly 'an important indicator of control over information exchange or resources flows within a network'.[75]

As originally proposed by Freeman,[76] betweenness centrality is given by the formula:

$$C_B(N_i) = \sum_{j<k} \frac{g_{jk}(N_i)}{g_{jk}}$$

In the above formula, g_{jk} is the number of geodesic paths between the two nodes j and k (dyad), and g_{jk} (N_i) is the number of geodesics between j and k that contain node i. Then, dividing g_{jk} (N_i) by, g_{jk} measures the proportion of geodesic paths connecting j and k in which node i is involved. Summing across all the dyads not including node i measures the extent to which i sits on the geodesic paths of the other network members.'[77] Again Wasserman and Faust suggest standardizing the actor betweenness centrality by dividing it by the maximum theoretical value of $\frac{(g-1)(g-2)}{2}$ (assuming that each pair has only one geodesic) according to the formula:[78]

$$C'_B(N_i) = \frac{C_B(N_i) \times 2}{(g-1)(g-2)}$$

'The standardized actor betweenness centrality is 0.0 when the original betweenness centrality is 0, and it is 1.0 when node *i* falls on the geodesic path of every dyad among the remaining $g-1$ nodes. Therefore, the closer the standardized actor betweenness centrality is to 1.0, the more the actor controls or mediates relations in the network.'[79]

The actor *Closeness Centrality*, developed by Sabidussi,[80] measures the extent to which a node is close to other nodes in a social network. It is based on the total distance between the node and all other nodes, where larger distances imply lower closeness centrality values. Closeness and distance refer again to how quickly an actor can interact with others, for example, by communicating directly or through very few intermediaries; and again the geodesic, that is the length of the shortest distance, or the smallest number of links connecting a pair of nodes, is a key concept.

In fact, the closeness centrality (C_C) of an actor/node (N_i) is based on its geodesic distance to all other nodes, 'and is computed as the inverse of the sum of the geodesic distances between actor *i* and the $g-1$ other actors':[81]

$$C_C(N_i) = \frac{\quad}{[\sum_{j=1}^{g} d(N_i, N_j)]} \; (i \neq j)$$

Again closeness centrality might vary with network size. Therefore Beauchamp suggested that the index of actor closeness centrality should be standardized by multiplying it by the maximum number of nodes in the network minus one:[82]

$$C_C(N_i) = (g-1)(C_C(N_i))$$

Social Network Analysis and Proto-Urban/Urban Centres in Central Italy: Analyses

The social network analysis indexes of centrality described above have been calculated for a number of networks modelled on: *1*. an ideal system of connections based on proximity analysis; 2. river connections; and *3*. road connections. As already mentioned this procedure is based on the assumption that river and road networks are means of transports for goods, people and ideas and therefore imply cultural, economic and socio-political relationships. As this study is mainly intended to assess the value of social network analysis, at this stage of the project no specific type of goods or items has been considered, which might have indicated a direction and intensity of the movements and contacts. Therefore all of the networks modelled have been considered as simple and undirected, which means that flows of connections between any two nodes are assumed to take place evenly in reciprocal directions.

Fig. 4. Terrestrial routes used to model the road networks of Final Bronze Age Latial settlements (from Guaitoli 1981, 31, fig.5).

In particular, the network based on proximity analysis has been produced by running a script, written by De Nooy, with the statistical software package R, available as a free source on the web (http://www.r-project.org/, 4 June 2010). The network has been modelled by using the Delaunay triangulation algorithm, which divides space among points into a triangle, in a way that any of the original sets of point is contained in the circles circumscribing each triangle. Figure 6 shows an example of this procedure. According to the predictive model proposed by Evans, Knappet and Rivers, proximity analysis based on Delaunay triangulation[83] could be improved by weighting dis-

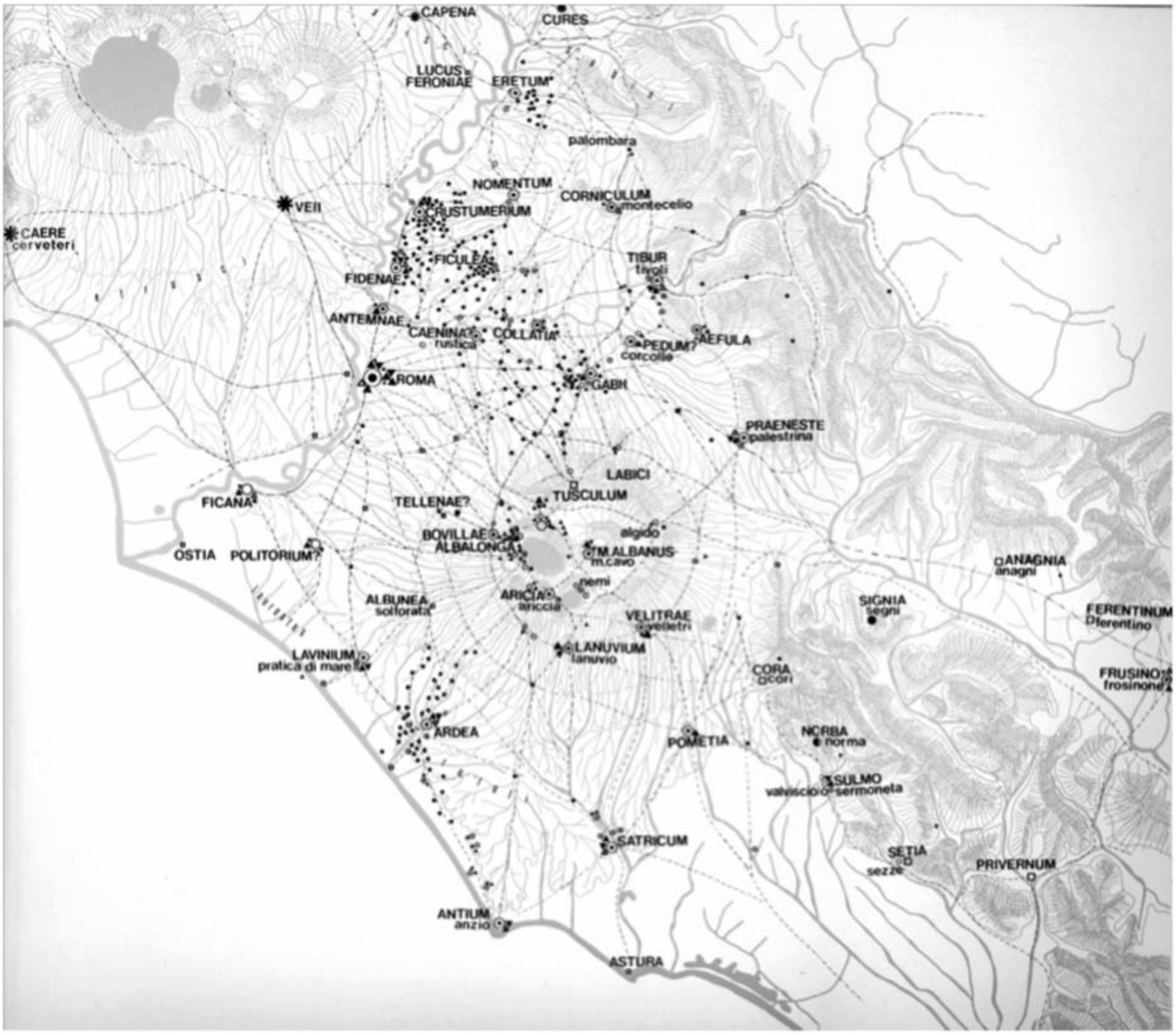


Fig. 5. Terrestrial routes used to model the road networks of Early Iron Age, Orientalizing and Archaic Age Latial settlements (from Colonna 1976, pl. 1).

tance in relation to settlements size and other variables.[84] However, in this case it has been decided to keep the two variables independent because settlements size will be one of the elements against which results will be analysed and therefore it would not be correct to consider it as a variable in the analysis.

The rivers and road networks have been modelled by connecting two sites directly and reciprocally reachable via a river or a road (see examples in Appendix 2). The river network has been based on digital data provided by Regione Lazio. In particular, rivers associated in modern time with alluvial soils have been included for the study, because they are more likely to have been consistent and more important for middle and long distance communication also in antiquity.[85]

As already mentioned, the road networks have been modelled on routes reconstructed by Guaitoli for the Final Bronze Age (*fig. 4*)[86] and Quilici and Quilici Gigli for the Early Iron Age (*fig. 5*).[87] Again middle and long distance routes have been considered. Although both studies used are not very recent, their validity seemed to be confirmed by the fact that novel sites, discovered by more recent research, superimposed on Guaitoli's and the Quilici's maps, show a very good alignement with routes already identified by those scholars.

As introduced in the previous section, centrality social network analysis indexes have been compared with 'central places' predicted by settlement size and contextual archaeological knowledge. In particular, for each index, settlements have been ranked from the highest to the lowest scores and the first 'N' highest scores have been highlighted, where 'N' corresponds to the number of settlements predicted to be central by settlements size. Then the number of settlements predicted to be central by each centrality index and at the same time by settlement size, have been counted and calculated in percentages against the total number of settlements predicted to be central solely by size. In this way, it has been possible to evaluate in terms of percentage the number of central places correctly predicted by social network analysis centrality indexes.

In table 1 the figures, calculated for the degree centrality of the Early Iron Age 2 roads network have been shown as an example. In this case 24 settlements are considered to be primary centres or central places, according to their size; and 16 of these settlements are predicted to be central by the degree centrality index, calculated for the network modelled on road connections. This means that this type of model has a success of prediction of the 67%, which is normally considered more than acceptable (see also below).[88] The same calculation has been performed for all three types of indexes (degree centrality, betweenness centrality and closeness centrality) and for all three types of networks (Delaunay triangulation networks, rivers networks and road networks).

Table 2 summarises the results of the calculation of the percentages of correctly predicted central place sites for each phase, according to the three indexes for the three types of networks, in relation to the sites predicted to be central for each phase by their size; and figures 7, 8 and 9

vertexID	**settlement**	**size**	**area**	**Normalized Degree Centrality**	**Predicted Central Sites**	**Percentage of Predicted Central Sites**
1	*Roma*	1	2100000	0.13207547	1	
2	*Gabii*	1	918782	0.113207547	1	
3	Ardea	1	848969	0.075471698	1	
4	Alba	1	756100	0.028301887		
5	*Ficulea*	2	552989	0.08490566	1	
6	C. della Coedra-*Cora*	2	542885	0.056603774	1	
7	*Crustumerium*	2	519072	0.037735849		
8	*Satricum*	2	507406	0.075471698	1	
9	*Astura*	3	464995	0.028301887		
10	Cisterna di Latina	3	448530	0.066037736	1	
11	*Fidenae*	3	413473	0.056603774	1	
107	Gallicano	3	397783	0.047169811		
12	Valmontone-*Tolerium*	3	394611	0.075471698	1	
13	Corcolle	3	335871	0.028301887		
14	*Lavinium*	3	334476	0.08490566	1	
15	*Bovillae*	3	298673	0.056603774	1	
16	Velletri	3	287060	0.056603774	1	
17	Tivoli	3	280989	0.056603774	1	
18	Lunghezza-*Collatia*	3	279314	0.066037736	1	
19	*Ficana*- M. Cugno	3	254142	0.037735849		
20	Palestrina	3	242783	0.056603774	1	
21	T. Torrino-*Politorium*?	3	229770	0.037735849		
22	*Tellenae*	3	213244	0.08490566	1	
23	S. Giovanni in C.	3	208097	0.037735849		
Totals			**24**	**24**	**16**	**67**

Table 1. Settlements predicted to be central by the normalized degree centrality (in dark grey, while missed central settlements are blank), compared against settlements predicted to be central by their size (sizes 1-2 and 3), for the road network of Early Iron Age 2 Latium vetus.

		Final Bronze Age 1-2	Final Bronze Age 3	Early Iron Age 1 Early	Early Iron Age 1 Late	Early Iron Age	Orienta-lizing Age	Archaic Age
Degree Centrality	Delaunay Networks	42	57	30	38	54	57	60
	Rivers Networks	42	54	45	48	38	46	43
	Road Networks	47	39	50	48	65	61	67
Betweenness Centrality	Delaunay Networks	37	36	35	43	31	50	57
	Rivers Networks	32	39	40	43	38	36	53
	Road Networks	42	43	35	48	54	50	57
Closeness Centrality	Delaunay Networks	32	36	45	33	35	36	60
	Rivers Networks	37	39	30	43	35	32	50
	Road Networks	32	46	25	38	46	46	53

Table 2. Percentages of settlements correctly predicted to be central by social network analysis indexes in comparison with settlement predicted to be central by their size. Percentages above 50 % (considered to be successful in similar analyses, Rihll/Wilson 1991, 73) are highlighted in grey.

present the same results plotted on bar charts. As can be seen from the summary table and the bar charts, all the percentages of correctly predicted central place sites for the different types of networks by the different centrality indexes are above 30%. The only exception is represented by the closeness centrality calculated on the road networks for the Early Iron Age 1 Early (950/925-900 BC ca) with the lowest rate of success at only the 25%. In particular, it is important to note that most percentages of correctly predicted central place sites are above 40%, which, in similar studies, is considered a reasonable percentage of success.[89]

When comparing the rates of correctly predicted central place sites by the different indexes, in relation to the different types of networks, the highest percentages are given by the degree centrality and the betweenness centrality calculated on the Delaunay and road networks for the later phase of the Early Iron Age (Early Iron Age 2), the Orientalizing and Archaic Ages. In particular, it seems that these percentages grow slightly from earlier to later phases. On the contrary, the sites predicted to be central by centrality indexes calculated on river communications have the worst percentages of correctly predicted central sites. In particular, the lowest percentages are related to the late Early Iron Age (Early Iron Age 2) and the Orientalizing Age.

This seems to imply that first degree connections (Delaunay networks) and terrestrial communications (road networks) were determinant factors in the formation of central places in *Latium Vetus* during the late Early Iron Age and subsequent phases (Early Iron Age 2, Orientalizing and Archaic Age). In particular, easy access to exchange and information, facilitated by a high number of neighbours (degree centrality), and the control over the flow of information and exchanges through the whole network (betweenness centrality) seem to have been key elements in their development.

However, as mentioned earlier, and in contrast with the above results, the low percentages of correctly predicted central places by centrality indexes, calculated on rivers networks, seem to indicate a less important role of fluvial routes as a mean of communications between centres at that time; at least this seems to be the case at the local, intra-regional level, within the limit of *Latium Vetus*. Enlarging the network, by including Etruscan centres on the other side of the Tiber or other centres from neighbour regions (inter-regional level), would probably give different results.

The significance of terrestrial communications

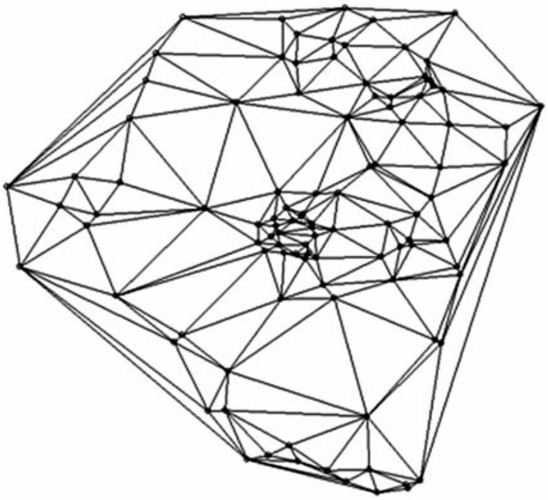


Fig. 6. Network of Early Iron Age 2 Latial settlements, modelled by using the Delaunay triangulation.

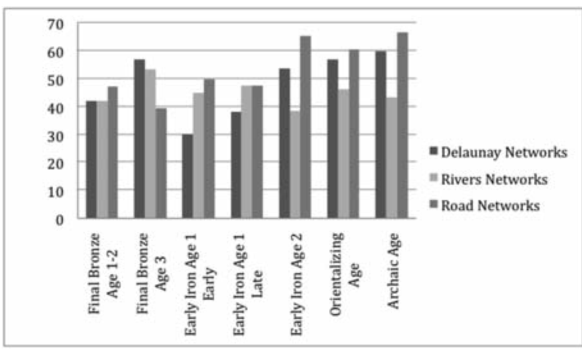


Fig. 7. Percentages of Latial settlements predicted to be central by the normalized degree centrality index in relation to settlements predicted to be central by their size.

for the Early Iron Age 2 and subsequent phases seems to be confirmed by the result of the percentage of corrected predicted central sites, based on the calculation of the closeness centrality for the road networks. This index, which measures the extent to which a node is able to communicate with all other nodes of the network, on the basis of the shortest distance, that is the minimum number of links or intermediaries, rates 47% of successfully predicted central places, which is high, althouth not quite the 50%, which can be considered fully successful.[90]

The importance of easy access to interactions and control over flow of information and goods,

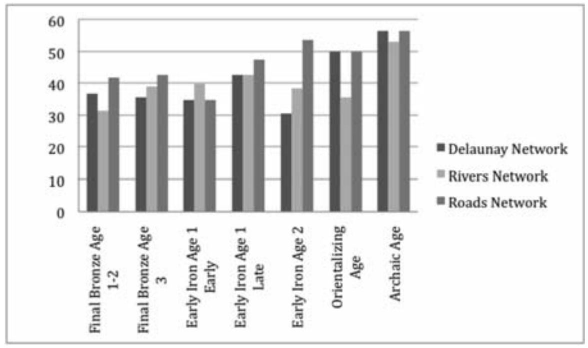


Fig.8. Percentages of Latial settlements predicted to be central by the betweenness centrality index in relation to settlements predicted to be central by their size.

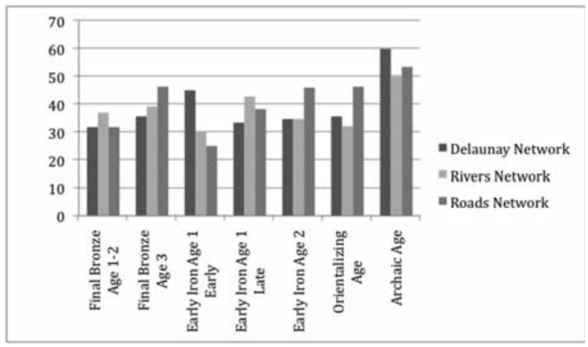


Fig. 9. Percentages of Latial settlements predicted to be central by the closeness centrality index in relation to settlements predicted to be central by their size.

especially on terrestrial routes networks, highlighted by the above results seem to be consistent with the historical interpretation by other scholars, who adopted different approaches. In particular di Gennaro suggested the importance of control over terrestrial communication routes (and therefore trade and commerce) for the development of proto-urban and urban Latial centres.[91]

Similarly, Jelle Bouma and Elisabeth van 't Lindenhout studying the architectural and spatial organization of three coastal towns of archaic Latium (6th century BC), noticed that in all of them 'one of the main regional roads crosses the urban area in a straight line' and that 'a traveller in Latium could not avoid passing through the towns'.[92] As emphasised by these authors, people passing through Latial urban centres would have been engaged in transhumance or commerce and would probably have to pay a toll for their passage.[93] In particular, these scholars advanced the hyphotesis that people controlling these passages and their tolls would have been local people, engaged in residential activities such as cults, rituals or agriculture.[94]

The greater importance of terrestrial routes for Early Iron Age and Archaic central Italy proto-urban and urban settlements, suggested by di Gennaro, Bouma and van 't Lindenhout and previous scholars, has also been demonstrated by the analysis of settlements' location, conducted by U. Rajala in Etruria[95] and myself in *Latium Vetus*.[96] Both studies detected, during the Early Iron Age (especially the later phase), and the following Orientalizing and Archaic Ages, a greater and growing importance for settlements location of accessibility to terrestrial routes, at the expense of river communications; particularly in contrast to the Final Bronze Age, when waterways seem to have been more relevant as a mean of transport.[97]

Again, these interpretations are consistent with the results from analyses conducted in this work. In fact, in relative terms, the percentages of successfully predicted central sites for the rivers networks are generally slightly higher (although the decreasing trend is not dramatically clear) for the late Final Bronze Age (Final Bronze Age 3) and the early phases of the Early Iron Age (Early Iron Age 1 Early or 950/925-900 BC ca; and Early Iron Age 1 Late, or 900-850/825 BC ca), than for the subsequent Early Iron Age 2 and Orientalizing Age. The high percentage of correctly predicted sites for the Archaic Age might indicate a renewed importance for this phase of river communications, confirmed by the appearance of a number of new key sites along the Tiber to the south of Rome, such as Rupe di S. Paolo, Forte Ostiense and Sito dell'Eur.

The success of the degree centrality and the betweenness centrality with the Delaunay network is more difficult to assess in terms of historical interpretation. The model itself is built in a way which establishes links to nearest neighbour sites; however the number of nearest neighbours (on which the calculation of the degree centrality is based) is not determined by the model, but by their geographical location, which ultimately depends on the choice of their settlers.

Therefore, it can be reasonably excluded that the success of correctly predicted central place sites by the degree centrality index, calculated on the Delaunay networks, is due to the design of the model itself. To better evaluate this result, it would be interesting to analyze more specific 'economic', 'cultural' or 'social' contacts and interactions by studying networks modelled on the basis of the distribution of imports and or particular styles of objects/pots and/or their decoration. In this way it would be possible to better

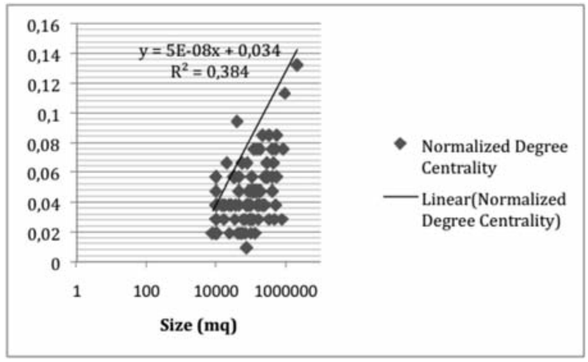


Fig. 10. Road Network of Early Iron Age 2 Latial settlements: correlation graph between settlements' size and the normalized degree centrality index.

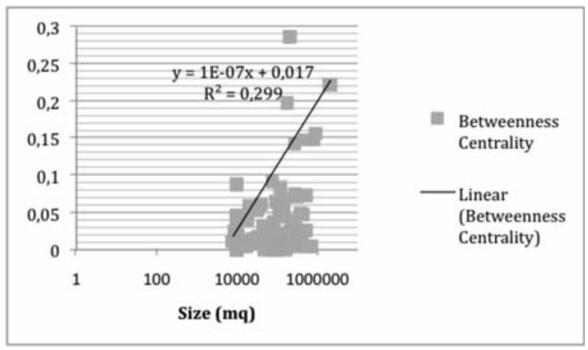


Fig. 11. Road Network of Early Iron Age 2 Latial settlements: correlation graph between settlements' size and the betweenness centrality index.

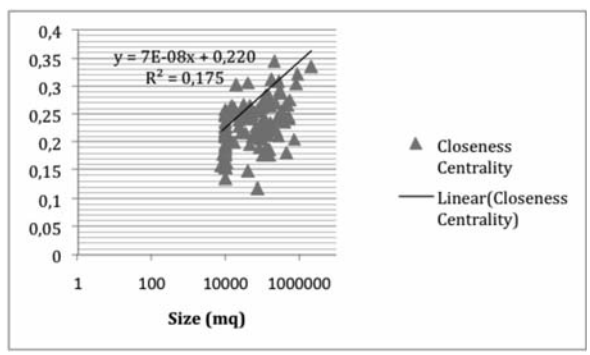


Fig. 12. Road network of Early Iron Age 2 Latial settlements: correlation graph between settlements' size and the closeness centrality index.

understand to what extent first degree contacts (direct links with no intermediaries) are more or less significant than contacts with more distant nodes of the networks (see also below the section Further Research Perspectives).[98]

Finally the correlation between social network analysis centrality indexes and settlements' size (which, as mentioned earlier, in this study is an indipendent indicator of centrality, based on archaeological and historical knowledge), has been verified statistically through regression analysis. Figures 10, 11 and 12 show, for example, the graphs of the correlation between settlements' size and social network analysis centrality indexes, calculated for the road networks during the Early Iron Age 2.

As shown in the graphs, the correlation between settlements' size and the normalized degree centrality appears to be positive and significant with a correlation coefficient value (R^2) of 0.384; the correlation between settlements' size and betweenness centrality is also reasonably strong, with a correlation coefficient value of 0.299. On the contrary, the correlation appears to be weaker for the closeness centrality with a correlation coefficient value of 0.175.

Figures 13, 14 and 15 show the results of the comparison of the coefficients of the correlations between settlements' size and their grade of centrality, based on the different centrality indexes, calculated for the various networks in the different phases. From these graphs, the correlation between settlements' size and social network analysis centrality indexes scores seems to be stronger for the degree centrality and the betweeness centrality; especially those calculated on road networks during the Early Iron Age and subsequent phases, with correlation coefficient values (R^2) between 0.2 and 0.5.

This is consistent with the results of the analyses, which gave particularly high percentages of correctly predicted central place sites by the degree centrality and the betweeness centrality calculated on road networks. However, while in those cases the percentage of correctly predicted central place sites increased in the later phase of the Early Iron Age (Early Iron Age 2) and subsequent phases (Orientalizing and Archaic Ages), the strenght of the correlation between settlements' size and the degree and betweeness centrality indexes seemed to follow, in relative terms, an opposite decreasing trend.

Differently from the other two indexes, while relatively higher for the road networks, the coefficient values of the correlation between settlements' size and the closeness centrality index scores, are never higher than 0.2. Similarly, the coefficient values of the correlation between settlements' size and centrality indexes scores for the Delaunay networks are generally rather low, nor-

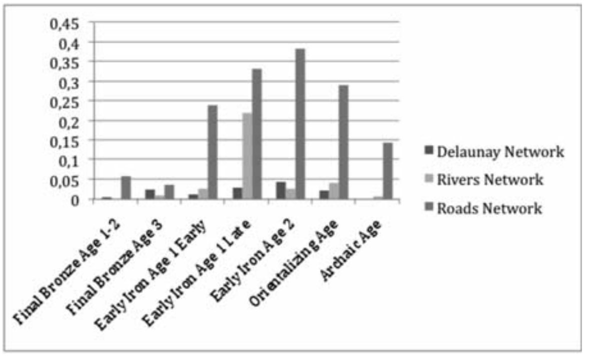


Fig. 13. Histogram of statistical correlation (R2) values between Latial settlements' size and their normalized degree centrality index scores.

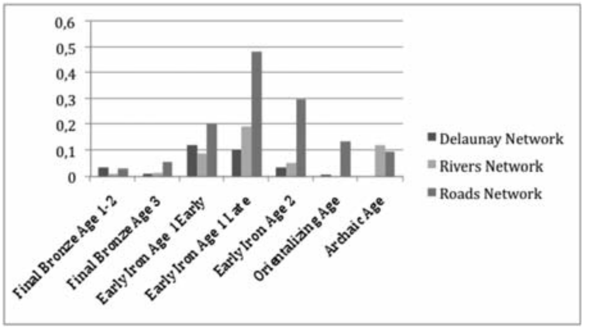


Fig. 14. Histogram of statistical correlation (R2) values between Latial settlements' size and their betweenness centrality index scores.

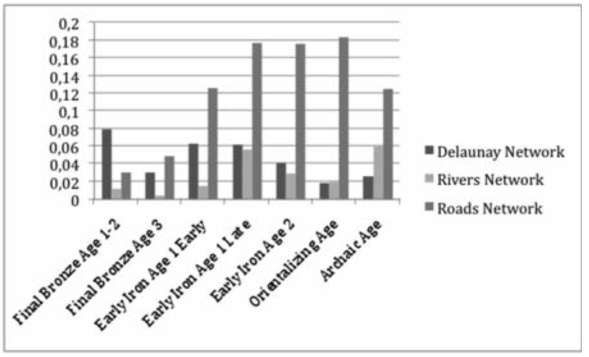


Fig. 15. Histogram of statistical correlation (R2) values between Latial settlements size and their closeness centrality index scores.

mally below 0.1-0.2. Finally, the coefficient values of the correlation between settlements' size and centrality indexes scores, calculated on the rivers networks, only appeared to be relatively high for all three indexes, during the Early Iron Age 1 Late (900-850/825 BC ca), and only for the closeness and betweeness centrality, during the Archaic Age (580-509 BC ca).

To conclude, the application of regression analysis to mathematically evaluate the correlation between settlements' size (as already mentioned, an 'archaeological' indicator of centrality used as indipendent benchmark to evaluate centrality predicted by social network analysis indexes) and social network analysis centrality indexes, calculated on the different types of networks, seemed to validate the good correspondence between larger, nucleated settlements (central places) and higher degree centrality and betweeness centrality scores.

It also confirmed the greater importance of terrestrial routes for the developement of Latial central place sites during the late Early Iron Age and subsequent phases; although, as mentioned earlier, in relative terms, the percentage of correctly predicted sites has an increasing trend from earlier to later phases, and the values of the correlation coefficient between settlements' size and centrality indexes have an opposite trend. Finally the greater significance of rivers communication for settlement location in the Final Bronze Age, partially suggested by the analysis results did not appear prominent from the statistical assessment.

Social Network Analysis and Proto-Urban/Urban Centres in Central Italy: Further Research Perspectives

In the present application of social network analysis in relation to proto-urban and urban centres in middle Tyrrhenian Italy only a limited number of networks have been considered: an ideally geometric network, rivers and roads. This application has been based on the assumption that roads and rivers imply contacts and exchanges of goods and ideas. However, further enhancements of this project could consider specific indicators of social relationships or cultural bonds such as pot decorations, imported goods or other characteristics of the settlements such as the presence of city fortifications or sanctuaries.

Literary sources could also be used to assess the extent of religious or political networks. For example, the participants in the Latin League, which annually celebrated the Latin feast on the Monte Cavo in the Alban Hills could be analysed as a network while the progressive conquests of Rome in Latium and further into Italy could be studied as an expanding network. Epigraphic evidence, such as Etruscan onomastic inscriptions could also be used to explore inter-cities links and family polities and alliances.

In addition, the area of study could be enlarged and a number of pre-Roman populations could be taken into account such as Etruria, the Sabine, Faliscan and Capenates regions, allowing for new comparative perspectives and possibly new insight on boundary issues among those communities. With particular reference to permeable frontiers, another potential case study would be the river Tiber and the network of sites along its basin.

When considering social network analysis as a tool, this article has presented a systemic approach, which considered the networks in their totality; however, an ego-network (or individual) approach is also possible, which considers particular, singular, sites in relation to all others. In this case it would be interesting to choose a few case studies, considering sites which succeeded and sites which did not succeed, and compare their position and characteristics within the network.[99]

In this application, specific social network analysis software, such as Pajek, has been adopted for the analysis. However, social network analysis (especially in relation to spatial problems and transportation) can be implemented within a GIS environment too.[100] In particular, a specific utility (SANET) has been developed by Atsu Okabe, Kei-ichi Okunuki, Shino Shiode and their team to perform spatial analysis on networks and analyse specific events that might occur along a network, such as car crashes on roads etc.[101]

With specific reference to spatial analysis within archaeology, similar questions and developments are being carried out by using other tools/methods such as Space Syntax. Although, to my knowledge, this method has been mainly used within an urban or built environment (infra-site), it could be probably used for wider scale (intersites) studies as well. Again, in the Netherlands I had the occasion to learn about this topic from Hanna Stöger and the Space Syntax research group from Leiden University.[102]

When considering social network analysis as an approach for the study of urbanization and the development of central places, this article has demonstrated the advantages of considering cities as a network, where not only nearest neighbours settlements are taken into account (as for example in traditional central place theory and other locational models) but also more distant settlements (within the whole system). However, as suggested by Douglas R. White,[103] the future challenge seems to be the integration, rather than the opposition between apparently conflicting models, such as the rank-size rule and social network theory, and/or the integration of these models with the theory of social fission versus corporate community, recently introduced in the debate on early Greek urbanization by John Bintliff.[104]

On a more theoretical level Actor-Network-Theory, introduced by Bruno Latour and other scholars, might provide the philosophical background rarely made explicit in social network applications. According to Latour, both technical networks (such as electricity, trains, sewages, internet and so on) and social networks can be represented by dots and lines but the former exist objectively, independently from the researcher, while the latter only 'represents one informal way of associating together human agents'.[105] In other words, according to Latour, '*work net*' or '*action net*', is only a concept or a way for sociologists to make sense of intangible realities such as 'society', 'culture', 'fields' etc.[106]

At this point, it should be noted that one of the stronger features of social network analysis is its ability to investigate and compare 'underlying frames'[107] that connect different agents, which might, or might not, be human. In this sense a deeper dialogue between actor network theorists (ANTs) and social network analysts, while complex, is desirable and potentially very rewarding.

Conclusions

This article presented an application of social network analysis principles to archaeological data. The purpose of the work was to verify the potential of social network analysis centrality indexes by using them to predict the emergence of central places. The case study has been built on Latial settlements from the Final Bronze Age to the Archaic Age. In fact, the main points of the evolution of these sites from small and dispersed Bronze Age villages to centralised, nucleated and large proto-urban and urban centres are already known from archaeological and historical evidence.

In this way it has been possible to compare sites predicted to be central by social network centrality indexes against sites already known to be central according to their size and contextual archaeological evidence. The experiment demonstrated that there is positive correlation between known settlements of given sizes with some social network centrality indexes.

In particular, the actor degree centrality, which is based on the number of its direct links to other actors/nodes (first degree neighbours), and the betweeness centrality, which measures the probability of a node to be visited if communications are exchanged between all other pairs of nodes in the network, via the shortest distance or geodesic (the minimum number of links/intermediaries), scored the highest percentage of correctly predicted central place sites.

These results seemed to indicate that access to information and interactions by the mean of numerous first degree neighbours (as indicated by the good results given by the degree centrality), and the control over flow of communications and exchanges (indicated by the good rates of correct predictions given by the betweeness centrality), were important factors in the development of proto-urban and urban central places in *Latium Vetus*. On the contrary, closeness and short distance (minimum number of links) to all other nodes of the network, seemed to have been a less important element, as indicated by the poorer percentages of central place sites correctly predicted by the closeness centrality index.

The degree centrality and the betweeness centrality indexes were particularly successful, when calculated on the Delaunay and the road networks, during the Early Iron Age 2, Orientalizing and Archaic Ages. While the social network analysis indexes calculated on rivers network gave the poorest percentage of correctly predicted central place sites, although in relative terms those of the Final Bronze Age and Early Iron Age 1 were slightly higher than those of later phases.

The high prediction rates of the degree centrality and the betweeness centrality on roads networks during the later phase of the Early Iron Age and subsequent phases and the relatively higher scores of the centrality indexes on the rivers networks during the Final Bronze Age and the first phases of the Early Iron Age, are consistent with the historical interpretation already advanced by other scholars, who adopted different approaches.

In fact, a number of studies have independently suggested that, at least at a local, intra-regional level, in *Latium Vetus* (and also in Etruria) the importance of rivers as a mean of communication declined from the Final Bronze Age to the Early Iron Age, when terrestrial routes and their control, became more important in the formation of central places (proto-urban and urban centres).

As mentioned above, the positive prediction results of the social network centrality indexes, calculated on the Delaunay networks are more difficult to evaluate. It can be noted that they are consistent with the poorer results of the closeness centrality index and point to a greater importance of interaction with close neighbours than more distant nodes. This might be logical, because in this case study 'contacts' and 'interactions' have been assumed to be equal and reciprocal in any direction and the main variables considered have been ultimatively 'geographical', such as rivers, terrestrial routes and settlement reciprocal location.

In this sense, as previously discussed, it would be interesting to compare the results from this study with analyses conducted on networks based on 'directed' and possibly 'valued' ecomonic, cultural and social relations, indicated by 'cultural' and 'social markers' such as the distribution of imports, and/or particular styles/decorations of pots and objects.

Finally, the major role of interactions with neighbours (degree centrality) and the importance of the control over communication and exchanges (betweeness centrality) especially on terrestrial routes during the later part of the Early Iron Age, Orientalizing and Archaic Age, indicated by the analyses, has been confirmed by the statistical evaluation of the results; although while the percentage of predicted correct central place sites augmented in the later phases the correlation between settlements' size and centrality indexes became relatively weaker. As mentioned earlier, the importance of rivers communications for central place sites during the Bronze Age and early phases of the Early Iron Age, suggested by analyses, was not proved by statistical evaluation.

To conclude, while the association between central places and some of the social network analysis indexes used in this study, could not conclusively be proved by statistical assessment, the consistency of the results with indipendent archaeological and historical interpretation by different scholars, who have adopted different approaches, demonstrates that social network analysis techniques can offer great potential in archaeological research, and it is worth pursuing new studies which apply its principles.

APPENDIX 1

Final Bronze Age Latial settlements (LS = known only from ancient authors)

Settlement	**Area (ha)**	**Final Bronze Age 1-2 (1175/1150-1050/1025 BC ca)**	**Final Bronze Age 3 (1050/1025-950/925 BC ca)**
Pratica di Mare (*Lavinium*)	23		x
Alba-Tofetti	21	x	x
Gabii	18	x	x
Roma-Palatino	17	x	x
Ardea-Civitavecchia	17		x
C. della Fragola	17	x	x
M. di Leva	13	x	
Marino (*Castrimoenium*)	12		x (LS)
Labico (*Bola?*)	12		x (LS)
M. Morra	10	x	x
Roma-Campidoglio	10	x	x
Valmontone (*Tolerium?*)	10		x (LS)
Buon Riposo (*Longula?*)	10		x (LS)
Alba-Cappuccini	10	x	x
C. del Vescovo	9	x	x
M. S. Angelo in Arcese (*Aefula?*)	8	x	x
M. Cugno (*Ficana*)	8	x	x
Fontan Tempesta	8		x
Borgo Sabotino s.s.a.	8	x	x
M. Savello	8		x
Ariccia (*Aricia*)	7		x (LS)

Settlement	Area (ha)	Final Bronze Age 1-2 (1175/1150-1050/1025 BC ca)	Final Bronze Age 3 (1050/1025-950/925 BC ca)
Fosso della Bottaccia	7	x	x
Albano Laziale	7		x
C. dell'Asino	6		x
Porta Neola	6	x	x
Gallicano (*Pedum?*)	5		x (LS)
Casale Nuovo	5	x	
Corcolle (*Querquetulum?*)	5	x	x
Tivoli (*Tibur*)	5		x
Ficulea-Acropoli	5	x	x
C. Rotondo	5	x	
Tor de Cenci	5	x	x
Campo del Fico	5	x	x
Castel S. Pietro	4		x
C. della Mola	4	x	
Castellaccio	4		x
C. Ripoli	4	x	x
Montecelio-M. Albano (*Corniculum?*)	4	x	x
Lavinium-Acropoli	4	x	
T. Torrino (*Politorium*?)	4	x	x
Ardea-Acropoli	4	x	x
M. Artemisio	4	x	x
Montecelio-centro (*Corniculum?*)	4	x	x
Castelgandolfo	3		x
M. dei Ferrari	3	x	x
M. Cavo	3		x
Sorgente Preziosa	3		x
Maschio d'Ariano (*Cusuetani?*)	3	x	x
Satricum-Acropoli	3	x	x
Fosso di S. Colomba	3	x	x
Torre Acqua Raming	3		x
Tusculum-Acropoli	3	x	x
Velletri	2		x
M. Crescenzio (*Apiolae?*)	2		x
Casale della Perna	2	x	x
Tor Caldara	2		x
Antium-Acropoli	2	x	x
A.A. Laurentina	2	x	x
Sacco Muro	2	x	x
Grottaferrata-S.V.	2		x
M. Cucco	1		x
Poggio Tulliano	1		x
La Rustica (*Caenina*)-Acropoli	0	x	x
Torre del Giglio	1	x	x
Bosco Nettuno	1	x	x
Pelliccione	1	x	x
Le Grottacce-villa	1	x	

Settlement	Area (ha)	Final Bronze Age 1-2 (1175/1150-1050/1025 BC ca)	Final Bronze Age 3 (1050/1025-950/925 BC ca)
Stop 4-La Banca	1	x	x
Via Riserve Nuove	1	x	x
Villa Maldura	1		x
Valle Violata B	1		x
Via Lucrezia Romana	1	x	x
Santuario di Diana	1		x
Camposelva	1	x	x
O. del C.-Quadrato	1	x	
Casa Calda	1	x	
Pozzo Carpino	1		x
O.del C.-Tor di Mezz. A	1	x	x
Cave di Breccia	1	x	
S. Pastore	1	x	x
Fosso Tavernucole	1	x	x
Fosso dell'Inviolata	1	x	
Le Caprine	1	x	x
Lago delle Colonnelle	1	x	x
Casale Redicicoli	1	x	
La Fibbia	1	x	x
Fosso Moscarello	1	x	x
Tivoli-Via di Poli	1	x	x
Ostia antica-borgo	1	x	x
Coste Caselle	1		x
Le Salzare	1		x
Prato della Corte	1		x
Castel Madama	1	x	
Paluzzi	1	x	x
O. del C.-Tor di Mezz. B	1	x	x
Marino-Conv. di C.	1		x
Casale Licia	1		x

Early Iron Age, orientalizing and archaic Latial settlements (LS = known only from ancient authors)

Settlement	Area (Ha)	Early Iron Age 1 Early (950/925-900 BC ca)	Early Iron Age 1 Late (900-850/825 BC ca)	Early Iron Age 2 (850/825-750 BC ca)	Orientalizing Age (750-580 BC ca)	Archaic Age (580-509 BC ca)
Roma	365		x (202)	x (210)	x (275)	x (365)
Sito dell'EUR	147				x	x
Gabii	92	x	x	x	x	x
Ardea-Casalazzara	85			x	x	x
Alba	76	x	x	x	x	x
Ponte Mammolo	65				x	x
Roma-Palatino	60	x				
Marco Simone Vecchio (*Ficulea?*)	55		x	x	x	x
Roma-Campidoglio	55	x				

Settlement	**Area (Ha)**	**Early Iron Age 1 Early (950/925-900 BC ca)**	**Early Iron Age 1 Late (900-850/825 BC ca)**	**Early Iron Age 2 (850/825-750 BC ca)**	**Orientalizing Age (750-580 BC ca)**	**Archaic Age (580-509 BC ca)**
Colle della Coedra (*Cora?*)	54	x	x	x	x	
Santa Maria delle Mole (*Mugilla?*)	54					x
Crustumerium	52	x	x	x	x	x
Borgo Le Ferriere (*Satricum*)	51	x	x	x	x	x
Astura	46	x	x	x		
Ardea-Civitavecchia	46		x			
Cisterna di Latina (*Pometia?*)	45	x	x	x	x	x
Villa Spada (*Fidenae*)	41	x	x		x	x
Gallicano (*Pedum?*)	40	x (LS)	x (LS)	x (LS)	x (LS)	x (LS)
Valmontone (*Tolerium?*)	39	x	x	x	x	x
Casale Capobianco (*Cameria?*)	34			x	x	x
Corcolle (*Querquetulum?*)	34	x	x	x	x	x
Pratica di Mare (*Lavinium*)	33	x	x	x	x	x
Rocca Priora (*Corbio?*)	32					x
Velletri (*Velitrae*)	29	x	x	x	x	x
Tivoli (*Tibur*)	28	x	x	x	x	x
Lunghezza (*Collatia?*)	28	x	x	x	x	x
Monte Cugno (*Ficana*)	25		x	x	x	x
Palestrina (*Praenestae*)	24	x	x	x	x	x
Tenuta Torrino (*Politorium?*)	23			x	x	x
La Giostra (*Tellenae?*)	21			x	x	x
San Giovanni in Camporazio	21	x	x	x	x	x
Rocca Massima (*Carventum?*)	20					x
Mentana (*Nomentum?*)	20			x	x	
Monte Giove (*Corioli?*)	20	x	x	x	x	x
Antemnae	17			x	x	x
Colle della Fragola	17	x	x	x	x	
Monte Fiore	17					x
Sant'Angelo Romano	16			x	x	x
Montecelio (*Corniculum?*)	15	x	x	x	x	x
Colonna (*Labici?*)	15	x	x	x	x	x
Anzio (*Antium*)	15		x	x	x	x
Lanuvio (*Lanuvium*)	14	x	x	x	x	x
Guadagnolo	13	x	x	x		
Tuscolo (*Tusculum*)	13	x	x	x	x	x
Marino (*Castrimoenium*)	12	x (LS)	x (LS)	x (LS)	x (LS)	x (LS)
Labico (*Bola?*)	12	x (LS)	x (LS)	x (LS)	x (LS)	x (LS)
Colli Santo Stefano	12			x	x	x
Ariccia (*Aricia*)	12	x (LS)	x (LS)	x (LS)	x (LS)	x (LS)
Campo del Fico	11		x	x	x	x
Castel di Decima (*Solonium?*)	11	x	x	x	x	x
Castel Savello (*Apiolae?*)	11	x	x	x		
Monte Morra	10	x	x	x		
Tenuta Trafusa	10			x	x	x

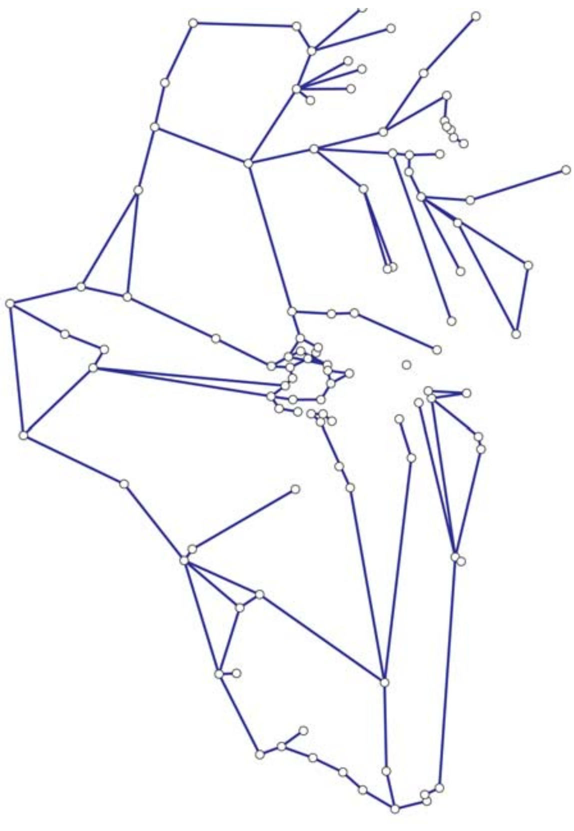
Settlement	Area (Ha)	Early Iron Age 1 Early (950/925-900 BC ca)	Early Iron Age 1 Late (900-850/825 BC ca)	Early Iron Age 2 (850/825-750 BC ca)	Orientalizing Age (750-580 BC ca)	Archaic Age (580-509 BC ca)
Buon Riposo (*Longula?*)	10	x (LS)	x (LS)	x (LS)	x (LS)	x (LS)
Torre Sant'Anastasio	10	x	x	x	x	x
Fosso del Cupo	10	x	x	x		
Colle del Vescovo	9	x	x	x	x	x
Rupe di San Paolo	9					x
Colle delle Crocette	8			x	x	
Monte Sant'Angelo in Arcese (*Aefula?*)	8		x	x	x	x
Colle Lepre	8		x	x		x
Fontan Tempesta	8	x	x			
M. Savell	8	x	x	x	x	
Borgo Sabotino Sopra Strada Alta	8	x	x	x	x	
Monte Carnale	8	x		x	x	x
Le Ces	7			x	x	
Fosso della Bottaccia	7	x	x			
Albano Laziale	7	x	x	x	x	
Buglioncino	7					x
Porta Neola	6	x	x	x	x	x
Forte Ostiense	6					x
Monte Cavo	6	x	x	x	x	
Colle di Fuori	6		x	x		
L'Altare	6	x	x	x	x	
Castelgandolfo	5	x		x	x	x
Marco Simone (*Ficulea?*)-Acropoli	5	x				
Passerano	5		x	x	x	x
Colle Rotondo	5	x	x		x	
Tor de Cenci	5					x
Colle Fiorito	5			x	x	x
Trigoria	4					x
Castellaccio	4	x	x		x	
Castellaccio	4			x	x	
Colle Ripoli	4	x		x	x	x
La Rustica (*Caenina?*)	4			x	x	x
Ardea-Acropol	4	x				
Monte Artemisio	4	x	x	x	x	x
Colle Tasso	4	x	x	x	x	
Casal Boccone	3					x
Monte dei Ferrari	3	x	x	x	x	x
Colle Cimino	3	x	x	x		
Monte Crescenzio (*Bovillae?*)	3	x		x	x	
Sorgente Preziosa	3	x	x		x	
Casale Redicicoli 2	3					x
Maschio d'Ariano	3	x	x	x	x	x

Settlement	Area (Ha)	Early Iron Age 1 Early (950/925-900 BC ca)	Early Iron Age 1 Late (900-850/825 BC ca)	Early Iron Age 2 (850/825-750 BC ca)	Orientalizing Age (750-580 BC ca)	Archaic Age (580-509 BC ca)
Monte Cucco	2	x		x		
Casale della Perna	2	x	x	x	x	
Tor Caldara	2		x			
Acqua Acetosa Laurentina	2	x	x	x	x	x
Colle Cesarano	2			x	x	x
Grottaferrata-Sopra Villa	2		x	x		
Galloro-Monte Gentile	2	x	x	x	x	
La Pasolina	1	x		x	x	
Poggio Tulliano	1	x	x			
Monte Arcese	1	x	x	x	x	x
Loricino	1			x		
Cretarossa	1			x	x	x
Bosco Nettuno	1	x	x			
Pelliccione	1	x	x		x	x
Torre Astura	1			x	x	
Acciarella	1	x	x	x		
Quartaccio	1	x	x	x		
Quartaccio Capanna	1	x	x	x		
Stop 4-La Banca	1	x	x			
Via Riserve Nuove	1	x				
Villa Maldura	1	x		x	x	
Tor delle Streghe	1				x	
Valle Violata B	1	x				
Camposelva	1	x	x			
Pozzo Carpino	1	x	x	x	x	
Finocchierelle	1	x	x	x		
Piani di Caiano	1	x	x	x		
Pescaccio	1	x	x	x	x	
Colle Pardo	1			x		
Vallericcia-Via di Mezzo	1			x	x	
Marco Simone Laghetto A	1			x	x	
San Pastore	1	x	x	x		
Le Caprine	1	x	x	x	x	x
La Fibbia	1	x	x			
Tivoli-Via di Poli	1	x				
Ostia antica-borgo	1	x	x			
Coste Caselle	1		x	x		
Orti Torlonia	1	x	x	x	x	
Prato della Corte	1	x	x	x	x	
Nettuno	1	x	x	x		
Paluzzi	1		x	x	x	
Casal Bruciato	1	x	x	x	x	x
Marino-Convento di Camporesi	1		x	x		
Mimose	1	x		x		

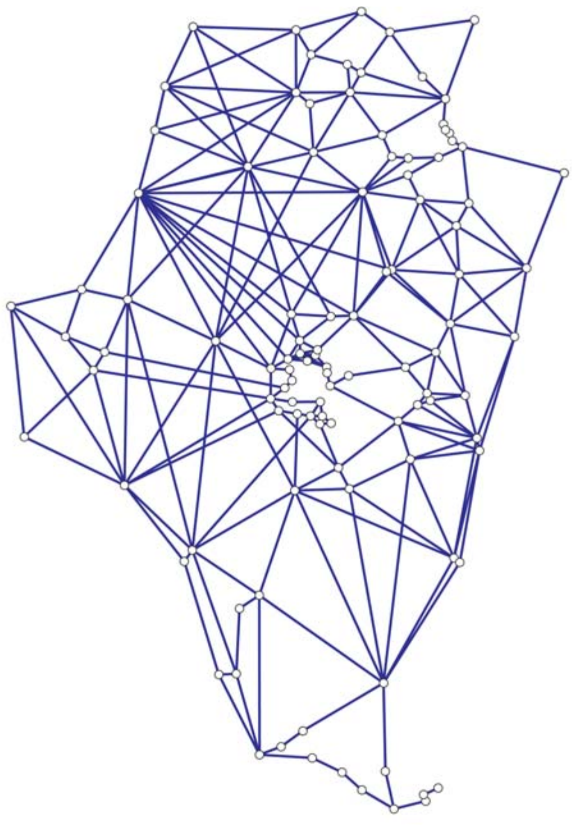
Settlement	**Area (Ha)**	**Early Iron Age 1 Early (950/925-900 BC ca)**	**Early Iron Age 1 Late (900-850/825 BC ca)**	**Early Iron Age 2 (850/825-750 BC ca)**	**Orientalizing Age (750-580 BC ca)**	**Archaic Age (580-509 BC ca)**
Casale Licia (*Bovillae?*)	1	x	x			
Palazzolo	1			x		
Monteripoli	1	x	x	x	x	x
Colle Ripoli-bis	1	x		x	x	x

Appendix 2

A. Rivers Network of Early Iron Age 2 Latial Settlements.



B. Road Network of Early Iron Age 2 Latial Settlements.



Notes

* This project was originally designed in collaboration with Dr. Bjoern Menze, under the auspices of the TiMe (Transformations in the Mediterranean 1200-500 BC) project, conducted by a team of scholars lead by Prof. Manfred Bietak of Vienna University (2006-2008). It was then initiated during the spring semester 2009 at the GCSC, Graduate Centre for the Study of Culture, of the Justus Leibig Universität in Giessen, Germany and conducted at NIAS, Netherlands Institute for Advanced Study in the Humanities and Social Sciences during the academic year 2009-2010. In both institutions the research profited from an interdisciplinary environment particularly favourable to such research. In particular, at Giessen I had insightful discussions with colleagues from the archaeology department such as Prof. Wolfram Martini and Prof. Anja Klöckner, the geography department with Dr. Stefan Henneman and doctoral researchers from the GCSC, namely Thies Bötcher and Alexander Friedrich. While at NIAS the project profited from precious inputs from Prof. Jan van Leewen, Dr. Jeroen Salman, Dr. Antheus Janse, Dr. Marten Jan Bok, Dr. Sholpan Gaisina and Dr. Joanna Tyrowic. In particular NIAS gave me the opportunity of collaborating with Prof. Wouter de Nooy, one of the leading experts in social network analysis, who provided help and support from the very beginning of the project. Finally I wish to thank Dr. Albert Nijboer, Prof. Peter Attema and their students, with Dr. Luca Alessandri, for their precious comments, when I first presented early results of this project in Groningen University; and Dr. Simon Stoddart, Dr. Francesco di Gennaro, Prof. Alessandro Guidi, Prof. John Bintliff and anonymous reviewers for their comments on an early draft of the article. All responsibility for mistakes, inaccuracies or omissions remains with the author.

1 Absolute chronologies adopted in this article take into consideration results from recent studies on Bronze Age and Early Iron Age chronologies in central Italy, based on dendrochronology and C 14 dating, such as Pacciarelli 2001, 2005; Nijboer 2005.

2 See e.g. Meijers 2007 for a comparison between a traditional locational model, such as the central place theory, and the new network paradigm.

3 In this study 'road' and 'road networks' refer to terrestrial routes, used in pre-historic, proto-historic and archaic times rather than the formally constructed roads from the later Republican and Imperial Periods.

4 For example Buchanan 1998; see also Johnson 2001; Barabási 2002; Barabási 2003 and Watts 2003.

5 Schnettler 2009.

6 Travers/Milgram 1969.

7 Knoke/Yang 2008.

8 See for example Barabási 2003 and Watts 2003 for non specialist publications; or Newman et al. 2006 for a collection of more technical articles.

9 UCINET, Pajek and Visone for example but see also the review by Huisman/van Duijn 2005.

10 For example Scott 2000 or Knoke/Yang 2008.

11 Stegbauer 2008 and Krempel 2008.

12 See the classic manual Wasserman/Faust 2007, complemented by Carrington et al. 2005 or the more accessible Knoke/Yang 2008.

13 For example Mayfair Mei-Hui 1994; see also Schweizer 1996a, b; Hage/Harary 1991, 1996.

14 Lang 1997.

15 Kappelhoff 2004 or a number of German PhD researches such as Walter 2004 or Müller-Prothmann 2006.

16 Batty 2003; Fisher 2003; Masucci et al. 2009.

17 Ter Wal/Boschma 2009.

18 Barabási/Oltvai 2004.

19 For example Gatrell 2005 on epidemic diffusion.

20 Alexander/Danowski 1990.

21 Ruffini 2008.

22 Padgett 2001; Padgett/Ansell 1993; Shaw 2005 and McLean, P.D. 2007.

23 For example, the group studying the reception of Dutch art in Asia, at NIAS during the academic year 2009/2010, has organized a session on *Social Network Analysis of Art Markets and Art Worlds in the Low Countries*, within the *Historians of Netherlandish Art Conference, 'Crossing the Boundaries'*, held in Amsterdam on the 27th-29th of May 2010.

24 Ikegami 2005.

25 Orsen Jr. 2005.

26 This type of research is, for example, being conducted by Alexander Friedrich, a doctoral candidate at the Graduate Centre for the Study of Culture (CSGC), of the Justus-Liebig Universität in Giessen, Germany.

27 Knoke/Yang 2008, 6-9.

28 Moreno 1934.

29 Knoke/Yang 2008, 45.

30 Harary 1969.

31 See for example Krempel 2008, 215-216, fig. 1.

32 Knoke/Yang 2008, 4.

33 Lock/Pouncett 2007.

34 Haggett/Chorley 1969.

35 Müller 2009.

36 Pitts 1965, 1978-1979.

37 Dicks 1972 with discussion by Langton et al. 1972; and Hutchinson 1972.

38 Rothman 1987.

39 Irwin 1983; Irwin-Williams 1977.

40 Santley 1991; Jenkins 2001; Graham 2006a, b, c, 2007, 2009; Sindbaek 2007b, a; and Isaksen 2008.

41 Mackie 2001; Alexander 2008; Classen 2004; Classen in press; Classen/Zimmerman 2004.

42 Wilkins 1991 and Smith 2005b.

43 Nuninger 2002, 2003.

44 A new project on *Tracing Networks. Craft Traditions in the Ancient Mediterranean and Beyond*, conducted since 2009 by the Universities of Leicester, Exeter and Glasgow and funded by the Leverhuulme Trust, combines theories such as chaîne opératoire and cross-craft interaction, in order to study 'networks of crafts-people and craft traditions, asking how and why traditions, techniques and technologies change and cross cultural boundaries, and exploring the impact of this phenomenon', from the Project web page Introduction at http://www.tracingnetworks.ac.uk/content/web/introduction.jsp (24 February 2011).

45 Wilkins 1991; Malkin 2003; Smith 2005b; Moore 2007; Sindbaek 2007a; and Malkin et al. 2009.

46 Graham/Steiner 2006; Rihll/Wilson 1991; Evans et al. 2008, 2009.

47 Partially initiated by Brughmans 2010.

48 Cornell 1995.

49 Di Gennaro/Peroni 1986; Peroni 1989, 1994, 1996, 2000; Stoddart/Spivey 1990; di Gennaro 1986a, 1988, 2000; di Gennaro/Guidi 2000; Guidi 1989, 2006; Barker/Rasmussen 1998; Smith 1996, 2005a; Pacciarelli 2001; and Torelli 2000.

50 For this definition see Vanzetti 2004.

[51] Di Gennaro/Peroni 1986; Peroni 1989, 1994, 1996, 2000; Stoddart/Spivey 1990; di Gennaro 1986a, 1988, 2000; Guidi 1989, 2006; Barker/Rasmussen 1998; Pacciarelli 2001; and more recently Rendeli 2009.
[52] See various contributions in Fontaine 2010.
[53] See di Gennaro/Guidi 2009 on central Italy or Fulminante/Stoddart 2012 for a comparative perspective on Etruria and *Latium Vetus*.
[54] As mentioned earlier, new research shows that these generalisations, while useful, are now less valid because a greater local variability has to be taken into account (Fulminante/Stoddart 2012). For example Final Bronze Age material is known from Tarquinia both from the citadel and the plateau (Mandolesi 1999), while material earlier than the Iron Age is known from *Veii*, only from the *arx* of Isola Farnese (Bartoloni 2006); in both cases it has been suggested that the citadels (Civita di Castellina for Tarquinia and Isola Farnese for *Veii*) migh have played a major role in the general inhabitation of the nearby plateaux, according to a model of occupation previously observed solely in *Latium Vetus*.
[55] Pacciarelli 2001.
[56] Pacciarelli 1994, 229.
[57] Pacciarelli 1994, 240-241.
[58] Pacciarelli 2001, 120-128.
[59] Pacciarelli 2001, 120-128.
[60] Fulminante forthcoming.
[61] Di Gennaro 1986; see also di Gennaro/Barbaro 2008.
[62] De Nooy et al. 2005. In addition, because this project has been conducted in the Netherlands thanks to a generous residential fellowship granted by the Netherlands Institute for Advanced Study in the Humanities and Social Sciences (NIAS), it has been possible to meet Wouter de Nooy, one of the developers of the software and leading expert in the discipline, who was very kind with his precious help and encouragement.
[63] Guaitoli 1981.
[64] Colonna 1976, pl.1.
[65] Belardelli et al. 2007.
[66] Kossinets 2006.
[67] Vanzetti 2004.
[68] For a number of examples see Fulminante 2003.
[69] For a brief discussion see Carandini 1997, 459-463 with references.
[70] Knoke/Yang 2008, 63.
[71] Knoke/Yang 2008, 63.
[72] Knoke/Yang 2008, 63, who quotes Wasserman/Faust 2007, 179.
[73] Knoke/Yang 2008, 63-64.
[74] Knoke/Yang 2008, 68.
[75] Knoke/Yang 2008, 68-69 but see also the seminal papers by Freeman 1977 and White/Borgatti 1994.
[76] Freeman 1977, quoted in Knoke/Yang 2008, 68.
[77] Knoke/Yang 2008, 68.
[78] Knoke/Yang 2008, 68, who quotes Wasserman/Faust 2007, 190.
[79] Knoke/Yang 2008, 68.
[80] Sabidussi 1966.
[81] Knoke/Yang 2008, 65.
[82] Beauchamp 1965, quoted by Knoke/Yang 2008, 66.
[83] Already used by Broodbank 2000.
[84] Evans et al. 2008, 2009.
[85] Bietti Sestieri/Sebastiani 1986 and Gianni 1991.
[86] Guaitoli 1981, 31 fig. 5.
[87] Colonna 1976, pl.1.
[88] Rihll/Wilson 1991, 73.
[89] Rihll/Wilson 1991, 73.
[90] Rihll/Wilson 1991, 73.
[91] Di Gennaro 2000.
[92] Bouma/van 't Lindenhout 1996-1997, 310.
[93] Bouma/van 't Lindenhout 1996-1997, 311; see also Ampolo et al. 1980, 150.
[94] Bouma/van 't Lindenhout 1996-1997, 311.
[95] Rajala 1999.
[96] Fulminante forthcoming.
[97] See also Bietti Sestieri/Sebastiani 1986 and Angle et al. 1992.
[98] For a similar approach see Classen/Zimmerman 2004.
[99] I am currently exploring some of these strands of research, whose results will be presented in other works. I thank again Wouter de Nooy for discussing with me some of these ideas, in particular the potential of the ego-network approach.
[100] See, for example, Batty 2003 or Fisher 2003.
[101] Okabe et al. 2006 and the website developed since 2009: http://sanet.csis.u-tokyo.ac.jp/index.html, (24th February 2011)
[102] See, for example, Stöger 2008.
[103] White 2003; see already in this direction, also Santley 1991, combining central place with graph theory.
[104] See for example Bintliff 1999, 2000, 2002, 2007.
[105] Latour 2005, 129, quoting Mark Granovetter.
[106] Latour 2005, 130-133.
[107] It is here preferred to use the term 'frame' because the term 'structure' might imply something fixed and immutable and emphasise a static view rather than something more dynamic and agile.

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