

# Network Analysis of Transport Vectors in Roman Baetica

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## Abstract

The Roman province of Baetica, roughly commensurate with modern Andalusia, Spain, provides an excellent case study of “Romanization” from its early days as a republican overseas possession to its development into a pillar of the imperial economy. The work presented here uses Network Analysis applied to our current knowledge of transport and communication routes in the region in order to better understand the relationship between the location and political/economic significance of sites. This paper focuses on the technological aspects of the study, in particular the methodology used, as well as the results, which indicate strong transport-influenced spatial patterning. The concluding section takes a deeper look at the nature of the source data and its “directionality.”

## 1 The Project

This paper is based on a master’s dissertation at the University of Southampton, Great Britain (Isaksen 2005) and complements a paper in preparation for the proceedings of the CAA UK Chapter (Isaksen In Press). The research itself has been undertaken in conjunction with Urban Connectivity in Iron Age and Roman Southern Spain, an Arts and Humanities Research Council funded project based at Southampton University that aims to “analyze changing social, economic and geographical relationships between towns and nucleated settlements in southern Spain...between c.500 BC and AD 500” (Southampton University 2003). The principle theme of the research is to explore and develop methodologies by which to understand the network of relationships that existed between nucleated settlements in the region. The scope of the project is limited to the province of Seville, once the economic hub of Baetica, and it is to this framework that the work below contributes, though the area considered has of necessity been extended in order to better understand some of the influences on the network.

In many ways the Roman province of Baetica is an ideal subject for exploring new approaches to historic transport geography. Perhaps surprisingly, this is not due to the completeness of its record (for it is not), but because it provides a remarkable *breadth* of pertinent data (Sillières 1990:9-16). It is only by approaching this variegated jigsaw from a range of angles that a picture begins to emerge. This has been done fairly recently in two major works, Sillières (1990) and Corzo-Sanchez and San Gil (1992), but despite much well-reasoned argument

and a wealth of data there is still a lot that is uncertain. This paper will contend that the branch of economics known as Transport Geography may be able to contribute a great deal, particularly in its use of Node Networks, an abstract model of the interactions between spatially separate locations.

## 2 The Lie of the Land

Baetica, a province created from the southerly part of Hispania Ulterior by Augustus in the late first century BC, is roughly commensurate with modern Andalusia (Figure 1). Its primary importance to Rome, and indeed many of its previous inhabitants, was the valley of the River Baetis (Guadalquivir) with its broad plains and fertile soil, and the Mons Marianus (Sierra Morena) mountain range to its

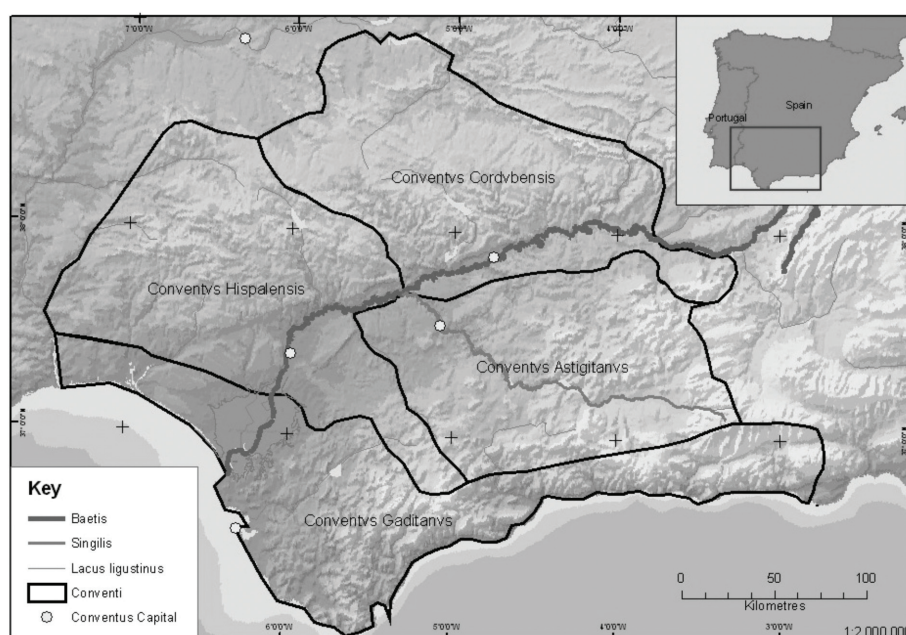


Figure 1. The Province of Baetica with district boundaries, capitals and principal watercourses.

north, rich in precious metals. The regional economy was not merely dictated by its resources, however—it was also greatly affected by its topography. The central valley is virtually cut off to the north, south, and east by two significant mountain ranges, the Sierra Morena and the Cordillera Sub-Bética. The natural entry and exit point was therefore via the large tidal estuary (the *lacus ligustinus*) to the West, which was exposed not to the Mediterranean but the Atlantic. The River Baetis (Guadalquivir) itself is navigable some 200 km inland and the colony of Corduba (Cordoba), capital of Hispania Ulterior and later Baetica, was founded at its furthest navigable point.

To complement this natural conduit, the province developed a complex network of roads. These are testified to by numerous milestones and a number of bridges throughout the region. They not only linked towns within the interior, but also connected them to neighboring provinces, often providing guidance and sure footing through tortuous mountain valleys. On a more regional level, they would also have been necessary to enable wheeled vehicles to transport local produce to local markets or entrepôts from whence it could be shipped to the wider empire.

It is not an understatement, however, to say that the River Baetis, after which the province was named (Pliny, *NH*, 4.4), is the single most important factor in understanding the transport geography of Baetica. To quote another scholar, “it was the one outstanding geographic feature in Baetica’s dynamic economic history” (Ponsich 1998:173). As just one indication of the river’s importance, three of the province’s four jurisdictional capitals, Cordoba (also the provincial capital), Hispalis, and Astigi lay at the ends of its navigable branches. The fourth, Gades, had jurisdiction of the coastal towns, relatively inaccessible from the interior, but was also close to the mouth of its estuary. In fact, if we return to what we know of the extents of the four Baetican *conventus*, based upon the location of towns within them, a clear pattern emerges (see Figure 1). The three northerly *conventus* are not divided east-west, but around the confluence of the Baetis and the Singilis. In other words, each capital’s authority seems to have been deliberately based on

a specific stretch of the river, and the rest of the territory divided approximately equally around these central axes. Of key importance, of course, is the main channel of the Baetis, which links the key towns of Corduba and Hispalis and provides access to the sea. Of lesser but still notable significance is the Singilis (Genil), a tributary of the Guadalquivir that is navigable as far as the colony of Astigi and which bisects much of the fertile plain.

### 3 The Mystery

One way of approaching landscape geography is to start with “coincidences” and a look at the map shows a coincidence that seems unusual. Despite the fact that the larger expanses of agricultural land are all south of the Guadalquivir, virtually all the towns on the lower Guadalquivir lie along its right (northern) bank. Of those mentioned by Pliny and Strabo, the towns of Caura, Osset, Italica, Ilipa Magna, Naeva, Canania, Arva, Axati, and Celti have been identified with locations to the north/west whereas only Orippe and Hispalis are to the south/east. This observation leads to the assumption that something other than agriculture was either attracting towns to the north bank or was discouraging them from occupying the south bank, or both.

A study of the elevation of the region hints at the reason for this occupation pattern. The sites are located not only at the points of maximum distance from the mean course, but also at points where the ground rises steeply away from the river. Virtually all the towns are built close to, but above, the river, a striking correlation which only begins to decrease as we approach the ancient *lacus*.

In fact, the cause is not a mystery and is well known to current long-term residents of region. The watershed of the river is a huge region incorporating several mountainous areas and, consequently, the river floods frequently and sometimes dramatically, especially downstream of its confluence with the Genil (Vanney 1970:89). Figure 2 shows the numerous floods since the 16<sup>th</sup> century, but the apparent increase in frequency is liable to be an artifact of better public record-keeping than due to a change in climate. A flood in the 12<sup>th</sup> century may have been responsible for as many as 63,000 deaths and there are no extant monuments in Seville from this period at less than 10 m above sea level. If the death toll is correct, it was the worst river flooding catastrophe in recorded European history (Vanney 1970:111-2).

It is likely, then, that the siting of the towns along the river is a response to this threat. The asymmetry between the left and right bank means that, to avoid the risk of flooding, those to the south must be situated at a

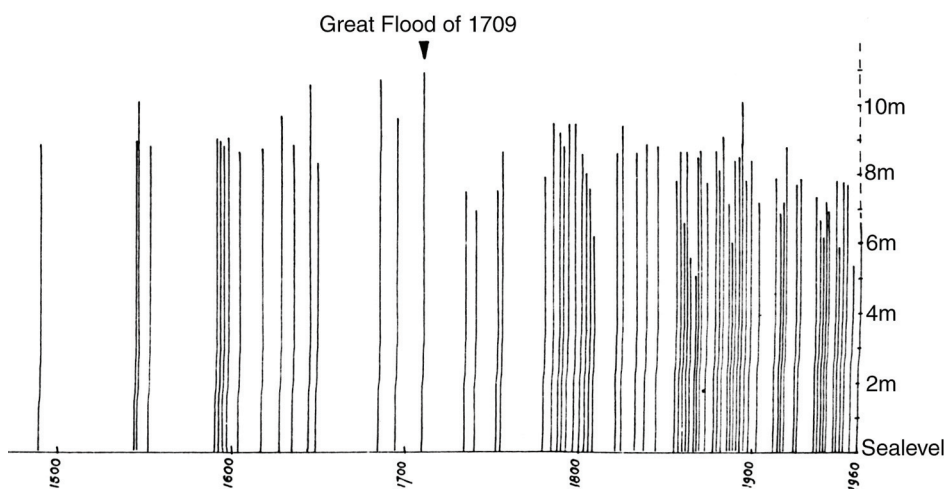


Figure 2. Flooding in Seville in meters above sea level since 1500. Much of the city lies at less than 10m above sea level (Vanney 1970:111).

distance several kilometers from the main stream. Despite the apparent disadvantages of the right bank, it provides a series of low bluffs which remain above the floodwaters but, crucially, give direct access to the water. Fresh water is not likely to be the principle reason for proximity to the river; with access to much cleaner sources from the faster flowing mountain streams, and fishing as only part of a mixed economy, it can be concluded with a reasonable degree of likelihood that direct access to the river itself, i.e., for transportation, is the determining factor.

Given the remarkable uniformity of, and logical rationale behind, the site location of the towns of the navigable Baetis, there are two extraordinary exceptions: Orippo and Hispalis. Both lie on the lower flood plain, close to the river, and much of both sites is less than 10 m above sea level. Whilst Orippo *may* have escaped the inundations, with the floodwaters rapidly dispersing into the broader area of the *lacus*, Hispalis most certainly did not. Borja Palomo's 1878 account of the 1709 flood left one scholar to reflect, "On reading this series of catastrophes, of dramas and of epidemics, one comes to ask one's self why a site both so dangerous and exposed should have been chosen for this town" (Vanney 1970:111, author's translation). Why should such a vital city be founded in a place that was so clearly at the mercy of the elements and yet not only persist, but thrive and flourish? The answer is summed up succinctly in two passages of Strabo:

After Corduba and [Gades], Hispalis, itself also a colony of the Romans...is most famous, and still remains the trade-centre [ἐμποριον] of the [province]...

Now, up to Hispalis, the river is navigable for merchant-vessels of considerable size...to the cities higher up the stream as far as Ilipa, for the smaller merchant vessels; and as far as Corduba, for the river boats...

(Strabo, *Geog.*, 3.2.1; 3.2.3, Jones 1969).

The primary reason for Hispalis's existence, then, is as a transport terminal. Just as the towns higher up the river enabled goods to be exchanged between the land and river craft, Hispalis was the hub from which imports were landed and exports were loaded onto sea-going vessels. It was here that ingots, and probably amphorae, were weighed so that customs could be paid (Domergue 1998:213-14). Still, the ever-present threat of flooding must have had its effect. It is not surprising that the most illustrious residents of Hispalis, including the emperors Trajan and Hadrian, lived not in the city from which they undoubtedly prospered, but in the town of Italica on the hill across the river.

## 4 Movement

Given that the selection of a location for its proximity to transport routes seemed to be a crucial element for both the development and political significance of Baetic towns, the purpose of this research was to use Network Analysis as a means to further understand the transport framework of the region. Along with the river, the other primary source

of available evidence is the Roman itineraries. Textual and epigraphic evidence strongly suggests that guides for travelers in the ancient world were based on topology rather than topography. That is to say, almost every certifiable "travel guide" we possess (pictorial or textual) indicates the position of locations in relation to other ones, rather than embedding them within an independent spatial matrix, such as a Cartesian coordinate grid (Brodersen 2001:9-12).

Most of our information comes in the form of various itineraries from around the empire. Some are epigraphic, others written lists. Perhaps the most famous is a visual depiction known as the Peutinger Table. Salway (2001) has argued forcefully that the larger texts are in fact composed of numerous shorter itineraries of uncertain origin but which probably vary in date to a considerable degree. In support of this argument, it is clear that, not only the style, but also the kinds of information recorded change markedly from region to region, even within a single document. It is important not to lose sight of this fact; the disparities are not always so evident at the provincial scale with which we are concerned, but can nevertheless be present. The origin of these shorter itineraries is still a matter of debate; Salway's (2001) interpretation is that the itineraries may be based on notes taken by travelers from *tabellaria*—monumental lists of itineraries placed in key locations that direct the reader to other destinations.

Looking beyond the raw lists of data that these documents provide, which shall be addressed in more detail later in this paper, two further aspects of the itineraries should be noted. First, they imply intentionality. In each case, their authors are suggesting that under rationale  $x$ , it is preferable to travel from  $A$  to  $B$  by way of  $C$ . If it is possible to understand this rationale, then it may be possible to begin to make sense of the way that people moved around the ancient world. In the majority of cases, however, it is possible only to hypothesize as to just what  $x$  might be. Secondly, the itineraries are also vectors, having a beginning and an end. It is very reasonable to surmise that the journeys described could just as well be undertaken in the opposite direction, but asymmetry may provide a crucial clue to the manner in which these ancient travel guides were created, and, therefore, their strengths and weaknesses as descriptions of the network. Only a few of the known itineraries are of direct relevance to the area with which we are concerned, and it will be important to look at each group in turn.

### 4.1 Vicarello Goblets

The Vicarello Goblets are four silver cups discovered in the Baths of Apollo at Vicarello, in southern Etruria, apparently as a votive offering. All of similar design, they appear to be in the form of a milestone and inscribed upon each is an itinerary leading from Gades to Rome, with distances in miles. It is believed that they may represent a monumental *miliarium* in Cadiz, similar to the *Miliarium Aureum* in the Forum Boarium at Rome, perhaps as a kind of memento of a journey. Despite their similarity, minor changes in the design and itineraries suggest that the first three goblets date from around the start of the principate (c. 27 BC), whilst the

fourth was made around 15 BC (Sillières 1990:38-9).

#### 4.2 Antonine Itineraries

The Antonine Itineraries list both land and sea itineraries between towns throughout the empire attributed to an emperor Antoninus. Analysis of the locations recorded in the text suggests a date around the end of the third century. The “lost” regions of Dacia and the *Agri Decumates*, between the Rhine and Danube, are notably absent, but on the other hand, Constantinople is generally referred to by its pre-Constantine toponym, Byzantium. The exact function of the Antonine Itineraries is unclear, although their internal structure suggests that several regional groups have been “stitched together” to create a “global” itinerary list (Salway 2001:39-43). Despite providing an invaluable catalogue of information, there are a number of surprising lacunae, and many routes do not follow the shortest path. Of the 225 routes described, 13 are directly relevant, wholly or partially, to this study.

#### 4.3 Ravenna Cosmography

The Cosmography, written by an anonymous monk of Ravenna, is an attempt to compile a list of all the towns in the known world at the end of the seventh century. The (corrupt) version that exists is a Latin translation from the Greek that dates from the ninth century. Though claiming to draw on a variety of ancient sources, recent scholarship suggests that it is based principally on the Peutinger Table—a spatial (though abstract) itinerary map of the ancient world dating from the mid-fourth century. Although a later medieval copy of the Peutinger Table has survived, frustratingly, the westernmost section is missing, leaving the Ravenna Cosmography as the only guide to its contents. To further complicate matters, analysis of place names on the map shows that the grammatical declension is not consistent, indicating that it in turn was compiled from a series of written itineraries. These undoubtedly came from several sources as they juxtapose towns destroyed by Vesuvius with those built in the reign of Constantine, a disparity of more than 200 years (Salway 2001:28, 44).

With a handful of notable exceptions, few material remains of transport infrastructure outside of urban settlements exist. The itineraries, however, along with a limited number of well established routes from other sources, enable the construction of a *theoretical network*. Network Analysis applies a powerful set of tools to create metrics showing the relative importance of individual locations and routes within their wider nexus. A very large number of sites at which transport activity took place (e.g., towns, bridges, *miliari*) have been identified, as well as evidence linking some of those sites to the toponyms in our network. With these two sets of data, it is possible to begin to unravel some of the structural elements of the system and begin to understand the spatial nature of the system.

## 5 Methodology

Network Analysis is the central methodology utilized in this research. A network is, very simply, a number of entities, called nodes or vertices, in real or abstract space that are linked together by lines, known as edges (or arcs, if directional). These may represent anything from molecules, to the World Wide Web, to social networks. In this case, nodes were used to represent route systems. Besides providing a useful and intuitive tool for describing such systems, nodes are also susceptible to mathematical analysis in order to ascertain the importance of individual nodes within a network. This research considered two measures, known as “closeness centrality” and “betweenness centrality” and only looked at bi-directional links (edges).

*Closeness centrality* can be stated as the ease with which a node can reach, or be reached by, any other node on the network. It is an index of how easily accessible a node is to all the other nodes in the network and is a value between 0 (inaccessible) and 1 (directly accessible in one step by all). Two graphs that demonstrate this most clearly are a simple star graph, in which the central node has a closeness centrality of 1, and a cycle graph in which all the nodes will have identical closeness centralities. In a network of vertices and lines,  $(V,L)$  the function,  $cl(v)$ , of the normalized closeness of a vertex,  $v$ , is formally defined as:

$$cl(v) = \frac{n - 1}{\sum_{u \in V} d(v, u)} \quad (1)$$

Where:  $d(v,u)$  is the shortest path (or *geodesic*), in terms of nodes traversed, between  $v$  and any other node,  $u$ .

These distances are summed, and this value is then normalized by dividing by the total number of vertices ( $n$ ),  $- 1$  to give an index (a value between 0 and 1). Normalization is important as it enables us to compare this node’s closeness with that of nodes on other networks (Batagelj 2005).

*Betweenness centrality* is defined as the probability that a node will be passed by traffic traveling along the shortest route between two other nodes on the network. The index indicates not how easy it is to reach other nodes, but the likelihood of it being *en route* when taking the shortest path between other vectors. Nodes with high betweenness need not necessarily have a high closeness centrality but they are classically associated with bottlenecks and hubs in systems. Formally,

$$b(v) = \frac{1}{(n - 1)(n - 2)} \sum_{\substack{u, t \in V: g_{u,t} > 0 \\ u \neq v, t \neq v, u \neq t}} \frac{g_{u,t}(v)}{g_{u,t}} \quad (2)$$

Where:  $v$  is a node in a network of vertices and lines  $(V,L)$ ,  $g_{u,t}$  is the number of geodesics from node  $u$ , to  $t$ , and  $g_{u,t}(v)$  is the number of geodesics from node  $u$ , to  $t$  that pass through  $v$ .

Once again, the value is normalized to a value between 0 and 1, this time also to take into account the fact that geodesics from  $u$  to  $t$ , and from  $t$  to  $u$  will both be included in the equation (hence  $(n-1)(n-2)$ ) (Batagelj 2005).

Betweenness is the metric that is most relevant to this research, because it indicates which nodes have a higher degree of control over the network (Freeman 1977:35-36). In a transport context, although this is not likely to be in the form of obstructing traffic, such key nodes have the potential to influence the way in which that traffic flows, perhaps in a very concrete fashion. They may also benefit from the increased degree of economic activity that is created by the confluence of separate linear routes (Pitts 1965:15).

The three elements required to undertake the analysis are a Relational Database Management System (RDBMS) in which to store the information, a Network Analysis package with which to analyze it, and a GIS which provides both data visualization and manipulation capabilities. To generate and analyze the network, the Pajek software package was used. This software is a specialist node Network Analysis tool written by Vladimir Batagelj and Andrej Mrvar of the University of Ljubljana, and available free for non-commercial use (specific licensing info is available at the Pajek website: <http://vlado.fmf.uni-lj.si/pub/networks/pajek/>). The database was implemented in Microsoft Access 2000 and the GIS system was ESRI ArcInfo.

## 6 Modeling

When using Network Analysis to explore what is known of ancient terrestrial routes, it is important to remember that we are not looking at a single *network*, but a number of inter-related *networks*. The data used for this research come from a variety of sources, most of them written. As these do not describe identical networks, it must be assumed that they a) have different functions, and b) reflect only aspects of some broader reality, or super-network. As at least one known route is not covered by the written sources; it must also be assumed that our knowledge of these routes is incomplete. There will undoubtedly be elements missing from the model generated, and further limitations will become clear in the course of the discussion.

### 6.1 The River and the Vicarello Goblets

Initially, a node network of towns along the river, based on the Vicarello Goblets, was constructed. Such a network was not the high speed link of those on official business, but it was the economic backbone of the region. It served to convey goods to, from, and between the jurisdictional capitals and enriched the occupants of the towns along its route. By creating a node network of those centers, it is possible to begin to understand its advantages and disadvantages to individual towns.

The results of creating the network are displayed in Figure 3; the closeness and betweenness centrality values are also indicated.

As might be expected from a fairly linear network, the sites with the highest values lie fairly close to the centre of the diagram. More counter-intuitively, all of the jurisdictional capitals have low scores. In order for the results to be interpreted meaningfully, it is important to remember that although the indices show a high degree of correlation, they say different things. The closeness value indicates that it is easier to reach the central towns from the outliers than it is to reach the outliers from the outliers. The betweenness shows that the central towns are likely to see a *greater volume of traffic* than the outliers. The implications of this interpretation in relation to the river must also be considered.

It is certainly true that, by river, it would be hard to set the capitals farther apart. In other words, the capitals have the least possible closeness *that access to the river permits*. One interpretation of such a distribution is that their

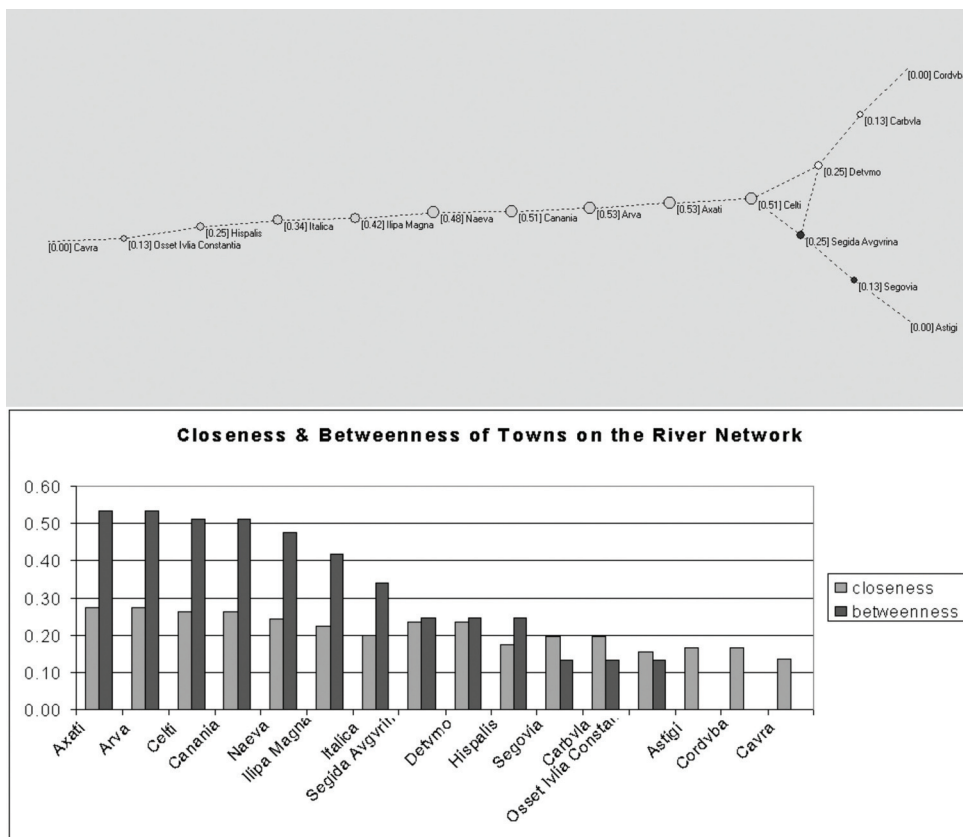


Figure 3. Node network of towns on the Baetis and Singilis with closeness and betweenness centrality values shown.

location is dictated by two competing forces—one which is tending towards dispersion, and that of the river’s navigability, which acts as a restraint. So what is this “force of dispersion?” The hypothesis explored below by an examination of land routes is that they are being drawn outwards by the forces of closeness and betweenness within other “constellations.”

## 6.2 The Via Augusta

The next network that was examined is the best known and best documented of all the roads in the region—the

Via Augusta. The importance of this route is evident in the presence of numerous *miliari* and several bridges; most significantly, it was followed by the itineraries on the four Vicarello goblets. It was one of the great roman highways and undoubtedly a jewel of imperial propaganda (Corzo Sánchez and San Gil 1992:90-1). It is crucial in this context for two reasons: it provides a direct link between all four of the Baetican jurisdictional capitals, and it suggests that it was a *kunststrasse*, or engineered road, something that is not certain for the other itineraries.

In this analysis the route by itself gives a rather unspectacular set of figures with a regular distribution curve, but when combined with the river network, the resulting change

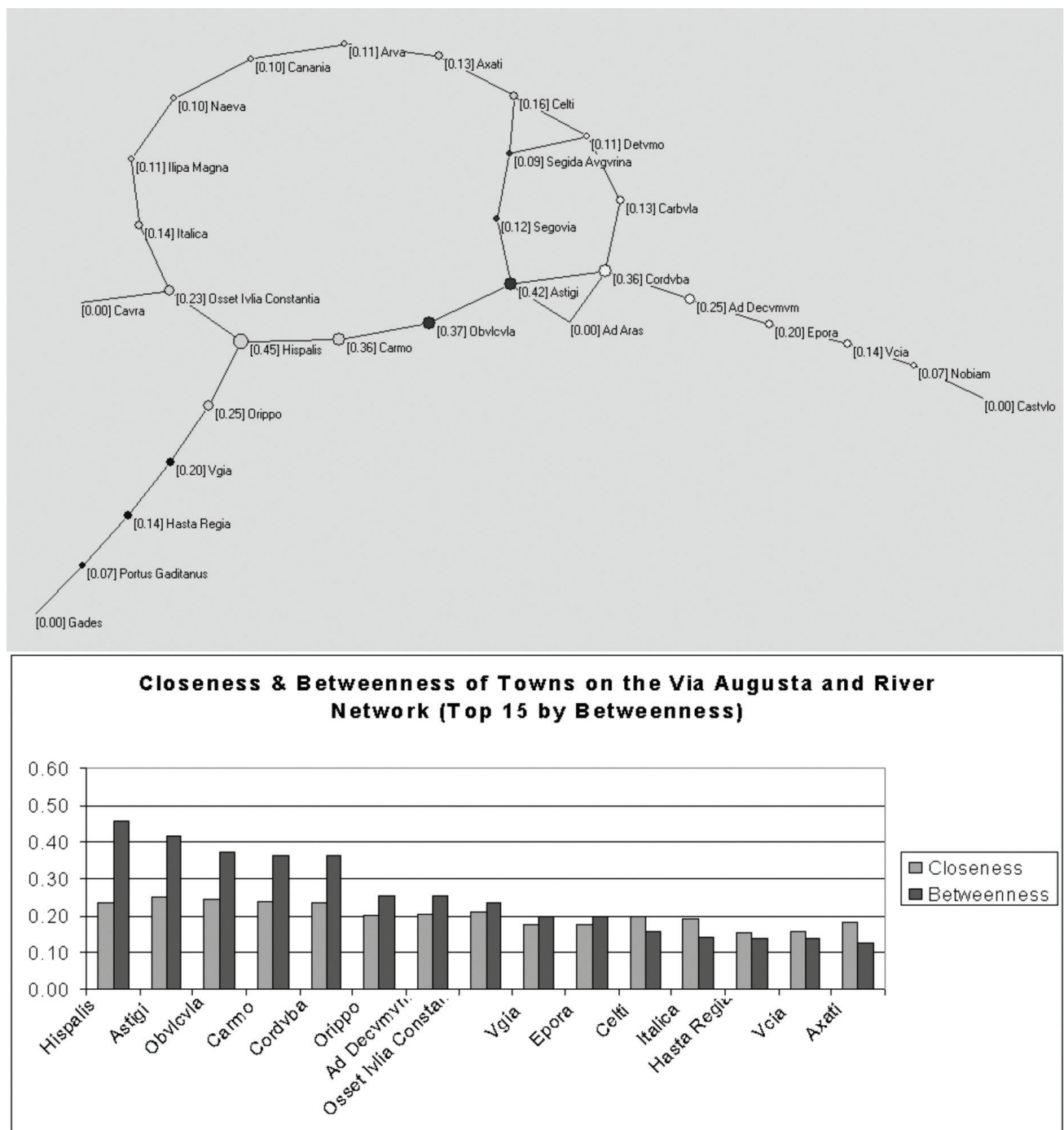


Figure 4. Node network of towns on the river network and Via Augusta with betweenness centrality values shown.

is striking. The results of the top 15 sites by betweenness are shown in Figure 4. From having amongst the lowest closeness and betweenness values of sites on the river, our three interior jurisdictional capitals now rank amongst the highest, with Hispalis ranked first.

The simple reason for this is that the inland capitals act as the interfaces between the two networks. Travelers using the road system must pass through them to access the river and vice versa—hence a higher betweenness value. Likewise, they are best placed to access, and be accessed by, the sites along the road, as well as those on the river, hence a higher closeness value. In Figure 4, it is possible to see how, with the fusion of just two simple networks, disparities in centrality can change remarkably. Finally, the road has brought together these three key sites themselves. Travelers between them are no longer obliged to pass via the numerous river sites, and so the relative importance of the latter as “sites of passage” falls off. This system integrating road and river networks is certainly not unique in the Roman world. The Great Northern Road in Britain linking the capitals of London and York also ran through towns (Bawtry on the Trent and Doncaster on the Don) located at the head of navigation of rivers flowing into the North Sea (Evans 1988:390).

### 6.3 Antonine Itineraries

The next network to be incorporated into the model was the series of linear routes known as the Antonine Itineraries. Unlike the Via Augusta, it is unknown as to whether they follow *kunstrassen*, though some of them certainly do for at least part of their length. They appear to provide, rather, a list of “advisable routes,” which may or may not correspond to Baetican transport infrastructure. As described above, the itineraries cover a much larger region than the study area for this research, but a number of the routes either pass through or link towns within it. Again, the values of centrality we are generating are network dependent so it would not make sense to include all of them, but in this case, they are short enough to decide on a case by case basis. In fact, many of them stop either at, or close to, the limits of Baetica.

The centrality indices clearly indicated the importance of a network, especially when displayed visually. Although closeness did not vary dramatically between sites, betweenness did, and it was no surprise to find, once again, that three of the provincial capitals for this study were dominant (see Figure 5).

Towns along the Via Augusta have high betweenness values, and it is important to remember that, not only has

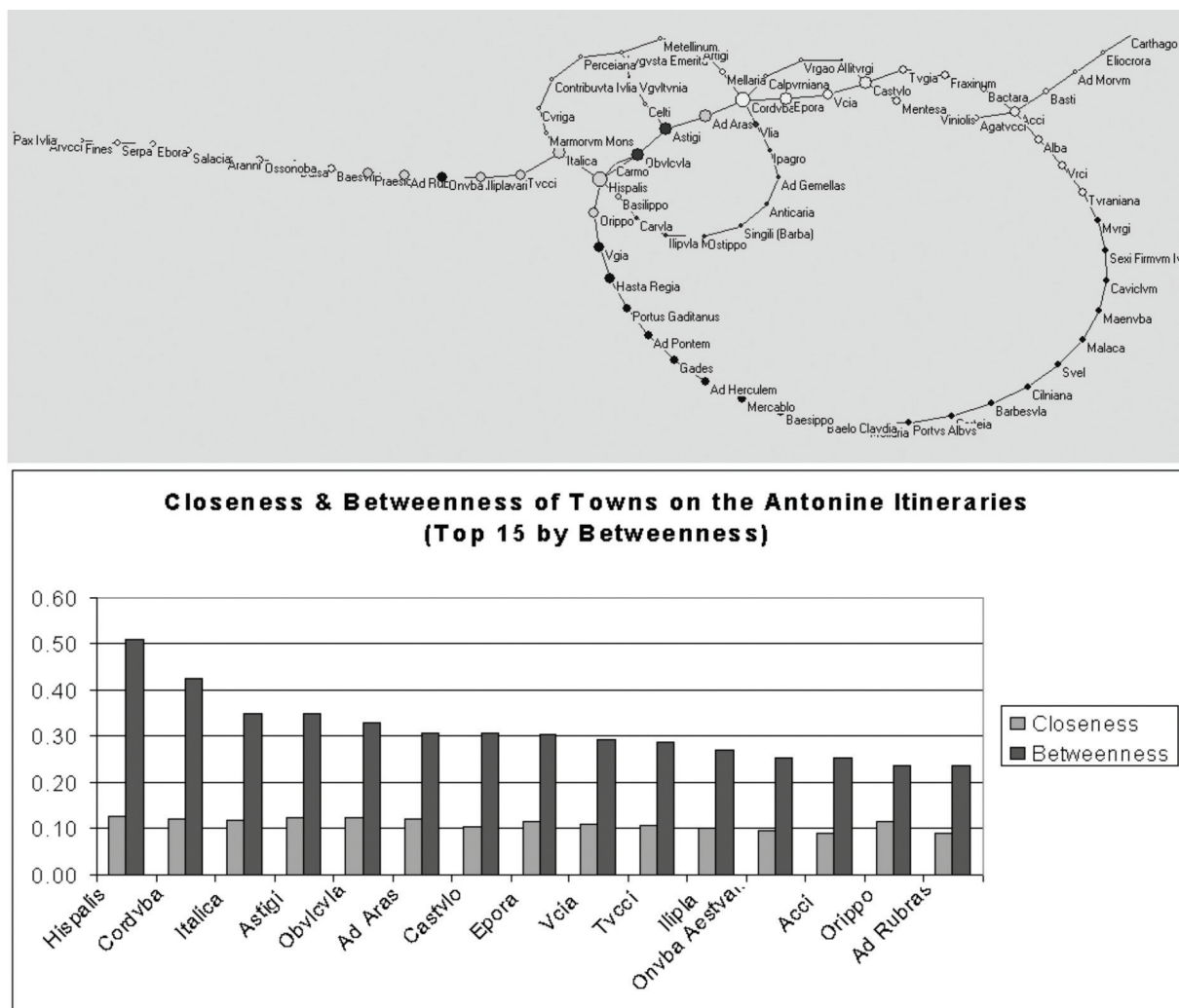


Figure 5. Node network of towns mentioned in the Antonine Itineraries.

that route not been directly included within this model, but that no individual Antonine itinerary actually follows the route all the way through Baetica.

The system seems to work remarkably well. Although it has no geographical data whatsoever, it automatically generated a model that is identifiably Baetica, albeit with some distortions in relative distance. The correlations between models also correspond remarkably well to intuitive assumptions about the relative importance of the jurisdictional capitals. The exception here is Gades, but it appears, at least from the Antonine Itineraries, that it would be hard for any town within its jurisdiction to have a high terrestrial betweenness. This should not be surprising; the Baetican littoral appears to have been, above all, a region economically dependent on maritime activity.

### 6.4 Ravenna Cosmography

The Ravenna Cosmography provided a separate list of itineraries, this time without distances and, once again, it is impossible to know the degree to which it followed engineered roads. An initial mapping generated a surprising result, however—there appear to be three separate networks that do not interrelate. It might be possible that the compiler had made a mistake, perhaps by lifting sections out of an unknown source that links itineraries together, or starting at hubs on the Peutinger table and stopping before the next to avoid duplication. Almost all of the itineraries lead toward, but then stop prior to, important towns. If the most obvious candidate in each case is considered (following Sillières [1990:32]), the network connects itself in a much more understandable fashion (Figure 6).

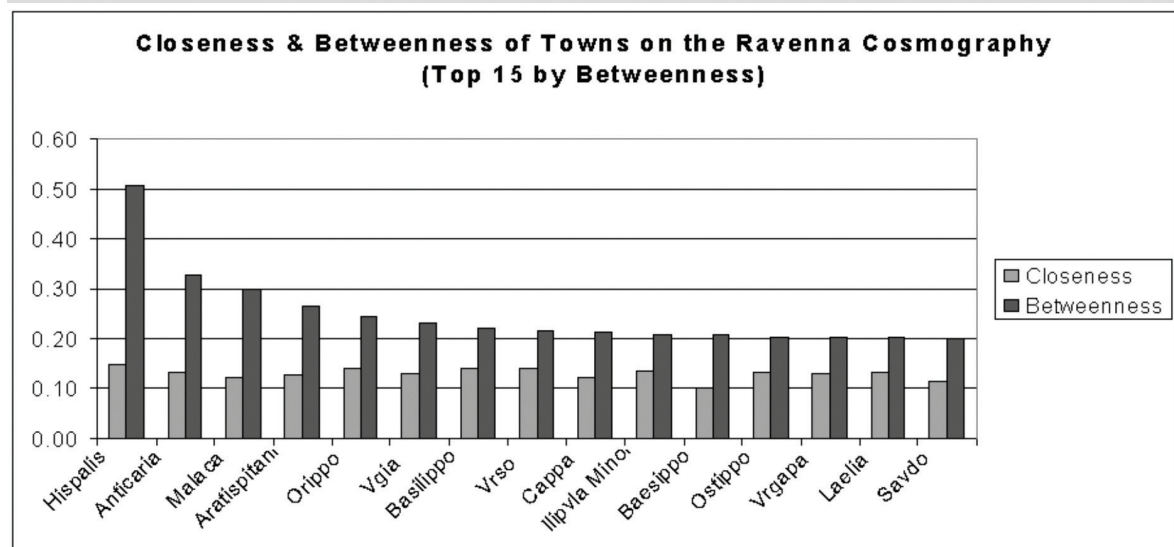
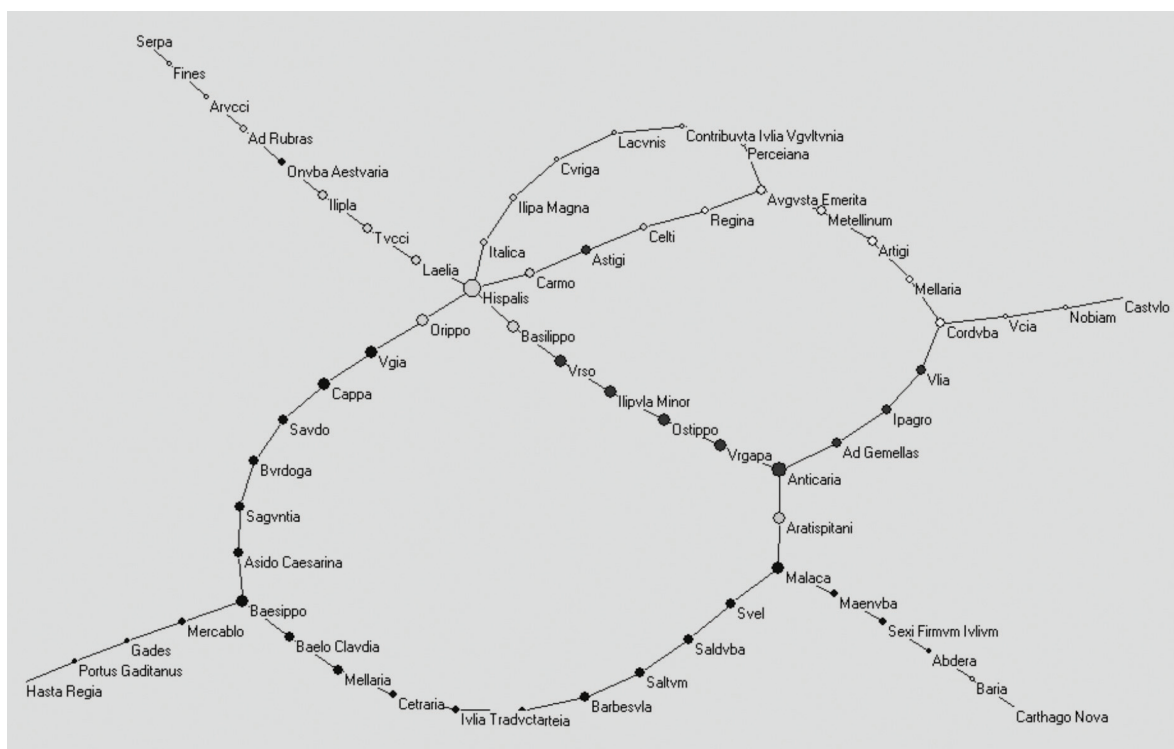


Figure 6. Node network of towns mentioned in the Ravenna Cosmography.



There were some noticeable differences to the first two networks. First, the Via Augusta played little or no role. Second, although the *conventus* of Hispalis and Gades were well connected, those of Corduba and Astigi were not. In fact, Astigi had no connection with the towns in its provinces, and Obulcula is missing altogether. Looking at centrality, although Hispalis was once again the key node, the other capitals did not appear in the top 15 at all.

In this network the chief axis was between Hispalis and Malaca, if the additional step from Aratispitani to the coast is correct. It may be debatable as to whether the itinerary Hispalis-Asido lead to Baesippo or Gades, in which case we might expect the latter to have a higher betweenness rating, but nonetheless, the irrelevance of district factors was striking.

### 6.5 A Combined Network

The strength of the chosen database system was that it enabled the researcher to combine multiple networks easily,

adding or removing itineraries and nodes as desired. To investigate the entire known transport system, a “super-network” composed of the three networks discussed above with one further addition was created. A route of a single day’s journey is known both from *miliari* and from aerial photographs between Astigi and Ostippo (Sillières 1990:506-508). It was, in fact, an important route, as can be seen from the network. Without this route, Astigi would have no direct connection to the majority of towns within its jurisdiction. It was also the final link in a chain which runs directly North-South from Malaca to Emerita. On this note, it should also be noted that, with the exception of Regina, it appeared that all the towns that lay upon known routes were able to reach their jurisdictional capital. Figure 7 shows which nodes were most important for betweenness and closeness.

Despite the fact that closeness values still do not vary much, Astigi, Hispalis, and Corduba are considerably more important than any of the other towns in terms of betweenness. In other words, *if* the data can be taken as broadly representative of the primary transport routes in Baetica,

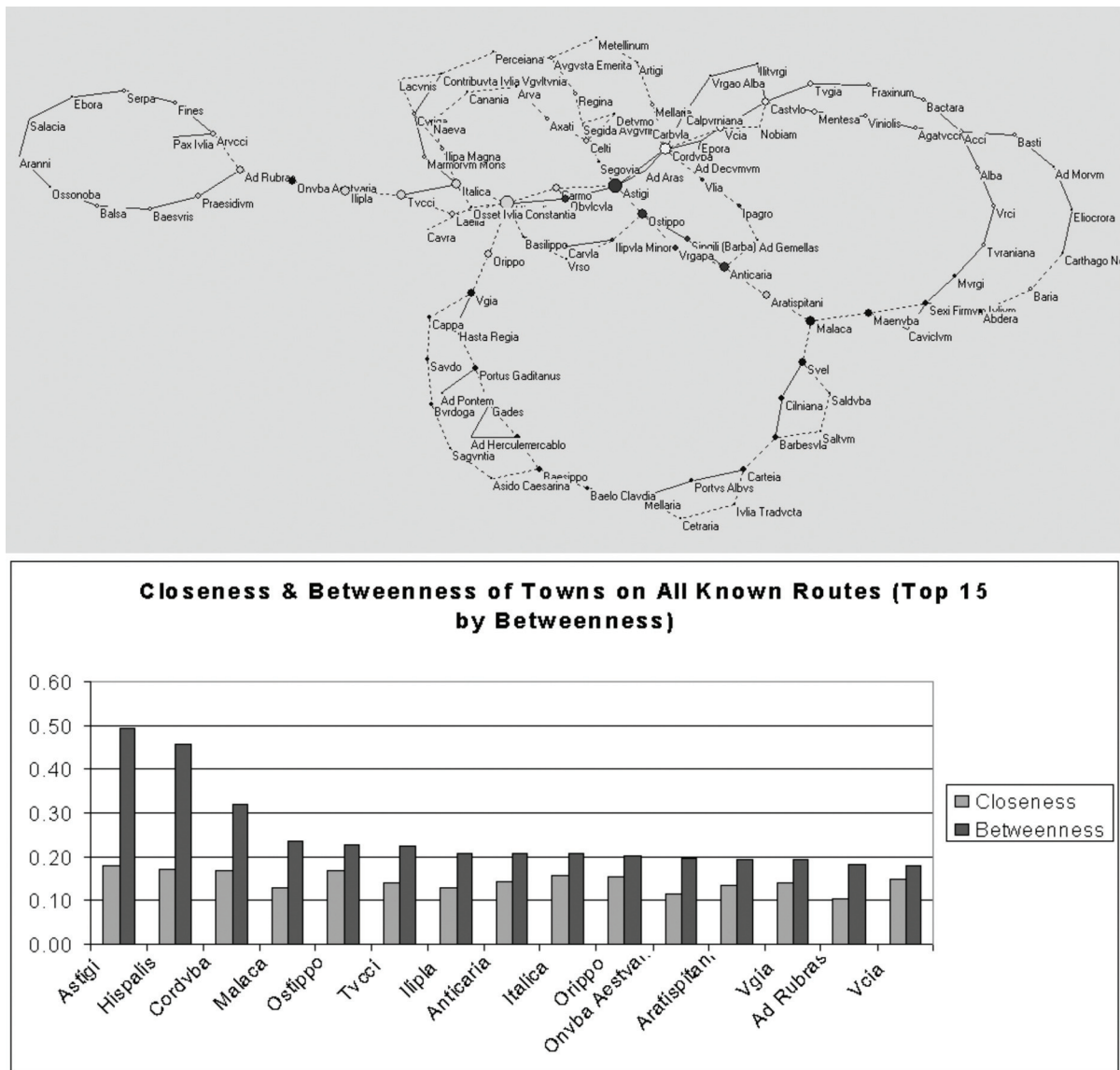


Figure 7. Node network of towns in all sources.

they were unquestionably the focal points of the Baetican transport system. This apparent confirmation of the research expectations was a striking result, since the very first network, that of the river, gave a different impression.

What do the results suggest about the idea of key itinerary nodes with *tabellaria*? The evidence seems to be mixed. If the theory is true, one might expect to observe two sets of phenomena in the data. First, there would be a limited number of departure and arrival points based at strategic locations and they would be highly correlated. The evidence in Baetica does seem to bear this out. Both sets of itineraries used a very similar set of start and end points, and they could all be reasonably interpreted as having had strategic importance within a transport network. Second, as the hubs within the network, a correlation in betweenness and these key nodes would be visible. Here the results were more mixed. Clearly, Hispalis and Corduba were important, both as centers on the network and as frequent departure points and destinations within the itineraries. Unfortunately, not much can be said about the external towns since they were also connected to networks that were not considered in this research. Likewise, the port towns of Malaca, Gades, Baelo/Baesippo and perhaps Baesuris could all reasonably be seen as parts of wider networks. There was, however, one glaring exception, Astigi, which along with Hispalis and Corduba appeared to be in a league of its own and does not feature as a terminal node on any of the itineraries. If certain locations were centers of transport information and that *was* reflected in the itineraries, then Astigi, a district capital and focal point of the network, did not appear to have been one of them. This was certainly not strong proof *against* the

theory, but suggested that a much broader study needs to be done to give further support to this interpretation, one way or the other.

## 7 Movement Again

Being able to break the network down by individual itinerary also gives us a clearer idea of how each related to the other, and some further clues as to their origin. As seen earlier, there seems to be something in the idea of “key nodes of origin/destination,” but some troubling aspects, as well. Some of the itineraries clearly could be described at their origin and took a fairly direct route. Others took diversions that might also be permissible, especially when they went by way of important towns such as Astigi, Acci, or Corduba. There were one or two routes, however, that could surely not have been described on a public itinerary table. Only the initial stages of the Gades-Corduba Antonine Itinerary could have been described on a tabellarium at its departure point, and it is unlikely that the remainder would even be described at Hispalis. The itinerary from Baesuris to Pax Julia is even more bizarre, circling its goal almost entirely. Such itineraries suggest very specific purposes and must have been created either post factum, or with some other kind of guidance available. As Salway (2001) points out, the compilations were probably comprised of itineraries created under various circumstances, and it is certainly possible that these were exceptions to a general rule, but without looking at a larger dataset, the evidence from Baetica is not yet compelling.

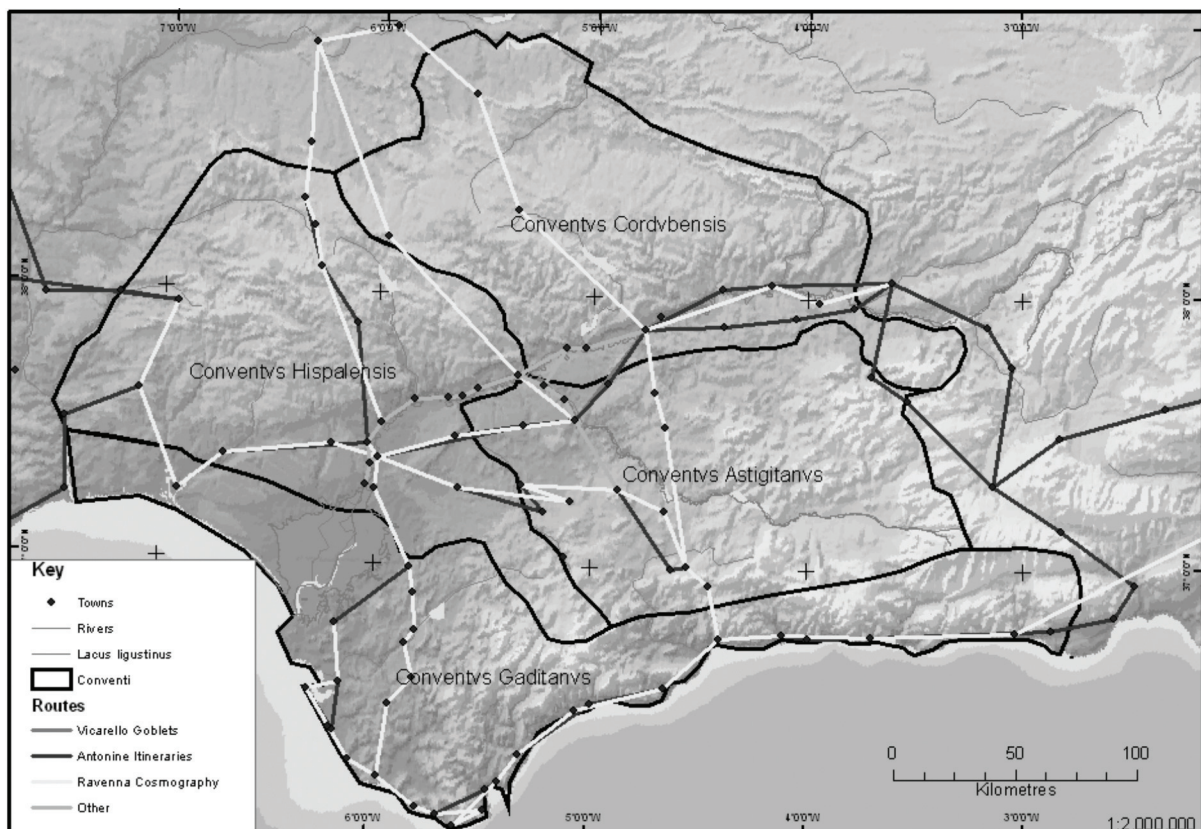


Figure 8. Spatial schematic of itineraries from all sources.

Table 1. Start and end points of Antonine Itineraries.

Itinerary	Type
Gades-Corduba	Capital-Capital
Hispalis-Corduba	Capital-Capital
Hispalis-Emerita	Capital-Capital
Mouth of Anas-Emerita	Frontier/Port?-Capital
Hispalis-Italica	Capital-?
Corduba-Emerita	Capital-Capital
Corduba-Castulo (1)	Capital-Frontier
Corduba-Castulo (2)	Capital-Frontier
Malaca-Gades	Port-Capital
Castulo-Malaca	Frontier-Port
Baesuri-Pax Julia	Frontier-Capital
Carthago Nova-Castulo	Capital-Frontier

Table 2. Start and probable end points of Ravenna Cosmography.

Itinerary	Last Stage?	Type
Carthago Nova-Baelo (1)	Baesippo?	Capital-Port
Carthago Nova-Baelo (2)	Baesippo?	Capital-Port
Baesippo-Hasta- (last stages missing)	?	Port-?
Emerita-Italica	Hispalis?	Capital-Capital?
Emerita-Carmo	Hispalis?	Capital-Capital?
Emerita-Castulo	Castulo	Capital-Frontier
Corduba-Anticaria	Malaca?	Capital-Port?
Hispalis-Aratispitani	Malaca?	Capital-Port?
Hispalis-Asido	Baesippo/ Gades?	Capital-Port/ Capital?
Hispalis-Seria	Pax Julia?	Capital-Capital?

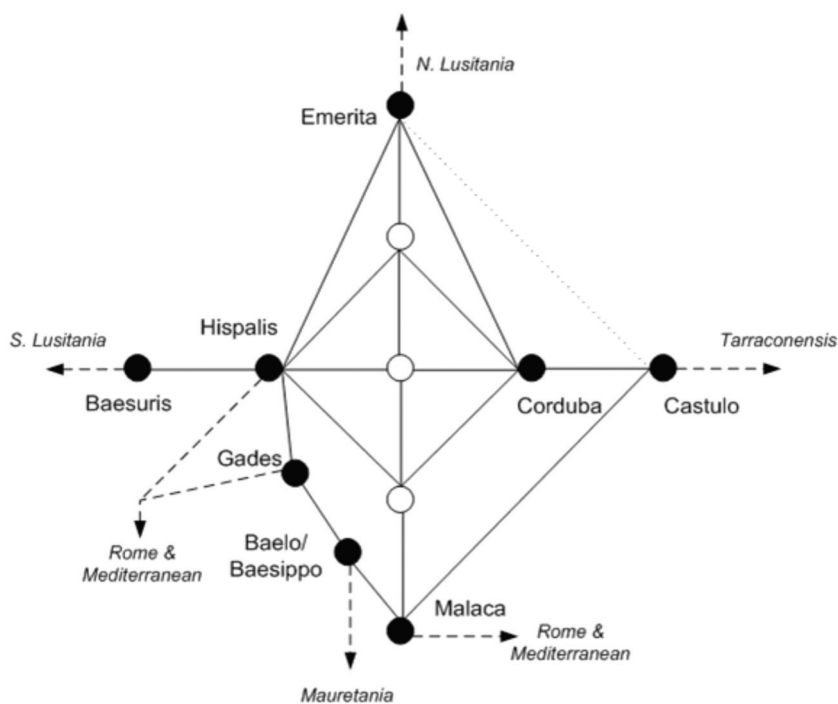


Figure 9. Abstract schematic of itineraries with points of departure.

The information gathered through this research may provide a new way of looking at the problem (Figure 8). The GIS demonstrates that the general shape of the overall network is surprisingly regular, and this regularity is also seen clearly in the Network Analysis diagrams. In fact, it was remarkable how many similarities exist between the Ravenna Cosmography and Antonine Itineraries, and how well they complement each other, especially as the individual itineraries are quite different. Such similarity suggests, though it cannot prove, that the rationales behind them may reflect some wider reality. Including the river network and the extensions of Sillieres, the chief features, with starting points here chosen arbitrarily, seem to be:

- Two central axes running north-south and east-west. The former running *Emerita-Celti-Astigi-Antikaria-Malaca*. The latter, *Castulo-Corduba-Astigi-Hispalis-Baesuris*.
- A separate circuit seems to trace the main extent of the Guadalquivir Valley, running *Hispalis-Urso-Antikaria-Corduba-Celti-Italica-Hispalis*.
- To the east, a route connects the end nodes of Malaca and Castulo, whilst another (not included in the database as it lies entirely outside of Baetica) joins Cordoba and Emerita. There is also a direct road between Emerita and Corduba, the provincial capitals.
- To the west, the *lacus* prevents any direct land route between Malaca and Baesuris, but there is a route to Hispalis. There is also a route from Hispalis to Emerita.

There is a further interesting correlation, at least within the itineraries considered. Almost all of the itineraries lead between district and provincial capitals, and/or 'provincial frontiers'. This is summarized in the table of Antonine Itineraries (Table 1).

The correlation is curious as the routes themselves do not necessarily respect provincial divisions, nor do they take the fastest route. It might also be noted that the number of non-capitals is actually very small, there are only four: Italica (x1), Malaca (x2), Baesuris/Mouth of Anas (x2), and Castulo (x3). In fact, Baesuris and Castulo also form the initial/terminal nodes of other itineraries not included in our network. In the Ravenna Cosmography, Table 2, links between the capitals and frontiers were once again clear.

Malaca features again (x2), as does Castulo (x1). The new case appears to Baesippo/Baelo, though in two cases this is mentioned within the context of the straits of Gibraltar and the third case

is a repetition of the first. It is known from the Antonine Itineraries that Baelo seems to have been a port for crossing over to Tingitania, which fits the pattern of “frontiers” nicely.

When a schematic diagram of the principle route network is drawn and marked with the places at which itineraries began, an interesting pattern emerged (Figure 9). *All* of the itineraries began on the boundaries of Baetica, except for the provincial capital, Corduba. It is particularly common to find them starting at port towns as well, notably those that are known to have direct connections with other provinces. Whilst it is difficult to understand how they could have been constructed from monumental *tabellaria*, the idea of travelers taking notes on *arrival* at a new province does not seem at all far-fetched. Likewise, it is logical to expect such information to be available at its capital. If the system did work in this way it would provide an explanation for Astigi’s absence from the list of starting nodes, as well as explain its fundamental role within the route system as a whole—it is the central node of the entire network.

It would be foolish to jump to conclusions on the basis of just one province, but the co-occurrence of starting points with clear points of provincial interface is one worthy of further investigation. To use the Roman itineraries, it is important to understand the rationale behind them. The implication of the study just described is that the itineraries may well have been written by *visitors* to Baetica, rather than the local population.

## 8 Conclusions

The preceding exposition has been a summary of some of the interesting conclusions derived from the Network Analysis methodology. The paper was not able to cover many of the necessary caveats involved, for details of which the reader is invited to turn to the original thesis. It should be stated clearly, however, that although the results have been remarkably strong, they are still based on a data model that is incomplete, and the significance of which is not entirely clear. Thus, whilst the data were reasonably structured and fairly homogenous, it is vital to contextualize all conclusions against other historical sources and perspectives in order to make sense of them. Still, the outlook is good for Network Analysis as a computational technique within archaeology and ancient history. The dataset used here is but a small fraction of the Roman itineraries, and indeed, Michael McCormick has recently demonstrated that there is a huge body of evidence for transport in the post-Roman period, as well (McCormick 2002). Whilst Network Analysis may not be a new approach (see, in particular, Pitts 1965), the power of modern computing can make it a powerful tool for understanding the inherent structures in ancient communication systems.

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