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Chapter 1: Introduction

The Project

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. It is only by approaching this variegate jigsaw from a range of angles that a picture begins to emerge. This has been done fairly recently in two major works: Pierre Sillières’ comprehensive Les Voies de Communication de L’Hispanie Meridionale (1990) and Las Vías Romanas de Andalucía (1992) by the historian Ramón Corzo-Sanchez. Why, then, the need for another report?

The first reason is that, despite much well-reasoned argument and a wealth of data, there is still much that is uncertain. I believe that there is a great deal that the branch of economics known as Transport Geography may be able to contribute, in particular the concept of a Node Network, an abstract model of the interactions between spatially separate locations. Secondly, I wish to improve the level of epistemic transparency. In other words, to increase the degree to which future researchers can instantly understand the source and nature of the data. Much of this information is lost (or at least obscured) in the transition from linguistic to spatial (i.e. visual) media which tend to present information in a monolithic or even reified fashion when divorced from their texts. This dissertation intends to demonstrate the potential of a standard relational database, coupled with a GIS and Network Analysis software package, to make a spatial argument about the relative importance of key towns within a transport network and expose the constituent elements of that argument in a visual manner.

Urban Connectivity in Iron Age and Roman Southern Spain is an AHRC-funded project based at Southampton University that aims to “analyze changing social, economic and geographical relationships between towns and nucleated settlements in

1 Sillières 1990 pp. 9-16
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southern Spain...between c.500 BC and AD 500.” 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 my work intends to contribute, though the area considered has of necessity been extended in order to better understand some of the influences on the network. Whilst the overall issue of Baetican transport routes will be addressed throughout the ensuing chapters, it will be worthwhile to discuss here some contextual issues that have determined the techniques and technologies I wish to adopt.

First, it is important to distinguish between transport networks and day-to-day travel. The great majority of human motion takes place in an extremely complex and essentially unpredictable fashion. However, modern anthropological studies suggest that across virtually all sedentary cultures it is a) limited to approximately one hour a day, and b) there is tendency to return to a place of residence each day. This places a hypothetical ‘upper limit’ on the distance most individuals will travel which we might loosely describe as intra-site (by which is meant the ‘home’ location and its immediate environs). Indeed, it is one of the restraining factors on the growth of ancient cities, which, despite occasionally being able to marshal vast resources and being densely populated, never grew more than a few kilometres in diameter. Based on these facts we shall postulate that most inter-urban transport takes place only under special economic circumstances that require it. It is the routes used in this type of long-distance transport, and the specific conditions that gave rise to them in Roman Baetica, that will form the main subject of this inquiry.

The primary source of information that we can draw upon in identifying such routes are the Roman itineraries. Looking beyond the raw lists of data that these documents provide (which we shall address fully later), two further aspects of them should be

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2 In collaboration with the Seville Office of Culture and the Department of Prehistory at Seville University
3 From UCIARSS website, http://www.arch.soton.ac.uk/Projects/projects.asp?ProjectID=64
4 Ausubel & Marchetti 2001 pp. 20-22
5 Ibid.
6 Turton & Black 1998 pp. 159-60

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remarked upon. First of all, 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 we are able to understand this rationale then we can begin to make sense of the way that people moved around the ancient world. That said, in the majority of cases we can currently only hypothesize as to just what $x$ might be. Secondly, they are also vectors, having a beginning and an end. We might very reasonably surmise that the journeys described could just as well be undertaken in the opposite direction, but this asymmetry is not something we should entirely lose sight of. As we shall see, it may give us a crucial clue into the manner in which these ancient travel guides were created, and hence their strengths and weaknesses as descriptions of the network.

The next source of evidence to take into account is the Roman road system itself. As this has developed an almost iconic status in Western culture, variously symbolizing ancient practicality, munificence and imperialism, it is important to bear in mind the distinction between kunststrassen - roads created by artifice - and those created by erosion and compaction due to frequent passage. Both played an important role in the ancient world and they each indicate differing kinds of intention. The construction and maintenance of the former display the desire of at least one party to ease friction (i.e. reduce the cost) of certain modes of transport between two locales, either to encourage flow or to foster support from its beneficiaries, or both. ‘Natural’ routes on the other hand imply regular use and are perhaps indicative of flows in better equilibrium with local economic and cultural conditions. Regrettably, for precisely this reason, natural pathways tend to be highly transient, and even when they are not it is virtually impossible to distinguish a chronology of usage. Despite the fact that correlations can sometimes be established, we cannot assume a priori that itinerary descriptions are more likely to follow kunststrassen. When we can establish a connection though, it may give us some insight as to the way Roman transport planners responded to extant networks, and vice versa.

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7 Bekker-Nielsen 2004 p.14
8 The Via Augusta, discussed later, is a case in point, and a very recent discovery in Portugal may be evidence for a paved road following one of the other itineraries used in the study. See “Roman calçada road discovered in Santa Catarina (Tavira)” in Região Sul (English online edition) 24 November, 2005.
The chronological development of the system is a further area in which our evidence is sparse. It is very difficult to distinguish, from a transport perspective, between the Tartessian, Phoenician, Punic, republican and imperial periods, yet surprisingly this is not as problematic as might be thought. The sources upon which this study is based are entirely Roman (or post-Roman) so they reflect the reality of the classical era (though sadly shed little light on pre-Roman development). We should nonetheless expect, as with most transport infrastructure throughout history, that it was a response to, and often a reinforcement of, the systems of communication which had hitherto served the area. As such, whilst this study is concerned specifically with Roman route networks (a period itself spanning no less than six centuries), many of the routes we shall be discussing may well have been used since the earliest times. It should by no means be assumed that the plains and valleys were a *tabula rasa* upon which the pattern of Roman hegemony was inscribed.

With a handful of notable exceptions, we have few material remains of transport infrastructure outside of urban settlements. The itineraries however, along with a limited number of well established routes from other sources, will enable us to construct a *theoretical network*. It is to this sort of data that Network Analysis can apply a powerful set of tools to create metrics showing the relative importance of individual locations and routes within their wider nexus. We also have knowledge of a very large number of sites at which we can be fairly certain transport activity took place (towns, bridges, *miliari*, etc.), as well as evidence linking some of those sites to the toponyms in our network. With these two sets of data we can not only begin unravel some of the structural elements of the system, but we can also begin to understand its spatial nature as well. To perform this task we will need to use three different types of software, and it is to these that we shall now turn.

**Software**

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 analyse it, and a GIS which provides both data visualization and manipulation capabilities. As an over-arching principle, the GIS and

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9 White & Senior 1983 p.11
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Network Analysis software will merely act as client applications to the RDBMS. That is, the database application will provide a standalone resource that can be read and manipulated externally but is not dependent on third-party software, allowing for greater flexibility in future. It also has to be easily exportable. Software products and standards come and go with alarming regularity which can drastically reduce the functional life of a resource if not accounted for. By decoupling the data from the applications as much as possible, the system can easily be adapted for use by alternative GIS packages or databases. As those used here are both proprietary and Windows-based, this is an important consideration. The various components are described below and a diagram describing their interaction can be found in Appendix F.10

The Database
Microsoft Access 2003 is the Relational Database Management System (RDBMS) in which the database is implemented. It allows for the simple manipulation and browsing of tables via query forms and although it only permits single-user access, this is within the requirements of the UCIARSS project. More pragmatically, Access comes bundled with most MS Windows installations making it easily distributable. None of the underlying data structure is Access dependent however, so migration to an open source or multi-user platform should not prove difficult if desired. The data has also been exported to comma-delimited ASCII files and table diagrams have been included in the appendices11, in the eventuality that a user might not have access to a Windows platform. The principle difficulty to be encountered would be rewriting an additional import/export module that has been written to interface with the GIS and Network Analysis software, so this is heavily commented and listed below.12

The Geographical Information System
The key goals attained by using a GIS are:

- Providing full access to the data
- Permitting visualization of the data
- Allowing for spatial analysis of the data

10 Diagram 1
11 Table diagrams 1 & 2, Appendix F
12 Import/Export Code, Appendix F

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• Being able to display alternative models supported by the data

ArcGIS ArcInfo 9.0, a proprietary GIS developed by ESRI, is the software package we will use here for processing and displaying spatial data. Although using such software introduces some issues of cost, alternative open source products do not yet provide a mature and user-friendly interface for Network Analysis. Furthermore, both the author and members of the wider UCIARSS project have access to the software and experiencing in using it. On the whole, ArcGIS also has a reasonably user-friendly interface with the Microsoft Jet 4.0 Database Engine (upon which MS Access is based) thereby minimizing the need for data duplication caused by having to change formats. It is not possible to read linear data directly however, and it is partly for this reason that the extension module mentioned above\(^{13}\) has been added to the database to create files importable by ArcGIS.

**Network Analysis Software**

To generate and analyse the network, the Pajek\(^{14}\) software package will be used. It is a specialist node Network Analysis tool written by Vladimir Batagelj and Andrej Mrvar of the University of Ljubljana, and free for non-commercial use\(^{15}\). Its main strength lies in reading very simple ASCII tables that can be exchanged with MS Excel with relative ease. It also provides a large suite of analysis and visualization tools, and results can be exported as Scalable Vector Graphics or Bitmaps. Of principle interest to this investigation is its ability to quickly generate networks and then calculate various indices (described below) for each node. It also enables the user to assign values to network links and categorise nodes in nominal or numeric fashion. The greatest drawback in its use is the inability to integrate it directly with other software. To enhance its usability, the extension module mentioned above has been further extended, enabling the database to automate the export of data into Pajek-readable files. The export function enables a user to export networks from the database consisting of towns within the region and routes that connected them. A further option permits the classification of the towns by Boolean or nominal values.

\(^{13}\) Written in Visual Basic with the aid of Fox 1999

\(^{14}\) Slovenian for ‘spider’

\(^{15}\) Specific licensing info is available at the Pajek website: [http://vlado.fmf.uni-lj.si/pub/networks/pajek/](http://vlado.fmf.uni-lj.si/pub/networks/pajek/)

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**Network Analysis**

As Network Analysis is the central methodology utilized in this inquiry, a brief exposition will be worthwhile. 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 we are using them to represent route systems. Besides providing a useful and intuitive tool for describing such systems, they are also susceptible to mathematical analysis in order to ascertain the importance of individual nodes within a network. This project will only be looking at two measures which are known as *closeness* and *betweenness centrality*, and will only be looking 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 1 step by all). Two graphs which demonstrate this most clearly are a simple star graph, in which the central node has a closeness centrality of 1.0, 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:

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

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. Normalization is important as it enables us to compare this node’s closeness with that of nodes on other networks.

**Betweenness centrality** is defined as the probability that a node will be passed by traffic travelling 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

\[\text{Batagelj 2005}\]

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betweenness need not necessarily have a high closeness centrality but they are classically associated with bottlenecks and focal points of systems. Formally,

\[ b(v) = \frac{1}{\binom{n-1}{2}} \sum_{u, t \in V, g_{u,t} > 0, u \neq v, t \neq v} \frac{g_{u,t}(v)}{g_{u,t}} \]

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 \((n-1)(n-2))\).

Betweenness is the metric that interests us here most because it indicates which nodes have a higher degree of control over the network\(^{18}\). 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, as we shall see. They may also benefit from the increased degree of economic activity that is created by the confluence of separate linear routes\(^{19}\).

The next chapter will focus on the history and economic structure of Baetica insofar as they are understood. Following this, Chapter Three is a more detailed evaluation of the sources directly relevant to this study and an exposition of the database structure designed to accommodate them. Chapter Four will focus on riverine transport which is the context essential for our comprehension of the wider transport system. It will also provide a first opportunity to look at the application of Network Analysis. Chapter Five builds upon this basis and will investigate how route networks developed in relation to the infrastructure already provided by the river. This is the chapter where Network Analysis will be used as the main approach for understanding the way in which these systems interrelated. Chapter Six looks at a way of

\(^{17}\) Batagelj 2005

\(^{18}\) Freeman 1977 pp. 35-36

\(^{19}\) Pitts 1965 p. 15
representing the compiled and generated data in a fashion which highlights correlations whilst maintaining distinctions, as well as enabling it to be integrated with other spatial data. Chapter Seven will critically reappraise the work undertaken and will also be used to look at some potential directions for the future.
Chapter 2: Background

Travel does not happen in a vacuum. Ultimately it is a choice that individuals make based upon the political, economic and social circumstances of their time. This chapter will therefore provide a brief overview of the historical and economic context of Baetica during the Roman period. Following on from this, we will then look at the specific information available to us regarding ancient movement and a way of storing it so as to be applicable to computational analysis.

Baetica

The history of Baetica’s territory is both long and complex. It played host to a number of literate cultures in antiquity, beginning with the Tartessians\(^{20}\) in the late Bronze Age, and later to Phoenician traders, Punic colonists and finally the Romans themselves. The relative impact of these societies on the area’s inhabitants and their relations with one another varied considerably, but through the keyhole of the classical sources and a wealth of archaeological data we can at least be certain that a sophisticated network of communications was present long before its conquest by the Scipios\(^{21}\).

Baetica itself, a province created from the southerly part of Hispania Ulterior by Augustus in the late first century BC\(^{22}\), is roughly commensurate with modern Andalusia\(^{23}\). 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 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\(^{24}\). 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. It is no coincidence that the first

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\(^{20}\) On Tartessian literacy, see Strabo 3.1.6

\(^{21}\) Aubert Semmler 2002 pp. 101-8

\(^{22}\) Keay 1988 p. 49

\(^{23}\) See Map 1, Appendix B

\(^{24}\) Keay et al. 2000 p. 1
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known colonists were the sea-faring Phoenicians, establishing an outpost on the island of Gadir (Cadiz) to trade with the indigenous peoples during the mid-eighth century BC\textsuperscript{25}. The Guadalquivir itself is navigable some 200km 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 neighbouring provinces, often providing guidance and sure footing through tortuous mountain valleys. On a more regional level, they would also have been necessary in enabling wheeled vehicles to transport local produce to central markets, or entrepôts from which they would be shipped to the wider empire.

Besides traders of economic goods, the other great beneficiary of Roman roads was of course the army. Indeed, early studies of Roman transport infrastructure suggested that all other usage was of secondary benefit\textsuperscript{26}. We should be wary of such a view. There is no doubt that the Roman military machine made good use of them, and the great artery roads in particular, whilst mobilizing. On the other hand, accounts of military action in the sources suggest that campaigns were often fought fast and loose\textsuperscript{27}. And after all, the Roman army intended to fight on enemy soil rather than its own. As a result, it had to develop transport and logistical methods that benefited from, but could not be reliant on, the roads. Pack animals, rather than wagons, would have formed the main mode of transport\textsuperscript{28}. For this reason we should only cautiously incorporate the numerous but varied reports of military movements into our data. That an army travelled from one town to another may suggest that there was an identifiable road between them, but it is hardly conclusive evidence. And the knowledge of a single journey does not justify the inference of a regular thoroughfare.

\textsuperscript{25} Ruiz Mata 2002 p. 158 (for the traditional account see Strabo 3.5.5)

\textsuperscript{26} Bekker-Nielsen 2004 pp. 17-8.

\textsuperscript{27} In an episode involving the praetor Q. Cassius Longinus and the quaestor M. Marcellus, at least seven known sites are involved, including Hispalis, Naeva, Carmo, Obulcula, Segovia, Ulia and Corduba. Caesar, \textit{Bell. Alex.} 57-63

\textsuperscript{28} Coulston 2001 pp. 110-3
Turning to the issue of transport planning, we need to remember that roads require maintenance as well as construction if they are to prove a help rather than a hindrance to wheeled transport\(^29\). The record of *miliarium* in Baetica makes clear that the emperors from Augustus to Magnentius did indeed concern themselves with their upkeep\(^30\). This may have had as much to do with propaganda as influencing regional politics and economics, but nonetheless, it is a strong indicator of their continuing importance within the imperial programme. So what were the political and economic objectives that required such huge, and continuous, expenditure?

Politically, the Roman era in Baetica can be broken down fairly neatly into the republican and imperial periods. The republican period is characterised chiefly by exploitation (especially of precious metals), thirst for military glory, and later the civil war. The historical sources, pre- and post-Augustan, make clear that many of the Roman generals and governors in Spain, such as the unscrupulous consul L. Lucullus, were more interested in their personal fortunes than the subjects in their custody\(^31\). Though considered to be by far the most civilized province in Hispania\(^32\), Baetica was not immune to banditry, invasion, internecine strife and, of course, the rapacity of the Romans themselves. There were a number of permanent legions stationed in and around Baetica, and even a native one, possibly levied from indigenous peoples and *hybridae*\(^33\). Guerrilla tactics were frequently employed by those challenging the regime, and campaigns were fought in all corners of the region. This is in stark contrast to the imperial period. From the last uprising of a Spanish tribe in 16 BC until the Vandal and Visigothic invasions during and after AD 409, the entire peninsula experienced almost four and a half centuries of peace and security. This is reflected in the number of imperial legions. In AD 24 there were three legions stationed in Hispania (Hispania Tarraconensis). By AD 74 there was just one\(^34\). As most of our information refers to roads and itineraries dating from the imperial period, military expediency is likely to have played only a legacy role in their distribution.

\(^{29}\) Evans 1988 p. 386. Road improvements in Britain meant that whilst in 1660 seven horses were required to pull 1.5 tons, by 1765 six tons could be pulled by just five.

\(^{30}\) Sillières 1990 pp. 63-173

\(^{31}\) Appian, *Iberike* 51-5

\(^{32}\) Strabo 3.1.6

\(^{33}\) Caesar. *Bell. Alex.* 57

\(^{34}\) Cornell & Matthews 1982 p. 79
The Baetican Economy

What then of the Baetican economy? Of particular interest to us is the fact that it centred on exports. In contrast to many other regions whose economic surplus appears to have been derived either from services to the military or limited regional trade, Baetica produced and exported in large volumes. The five principle commodities were metals (especially iron, gold, copper, and silver), fish, wheat, wine, and most importantly, olive oil\textsuperscript{35}. The area’s natural bounty had not eluded any of its previous inhabitants, and the Phoenicians in particular had been keen to trade it the length of the Mediterranean\textsuperscript{36}, but it was under the Romans that systematic investment in their exploitation began. The development was a long time in coming, however. The appropriation and export of metals and wheat did not lead to widespread settlement or farming by Romans during the republic, perhaps due to the continuing instability of the region. From the reign of Augustus however, we see evidence for an explosion in agriculture represented in villa and production sites\textsuperscript{37}, as well as that most unintentional of Roman monuments, Monte Testaccio.

Metals were almost certainly the first reason for external traders to visit the future Baetica from the Mediterranean, perhaps made conspicuous by the legendary wealth of Tartessos\textsuperscript{38}. As a compact, non-perishable material they are ideal for long-distance trading and were mined throughout antiquity. The majority of the mines are in the Sierra Morena, from where the cast ingots would be conveyed directly to the coast for export\textsuperscript{39}. Transport infrastructure is thus likely to have played an important role in the industry. Salted fish (\textit{salazones}) and a fish sauce by-product known as \textit{garum}, were also highly lucrative industries. A number of sources refer to the plenitude of the fishstocks\textsuperscript{40} and more than 100 fish-salting installations have been found, along with 41 amphora production sites\textsuperscript{41}. They are especially prevalent in the regions around the

\begin{itemize}
\item \textsuperscript{35} Ponsich 1998 pp. 171-82
\item \textsuperscript{36} Aubert Semmler 2002 pp. 101-8
\item \textsuperscript{37} Keay 1992 pp. 303-6
\item \textsuperscript{38} Ponsich 1998 p. 171-2
\item \textsuperscript{39} Domergue 1998 pp. 203-6
\item \textsuperscript{40} Oppian 3.573; Strabo 3.2.7
\item \textsuperscript{41} Peacock & Williams 1986 pp. 35-9. Map 2, Appendix B
\end{itemize}
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towns of Gades, Malaca and Carteia and fish motifs found on coins originating from these towns are in all likelihood a reference to its production. Similar motifs are also found on the coins of towns that lie along the lower Guadalquivir and the lacus ligustinus, Ilipe Magna, Caura and Cunbaria in particular, indicating that they too benefited from fishing. Wheat and wine were yet other strengths in the Baetican economy, testified to by numismatics and the ancient sources. Although it is harder to find traces of their production within the material record, coins again give us some idea of their distribution.

With the production of olive oil, however, we are on much firmer territory. It is notable that it was to become the symbol of the region. A mosaic in the Calle de Caserne de Vigiles in Ostia, near Rome, displays Baetica represented as a woman, her head wreathed with olive branches, and one of Martial’s epigrams depicts the river likewise. Strabo remarks that numerous large ships left Baetica, laden with olive oil and other goods, bound for the deep-water port of Puteoli (Pozzuoli, Italy), as well as Rome’s shallower harbour at Ostia. Not only do we have a reasonable idea of site distribution (thanks to the work of Ponsich), we also know a lot about its distribution and producers, and can infer much of its transport methodology and export volume thanks primarily to its uniform packaging: the Dressel 20 amphora. Dressel 20 are found throughout the Western empire and are especially prevalent in the northern military provinces and the Rhine/Rhone axis in particular. But nowhere are they to be found in remotely the same quantity as at Monte Testaccio behind the ancient river port at Rome. A dumping ground some 45m high and estimated to contain 1.3m tonnes of amphora sherds, almost 85% of them are Dressel 20 from Baetica. Even more importantly, the sherds are often marked with producers’ and transporters’ marks and instructions, enabling us to glean a wealth of further information about the industry.

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42 Ponsich 1998 pp. 178-81. See Figure 1, Appendix A
43 Strabo 3.2.6
45 “Baetis, your hair wreathed with crown of olive” (Martial 12.98)
46 Strabo 3.2.6
48 After a categorization by the great amphora scholar, Heinrich Dressel.
49 Peacock & Williams 1986 p. 136
50 Etienne & Mayet 2004 p. 33
51 Remesal Rodriguez 1998 pp. 189-93
An interesting aspect of these ‘industries’ is that they appear to exhibit the economic phenomena of complementarity\textsuperscript{52}. As Ponsich has noted, Baetica’s regions, each with their own micro-climate and geography, are suitable for differing local economies, but also depend on one another, requiring systems of inter-zonal transport\textsuperscript{53}. Of particular relevance to this discussion is the fact that these distribution systems also relied on multimodal transport. In other words, goods tended to be transferred by a combination of land, river and sea to their final destination, be it in Baetica or the wider empire. These industries therefore provide us with as good a case-study as we could hope for. The question to be resolved is, how can we relate the knowledge of a dynamic, transport-based economy, to our more diffuse understanding of communication routes?

Before we can attempt to do so, we will need to examine the specific evidence available to us, and find a way to store and interrogate it. In the following chapter we shall we consider each of our sources and then describe the database used to record them. With this tool in hand we will then attempt to see how the economic, political and transport systems influenced each other in their distribution.

\textsuperscript{52} A concept first expressed in Ullman 1956.
\textsuperscript{53} Ponsich 1998 p. 182. Map 5, Appendix B
Chapter 3: Sources

The data available for understanding the Baetican transport network is broad, irregular, and from a variety of sources. This chapter will examine this historical and archaeological evidence and provide for it the formal structure that Network Analysis requires. The first task is therefore to identify and collate it in order to establish an organised corpus of material with which to work. We will then discuss the structure of the database in which it will be tabulated.

Historical Sources

Itineraries

Textual and epigraphic evidence suggests strongly that guides for travellers 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)\(^54\). This is certainly not to imply that the ancients had no notion spatial relationships. On a small scale, plans such as the *Forma Urbis* in Rome or the Orange Cadastres are clearly designed to represent a totality of spatial information, albeit schematically and within limited extents. On a wider scale, Ptolemy’s project, during the mid-second century, was certainly an attempt to locate sites independently of one another. Much of the first part of his *Geography* was devoted to the problem of representing sites on a curved, 3-dimensional surface (the Earth) in a flat, Euclidean plan\(^55\). The recently discovered ‘Soleto Map’ (an *ostrakon* discovered in 2003 and dating from around 500 BC) also appears to show the spatial distribution of towns, in that case those of Salentine peninsula in Italy. Finally, much ink has been spilt over the nature of Agrippa’s ‘World Map’. Whilst it is indisputable that he was interested in *measuring* the empire we are still uncertain as to whether the final product, displayed in the Porticus

\(^{54}\) Brodersen 2001 pp. 9-12

\(^{55}\) Bekker-Nielsen 2004 p. 36
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Vipsania in Rome, was a visual ‘plan’ or simply a written description\(^{56}\). In any case, the failure (or decision) not to utilise such information in what we would understand to be a ‘world’ or even provincial map for at least another two centuries after Ptolemy\(^{57}\) indicates that, to a pragmatic traveller, such information was redundant or perhaps even misleading. It was more important to possess a navigation aid directing the user from departure point to destination, as well as providing information on changing posts, accommodation, and perhaps more besides\(^{58}\).

This information has come down to us as itineraries in a number of forms from around the empire. Some are epigraphic, others written lists, and 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 we can see 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, as 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, and we shall come back to Salway’s further view that they may be based on notes taken by travellers from *tabellaria*, monumental lists of itineraries placed in key locations which direct the reader to other destinations. Only a few of the known itineraries are of direct relevance to the area with which we are occupied and it will be important to look at each group in turn.

**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\(^{59}\). 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

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\(^{56}\) See, for example, Brodersen *contra* Salway. Brodersen 2001 p.20 n. 9

\(^{57}\) Brodersen 2001 p. 9

\(^{58}\) Salway 2001 p.34

\(^{59}\) See Figure 2, Appendix A

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similarity, minor changes in the design and itineraries suggest that the first three vases date from around the start of the principate, whilst the fourth was made around 15 BC\textsuperscript{60}.

**Antonine Itineraries**
The Antonine Itineraries are a list of 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-Constatantine toponym, Byzantium\textsuperscript{61}. Their exact function is unclear, though their internal structure suggests that several regional groups have been ‘stitched together’ to create a ‘global’ itinerary list\textsuperscript{62}. 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, thirteen are directly relevant (wholly or partially) to this study.

**Ravenna Cosmography**
The cosmography, written by an anonymous monk of Ravenna, is an attempt to compile a list of the all the towns in the known world at the end of the seventh century. The (corrupt) version we possess 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\textsuperscript{63}. Although a later medieval copy of the Peutinger Table has survived, frustratingly the westernmost section is missing, leaving the Ravenna Cosmography as our only guide to its contents. To further complicate matters, analysis of placenames on the map shows that their grammatical declension is not consistent, indicating that it in turn was compiled from a series of written itineraries. These

\textsuperscript{60} Sillières 1990 pp. 38-9
\textsuperscript{61} Salway 2001 p. 39
\textsuperscript{62} Ibid. p. 43
\textsuperscript{63} Ibid. p. 28
undoubtedly came from several sources as they juxtapose towns destroyed by Vesuvius with those built in the reign of Constantine\textsuperscript{64}.

**Classical Texts**

Numerous ancient authors refer to locations, infrastructure, the economy, and routes taken by individuals which have direct or indirect relevance to Baetica. Of particular note are the *Geographys* of Strabo and Ptolemy, Pliny the Elder’s *Natural History*, the *Bellum Alexandrinum* and *Bellum Hispaniensis* (attributed to Caesar though authorship unknown), Appian’s *Iberike*, and the *De Situ Orbis* of Pomponius Mela.

Strabo, a Greek geographer during the Augustan period is invaluable in understanding the region. Although he does not appear to have visited it himself, drawing on reports from other travellers such as Posidonius, he writes both on the physical nature of the region, including its mineral wealth and unusual hydrology, as well as describing many of the towns along the river and the nature of their economy. The *Geography* was published around 7BC, and was therefore not influenced by Agrippa’s ‘World Map’\textsuperscript{65}. This is contrast to Pliny, who writing in the first century AD is vital in providing Baetica’s political geography during the early empire. As Procurator in Spain\textsuperscript{66} he would almost certainly have had first hand experience of the region and it is through his work that we have some knowledge of the extent of the *conventi* (jurisdictional districts) and of which towns lie within them.

The three works by Caesar and Appian refer to a number of military campaigns during the middle and late republic. These are of some use in understanding the locations and strategic importance of various towns in the area, as well as their history during the republican era. On the other hand, they must be handled with particular caution when used as evidence for transport routes for the reasons described above. Furthermore, Appian was writing a great deal later (the mid-second century) than the events he was describing. Finally, Pomponius Mela, probably a native of Baetica, wrote a geography of the world c. 43 AD, although sadly he covers only the towns and features along the coastline and one or two other important locations. It is still important for understanding the *conventus* of Gades, however.

\textsuperscript{64} Ibid. p. 44
\textsuperscript{65} Jones 1969 p. xxvi
\textsuperscript{66} Rackham 1969 p. vii
Archaeological Sources

Aerial Photography
Prior to this analysis, hypothesized vectors, based on previous research\(^\text{67}\), were compared with ortho-rectified, georeferenced aerial photos\(^\text{68}\) to try and establish whether any clear traces of them could be identified within the landscape to give further ‘anchor points’ to the network. Initial results seemed promising, with roads and field-markings providing extensive linear features with low curvature, oblique-angled bends, apparently linking key locations. Sadly, the results really were too good to be true. Overlaying a digital map of Andalusia’s modern infrastructure\(^\text{69}\) demonstrates beyond doubt that all of the most promising candidates, other than those previously identified, were in fact due to soil disturbance from buried oil pipelines. This nevertheless allows the conclusion to be drawn that any surface traces of the roads are at most fragmentary, and in all likelihood almost entirely absent.

Archaeological Sites
There are a huge number of archaeological sites in Andalusia, ranging from a few pottery sherds to large excavations such as that at Italica. Clearly, one of the key prerequisites for understanding the spatial network is relating these sites to their historical toponyms. In many cases we can be reasonably certain of the sites’ identity, but a surprising number still elude us, so it is vital to conceptually separate the sites from the historical names assigned to them. In this way we can generate maps that choose either to ignore or include uncertain identifications. In some cases we may even be able to provide evidence for or against the identification of a town with a particular site.

Miliari and Bridges
Milestones are, theoretically, the most ideal indicator of an imperial highway. Unfortunately their aesthetic nature and conspicuous, coupled with human nature,
mean that few remain and fewer still are of clear provenience. Where present, however, their inscriptions can provide invaluable spatial and chronological information. Bridges are one of the very best sources we have, although not many are still standing. They locate with absolute certainty an intentionality to cross a river at a specific location. In some cases, an inscription can even inform us of the date of construction.

**Secondary Sources**

A large number of books and articles have been written about aspects of Baetica and its roads, but most are referred to or collated in the two works by Sillières and Corzo-Sánchez mentioned in the introduction\(^70\). Supplementing these will be the two volumes of the *Tabvla Imperii Romani (TIR)* that cover the area of Baetica (J-29 and J-30)\(^71\). Although the latter consist of brief, encyclopaedic entries with only brief supporting argument they thereby provide an ideal starting point for a database. The more detailed works can be used to improve accuracy thereafter.

**The Database Structure**

Having established the principle sources, it is necessary to find some common, structure in which they can be related. The first consideration is to find a way to separate source information from the entities to which they refer. This can be done by dividing the database into an ‘ontic’ and an ‘epistemic’ layer, to permit bi-directional querying from source to routes, and from route to sources. A table diagram, showing these two layers is shown as Table Diagram 1, Appendix F.

The epistemic layer deals with assertions by our primary and secondary sources that transport activity took place between two named locales. Even the briefest survey of the data makes clear however that larger routes, such as the *Via Augusta*, are in fact composed of smaller ones, e.g. the Hispalis-Carmo route, the Carmo-Obulcula route, and so on. The layer therefore requires three tables. At the lowest level are the sources. This is simply a list of the sources used for the data. Dependent upon this is a

\(^{70}\) Sillières 1990; Corzo Sánchez 1992

\(^{71}\) International Academic Union 1995 & 2000
list of each itinerary description\textsuperscript{72}. An itinerary is any entire route described by a source. It is important to remember that we are dealing here with *descriptions* of itineraries, and so for a number of records the itinerary is the same, but the sources differ. For this reason each itinerary is given a unique alphanumeric code as well as a database ID. In this way we can see that, for example, RC 01 is a different itinerary in the Ravenna Cosmography than RC 10, even though they both pass through the same towns. As these itineraries are also directional, the beginning and end locations were also recorded. Finally, in the highest level table (*Route.Desc*) are records of the constituent parts of each itinerary. Of particular note are the names used for the nodes as these vary from source to source, even when the same route is being described. Also stored, though not used in the current study for reasons explained below, are the mileage (where recorded) in both Roman and Arabic numerals to allow for both computational and scriptural analysis. Although this gives some potential for inconsistency, there is no simple way to convert between them automatically without adding extra complexity into the database which would inhibit portability. Again, the start and end locations are recorded.

The ontic layer differs by referring to the *actual* routes themselves\textsuperscript{73}. Although in principle this should involve a simple atomic table with an id, a departure point and a destination, the problem is that although every route description has a beginning and an end, we may want to suggest that two descriptions going in opposite directions are referring to the same route. In order to allow for this, the route table consists simply of an id and a notes field (mainly used to enter guidelines for data entry) and the nodes are linked via a mapping table. Each route is mapped to precisely two nodes (or ‘termini’), one of which is marked as being the start. The route descriptions were then linked to the routes, with a Boolean field to indicate whether they were going in the ‘reverse’ direction\textsuperscript{74}. The *Nodes* table records information that can be assigned to the

\textsuperscript{72} The sources used for the primary itinerary data are the appendices in Corzo Sánchez 1992

\textsuperscript{73} It is of course a matter of philosophical debate as to whether such things as routes ‘exist’ in any objective sense. We might therefore define our database entities as logical statements to the effect that ‘any traveller is able to go from location \(A\) to location \(B\), more or less directly without topographical or legal restriction.

\textsuperscript{74} There something semantically uncomfortable about appearing to assign directionality to the routes themselves, but this is required to enable mapping to the descriptions, which are vectors.
historical toponyms, such as references by classical sources. The nodes have been given standardized names taken from the *TIR*. As there are a number of sites within the region and its surrounds that have the same or similar names however, each is also given a primary key. Town status and jurisdiction were mapped to two further tables to ensure consistency.

By separating the descriptions of the itineraries from the nodes and edges they represent, it is simple to create a user interfaces that enable the data to be easily accessed. The user can iterate through the itineraries, and within each itinerary, to step through the various stages it is made up of. As well as giving the actual textual information, such as the name of each town as used by the author, it also displays information about the node that the cited place name is identified with. Attached to this data is other historical information related to it. The form is shown in the appendices (Form 1, Appendix F). Further forms could be added, permitting browsing in the other direction, but as the primary interface to be used is the GIS, these have been left to be implemented by those with specific querying needs.

The final step is exporting this information into the ASCII file format used by Pajek. Fortunately, Access supports customization using the VBA programming language. An additional button has been created that enables the user to select which itineraries to export by means of a simple SQL criterion. There is then also the possibility of categorizing the nodes by field. The files produced are saved to a user-defined directory with the appropriate extensions.

The resulting database structure is surprisingly simple, being composed of only a few tables, and hinging on an axis between the routes and their descriptions. As a formal structure it gives us the ability to query the data relating to individual sources, itineraries and nodes computationally. Having linked this to Pajek, we are finally in a position to begin comparing our knowledge of Baetica’s economy with our information regarding movement within the region. In the next two chapters we will use this ability to explore a number of issues relating to the distribution, importance, and interaction of the region’s land and river networks.

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75 E.g. [WHERE] sources LIKE “Rav*”.

76 E.g. status
Chapter 4: The River Network

It is not an understatement to say that the River Baetis, after which the province was named\textsuperscript{77}, 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”\textsuperscript{78}. We shall therefore commence our investigation by analysing the river network, in one sense inverting the question that has thus far been discussed. Rather than inquiring as to which transport routes linked sites, we will be investigating why certain sites benefited from their position within an extant ‘natural’ network. We will also have the opportunity to create our first, albeit simple, node network.

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 Baetican \textit{coventi}\textsuperscript{79}, based upon the location of towns within them, a clear pattern emerges. The three northerly \textit{coventi} are not divided East-West, but around the confluence of the Baetis and the Singilis\textsuperscript{80}. 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. Finer details, such as whether the boundary followed the line of the modern River Corbones, are open to debate, but Pliny’s assertion that the encircling towns of Detumo, Celti and Obulcula lay in the districts of Corduba, Hispalis and Astigi respectively should not be dismissed lightly. Furthermore, we do know the jurisdiction of many of the towns considered in this analysis and for many others it can be inferred from their location.

\textsuperscript{77} Pliny 3.3
\textsuperscript{78} Ponsich 1998 p. 173
\textsuperscript{79} See Map 1, appendix B
\textsuperscript{80} The extents of the \textit{coventi} have been digitized from the maps in the \textit{TIR} (J-30 & J-29)
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We also have several references which specifically refer to the river’s impact on trade. Strabo in particular seems ahead of his time when he states that “the best known [towns] are those situated on the rivers, on the estuaries, and on the sea; and this is due to their commercial intercourse”. In the same paragraph, “the Baetis river has also contributed in great measure to [Corduba’s] growth.”\(^{81}\), and finally,

> “Turdetania itself is marvellously blessed by nature; and while it produces all things, and likewise great quantities of them, these blessings are doubled by the facilities of exportation; for its surplus products are bartered off with ease because of the large number of the merchant vessels. This is made possible by the rivers, and by the estuaries as well, which…are navigable inland from the sea…to the cities of the interior.”\(^{82}\)

In fact, the great pre-industrial economist Adam Smith would voice the same ideas in his *Inquiry into the Wealth of Nations* more than one and a half millennia later:

> “As by means of water carriage a more extensive market is opened to every sort of industry than what land carriage alone can afford it, so it is upon the sea-coast, and along the banks of navigable rivers that industry of every kind begins to subdivide and improve itself, and it is frequently not till a long time after that those improvements extend to the inland part of the country.”\(^{83}\)

Even in an industrialized world, the bulk of economic activity still appears to be bound to coastlines and navigable rivers\(^{84}\).

It should therefore come as no surprise that archaeological prospection has established a close correlation between olive oil production sites and the river’s course, and guild inscriptions\(^{85}\) indicate that there was an industry entirely devoted to the conveyance of people and goods along its route. But beyond such generalised statements can we be more specific in its effect on the development of the region?

\(^{81}\) Strabo 3.2.1  
\(^{82}\) Strabo 3.2.4  
\(^{83}\) Smith 1976 p. 32  
\(^{84}\) Mellinger et al. 2000 p. 191  
\(^{85}\) Garcia 1990 pp. 74-8
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Of key importance, of course, is the main channel of the Baetis (Guadalquivir) 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 which is navigable as far as the colony of Astigi and bisects much of the fertile plain. The hydrology of the region also includes a large number of smaller and seasonal waterways (arroyos). Though they may have been of some limited benefit during antiquity (as well as causing a hindrance to land-based transport), they fall outside the scope of this inquiry, as no reliable data exists as to their nature and extent during the classical period. This highlights one of the chief difficulties in such a discussion - the intervening years have transformed the hydrological geography of the region to an extent which is very difficult to gauge. Most immediately evident is a combination of siltation and land reclamation which have converted the estuary into a mixture of marismas and agricultural land which would be entirely unrecognisable to an ancient observer (a process all but complete by the sixteenth century as shown by maps of the period86). Less apparent, but no less important to this study, are changes in the meander of the Guadalquivir. Eighteenth century maps show a series of large bends which no longer exist, though a few can be readily identified in modern field boundaries and aerial photographs.

If such dramatic change can occur in only a few centuries, how can we be certain of the form of the landscape two millennia ago? Fortunately, we are not entirely in the dark. A few general factors have certainly not changed: The Guadalquivir continues, on the whole, to flow alongside a geological boundary on the north side of the valley as it has always done, before turning south towards Seville and the Bay of Cadiz. It is bounded by steeply rising hills on its northern bank, while the other side rises more gradually before reaching a chain of terraces divided by its tributaries. The overall extent of the lacus can likewise be determined (at least approximately) as coextensive with the remarkably flat plain of the Doñana National Park and its surrounding agricultural land. Furthermore, as mentioned above, we have several accounts from antiquity which describe one or more aspects of the area, at least one of which was written by a native of the region. From these we can ascertain not only some of its principle features but also how they relate to human geography: which towns lay along the river and coastline, which rivers were navigable for what distance, and so

86 See Map 6, Appendix B
forth. Archaeological and geographical studies have, for the most part, supported these ancient accounts. We shall also see, whilst we must be wary of self-supporting arguments, that the very location of towns suggests that the course of the Guadalquivir may in fact have been more static than we might expect.

**The Baetis**

One way of approaching the subject is to start with ‘coincidences’. A look at Map 7 shows an unlikely one. Despite the fact that the large expanses of agriculturally suitable land are all south of the Guadalquivir, virtually all the towns on the Guadalquivir lie along its right (northern) bank. Of those mentioned by Pliny and Strabo, Caura, Osset, Italica, Iliipa Magna, Naeva, Canania, Arva, Axati and Celti have been identified with locations to the North/West whereas only Orippo and Hispalis are to the South/East. Regardless of whether such a distribution indicates intentionality, it is certainly clear that these are the towns which flourished from at least as early as Caesar’s day, and indeed, all of the towns between Osset and Axati were to achieve the status of *municipium*. The observation leads us to assume that something was either attracting towns to the north bank or discouraging them from occupying the south, or a mixture of both.

A first clue is gained by taking a closer look at the course of the river. We should rightly be suspicious that several sites are now some distance from it. Consultation with the older maps mentioned above shows why. The hydrographical work of Drain et al. (1971), correlated with visual identifiers from georeferenced aerial photographs was used to map the probable course of the river during the eighteenth century. By overlaying this with the modern course we can immediately clear up the apparent discrepancy. In the past few hundred years a number of the river’s meanders have either reduced in size or disappeared completely. The new map shows that the

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87 Appendix B
88 Outwith the region of this study, Carbula and Corduba continue this trend, whereas although Pliny locates Detumo on the south bank (“on the same side as the Singilis”, Pliny 3.10), it has been tentatively associated with the remains of a settlement to the North (TIR J-30)
89 Celti may well also have been a *municipium*. See Keay *et al.* 2000 pp. 201-6
90 Drain *et al.* 1971. See Map 8, Appendix B
91 Source: Consejería de Obras Públicas y Transportes, Junta de Andalucía

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towns and meanders align extremely well, along with another interesting correlation: all of the known towns are located at the greatest deviation from the river’s median course. Historically, many towns are built within the bend of river, both for defensive purposes and to provide the maximum possible shoreline (indeed, at least one site on the Genil does so), so the tendency requires an explanation. A study of the elevation of the region hints at the answer. The sites are located not merely at the points of maximum distance from the mean course, but they are also located at points where the ground rises steeply away from the river. To examine the issue more carefully, a topographical cross-section was taken of the river at each of the sites\textsuperscript{92}. These were generated by using a 10m contour map\textsuperscript{93}, and measuring the distance along a line taken from the site’s approximate centre point to the nearest stretch of river and across the valley\textsuperscript{94}. The method is very crude as variation with the 10m bands cannot be shown, occasionally where it may have had an important effect. Key areas were generally on the ‘peaks’ and ‘troughs’ and it is specifically in these areas that interpolation becomes closest to speculation. It was therefore specifically decided to use only known data rather than interpolate, despite the drawbacks. Nonetheless, the results show a striking correlation which only begins to deteriorate as we approach the ancient *lacus*. Virtually all the towns are built close to, but above, the river.

So why such patterning? In fact the answer is not a mystery and well-known to long-term residents of region. Despite the long, arid summers, the annual rate of precipitation in the Guadalquivir valley varies tremendously from year to year. The watershed of the river is a huge region incorporating several mountainous areas and the result is that the river floods frequently and sometimes dramatically, especially downstream of its confluence with the Genil\textsuperscript{95}. The chart below shows the numerous floods since the sixteenth century, but the apparent increase in frequency is liable to be an artefact of better public record-keeping than due to a change in climate.

\textsuperscript{92} See Map 9, appendix B and River Profiles in Appendix E
\textsuperscript{93} Source: Instituto de Cartografía, Consejería de Obras Públicas y Transportes, Junta de Andalucía
\textsuperscript{94} In one case, the section had to be dog-legged, due to the town’s position in relation to the curve of a meander.
\textsuperscript{95} Vanney 1970 p. 89
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Chart 1: Flooding in Seville in metres above sea level since 1500.

A flood of the twelfth 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 10m above sea level. If the death toll is correct, it was the worst river flooding catastrophe in recorded European history.\(^6\)

It is likely, then, that the location of the towns along the river is a response to this threat.\(^7\) The dissymmetry between the left and right bank mean that, to avoid the risk of flooding, those to the South must be situated at a distance several kilometres 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. As 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 was only part of a mixed economy, we can conclude with a reasonable degree of likelihood that it is direct access to the river itself, i.e. transport, that is the determining factor.

But if transport potential is such an important feature of their location, what is being transported that requires such regular terminals? Our ancient sources leave us in no doubt as to the answer. Before oil, wine, wheat and fish were to become further staples of the Baetican economy there was just one overarching interest in the minds of Baetica.

\(^6\) Vanney 1970 pp. 111-2

\(^7\) A likelihood noted by other scholars. See, for example, Keay et al. 2000 p. 4

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of the Roman generals and administrators: precious metals. The Sierra Morena provided some of the richest deposits of silver, copper, gold and iron in the ancient world\(^8\). Metal is, however, almost as difficult to transport as it is to extract. In a world where transport is based on animal and manpower, only very limited quantities can be transported from the mountainous Iberian terrain where it was excavated to the coast. The solution was to take advantage of the Baetis. The ore was processed into ingots on site. These could then be carried transported by pack animal to one of the towns along the North Bank of the Baetis\(^9\). From there they could be ferried downstream to the coast from whence it could be transported, in bulk, to the public and private coffers of Rome. A regular distribution of towns along the river’s course provided at least two advantages. First, it reduced the distance necessary to travel before access to the river, and the required harbour facilities, could be gained. Secondly, in the tempestuous times of the late Republic, and with the as yet ‘un-Romanized’ tribes of the interior to contend with, it would enable the valuable cargoes to be moored in relative safety during their long journey downstream.

There is a final, tentative conclusion that we might draw from this study of the Guadalquivir above Seville. With a couple of notable exceptions (particularly at Naeva), the sites of the Roman towns are still close to the river. There have been marked alterations in its course, but on the whole these can be categorised as either changes in the amplitude of a meander, or in a bend being lost altogether when the river breaks through, creating an oxbow lake which eventually silts up. Even these changes tend be of an increasingly smaller magnitude as the river valley narrows in its higher reaches. This suggests (though it would be difficult to prove with any certainty) that the river’s course has in fact remained remarkably static over the past two thousand years. This in turn may enable us to generate a few, albeit provisional, metrics.

The distances in table X show the approximate distances, direct and by river, in kilometres between the ancient towns of the lower Baetis in kilometres and Roman miles (≈ 1.48 kilometres) based upon the river course as known from the eighteenth

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\(^8\) Strabo 3.2.8
\(^9\) See Map 10, Appendix F
Network Analysis of Transport Vectors in Roman Baetica

century. The most significant factors are the inclusion of a number of now-lost meanders.

<table>
<thead>
<tr>
<th>Course</th>
<th>river distance (km)</th>
<th>river distance (miles)</th>
<th>direct (km)</th>
<th>direct (miles)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Celti-Axati</td>
<td>29</td>
<td>19.6</td>
<td>18</td>
<td>12.2</td>
</tr>
<tr>
<td>Axati-Arva</td>
<td>9</td>
<td>6.1</td>
<td>6.3</td>
<td>4.3</td>
</tr>
<tr>
<td>Arva-Canania</td>
<td>13</td>
<td>8.8</td>
<td>5.8</td>
<td>3.9</td>
</tr>
<tr>
<td>Canania-Naeva</td>
<td>25</td>
<td>16.9</td>
<td>14.5</td>
<td>9.8</td>
</tr>
<tr>
<td>Naeva-Ilipa Magna</td>
<td>30</td>
<td>20.3</td>
<td>16.3</td>
<td>11.0</td>
</tr>
<tr>
<td>Ilipa Magna-Italica</td>
<td>12</td>
<td>8.1</td>
<td>10.3</td>
<td>7.0</td>
</tr>
<tr>
<td>Italica-Hispalis</td>
<td>12</td>
<td>8.1</td>
<td>8.5</td>
<td>5.7</td>
</tr>
<tr>
<td>Hispalis-Cavrium</td>
<td>16</td>
<td>10.8</td>
<td>14.4</td>
<td>9.7</td>
</tr>
</tbody>
</table>

It is interesting to note that whilst the direct distances are relatively short, most of the river distances (especially if we discount Italica) fall between 15 & 20 Roman miles. As the boats would most likely be towed by men or oxen\(^{100}\), this is approximately the minimum distance for a day’s travel\(^{101}\), and correlates well with distances we find on the Antonine Itineraries and Vicarello goblets. To put it another way, given that the difference between the direct and the river route can be a factor of two, and that towns away from the river are often over twenty miles apart, it seems significant that it is *never* more than day’s river journey between them.\(^{102}\)

**The “Harbour of Seville”**

Given the remarkable uniformity of, and logical rationale behind, the site location of the towns of the navigable Baetis, we are confronted with two extraordinary exceptions: Oriippo and Hispalis. They both lie on the lower flood plain, close to the river, and much of them is less than 10m above sea-level. Whilst Oriippo *may* have escaped the numerous 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\(^{103}\) left one scholar to reflect,
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“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.” 104

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 more lines of Strabo,

“After Corduba and [Gades], Hispalis, itself also a colony of the Romans...is most famous, and still remains the trade-centre [ἐμπορίον] of the [province]....”105

“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...”106

The transformation of the *lacus ligustinus* into dry (and semi-dry) land makes it easy to forget that Hispalis was originally much closer to the mouth of the narrower reaches of the Guadalquivir. The primary reason for Hispalis’s existence then is as a transport terminal and Strabo’s use of “still remains [συμμένει]” suggests that it had been pre-eminent since at least its official foundation by Caesar.107 Just as the towns higher up the river enabled goods to be exchanged between the land and river craft, so Hispalis was the hub from which imports were landed and exports were loaded onto the sea-going vessels of the day. It was here that ingots and probably amphorae were weighed so that customs could be paid108. It is one of history’s great ironies that the same port that received the wealth of the New World in its notorious *Torre d’Oro* (Tower of Gold) was also part of a system which saw the exploitation of Iberia’s own natural resources.

Given its unlikely position, we should also seek to explain why Gades was not the principle harbour, offering, as it does, a natural geography more suited to larger

104 Vanney 1970 p. 111
105 Strabo 3.2.1
106 Strabo 3.2.3
107 TIR J-30
108 Domergue 1998 pp. 213-14
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vessels, and, perhaps, being connected to the lacus by canal or a branch of the Baetis\textsuperscript{109}. The most obvious explanation is that the river boats were unable to reach it, either because no such aquatic link existed, or they were simply unsuitable for an estuarine environment and the strong currents and riptides which Strabo describes so colourfully.\textsuperscript{110}

Hispalis also appears to have provided harbour facilities that were not entirely rudimentary. Compared to Ostia, it was protected from the worst of the sea weather and possibly, as today, offered two separate channels enabling the complex manoeuvring required of shipping without obstructing passage up and down stream. It was also large enough to provide mooring for numerous vessels and must have had enough skilled tradesmen to build them. We know from the history of the Alexandrian Wars that Julius Caesar’s Propraetor, Q. Cassius Longinus, built a fleet there of 100 ships\textsuperscript{111}. Still, the ever-present threat of flooding must have had its effect. Perhaps we should not be surprised to note that the most illustrious residents of its locale (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.

**The Singilis**

The River Singilis (the modern Genil) played an important secondary role in the ‘natural’ transport geography of Baetica for two reasons. First, it linked the Guadalquivir, the colony of Astigi (Ecija) and at least two other towns (Segovia and Segida Augurina) with a navigable waterway. Secondly, along with the Guadalquivir, it is the transport ‘spine’ of the olive oil industry which was such an important part of the Baetican economy in the imperial period. It is considerably narrower than the Guadalquivir and it meanders to a tremendous degree within the narrow valley it has carved from the surrounding vega. In fact although the distance from Astigi to Celti is only 34 km (about 22 Roman miles) as the crow flies, the same distance by river is 68

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\textsuperscript{109} TIR J-29

\textsuperscript{110} Strabo 3.2.4; On the need for and interaction between specialist vessels in riverine, estuarine and maritime environments, see Evans 1988 pp. 369-70 & 383

\textsuperscript{111} Caesar *Bell. Alex.* 51 & 56

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km (44 Roman miles), effectively doubling transport time\textsuperscript{112}. This suggests that boat travel would only makes sense if load, rather than speed, was the principle factor.

We are fortunate to possess, in Ponsich’s exhaustive catalogue, an approximate distribution map of known olive-oil production sites in the lower Guadalquivir valley. Composed of a number of studies, it should be treated with some caution as it ignores sites outside of its clearly defined scope, and is a compilation of previously acquired data rather than a study undertaken under strict methodological principles. Nonetheless the trends are clear\textsuperscript{113}. In the first place we can see that kiln production focuses on the river banks along most of their navigable extent, but no further. From this we can be fairly sure that, whilst clay from the river bed may have been the material of production, it was their proximity to a transport network that dictated their location. In turn, we see that the sites of olive oil production are located within a reasonably short distance of the kiln sites\textsuperscript{114}. The olives were grown on the plains close to the river, pressed so as to discard the redundant weight of skins, stones and flesh, and then the oil was conveyed to the riverside (presumably in hides\textsuperscript{115}) and decanted into the amphorae to be taken downriver to Seville. There, as we have seen, it could be transhipped to larger vessels and delivered to Rome and the frontiers. Here as with the metals, we can see a clear process of transporting only what is required as short a distance as possible until a mode of transport requiring lower economic cost can be adopted. The transportation of other products, though no longer evident in the material record, almost certainly followed a similar pattern. Whilst we should be wary of calling this industrialization, in the absence of other arguments we have no reason to doubt or disparage Roman transport efficiency.

\textit{The River Transport Network}

With the foregoing discussion in mind, we can now construct a node network of towns along the river. Such a network was not the high speed link of those on official

\textsuperscript{112} It is worth remarking that the Antonine Itineraries give a distance of 37 miles.

\textsuperscript{113} See Map 11, Appendix B

\textsuperscript{114} Oil production also took place further West, away from the river, but as can be seen from Map 4, Appendix B, it was a great deal more dispersed.

\textsuperscript{115} Garcia 1990 pp. 81-2

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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 centres we can begin to understand its advantages and disadvantages to individual towns.

On constructing a node graph for the river, two choices must be made. The first is how to represent the junction of the confluence of the rivers. Theoretically, it should be modelled as a tree graph with a further node at the juncture between the two branches. Such a graph would, however, introduce a further, arbitrary node into the diagram. As we have seen above, the values generated are affected by the number and location of nodes within a network and as we are only interested here in relations between towns (i.e. routes between them), to include such a node would be nonsensical. In order to solve the problem, 3 separate edges are used, one for each of the 3 possible (bi-directional) routes between Celti, Detumo and Segida Augurina. The second decision is whether to use a directed or undirected network. As traffic must have occurred in both directions, an undirected network has been used.

The results of creating the network are displayed in Network Diagram 1 in Appendix C. The closeness and betweenness centralities were calculated and the results are displayed in the chart below. The complete set of results are shown in Table 1, Appendix D.
As we might expect 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 our jurisdictional capitals have low scores. How can we interpret these results in a meaningful sense? First of all, although the indices show a high degree of correlation we must remember that 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. Let us consider these implications for the river.

The phenomena so far observed might tentatively be summarized as follows:

- Three of the jurisdictional capitals (including the provincial capital) lie on the navigable Baetis, the fourth lies on the coast
- Jurisdictional boundaries converge upon the juncture of the Singilis and Upper and Lower Baetis.
- Towns along the river appear to be located within a day’s walk of each other at most.
- The jurisdictional capitals have virtually the least possible closeness centrality on the river network. i.e. They are about as far apart as possible
- The jurisdictional capitals have the almost the least possible betweenness centrality on the river network i.e. they receive virtually no ‘through-traffic’ on the river.
- The jurisdictional capital of Hispalis is a terminal for extra-regional transport activities.

It is certainly true that, by river, it would be hard to set the capitals further 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 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 to be explored within the next chapter, through an examination of land
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routes, is that they are being drawn outwards by the forces of closeness and betweenness within other ‘constellations’.
Chapter 5: The Land Network

Some of the curiousness of the foregoing discussion has come about for a very obvious reason. So far, we have deliberately not included land-based transport into the equation. We must now use Network Analysis to explore what we know of ancient terrestrial routes and see if it creates a network more in line with our expectations. In doing so, we must be careful to remember that we are not looking at a network, but a number of interrelated networks. The data we shall be using comes from a variety of sources, most of them written, rather than material. As these do not describe identical networks we must assume that that a) they 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, we must also assume that our knowledge is only partial. There will undoubtedly be elements missing from the model we will generate, and further limitations will become clear in the course of the discussion. Nevertheless, as will be seen, the information we do have suggests, at least provisionally, some interesting conclusions.

The Via Augusta

The next network we shall introduce is the best known and best documented of all the roads in the region – the Via Augusta. It is testified to by numerous miliari and several bridges, but most importantly we know that it is followed by the itineraries on the four Vicarello goblets discussed in Chapter Three. It was one of the great imperial highways and undoubtedly a jewel of imperial propaganda. It is crucial in this context for two reasons: it provides a direct link between all four of the Baetican jurisdictional capitals, and we also know that it was a kunststrasse, something that is not certain for our other itineraries. Again, some decisions have to be made as to how to include it within our network. First, we must choose which sites to incorporate. The Via Augusta runs across much of a continent – should we add every town from Gades to Rome? We could do so, and indeed there is nothing methodologically wrong with

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116 Corzo Sánchez 1992 pp. 90-1
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such an approach, but there would be little point. As we have seen, the distribution would give higher values to those towns around the centre (somewhere around Narbonne, say) gradually tapering off towards the extremities. The sites in Baetica would all be influenced more or less equally by this skew, however, so relative to one another their values would remain more or less in proportion. As it is Baetica’s transport structure we are interested in (and which we are postulating as a ‘system’), we shall only include the towns along its route within the region extending as far as Castulo which lies just beyond the ‘Janus Augustus’, a monumental arch which marked the passage from the province of Tarraconensis into Baetica. Castulo was also one of the boundary points between the republican divisions of Hispania Ulterior and Citerior\textsuperscript{117}. Although the town does not lie directly within Baetica, it is the end node of a number of other itineraries and provides a helpful reference point when integrating the model.

The route by itself gives a rather unspectacular set of figures\textsuperscript{118} with a regular distribution curve, but when we combine it with the river network the resulting change is striking\textsuperscript{119}. From having amongst the least closeness and betweenness on the river, and being only part of a series of high-scorers on the itinerary, our three interior jurisdictional capitals now rank amongst the highest with Hispalis ranked first.

\begin{figure}
\centering
\includegraphics[width=\textwidth]{chart.png}
\caption{Closeness & Betweenness of Towns on the Via Augusta and River Network (Top 15 by Betweenness)}
\end{figure}

\textsuperscript{117} Kramer & Kramer 2000 pp. 320-2

\textsuperscript{118} Node Network 2, Appendix C

\textsuperscript{119} Node Network 3, Appendix C; Table 2, Appendix D. The river network has been adapted to take account of land transport on the right bank. Hispalis is connected by way of Osset.
How has this come about? The simple answer is that they act as the interfaces between the two networks. Those 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) both those sites on the road, and those on the river (hence a higher closeness value). It is with this diagram that we begin 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. They 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.  

**The Antonine Itineraries**

The next network to be incorporated into our model is the series of linear routes known as the Antonine Itineraries. Unlike the Via Augusta, we do not know if they follow kunstrassen, though some of them certainly do. They appear to provide, rather, a list of ‘advisable routes’, which may, or may not, correspond to Baetican transport infrastructure. As described above, they cover a much larger region than our study area, but a number of them 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 inclusion of a number of individual cases should be clarified, however.

Several of the routes begin or end at Castulo, just outside of Baetica, but involve locations within the province. Three other itineraries lead to Emerita Augusta, which lies within its own conventus (and was the capital of Lusitania). Although two of these itineraries probably converged before Emerita, this is not indicated in the itineraries themselves and so the junction is not modelled in the network. Finally, the

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\(^{120}\) Evans 1988 p. 390

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Itinerary from Baesuri to Pax Julia lies mainly within the neighbouring province of Lusitania but includes three Baetican towns. The network generated is shown in Node Network 4, Appendix C\textsuperscript{121}.

It should be clear from the foregoing discussion that the itineraries do not seem to be affected by district or provincial boundaries. On the other hand it is clear that they do not always take the shortest route either (for example, Gades-Corduba by way of Antikaria), and some even double back on themselves (Baesuri-Pax Julia, for example, which does so twice). We might also note that it occasionally leaves out cities of note such as Carmo on the itinerary Hispalis-Corduba. As the marked mileage appears correct (42 miles equals the 22 + 20 miles listed in a later itinerary) this is presumably not a simple error in transcription. For some reason Carmo has been deliberately omitted.

There is a further interesting correlation, at least within the itineraries considered. Almost all of them\textsuperscript{122} lead between district and provincial capitals, and/or ‘provincial frontiers’. This is summarized in the table below:

\textsuperscript{121} Betweenness values are not displayed to improve clarity. These are given in Table 3, Appendix D

\textsuperscript{122} The exception being the curious, single-step route from Hispalis to Italica
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<table>
<thead>
<tr>
<th>Itinerary</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gades-Corduba</td>
<td>Capital-Capital</td>
</tr>
<tr>
<td>Hispalis-Corduba</td>
<td>Capital-Capital</td>
</tr>
<tr>
<td>Hispalis-Emerita</td>
<td>Capital-Capital</td>
</tr>
<tr>
<td>Mouth of Anas-Emerita</td>
<td>Frontier/Port?-Capital</td>
</tr>
<tr>
<td>Hispalis-Italica</td>
<td>Capital-?</td>
</tr>
<tr>
<td>Corduba-Emerita</td>
<td>Capital-Capital</td>
</tr>
<tr>
<td>Corduba-Castulo (1)</td>
<td>Capital-Frontier</td>
</tr>
<tr>
<td>Corduba-Castulo (2)</td>
<td>Capital-Frontier</td>
</tr>
<tr>
<td>Malaca-Gades</td>
<td>Port-Capital</td>
</tr>
<tr>
<td>Castulo-Malaca</td>
<td>Frontier-Port</td>
</tr>
<tr>
<td>Baesuri-Pax Julia</td>
<td>Frontier-Capital</td>
</tr>
<tr>
<td>Carthago Nova-Castulo</td>
<td>Capital-Frontier</td>
</tr>
</tbody>
</table>

The correlation is curious as the routes themselves do not necessarily respect provincial divisions, nor do they take the fastest route. We might also note that the number of non-capitals is actually very small – in fact there are only four: Italica (x1), Malaca (x2), Baesuris/Mouth of Anas (x2), and Castulo (x3). In fact, Baesuris and Castulo form the initial/terminal nodes of other itineraries, not included in our network, as well.

This observation would seem to fit extremely well with Salway’s theory that some locations might have ‘destination’ boards that could be consulted for information on how to reach other locations.\(^{123}\) The idea, put simply, is that long distance travellers would plan only the key locations of their journey. At each of these locations they would take notes from these monumental itinerary lists of the sub-routes (each of a day’s travel) required to reach the next. In this way, geographical knowledge could be provided at a provincial or district level to those who required it. The itineraries that have come down to us, so the theory goes, are compilations of these ‘travellers notes’, perhaps to save a regular traveller the trouble of having to consult these public route-planners on each journey. It might even have been a good way of finding more direct routes that would not be known to an itinerant, planning only from the main nodes. ‘Shortcuts’ are certainly marked in the itineraries. The idea is attractive but the data is ambiguous. First of all, we would need to explain why some of the routes are so tortuous, and secondly, why they appear in some cases to take no account of provincial boundaries at all. We will return to this hypothesis again later.

\(^{123}\) Salway 2001 pp. 54-60
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What do our centrality indices tell us? Here the importance of a network is shown clearly, especially when displayed visually. Although closeness does not vary dramatically between sites, betweenness does, and it is no surprise to find, once again, that three of our provincial capitals dominate the graph below.

![Closeness & Betweenness of Towns on the Antonine Itineraries](image)

We can also see that towns along the Via Augusta have high betweenness values, and it is important to remind ourselves that, not only have we not included that route directly within this model, but that no individual itinerary actually follows it all the way through Baetica.

One town is conspicuous by its absence, however. In fact Carmo is not only absent from the top 15 towns, but has a betweenness of 0. How can this be? We recall that betweenness is a measure of the likelihood that a node will be passed by traffic taking the shortest route between two other nodes. As was mentioned above, the itinerary Hispalis-Corduba leaves out Carmo, implying that it can be bypassed. As a result all traffic will take this shorter route, and nothing will pass by the town. Although we happen to know that the route does in fact pass through Carmo (as implied both by the passage of the road and the mileage given in the itinerary) this is not explicitly stated in the itinerary and so cannot be taken into account by the network. Does this make nonsense of our results? No, it does not – on the whole, the correlation between the two models that have been generated, one from a written description, the other from
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data with strong support from the material record, should make it clear what a powerful tool they can be. But it is always important to bear in mind that they are only models, and individual cases may be distorted by local factors.

A further point to remember is that network distance is measured by nodes travelled rather than geographic distances. For this reason, a large number of closely spaced towns (e.g. those on the river) are, with respect to the network, a greater distance to travel than a small number over a greater distance, (e.g. those in the Sierra Morena). Shorter distances, as we have seen, tend to attract traffic. This is to some degree counter-balanced by the fact that the greater the number of nodes that lie on a route, the greater the amount of traffic required in accessing them, but the more central a node is on that route, the less it will be affected. This is why central nodes on long routes usually also have a very low betweenness. Nonetheless, nodes with extremely low betweenness values should be considered with some caution. Lastly, we should recall from an earlier discussion that external sites may well have low scores because other networks upon which they are nodes are not represented in this model. Carthago Nova and Emerita Augusta are cases in point.

Despite all these caveats the system seems to work remarkably well. Although we have given it no geographical data whatsoever, it has automatically generated a model that is identifiably Baetica, albeit with some distortions in relative distance. The correlations between models also correspond remarkably well to our 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 surprise us, for the Baetican littoral appears to have been, above all, a region economically dependant on maritime activity.

The Ravenna Cosmography

The Ravenna Cosmography provides us with a separate list of itineraries, this time without distances and, once again, we are ignorant of the degree to which it follows engineered roads. An initial mapping creates a surprising result however – there
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appear to be three separate networks which do not interrelate.\textsuperscript{124} We might suppose, however that the compiler has 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 we add in the most obvious candidate in each case (following Sillières\textsuperscript{125}), the network connects itself in a much more understandable fashion\textsuperscript{126}.

There are some noticeable differences to our first two networks however. First of all, the Via Augusta plays little or no role. Secondly, although the conventi of Hispalis and Gades are well connected, those of Corduba and Astigi are not. In fact, Astigi has no connection with the towns in its provinces (and Obulcula is missing altogether). Looking at centrality (see graph, below), although Hispalis is once again the key node, the other capitals do not appear in the top 15 at all.

\begin{figure}
\centering
\includegraphics[width=\textwidth]{closeness_betweenness_graph.png}
\caption{Closeness & Betweenness of Towns on the Ravenna Cosmography (Top 15 by Betweenness)}
\end{figure}

\begin{flushright}
\textsuperscript{124} Node Network 5, Appendix C
\textsuperscript{125} Sillières 1990 p. 32
\textsuperscript{126} Node Network 6, Appendix C; Table 4, Appendix D
\end{flushright}

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In this network the chief axis is between Hispalis and Malaca (if we are right in taking the additional step from Aratispitani to the coast). It is debatable as to whether the itinerary Hispalis-Asido leads 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 is striking. Still, the political geography of the province itself may still be important. Once again, we see links between the capitals and frontiers:

<table>
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<th>Itinerary</th>
<th>Last Stage?</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carthago Nova-Baelo (1)</td>
<td>Baesippo?</td>
<td>Capital-Port</td>
</tr>
<tr>
<td>Carthago Nova-Baelo (2)</td>
<td>Baesippo?</td>
<td>Capital-Port</td>
</tr>
<tr>
<td>Baesippo-Hasta- (last stages missing)</td>
<td>?</td>
<td>Port-?</td>
</tr>
<tr>
<td>Emerita-Italicica</td>
<td>Hispalis?</td>
<td>Capital-Capital?</td>
</tr>
<tr>
<td>Emerita-Carmo</td>
<td>Hispalis?</td>
<td>Capital-Capital?</td>
</tr>
<tr>
<td>Emerita-Castulo</td>
<td>Castulo</td>
<td>Capital-Frontier</td>
</tr>
<tr>
<td>Corduba-Anticaria</td>
<td>Malaca?</td>
<td>Capital-Port?</td>
</tr>
<tr>
<td>Hispalis-Aratispitani</td>
<td>Malaca?</td>
<td>Capital-Port?</td>
</tr>
<tr>
<td>Hispalis-Asido</td>
<td>Baessipo/Gades?</td>
<td>Capital-Port/Capital?</td>
</tr>
<tr>
<td>Hispalis-Seria</td>
<td>Pax Julia?</td>
<td>Capital-Port?</td>
</tr>
</tbody>
</table>

The patterning is similar to that of the Antonine Itineraries, and with similar ‘frontier-towns’. 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\(^ {127}\) and the third case is a repetition of the first. We know from the Antonine Itineraries that Baelo seems to have been a port for crossing over to Tingitania which fits the pattern of ‘frontiers’ nicely. Let us finish our Network Analysis before evaluating its support for the ‘tabellaria theory’.

**A Combined Network**

The strength of the database system used is that it enables us to combine multiple networks easily, adding or removing itineraries and nodes as desired. To investigate the entire known transport system we can create a ‘super-network’ composed of the three networks discussed above with one further addition. A route of a single day’s journey is known both from *miliari* and from Aerial photographs between Astigi and Ostippo\(^ {128}\). It is in fact an important route as can be seen from the network\(^ {129}\).

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\(^{127}\)”*Item super fretum Septem sunt cicitates, id est. Bepsipon...”* (Ann. Rav. 305-6)

\(^{128}\)Sillières 1990 pp. 506-8

\(^{129}\)Node Network 7, Appendix C; Table 5, Appendix D

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this route, Astigi would have no direct connection to the majority of towns within its jurisdiction. It is also the final link in a chain which runs directly North-South from Malaca to Emerita. On this note, we should also mention that, with the exception of Regina, it appears that all the towns which lie upon our known routes are able to reach their jurisdictional capital.

Which nodes are most important for betweenness and closeness? The graph below leaves no doubt:

![Closeness & Betweenness of Towns on All Known Routes](image)

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 our data can be taken as broadly representative of the primary transport routes in Baetica, they are unquestionably the focal points of the Baetican transport system. Despite this apparent confirmation of our expectations, it is a striking result in some ways, as our very first network, that of the river, gave a different impression. If the importance of these centres as key hubs on the transport network is now fairly clear, why do they not appear to be so on the river network? The answer may be provided by looking at networks of each district.¹³⁰

¹³⁰ Node Networks 8-11, Appendix C
Although Corduba has the highest betweenness in its district, it would not do so if it were in the place of, say Carbula, which has a much lower rating. Even more striking are Astigi, which is less important than Ostippo, and Hispalis which has a lower betweenness rating than two other towns in its jurisdiction. Here then, perhaps, is the answer to our problem. The location of the three interior capitals appears to be restricted by the river. This is not surprising – we have seen the importance waterways played in terms of economic development. On the other hand, the navigable stretch of the Baetis-Singilis is relatively limited with regard to the Guadalquivir valley as a whole, especially if we take the Sierra Morena into account as well. As a result, in order place them as centrally as possible, they must be located at its furthest reaches and mouth (Hispalis also serves the double function of providing the main interface for sea transport). With these locations established, a road network has developed which reflects their central importance within the political and economic structure of the region.

There is in fact ancient testimony that suggests this is precisely what is going on. Once again, we turn to Strabo, this time speaking of Gaul:

“Lugdunum [modern Lyon, provincial capital of Lugdunensis] is in the centre of the country – an acropolis, as it were, not only because the rivers meet there, but also because it is near all parts of the country. And it was on this account, also, that Agrippa began at Lugdunum when he cut his roads…”

But if we are to accept this as at least a partial explanation for the locations of three of the district capitals, then what of Gades? So far, it has maintained fairly low values in all of our networks. If betweenness really plays such an important role, then why was Gades, rather candidates such as Carteia, which is more central within the district, or Malaca, with better access to the interior, chosen as capital?

This is a difficult question to answer, and indeed there may be a number of reasons. It may be as a result of its historic significance and development during the previous Phoenician and Punic periods. It has a deep water port but is also easily defensible from attacks from the mainland, a useful advantage during the civil wars of the

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131 Strabo 4.6.11
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republic. It is also the principle port in the Bay of Cadiz and provides relatively easy access by boat to the other three capitals. Towns further east would have to pass through the straits of Gibraltar, a passage which was periodically closed by bad weather. Yet a more convincing explanation might be provided by looking at which towns on our network are cited by the sources. Of the three maps, it is clear that the most commonly cited towns are those along the coast (on the bottom edge of the diagrams) and near the river. Strabo says as much himself. What can we infer from this? These towns are better known and more frequently visited than those of the interior, but by a different transport mechanism altogether – by boat. The model we have been using for our land networks makes no reference to this mode of transport, and incorporating it would be a major challenge. Nonetheless, we can be certain that some patterns existed. Winds, tides and currents all interact with ship technologies in ways that restrict, or encourage the use of, different harbours. That is a topic well beyond the scope of this dissertation, but one that would undoubtedly enlighten, and be enlightened by, Gades’s role within Baetica.

In summary, scale seems to play an important role. Corduba is very important at supra-Provincial and district level, but less important within the ‘Baetican’ network. Both Hispalis and Astigi are important at the provincial and supra-provincial scale, but less so at the district level. Gades is relatively unimportant on all the networks, but this is likely to be because it forms a key hub upon maritime shipping routes. These differences may reflect the conflicting demands of tasks each city was required to perform at different scales of government – a phenomenon we may also see reflected in the construction of separate fora at Corduba and Augusta Emerita. Jurisdictional demands called for a site close to the centre of the district. Yet at a provincial level, access to water transport was required, both to control the economy and to allow for the imports necessary for a high status town.

What do our results suggest about the idea of key itinerary nodes with tabellaria? The evidence seems to be mixed. If the theory is true, we might expect to observe two sets of phenomena in our data. First, there would be a limited number of departure and

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132 Node Networks 12-14, Appendix C
133 Strabo 3.2.1
134 Evans 1988 p. 367
135 TIR J-29 & J-30

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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 use a very similar set of start and end points, and they can all be reasonably interpreted as having strategic importance within a transport network. Secondly, as the hubs within the network, we would probably see a correlation in betweenness and these key nodes. Here the results are more mixed. Clearly, Hispalis and Corduba are important, both as centres on the network and as frequent departure points and destinations within the itineraries. Unfortunately we do not have much to say about the external towns as they are also connected to networks which we have not considered. Likewise, the port towns of Malaca, Gades, Baelo/Baesippo and perhaps Baesuris could all reasonably be seen as parts of wider networks. There is, however, one glaring exception. Astigi, which along with Hispalis and Corduba appears to be in a league of its own, does not feature as a terminal node on any of the itineraries. If certain locations are centres of transport information and that is reflected in the itineraries, then Astigi, a district capital, does not appear to be one of them. This is certainly not strong proof against the theory, but it suggests that a much broader study would have to be done to give further support, one way or the other.

The analysis just undertaken has provided us with a wealth of data for analysing the networks and subnetworks which together constitute the known Baetican transport system. It is, however, just the tip of the iceberg. In order to fully make use of the database and fulfil the goals set out in Chapter One, it is time to turn the dissertation’s second goal – improving epistemic transparency. Broadly stated, the aim is to represent the network in a fashion which enables future researchers to quickly understand the structure of the underlying data, as well as integrate it with information from other sources.
Chapter 6: Visualization: Space and Epistemic Transparency

The experience of seeing the network diagrams generated by Pajek has no doubt made the reader aware that visual representations of the data provide a much more intuitive and comprehensive experience than textual ones. A database form is good at providing an overview of the minutiae, but it is difficult to perceive how all the nodes relate to one another. On the other hand, a network diagram enables us to understand such relationships quickly, but at the expense of displaying only one or two of the nodes’ attributes at a given time. Furthermore, the network diagram only exists in an abstract space. This is no bad thing in itself. As the values we have generated are based entirely on just one parameter (essentially just the presence or absence of links within the network) there is a danger inherent in presenting it in a more complex setting, thereby implying influence from other factors (distance, topography, etc.).

The network is simply a model, and nothing more than that. On the other hand, such information is fairly meaningless within a vacuum. We are not interested in the fact that node “Hispalis” and node “Astigi” show higher betweenness values than the other $n - 2$ nodes in set $x$. What interests us are the historic towns of Hispalis and Astigi, and the implication that they formed transport hubs within several integrated networks. By mapping the network on to Cartesian space and superimposing other features we can identify correlations between features in all three.

The first step in achieving this goal is to map the abstract framework onto the concrete geographical reality of southern Iberia. This enables us to make better sense of how it relates to phenomena external to the dataset. By placing it within a spatial framework further information, such as the extent of the study area, topography, hydrography, aerial photography, etc., can be added to provide a contextual backdrop as an aid to interpretation. This information enables a user to obtain a far clearer overview of the locations’ spatial relationships to one another, as well as the potential barriers and links between them. The second step is to ensure that in providing the data in this fashion, we do not ‘reify’ it. In other words, two things should be made as evident as possible to the user. First we have to be able to clearly distinguish between
different sources of information, and secondly we have to be able to show our level of certainty in some way. Some of our information has been confirmed to within a high level of probability. Much has not. It is important to be able to compare and contrast alternative theories, whilst highlighting the areas which are most open to debate. In accomplishing these tasks, the information gathered thus far can be incorporated with much greater ease into a wider academic dialogue on the development of Roman civilization in the Western provinces.

**Spatial Representation**

As a network of routes in hypothetical space has already been established, we can start this process by fixing them within a geographic framework. In practice, this means giving nodes, and thereby routes, a location. The immediate difficulty that presents itself is that our place names do not actually exist in real space. They are entities which were, and, in general, no longer are. As a result, it is not possible to assign them geographical coordinates directly as in many cases they are simply unknown. A solution to this problem is to introduce a mapping table and link them with a table of archaeological sites which have Eastings and Northings.

The site table used for this project has been created using information from the UCIARSS project, supplemented by the TIR for sites outside Seville province. The map provided with the text of the TIR was scanned at a resolution of 150dpi and georectified in ArcGIS 9.0 using the 1924 UTM 30N coordinate system. A point data shapefile was then created with the same coordinate system and each known location was then added to the point layer by heads-up digitizing, and X and Y coordinates were generated. It is important to remember that these coordinates apply only to the system on which they are based. *Using the coordinates with a different coordinate system will locate them in the wrong area.* To inform the user which system has been used, the sites table includes a Coordinate_System field. The data can now be imported into the database and further relevant fields added, in this case, the area, the number of inscriptions, and any fortification types have been included where known from the UCIARSS project, and two further Boolean fields

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136 This was chosen as much of the legacy data available uses this system
have been added, *Miliarius* and *Bridge*, showing their known presence, if known, for all sites\(^\text{137}\). It should be stressed however, that the importance of this system is the structure, rather than its data. It enables us to provide alternative mappings if desired without having to amend the node table itself. This way alternative hypotheses can be visualized quickly simply by swapping mapping tables.

Two groups of point data deserve special attention. A large number of the nodes included in the database (about 30%) are only uncertainly identified with specific locations by the *TIR*. For this reason, the mapping file has an extra Boolean field: *loc_cert*. An ‘optimistic’ approach has been taken - for cases in which the *TIR* states explicitly that there is only a tentative association between a site and a historic name, the field is set to *false*. This avoids introducing a further level of interpretation on the part of the author. As we shall see however, there are a number of cases in which the *TIR* seems to be too confident in its judgement! The second case is a smaller number of sites which are not present on the map as no site has been associated with them. In such cases, an alternative source has been used if possible.\(^\text{138}\) Otherwise, the node is not mapped and needs to be interpolated by the system\(^\text{139}\). To make the inclusion of other data providers transparent, the mapping table contains a further *source* field. This allows for the provision of mixed data sets, giving greater flexibility when weighing alternatives. The *TerminusId* field in the mapping table is a primary key to ensure that no node is mapped twice, although conceivably two different nodes could refer to the same site. Table Diagram 2, showing the additional tables, is shown in Appendix F.

**Software Integration**

Although it is clearly advantageous to keep all our data, spatial, quantitative and numeric, in one place (the database), we are then required to make it available to the GIS. ArcGIS 9.0 is not entirely user-friendly in this regard. Although point data, such as our sites, can be plotted and analysed with relatively few restrictions based on

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\(^{137}\) Based on the TIR descriptions, supplemented by Silières 1990

\(^{138}\) Generally Silières 1990, although for the case of Aranni in Lusitania, the location was taken from Silva 2005 pp 45-7.

\(^{139}\) There were just three cases, specifically, Agatucci, Bactara and Ad Gemellas.
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Eastings and Northings read from a database table, there is no direct way of reading linear data, like our routes. The ArcInfo license for ArcGIS 9.0\textsuperscript{140} includes a ‘generate’ tool, however, which can create vector line coverages from ASCII text files. Of particular benefit is the fact that only the coordinates of vertices within the line need be given, so simply by excluding uncertain nodes, lines will be drawn directly between the certain ones.

To allow for both possibilities, the export function used to export to Pajek has been extended both to write the ASCII file needed for ArcGIS (with the suffix CovInput.txt) and to give the user the choice of whether to incorporate uncertain nodes based on the value of the loc_cert field. The two systems work best in parallel with one another as they allow for either a complex but provisional network, or a simplified and more certain one. A drawback of the latter is that when uncertain nodes form the final links in an itinerary, the final portion cannot be drawn at all. A case in point is the itinerary from Ulia to Anticaria which is entirely absent from the simplified model. As with the analyses in Chapters Four and Five, it is always important to keep in mind the limitations of the model we are using, even when it ostensibly provides a more definite body of information. The input file also assigns each linear feature an ID based on the itinerary. Using this as a handle, it is then simple to link them back to the itinerary table in the database using an OLE connection. The joined table in ArcGIS can then be recategorized, representing each of the itineraries based on its name or source. The standard symbology tools and labelling system provided by all ArcGIS licenses then instantly enable the user to generate an overview of the framework underlying the projected route network that is epistemically transparent\textsuperscript{141}. In this way it becomes clear, in a way not obvious on other maps, on what basis we are constructing the hypothesized transport system.

As the spatial information is being processed within the GIS it also necessary to be able to import the data produced by Pajek. This requires a more complex solution because Pajek does not export information in a GIS-readable format. As Pajek also has no Application Programming Interface (API), the only option is to find a way of converting a Pajek-produced ASCII file into a format that can be understood by a

\textsuperscript{140} This is the ‘full-price’ licensing option, providing their complete suite of standalone GIS tools.

\textsuperscript{141} See Figure 4, Appendix A
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GIS. Several factors come into play. The first is that, although ArcGIS can be modified with relative ease using its own Visual Basic API, such modifications are saved in map files or templates, rather than application level. This means that the extension would have to be loaded separately for each new map. Of greater importance is the fact that visualization would then become increasingly dependent on a specific (and proprietary) software tool. This is already partially the case in the generation of the file imported to create line coverages described above. However, this is not a proprietary format itself, and other GIS packages may be able, or adapted to be able, to import it. Most problematic of all is the fact that Pajek does not maintain the database ids of the nodes, as each must be numbered serially (starting at 1) at import time. The result is that there is no way, other by name, of tying the results back to the information in the database and we have several cases of two locations sharing the same name.

In order to circumvent these problems, we need to import the Pajek data back into the database itself, in a separate `NAResults` table. Each time a file is written from the database for Pajek to import, the table is cleared and rewritten with both the database ids of each node, and the new, serial ids required by Pajek. Once centrality indices have been generated with the Network Analysis software, they can be saved easily as files. Some extra code and three further buttons have been added to the database that can import these files into degree, closeness and betweenness fields within the new table\(^{142}\). The table can then be accessed directly either by a database user, ArcGIS or any other data analysis package. There are two disadvantages to such a system, which should be made clear. The first is to repeat that centrality indices are entirely relative to the network which generated them and as such are not a property of the nodes themselves. Although the table contains only the nodes which form the network, it does not store the links between them, and it is entirely up to the user to ensure that centrality data is only displayed in conjunction with the network which generated it. *If values are displayed corresponding to other networks, the information presented is worse than useless - it is wrong.* To at least partially protect against this problem, the database checks the number of vertices described in the import file against the number of nodes in the table so that only the last network exported can be reimported\(^{143}\). The second disadvantage is that it only allows for one set of data to be imported at a time.

\(^{142}\) The code is listed under Import Code in Appendix F
This problem can be overcome if necessary by replicating the data either within the database (which should be discouraged due to issues of maintenance) or at the GIS level, where it can be integrated with a spatial distribution set and exported as a shape file if desired.

**An Initial Analysis**

It needs to be reiterated that the principle aim of this part of the dissertation was to produce a system of ‘deep’ representation. The difficulty faced in presenting any analysis on paper is that it inevitably produces maps which suggest some kind of ‘final verdict’. Nothing could be further from the truth. First of all, to even begin producing maps that clearly showed all the relationships between information available in the database, let alone all the possible networks, would easily double the number of pages in the dissertation. Secondly, the database has been deliberately designed to be easily extendable and alterable without losing old data. Importing new data will change results and those changes will also have to be analysed. In other words, whilst there is a great deal of potential for analysis, it is not within the scope of this dissertation to try and cover all of it. Nevertheless, a number of features become so immediately apparent on presenting the information in this way, that they demand a brief discussion and will also demonstrate the way in which the stated goals have been achieved.

On even glancing at the map of all the known routes\(^\text{144}\), the first thing that catches a reader’s eye is that a number of the site-node mappings stated by the *TIR* evidently seem to be wrong. The suggested location of either Julia Traducta or Cetraria does not appear to be correct as it would require those following (identical) itineraries 1 and 10 of the Ravenna Cosmography to backtrack in order to reach the latter, before carrying on in the original direction. An even smaller likelihood is the ‘certain’ identification of Ilipula Minor with a site lying on the Corbones river. If this were to be the case, two separate itineraries (Ravenna Cosmography 7, and Antonine Itinerary 6), leading

\(^{144}\) This is not a perfect system as two different networks could have the same number of nodes, although in practice this is unlikely to be the case.

\(^{144}\) Map 12, Appendix B
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from two separate towns (unless, ‘Carula’ is a serious corruption of ‘Cirseone’ [Urso]) would both have to turn back on themselves in order to reach it. It is considerably more likely that it is indeed to be identified with its traditional location near Repla, which is to the South-East of Osuna. It is clear that representing the networks in a GIS gives us the ability to both increase and challenge the certainty of our knowledge.

Being able to break the network down by individual itinerary also gives us a clearer idea of how each relates to the other, and some further clues as to their origin. As we saw above, 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, taking a fairly direct route. Others take diversions that might also be permissible, especially when they go by way of important towns such Astigi, Acci, or Corduba. There are one or two however that could surely not be 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 points out, the compilations are probably comprised of itineraries created under various circumstances, and it is certainly possible that these are exceptions to a general rule, but without looking at a larger dataset, the evidence from Baetica is not yet compelling.

Yet the information we now possess may give us a new way of looking at the problem. From the GIS we can see 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 is 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.

145 Which, peculiarly enough, is mentioned in the TIR but rejected without argument.
146 See Maps 13 & 14, Appendix B
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Including the river network and the extensions of Sillieres, the chief features (with starting points here chosen arbitrarily) seem to be:


- A separate circuit seems to trace the main extents of the Gudalquivir 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.

If we draw a schematic diagram of the principle route network, and mark on the places in which itineraries begin\textsuperscript{147}, an interesting pattern emerges. All of the itineraries begin on the boundaries of Baetica, except for Corduba, the provincial capital. They are particularly common in 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 travellers taking notes down on arrival at a new province does not seem at all far-fetched. Likewise, we would 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).

We would be foolish to jump to conclusions on the basis of just one province, but the co-incidence of starting points with clear points of provincial interface is one worthy of further investigation. If we are to use the Roman itineraries then we have to try and understand the rationale behind them. The implication of the study just described is that they may well have been written by visitors to Baetica, rather than the native population. If that is the case, it is no great wonder that the network appears strangely

\textsuperscript{147} Map 15, Appendix B
symmetrical whilst the routes meander, for they are plans made by people who have had Baetica explained to them.

In conclusion, we have seen how the GIS has made it simple both to understand the various networks we have examined and to bring it into a wider context. We have also established a way of comparing competing hypotheses, whilst allowing for a degree of uncertainty. Not all the possibilities have been examined here, but the economic maps in Appendix B have been georeferenced and included on the CD-ROM so that the reader may begin to explore some of the correlations. We can now move on to our conclusions and some questions for the future.
Chapter 7: Conclusion

The foregoing discussion will hopefully have made clear that there is a great deal more potential in the use of Network Analysis (coupled with a GIS) than can possibly be looked at within the scope of a dissertation. This concluding chapter will briefly summarize the initial findings of the analysis, as well as critically reappraise the approach taken in reference to the goals outlined in the introduction. Following this there will be a brief discussion as to how these results can be integrated with the wider UCIARSS project, as well as some reflection on directions in which the work could be taken further.

Critique of the Methodology

On the one hand, the Network Analysis has turned out to some surprisingly strong results. It should not surprise us that the district capitals show a higher degree centrality than other cities. Indeed, it would be curious if they did not. It is also not particularly unusual to see fairly even levels of closeness within the network as a whole, as there is a surprising degree of symmetry and it is quite strongly interlinked. What comes as a greater surprise is the variation in betweenness. This index shows to a high degree of probability that the capitals were chosen either as de facto, or intentional hubs within the province. As has been reiterated throughout this discussion however, such results must be approached with caution. The network remains a model founded on data that is both corrupt and incomplete. It does not take distances into account, nor links which are not explicitly stated within the record. It is also based on a subset of data which, though not selected arbitrarily, may conceivably not reflect the ‘real’ social, political and commercial structures of Baetica during the Roman period. But despite all this, they are interesting results. Even if they do not show the complete system of routes used by the resident traders, magistrates and other itinerants, they may well reflect the thoroughfares perceived to be important by external visitors. This may go some way towards explaining a layout which often seems to make more sense from an abstract perspective than it does on the ground.
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From a technological perspective, the goal has been to provide a simple system that enables a user to interrogate the data source visually and conceptually in a way that does not conceal its variegate nature. The database structure itself has been kept as simple as possible but there is plenty of room for additional fields should they prove desirable. For example, it might be worth linking towns to sources by means of a mapping table which also held a reference to their location within the text. Currently, those wishing to follow up a reference to a classical source would need to consult the TIR to find its location.

Pajek has proved itself to be an extremely useful tool for Network Analysis, though with a number of important limitations. One of the greatest advantages is that it is free for non-commercial use and fully, albeit tersely, documented. The user interface is not particularly intuitive, though fairly simple once grasped. The program is also remarkably quick, enabling results to be generated and visualized within a matter of minutes. The downside is that it has no API to allow for customization or integration with software packages. This entails that all interfacing has to be done through flat ASCII files. Such files are very quick to produce and process, but on the other hand, are meaningless if they become separated as the ordering of information within them is dependent on the order of nodes described in the initial Network (*.vec) file. An alternative considered was to write a program from scratch using the InfoVis CyberInfrastructure (IVC) software framework. This consists of a series of Java APIs which provide the functionality needed to build custom Network Analysis software. According to the website blurb, there is a considerable amount of overlap with Pajek, with the added advantage of having almost complete control over the functionality, but it was felt to be too risky an option for a project with such a short implementation time-span. Nonetheless, the author intends to investigate it further at a later date. In the meantime, Pajek also provides a much wider suite of tools than those used here and it would be interesting to see which, if any, could also have application for transport networks.

The GIS was principally used for visualization although it was also necessary for generating the river cross-sections. Whilst GIS software is beginning to provide researchers with an unparalleled opportunity to quickly understand relationships in

\[\text{http://iv.slis.indiana.edu/index.html}\]
spatial data, much of the technological development is being driven by commercial forces. On the one hand, this means that there are an ever-increasing number of tools with which to manipulate and explore the data. On the other hand, actions as simple as storing spatial information in a non-proprietary format still seem a long way off.

**Future Directions**

One of the more exciting aspects of the work is that now the framework has been created, it is in fact very simple to extend. The dataset considered within this dissertation is only a fraction of the itineraries that have come down to us. Both the Antonine Itineraries and the Ravenna Cosmography/Peutinger Table cover almost the entire ancient world, much of the latter in a visual format. There are numerous others, large and small. This is not to suggest that in creating a ‘super-itinerary’ we are mapping the Roman world. The problem with such approaches is that they tend to consolidate all the information into a unified network. But by introducing such data into a framework such as that described in the chapters above, we are able to see much more clearly the different sources, the starts and finishes, the virtually-certain, and the wild-speculation. In this way we may be able to glean some better understanding of the way itineraries worked and how they were used by travellers, rather than chasing the chimera of a complete knowledge of Roman transport structures.

Another direction to explore is the incorporation of distance into the equation. There are difficulties to be overcome. Pajek does not take distance into account, and ArcGIS, which represents it reasonably well, only has limited functionality for dealing with Network Analysis. The IVC framework described above, however, may be able to incorporate both. Even so, there are still data issues to be resolved – not least of which is what distances to use. The concept of distance actually requires some unpacking. As we have seen in the models above, it seems to be a more important factor for terrestrial transport than that using rivers and sea. Some progress has been made towards this in the application of ‘cost-distances’ which factor in the relative difficulties in crossing different kinds of terrain. Whilst this is clearly an improvement utilizing simple Euclidean distances, it is still an inadequate measure of transport cost.
First, transport is above all a value-based activity. It involves a playoff between the advantage gained and the cost (or ‘friction’) involved. This friction is better understood as an equation involving the two coefficients of time and effort/expense. The value of either may vary in both absolute and relative terms but no-one moves things if it’s not worth it. Secondly, transport friction is not a single conceptual entity but composed of (at least) the following factors:

a. Space. The actual distance involved.
b. Environment. The natural surface over which transport takes place, affected by both physical and socio-cultural barriers (e.g. mountains and borders).
c. Static technology. Infrastructure such as roads or jetties.
d. Dynamic technology. Planes, trains and automobiles, or in our case, ships, barges and oxen, etc.
e. Systems. The individual and collective behaviours through which the technologies are utilized. These include the abilities of the populace to use certain technologies, and the laws and norms that dictate how they do so.
f. Load. The volume of passengers and cargo (and dynamic technology) transported.

The challenge in modelling transport is that there is, and can be, no natural ‘friction’ for any point of space, nor any fixed ‘price’ for any mode of transport. Whilst all transport has a ‘cost’ it is always a unique calculation. Though it is possible to talk about ‘average costs’, they may bear no relation to actual realities of particular cases as any statistician knows. What we need to look for is the economic rationale behind the activity. The Grand Tours of the eighteenth century make no financial sense, but socially, and hence politically and economically, they do. In contrast, many early Roman military campaigns (of which transport logistics were a key component) were of greater financial than military benefit to their planners\(^\text{149}\). In short, there can be no common algorithm suitable for calculating transport costs or benefits in all circumstances.

Thirdly, the ubiquity and aggregative cost of transport makes it conducive to economies of scale. Transport technology, both static and dynamic, does not change

\(^{149}\text{ See, for example, the behavior of the consul L. Lucullus in Appian, Iberike 51-55} \)
frequently because the cost would be prohibitive and returns are only made in the long run. This is advantageous to the archaeologist, for transport networks have a heavy historical bias which will often be based on a wide range of interests, including many which are long since past. When considering such ‘legacy systems’, however, we must be careful to differentiate between the users and investors. *Most infrastructure reflects the agenda of those wealthy and/or powerful enough to create or influence it.* It will not necessarily represent the preferences of those who use it - it may just be the best means available for their requirements.

If we want to try and understand transport as anything more than historic contingencies of landscape we need to try and understand the forces at work behind it. Specifically we need to ask who was involved in the transport process, what their primary concerns were, and what obstacles and resources surrounded them. The inclusion of physical distances is just a single, if important, aspect of this.

Turning to the UCIARSS project, there is now the potential to compare these results with metrics measuring other aspects of connectivity. It will be particularly interesting to see whether road networks appear to have relevance in the distribution of coins and epigraphy and whether the work currently being done with β-skeletons reinforces or challenges the structure of the network. A further direction that can be explored, following visibility-analyses undertaken over the past two years, will be to see whether itinerary stages appear to fall between inter-visible sites. Are some of the intervening nodes simply chosen as being the most visible markers between starting points and destination with, perhaps, just one or two important nodes *en route*?

Finally, the data accumulated here also provides a useful ‘wider transport context’ for the region covered by UCIARSS.

It has become apparent throughout this study that any single mode of transport will rarely make sense on its own. It has been very clear that the role of the river has been fundamental both in the distribution of towns, and thence the roads or routes that led between them. Of equal importance is the sea, which has had a strong effect both on the location of Hispalis, but also on the apparently different nature of interaction between towns in the jurisdiction of Gades compared to those in the interior. And (at risk of stating the blindingly obvious) the river also leads to the sea, where we have
Network Analysis of Transport Vectors in Roman Baetica

seen that the interface between them is a crux upon which virtually the entire economic system has been built. The different manners in which these three environments have been used for transportation, and the complex interactions between them, may not be possible to model in their entirety. Yet Network Analysis has shown itself to be a powerful tool in exposing aspects of them. By using GIS technology to integrate those conclusions into other research, whilst keeping the premises that lie behind them transparent, I believe we have the capability to learn a great deal more about the transport geography of antiquity.
Reference Cited


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Appendix A: Figures

Figure 1: Coins from Alcolá del Río showing produce from the local area (Garcia 1990)
Network Analysis of Transport Vectors in Roman Baetica

Figure 2: One of the Vicarello Goblets inscribed with an itinerary from Gades to Rome (Corzo Sánchez 1992)

Figure 3: River barge being towed from the bank shown on a relief from Avignon (Garcia 1990)
Network Analysis of Transport Vectors in Roman Baetica

Figure 4: The GIS being used to identify information about a specific itinerary
Appendix B: Maps

Map 1: The location of Baetica and its approximate division into four conventi (after TIR J-29 & TIR J-30)
Network Analysis of Transport Vectors in Roman Baetica

Map 2: Coasts of southern Spain and Morocco. The numbered black squares mark the location of kilns producing amphorae for the transport of fish salazones (Ponsich 1998)

Map 3: Baetican vineyards. 1. Site of vineyards (underlined when coins were issued with the image of a grape); 2. Site of vineyards marked by coins issued with the symbol of a bunch of grapes; 3. Vineyards of Arab date (Ponisch 1998)
Map 4: Map showing the increasing importance of oleiculture along the Guadalquivir valley in terrain which was favourable to, and traditionally involved in, this crop (Ponsich 1998)

Map 5: The complementary economic zones of Baetica (Ponsich 1998)
Map 6: A sixteenth century chart showing the coastline of the Bay of Cadiz. The *lacus ligustinus* (centre left) has all but disappeared (Corzo Sánchez 1992)
Map 7: Roman Towns on the Guadalquivir and Genil with 100m contours. (Source data: Consejería de Obras Públicas y Transportes, Junta de Andalucía; UCIARSS)
Map 8: Evolution of the course of the Guadalquivir since the eighteenth century
(Drain et al. 1971)
Map 9: Roman towns on the lower Guadalquivir, with 10m contours (0-100m), historic river course and cross sections (for profiles see Appendix E)
Map 10: The mining areas of the Sierra Morena north of the Baetis, together with the right-bank ports where metal ingots could have been loaded onto rafts or small boats heading for the shipping port of Hispalis. 1. Linares-La Carolina (lead/silver); 2. Andújar-Montoro (copper); 3. Alcudia (lead/silver); 4. Pedroches (copper, lead/silver); 3.5 Córduba (copper); 6. Posadas (lead/silver); 7. La Serena (lead/silver); 8. Azuaga-Fuenteovejuna (lead/silver, copper); 9. Sevilla (lead/silver, copper, iron); 10. Aznalcóllar (copper) (Domergue 1998)
Map 11: Roman oil production and kiln sites on the Baetis and Singilis
(Source: Etienne & Mayet 2004; Ponsich 1991)
Map 12: All known routes within Baetica, by source. Note also that some site identifications (esp. Ilipula minor, south of centre, and Julia Traducta, at bottom of map) do not seem to be correct.
Map 13: The Antonine Itineraries in Baetica
Map 14: Schematic diagram of main Baetican routes with starting nodes of itineraries.
Appendix C: Node Network Diagrams

Node Network 1: Towns on the river by *conventus* with betweenness values. Green = Hispalis; Yellow = Corduba; Red = Astigi
Node Network 2: Towns on the Via Augusta by *conventus* with betweeness values. Green = Hispalis; Yellow = Corduba; Red = Astigi; D. Blue = Gades; Pink = External; L. Blue = Unknown
Node Network 3: Towns on the Via Augusta and river road network by *conventus* and scaled by betweenness values. Green = Hispalis; Yellow = Corduba; Red = Astigi; D. Blue = Gades; Pink = External; L. Blue = Unknown
Network Analysis of Transport Vectors in Roman Baetica

Node Network 4: Towns on the Antonine Itineraries network by conventus and scaled by betweenness values. Green = Hispalis; Yellow = Corduba; Red = Astigi; D. Blue = Gades; Pink = External; L. Blue = Unknown

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Node Network 5: Towns on the Ravenna Cosmography network by conventus. Green = Hispalis; Yellow = Corduba; Red = Astigi; D. Blue = Gades; Pink = External; L. Blue = Unknown.

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Node Network 6: Towns on the Ravenna Cosmography network (with extensions) by *conventus* and scaled by betweenness values. Green = Hispalis; Yellow = Corduba; Red = Astigi; D. Blue = Gades; Pink = External; L. Blue = Unknown
Node Network 7: Towns on all known routes by *conventus* and scaled by betweenness values. Green = Hispalis; Yellow = Corduba; Red = Astigi; D. Blue = Gades; Pink = External; L. Blue = Unknown.
Node Network 8: Towns in *conventus* of Corduba with betweenness values.

Node Network 9: Towns in *conventus* of Hispalis with betweenness values.
Network Analysis of Transport Vectors in Roman Baetica

Node Network 10: Towns in *conventus* of Astigi with betweenness values.

Node Network 11: Towns in *conventus* of Gades with betweenness values.
Network Analysis of Transport Vectors in Roman Baetica

Node Network 12: Towns on all routes mentioned by Ptolemy. Yellow = mentioned

Node Network 13: Towns on all routes mentioned by Strabo. Yellow = mentioned

Node Network 14: Towns on all routes mentioned by Pliny. Yellow = mentioned
### Appendix D: Tables

#### Table 1. Closeness and betweenness of towns on the river network

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#### Table 2. Closeness and betweenness of towns on the river and Via Augusta network

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Table 4: Closeness and betweenness of Towns on the Ravenna Cosmography network

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Table 5: Closeness and betweenness of towns on all known routes network
### Network Analysis of Transport Vectors in Roman Baetica

<table>
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<th>Location</th>
<th>Value1</th>
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</table>
Appendix E: River Profiles

River profiles were created from a 10m contour plan. This will obscure variation between these levels so heights between points should be taken as indicative only. The approximate centre point of towns is marked with a ■. Towns may of course extend half a kilometer or more in either direction. The approximate course of the Baetis during the Roman period is marked with a ■. For the line of the sections, please see Map 9, Appendix B.
Network Analysis of Transport Vectors in Roman Baetica

Canania

Naeva

Ilipa Magna

Leif Isaksen
Network Analysis of Transport Vectors in Roman Baetica
In the case of Cavrium, the actual cross section is misleading as it does not account for a curve that passes close by just South of the town. For this reason, the approximate distance to the curve has also been marked on.
Appendix F: Database Information

Software Diagrams

Diagram 1: Software diagram showing the interaction between different components of the system used.
Table Diagrams

Table Diagram 1. Tables required for Network Analysis
Table Diagram 2. Tables required for the GIS

Forms

Form 1: Form for browsing itineraries. The user is presented with further information regarding each stage and the towns at either end of it.
Import/Export Module Code

Option Compare Database
Option Explicit

Import Code
Public Sub import(dialogTitle As String, updateField As Integer, percentualize As Boolean)
'Imports data from a Pajek file into the PajekResults table

'open DB
    Dim db As DAO.Database
    Set db = CurrentDb()

'open recordset
    Dim NARsltRst As DAO.recordSet
    Set NARsltRst = db.OpenRecordset("NAResults",
dbOpenDynaset)

'open inputfile
    Dim inputString As String
    Dim inputFile As String
    Dim fin As Integer
    Dim fileLen As Integer
    Dim path As String

    fileLen = Len(Dir(db.Name, vbDirectory))
    path = Left(db.Name, (Len(db.Name) - fileLen))
    inputFile = InputBox("Please enter the file path of the import file", dialogTitle, path)
    fin = FreeFile
    Open inputFile For Input As fin

'check same number of nodes
    Input #fin, inputString
    Dim nodeCount As String
    nodeCount = Mid(inputString, InStr(inputString, " ") + 1)
    NARsltRst.MoveLast
    If Not nodeCount = NARsltRst.RecordCount Then
        MsgBox "The number of nodes in the file does not equal the number of nodes in the table"
        Exit Sub
    End If

'update
    NARsltRst.MoveFirst
Do While Not EOF(fin)
    Input #fin, inputString
    NARsltRst.Edit
    If percentualize Then
        NARsltRst.Fields(updateField) = inputString * 100
    Else
        NARsltRst.Fields(updateField) = inputString
    End If
    NARsltRst.Update
    NARsltRst.MoveNext
Loop
'tidy up
    NARsltRst.Close
    Close #fin
End Sub

Public Sub importCloseness()
'imports Betweenness Pajek files
    import "Import Closeness", 2, True
End Sub

Public Sub importBetweenness()
'imports Closenessness Pajek files
    import "Import Betweenness", 3, True
End Sub

Public Sub importDegree()
'imports Degree Centrality Pajek files
    import "Import Degree", 4, False
End Sub

Export Code
Public Function getFile(path As String, fPrefix As String, fSuffix As String)
    'returns a file access integer for the given file
    getFile = FreeFile
    Open (path & fPrefix & fSuffix) For Output As getFile
End Function

Public Sub export()
'Exports the database to Pajek-readable files
    'open DB
    Dim db As DAO.Database
Network Analysis of Transport Vectors in Roman Baetica

Set db = CurrentDb()

'open output files
Dim prefix As String
Dim netOut As Integer
Dim partitionOut As Integer
Dim xyPartitionOut As Integer
Dim covInputOut As Integer
Dim fileLen As Integer
Dim path As String
fileLen = Len(Dir(db.Name, vbDirectory))
path = Left(db.Name, (Len(db.Name) - fileLen))
path = InputBox("Please enter file directory", , path) & "\"
prefix = InputBox("Please enter new file name")
netOut = getFile(path, prefix, ".net")
partitionOut = getFile(path, prefix, ".clu")
xyPartitionOut = getFile(path, prefix, "XY.clu")
covInputOut = getFile(path, prefix, "CovInput.txt")

'open recordsets
'Clear PajekResults Table
Dim NARsltRst As DAO.recordSet
Set NARsltRst = db.OpenRecordset("NAResults")
Do While Not NARsltRst.RecordCount = 0
  NARsltRst.MoveFirst
  NARsltRst.Delete
Loop

'terni XYS
Dim siteRst As DAO.recordSet
Set siteRst = db.OpenRecordset("SELECT SiteTerminusMapping.terminusid, sites.x, sites.y, SiteTerminusMapping.loc_cert" _ & " FROM Nodes INNER JOIN (sites INNER JOIN SiteTerminusMapping ON sites.OBJECTID = SiteTerminusMapping.siteObjId) ON Nodes.id = SiteTerminusMapping.TerminusId;")

'All routes
Dim query As String
Dim criteria As String
Dim orderBy As String

query = "SELECT terminus, route, itinerary, stage, primary_name, miles_numeric, source, status, Route_desc.start, reverse" _
Network Analysis of Transport Vectors in Roman Baetica

& " FROM Itineraries INNER JOIN (Nodes INNER JOIN ((Routes INNER JOIN Route_Desc ON Routes.ID = RouteTerminusMapping.Route_id) INNER JOIN RouteTerminusMapping ON Routes.ID = RouteTerminusMapping.route) ON Nodes.id = RouteTerminusMapping.terminus) ON Itineraries.ID = Route_Desc.Itinerary"

criteria = InputBox("WHERE ", "Please enter criteria", ")

If Not Len(criteria) = 0 Then
    query = query & " WHERE " & criteria
End If

orderBy = " ORDER BY itinerary, stage, RouteTerminusMapping.start;"

Dim routeRst As DAO.recordSet
Set routeRst = db.OpenRecordset(query & orderBy)
routeRst.MoveFirst

'Build dictionary of towns and ids
Dim towns As New Dictionary

Do While Not routeRst.EOF
    Dim townId As Integer
townId = routeRst.Fields(0) ' has to be passed by value

    Dim townName As String
townName = routeRst.Fields(4)

    If Not towns.Exists(townId) Then
towns.Add townId, townName
End If

    routeRst.MoveNext
Loop

Dim townCount As Integer
townCount = towns.Count

'Build Vertex info array
ReDim townArray(townCount, 5) As String
Dim partitionType As String
Dim getPartition As Boolean

    partitionType = InputBox("If partition required, please enter field:")
getPartition = Not Len(partitionType) = 0

Dim i As Integer
For i = 0 To towns.Count - 1
    'get index and name
townArray(i, 0) = towns.keys(i)
townArray(i, 1) = towns.Item(towns.keys(i))

    'get Partition if desired
    If getPartition Then
        Dim townRst As DAO.recordSet
        Set townRst = db.OpenRecordset("SELECT " & partitionType & " FROM Nodes WHERE id = " & towns.keys(i))
townRst.MoveFirst
        If townRst.Fields(0) = "True" Then
townArray(i, 2) = 1
        ElseIf townRst.Fields(0) = "False" Then
townArray(i, 2) = 0
        Else
townArray(i, 2) = townRst.Fields(0)
        End If
        townRst.Close
    End If

    'get XYs
siteRst.MoveFirst
Do While Not siteRst.EOF
    If siteRst.Fields(0) = towns.keys(i) Then
townArray(i, 3) = siteRst.Fields(1) 'x
townArray(i, 4) = siteRst.Fields(2) 'y
    If siteRst.Fields(3) = "True" Then
        townArray(i, 5) = 1
    Else
        townArray(i, 5) = 0
    End If
    End If

    siteRst.MoveNext
Loop

' Default XYs
If Len(townArray(i, 3)) = 0 Then
townArray(i, 3) = -1
townArray(i, 4) = -1
townArray(i, 5) = 0
Network Analysis of Transport Vectors in Roman Baetica

End If
Next

'Write Vertices
Print #netOut, "*Vertices " & townCount
Print #partitionOut, "*Vertices " & townCount
Print #xyPartitionOut, "*Vertices " & townCount

For i = 0 To towns.Count - 1
  'print index + name in quotes + XYs
  Print #netOut, (i + 1) & " " & Chr(34) & townArray(i, 1) & Chr(34) & " " & townArray(i, 3) & " " & townArray(i, 4)

  'print partition
  Print #partitionOut, townArray(i, 2)

  'print location certain
  Print #xyPartitionOut, townArray(i, 5)

  'create entry in Pajek results table
  NARsltRst.AddNew
  NARsltRst.Fields(0) = i + 1
  NARsltRst.Fields(1) = townArray(i, 0)
  NARsltRst.Update
Next

'Write edges
Dim writeUncertain As Boolean
writeUncertain = InputBox("Do you want to include uncertain locations (y/n)?") = "y"
Print #netOut, "*edges"

'COVERAGE FILE: start first itinerary
Dim itinerary As Integer
routeRst.MoveNext
itinerary = routeRst.Fields(2)
Print #covInputOut, routeRst.Fields(2)

Do While Not routeRst.EOF
  'COVERAGE FILE: if necessary, start new itinerary
  If Not itinerary = routeRst.Fields(2) Then
    itinerary = routeRst.Fields(2)
    Print #covInputOut, "END"
    Print #covInputOut, routeRst.Fields(2)
  End If

  'get db codes
  Dim miles As Integer
  Dim terminusA As Integer
  Dim terminusB As Integer

  Leif Isaksen
miles = routeRst.Fields(5)
terminusA = routeRst.Fields(0) ' has to be passed
by value
routeRst.MoveNext
terminusB = routeRst.Fields(0)

'COVERAGE FILE: if reverse, swap termini
If routeRst.Fields(9) = True Then
    Dim terminusTemp As Integer
    terminusTemp = terminusA
    terminusA = terminusB
    terminusB = terminusTemp
End If

routeRst.MoveNext

'get filecodes (from their order in array)
Dim newCodeA As Integer
Dim newCodeB As Integer

'right terminus A first, then B (important for
coverage file)
For i = 0 To towns.Count - 1
    If townArray(i, 0) = terminusA Then
        newCodeA = i + 1
        
        'COVERAGE FILE: write XYs if not negative
        If (Not townArray(i, 3) < 0) And
            (townArray(i, 5) = 1 Or writeUncertain) Then
            Print #covInputOut, townArray(i, 3) & 
            " " & townArray(i, 4)
        End If
    End If
Next

For i = 0 To towns.Count - 1
    If townArray(i, 0) = terminusB Then
        newCodeB = i + 1

        'COVERAGE FILE: write XYs if not negative
        If (Not townArray(i, 3) < 0) And
            (townArray(i, 5) = 1 Or writeUncertain) Then
            Print #covInputOut, townArray(i, 3) & 
            " " & townArray(i, 4)
        End If
    End If
Next
Network Analysis of Transport Vectors in Roman Baetica

'write edge
   Print #netOut, newCodeA & " " & newCodeB & " " & miles
Loop
Print #covInputOut, "END"
Print #covInputOut, "END"
'tidy up
   NARsltRst.Close
   siteRst.Close
   routeRst.Close
   Close #netOut
   Close #partitionOut
   Close #xyPartitionOut
   Close #covInputOut
End Sub
Appendix G: The CD-ROM

The principle resource created for this dissertation is the database which can be used in conjunction with Pajek and ArcGIS ArcInfo 9.0. Data files created for the analysis above have also been included.

The contents of the CD-ROM are:

- Dissertation Report
- Database
  - CSV files
- Pajek Installation program
  - Pajek manual
- ArcGIS map file
  - Route coverages
  - Georeferenced economy maps (TIFF and world files)
  - Georeferenced topography map (TIFF and world file)
  - Cross-sections shape file
  - Rivers shape file
  - Boundaries shape file
- River profiles (Excel spreadsheet)
- Pajek results (Excel spreadsheet)
- README file