S17 The road not taken: Modelling approaches to transport on local and regional scales

Mark Groenhuijzen, Philip Verhagen

Research on transport systems thus far has largely focussed on the documented and partly surviving road systems, ranging from the Roman imperial road systems known from the itineraries and the Peutinger Table to the road systems documented by medieval cartographers, even when it is well known that secondary road systems were in use simultaneously. Empirical evidence for the existence, location and chronology, particularly for secondary roads, is however scarce in many cases. In addition, transport over water (both fluvial and coastal) is often not considered. In order to bridge the gap between our theoretical notions of short- to medium-distance transport and the surviving (archaeological and historical) evidence for transport systems, in this session we want to focus on the practical and theoretical implications of using spatial modelling and analysis techniques, such as GIS-based cost surface modelling and social network analysis, for better understanding transport at the local and regional scales. We want to explore in what way spatial modelling can provide more insight into the organisation of local and regional transport, as well as the implications it has for the interpretation of the position, function and potential for trade of settlements within the local and regional transport system. We specifically invite papers that deal with: 1) new approaches to modelling transport networks, including aspects of differential access to the system, different modes of (wheeled) transport and diverse cost considerations (energetic, economic etc.); 2) studies that combine transport network modelling and quantitative analysis approaches such as social network analysis; 3) studies that link transport networks to models of trade/exchange at the local and regional scale; 4) applications of transport network modelling in different landscapes and environments.

S17-01 Transport and trade: An energyscape model and transport network approach for trade in Roman times

Devi Taelman, Dimitrij Mlekuž

Movement of goods is vital in all human societies. Complex societies are characterised by an increased importance of movement as the production of goods tends to be distributed geographically among all members/cities of the society. Roman society is particularly known for its well-developed trade systems where goods - such as food, wine, olive oil, pottery and stone - were moved in enormous quantities and over long distances.

We believe that the distribution of bulky and heavy goods is particularly related to the cost of their transport and that physical geography can be a major constraint to this transport. While Roman water transport has already received significant scholarly attention, land transport is studied only superficially. Many urban centres could, however, not be reached without land transport. Land transport was thus inevitable and formed an integral part of Roman trade. In this paper, we present different energyscape models for depicting the predicted energy costs of transporting heavy loads by land. The resulting energy networks are compared to identify differences in the structures and the focal points of the networks, such as changes in the location of distribution hubs or changes in the locations of critical intermediary sites that determine the direction, quantity and volume of flow and therefore critically contribute to the cost of moving and trading heavy loads. This approach allows for a better evaluation of how land transport could have acted as a structuring variable for the Roman landscape and the Roman economy. As a case study, the trade of marble in Central Adriatic Italy in Roman times is selected. Stone resources suitable for ornamental use did not occur in central Adriatic Italy and thus had to be imported. The marble assemblages of several Roman towns in the area are compared with the results of the energyscape models and transport networks.

S17-02 A network model for the evolution of terrestrial connections in Central Italy (1175/1150–500 BC ca)

Luce Prignano, Francesca Fulminante, Sergi Lozano, Ignacio Morer

The period between the Final Bronze Age and the Archaic Age is a time of changes and developments in the Italian Peninsula which led to the creation of regional ethnic and political groups and to the formation of the first city-states in Western Europe.
We study the evolution of the interaction patterns among settlements by analysing terrestrial communication networks in Latium Vetus (LV) and Southern Etruria (SE) in several time snapshots. At a first overall inspection, the two regions appear to be very similar, except for some interesting differences. In order to understand to what extent the observed results are a consequence of either differences on the spatial distribution of settlements, or dissimilarities in the process that generated those networks (cultural and political factors), we design a simple network model. After locating the nodes at the positions we know them from the archaeological record, we start adding links where they are more needed, according to a geographical criterion. The total link length is the only data-derived constraint. The model reproduces with good accuracy the features of every real network, except for LV in the Early Iron Age, where it systematically underestimate the average shortest path length while overestimating the local efficiency. Our hypothesis is that this model, that implements an optimal resources (new roads) distribution, cannot reproduce structures shaped by the unbalanced tensions of a harsh competition such as the Latin region of those times. On the contrary, it works fine in the case of a heterarchical system, such SE, or when considering a centralized, hierarchical one, as LV in the Archaic Period. We measured the hierarchicity (Trusina et. al - 2004) of both real and artificial networks as a preliminary test obtaining results compatible with this explanation.

Cancelled **S17-03 Network analysis to understand the Roman commerce. Connectivity and transport costs of the Roman networks**

Pau de Soto

In the last few years, the author has been working in the development of new technologies that let him calculate and visualise the configuration and performance of the Roman transport networks. This project is based on the analysis of Roman infrastructures to understand the transport costs and the best commercial routes. This is an indispensable way to know the benefits and shortcomings of the transportation system created in Roman times. It is well known that the Roman Empire built the first big transport network, combining roads, inland waterways and maritime connections. Such a huge effort aimed to create an integrated economy covering all the Roman provinces on the Mediterranean Sea and Atlantic Ocean. This paper will be focused in two main aspects of this project. Firstly, in the integration of very diverse data that allowed the recreation and analysis of the Roman transportation models. And secondly, the analysis realised and the most recent results obtained will be presented. In order to obtain successful results, the Roman transport conditions have been reconstructed by modelling travelling costs and times with the help of GIS and Network Analysis applications based in ancient sources and archaeological and ethnographical data. To explain the methodology of this part of the project and the integration of the data, this paper will be framed in the works realised in the NE of Hispania. It was necessary devote a significant effort to the gathering, documentation, analysis and digitisation of Roman communications with high precision. Later, to explain the analysis and the most recent results, this paper will expand the geographical scope to the entire Iberian Peninsula, Italy and Britain. It will allow us to show very interesting patterns. The results of these applications provide us with new information to understand the distribution of commodities, product competition and problems of supplying in ancient economies.

Thanks to this project it has been possible to observe how the construction of a complex communication network, especially based on the creation of land routes, meant an important element for the integration of new territories into the Roman provincial organisation model. To understand the morphology of these networks, we have applied some personalised Centrality Degree analysis (Centrality, Betweenness and Closeness) in order to visualise the importance of the different settlements and territories depending of their weight and their position within the Roman transportation network. The calculations were designed applying different values of edges depending on the kind of transport that they represented. As a result, the edges representing roads had less value than other edges representing river or maritime routes.
Finally, the ability to see graphically and quantitative the morphology and the costs and time transportation values which until now they could only be guessed, can open new perspectives and justifications to the speeches made on this topic until today. In fact, the comparison between these results and the analysis of archaeological and historical interpretations should complement each other, clarifying and offering more elements for a global interpretation of the Roman transport and economy.

S17-04 Comparison of regional and local transport networks in 17th and 19th century AD pre-colonial stone-walled structures in the southern Gauteng Province, South Africa
Karim Sadr
Since 2008, as part of the South African National Research Foundation funded 'Southern Gauteng Stone Walled Structures' project a dozen postgraduate research assistants in Archaeology and Geography at Wits University, along with another dozen photo interpreters employed at SBL Geospatial Services in Cochin, India, have pored over freely available satellite images of an >8000 sq km study area between Johannesburg and the Vaal River using Google Earth software. Over 5000 pre-colonial stone-walled structures (SWS) have been detected and classified. This presentation focuses on the Group I and Group II pre-colonial SWS, comparing their distribution and probable transport networks within the 8000 square km study area. Group I structures date to the 16th and 17th centuries AD and represent the earliest Iron Age settlements in the study area. Previous studies on a restricted sample of Group I SWS suggest they represent a relatively egalitarian, more pastorally oriented society with a relatively dispersed settlement pattern. Group II structures date to the late 18th and early 19th centuries AD and are generally regarded as representing fairly complex and densely nucleated societies of Tswana-speakers in the immediately pre-colonial era. Using spatial modelling and analysis techniques, such as GIS-based cost surface and social network analysis, an attempt is made to compare the probable transport networks of Group I and II SWS at the local and regional scales. This involves the application of transport network modelling in the same landscape and environment but on two separate chronological periods. Combined with quantitative analysis, the aim is to see how the proposed differences in social, economic and political organization of Group I and II SWS that were ascertained through standard settlement pattern studies, might be reflected in their respective transport networks.

S17-05 Modelling the road network of central Cappadocia (Turkey): A matter of 'cost' and 'visibility'
Jacopo Turchetto
Analysing, reconstructing and modelling ancient road networks within a mountainous context is mostly a challenge. Often, several aspects and factors (both anthropic and natural) need to be taken into consideration at the same time, in order to propose a plausible hypothesis as for the route of the roads. The exploitation of the potential of Cost Surfaces and the subsequent creation of Least Cost Pathways (LCP) can produce very interesting results, in particular if

GIS-derived paths and historical/archaeological proved routes are compared in order to understand which factors could have played a major role in the definition of the layout of those same routes. In this paper, such a post-dictive approach has been applied to a specific case study, i.e. to the road system of central Cappadocia (Turkey), which is a semi-flat district strongly conditioned by the presence of the volcanic group formed by the Hasan Dağı, Göllü Dağı and Melendiz Dağları. Moreover, in any consideration of the morphological characters of that Cappadocian landscape, LCP are also combined with another factor, which surely played a central role in the itinerary choices adopted in that territory during the Byzantine era: visibility. In a period of instability, due to the different incursions which, between the 6th and the 9th centuries, made Cappadocia a strategic territory along the frontier line between the Byzantine Empire and its neighbours, the level of visibility (or invisibility) of the roads and from the roads really influenced the 'history' of those same ways of communication, together with the various settlements lying around them. The GIS-based modelling can reasonably explain the change which took place in the communication system of Cappadocia between the Roman and Byzantine periods, allowing to better understand the role and the functions of those road axes, and to evaluate the Byzantine military strategies in central Anatolia.

S17-06 Testing the validity of network analysis results in research on local transport networks

Mark Groenhuijzen, Philip Verhagen

Computational archaeology provides valuable tools for the reconstruction and analysis of transport networks. One such approach is a combination of a network constructed using least-cost paths and network analysis (Verhagen et al., 2014; Groenhuijzen and Verhagen, 2015), which can potentially provide valuable information regarding settlement location choice, site hierarchy, the role of settlements in transport networks and so on. However, testing the validity of the network analysis results and the archaeological interpretation thereof has so far been largely neglected. One of the key questions is thus: how reliant are the results of network analysis and their interpretation on nuances and uncertainties in the methodology and the dataset? This paper aims to test the robustness of network analysis results by measuring and analysing the development of local network statistics in randomly emerging transport networks. It is applied on a case study involving the Dutch part of the Roman limes, an area which is particularly interesting for research on local transport networks in the light of social and economic relations between the local rural population and the Roman military population, and an area for which a large amount of archaeological and palaeogeographical data is available.

Groenhuijzen, M. R., and P. Verhagen. 2015. "Exploring the dynamics of transport in the Dutch limes." eTopoi Journal for Ancient Studies Special Volume 4: 25-47. Verhagen, P., T. Brughmans, L. Nuninger, and F. Bertoncello. 2014. "The Long and Winding Road: Combining Least Cost Paths and Network Analysis Techniques for Settlement Location Analysis and Predictive Modelling." In CAA2012. Proceedings of the 40th Conference in Computer Applications and Quantitative Methods in Archaeology, Southampton, United Kingdom, 26-30 March 2012, edited by G. Earl, T. Sly, A. Chrysanthi, P. Murrieta-Flores, C. Papadopoulos, I. Romanowska, and D. Wheatley, 357ÔÇô366. Amsterdam: Pallas Publications.

S17-07 The need of topographic restitution in local mobility analysis

Diego Torres-Iglesias

When we conduct a landscape archaeology study in a GIS environment (especially the analysis of mobility) we should be aware that any territory undergoes a transformation, especially in the last 50 years. The Digital Terrain Models on which the study is based

depart from the current topography (whether models from contours or the latest from LiDAR point clouds), so the lack of a correction and topographic restitution it can lead to certain errors, as can be the layout of an optimal path on a current road, an industrial area blocking sightlines or the the impossibility of study a valley submerged in a dam. The probability of obtaining these errors increase in inverse proportion to the cell size of the digital model, and we need high resolution models if we want a higher accuracy in the calculations and results over the previous relief; the examples in this paragraph are evident when we work with a 5x5 m. DEM. For all these reasons, it is essential to make a correction that brings us as closer as possible to a hypothetical paleotopography that allows us, among other things, know the evolution of a particular territory or calculate least cost paths avoiding "current interferences" such as the aforementioned actual roads, towns or, if we have the help of historical planimetry and orthophotos, opencast mines, dams and other significant alterations in the landscape.

S17-08 From sea to land: Reflections on freight traffic during the Iron Age of the Northeastern Iberian peninsula (6th to 1st centuries BC)

Joan Canela Gràcia, Núria Otero Herraiz

It is known that maritime and fluvial shipping were the most efficient means of transport for distributing freights during the Antiquity. However; the distribution of goods to certain inner cities or significant Iberian settlements raises many questions. In this regard the use of carts and pack animals was common, but the roads the Iberian people travelled are mostly unkwnown. The objective of this paper is studying overland travels during the Second Iron Age in the northeast of the Iberian Peninsula. In this regard, the application of the least cost paths calculation methods should provide the opportunity to define the basis of a hypothetical Iberian road network during this period in the area. The results will be compared with the historic roads, in order to detect the presence or the lack of coincidences among them. This subject will be approached through two study cases, concerning two different political, ethnic and geographic territories. In one hand we have the Iberian Cesset├ánia, located in the coastal area, which grosso modo coincides with the province of Tarragona. On the other we have the western Ilergetia, a territory wich is nowadays split among the provinces of Lleida and Huesca. This area has been from ancient times a well known communication hub towards the inner lands of the Iberian Peninsula and the Atlantic coast, due to the significance of its fluvial networks. In conclusion with this work we pretend use the GIS least cost paths calculations in order to approach the Iberian terrestrial transport networks and their persistence over time and landscape.