

*Ignacio Fiz – Hèctor A. Orengo*

## Simulating Communication Routes in Mediterranean Alluvial Plains

*Abstract:* Societies exchange knowledge, ideas and merchandise throughout their territories. Topography plays a fundamental role in the trajectory of such movements whilst helping to explain the distribution of human constructions. Standard GIS functions have been employed widely to simulate communication routes between settlements, but the straight application of published least cost route models proved inadequate for Mediterranean alluvial plain areas in which seasonal floods become an important factor to acknowledge. The objective of this study is the production of a new model, using topographic and hydrologic factors as variables from which it would be possible to simulate a route, and test it against known Roman itineraries. The selected Roman stretches are Girona – Coll de Pannisars and Tarragona – Montblanc. The new model shows the need to consider each case individually but also stresses the hydrologic factor, expressed in seasonal floods, as being of prime importance in the creation and development of Roman roads in Mediterranean alluvial plains.

### *Introduction*

The aims of this paper are twofold: to create a model that allows the simulation of communication routes that are adapted to the typical morphology of Mediterranean alluvial plains and to evaluate which factors contribute to the setting of Roman roads in these areas. Those aims are intimately related since the setting of Roman roads was highly influenced by the physiological character of the terrain. Technical and cultural aspects also play an important role and are, thus, taken into consideration.

GIS has the potential to assist these studies, through the generation of cost surfaces adapted to environmental (topography being the most significant) and cultural factors, suggesting least cost route (LCR) models. These can be updated as new relevant information is implemented on the cost surface. GIS-related archaeological literature has made wide use of such models (DE SILVA / PIZZILO 2001; VAN LEUSEN 2002; BELL / WILSON / WICKHAM 2002; EJSTRUD 2005).

### *Methodology*

To tackle the objectives of this study various least cost route models from the literature were applied to documented Roman roads in the Catalanian alluvial plains in order to check their predictive

accuracy in these environments. The selected models were those developed by: VAN LEUSEN (2002), and DE SILVA / PIZZILO (2001). They were chosen according to their different approach to cost simulation. The first model includes variables as types of terrain and transport means while the second one is topography dependent.

The Roman routes Coll de Panissars – Girona and Tarragona – Lérida, documented in the Vicarello's Goblets and the Antonine Itinerary respectively as Summo Pyreneo – Gerunda and ab Asturica-Terracone, were chosen to test the models.

Numerous historical and archaeological studies were consulted to properly document these routes but, ultimately, the most interesting sources were those from the Roman period, describing contemporary itineraries: Vicarello's Goblets, Peutinger Table (medieval copy of the Roman *cursus publicus*) and the Antonine Itinerary. Old maps from the 1920s proved valuable for the identification of old cattle movement paths, known as *camins rals*, that have been commonly acknowledged as following the trace of ancient roads.

Different digital map sources were tested in an attempt to check their capability: a 100 m<sup>2</sup>/cell digital terrain model (DTM) and a 30 m<sup>2</sup>/cell DTM, freely distributed by the Cartographic Institute of Catalonia (ICC), appeared to be inadequate since some important landmarks, such as mountain passes or

sharp riverbanks, were smaller than the minimum cell size these maps offer. In the end, a 5 m<sup>2</sup>/cell DTM was produced from digital topographic maps of a scale of 1:5000 with spot heights, also distributed by the ICC. This was performed using the “natural neighbour” interpolation algorithm implemented in ESRI’s ArcGIS 9 software.

The resulting DTMs were checked against orthorectified vertical aerial photographs of the study areas, taken in 1956 by the American army, in order to confirm that these areas were not modified significantly during the past fifty years as was the case for most of the Spanish territory. Old maps were also employed to this end.

The first implementation of the published models suggested an over reliance on slope as a cost factor, producing long detours in the search of soft inclinations and also a tendency to follow riverbeds while constantly crossing from one bank to the other. These models have proved of great efficiency in suggesting least cost routes in mountain environments but they failed to explain the setting of communication routes in plain areas designed not only for the movement of people but also for goods.

Coll de Pannisars – Gerunda route presented an additional problem: some of the areas crossed by the LCR model were marshlands during the Roman period. Although this is merely a consequence of insufficient landscape modelling, it also suggests the problems associated with the tendency of the LCR models to follow flat areas.

CHEVALIER (1997, 107) has pointed out the need to avoid marshlands, moor lands, swamps or flooding areas in the location of Roman roads. These environments are supposed to have a higher friction index and, consequently, can lead to significant delays during the journey. Seasonal floods are common in southern Mediterranean countries and not only do they render transportation difficult but they can also interrupt passage while their effect on routes creates a need for continuous repairs of river fords, bridges and roads.

The importance of water-related factors in route modelling analysis became evident and led to the creation of a rivers’ network for a GIS-based hydrological analysis (JENSON / DOMINGUE 1988). In order to ensure the creation of a continuous vector-based rivers network, that is, without any gap in their trail, the 5 m DTMs were subjected to small-scale

sink identification and filling operations. Then, both flow direction and flow accumulation (FA) operations were performed to finally obtain a rivers network. A layer named “river” was also created to depict the existence of permanent water courses.

The effective friction (EF) was calculated employing De Silva and Pizziolo’s formulae (DE SILVA / PIZZILO 2001). In order to make the rivers and the effective friction layers proportional an index was developed:

$$Index = Max(EF)/Max(river, FA)$$

The hydrophobia factor (the tendency to avoid rivers or water flows) was calculated as follows:

$$Hydrophobia = (FA + river) \times index$$

Once the Hydrophobia factor was obtained it was added to the effective friction values to calculate the final cost surface:

$$Cost\ surface = EF + Hydrophobia$$

## Model Application

### Summo Pyreneo – Gerunda Route

The Hispanic stretch of the Roman road between Gades (modern Cadiz) and Rome is known as Via Augusta. This road was organised during the reign of Augustus on the prehistoric pathway known as Via Heraclea (NOLLA / CASAS 1997, 142).

The stretch to be analysed in this study goes from the mountain pass known as Coll de Pannisars<sup>1</sup> (Summo Pyreneo) to the city of Girona (Roman Gerunda). Two itineraries have traditionally been proposed to describe this stretch: the east route, closer to the coast, and the west route (*Fig. 1*). The first simulations, applying the “Hydrophobia model” as a cost surface, resulted in a LCR closely resembling the suggested east route. However, when flow accumulation values are significantly incremented in the cost surface map the resulting LCR varies significantly, adapting itself to the west route’s proposed course.

In order to choose between those two different LCRs (and the literature’s suggested routes that

<sup>1</sup> This pass over the Pyrenees communicated the Via Domitia (Narbonense Roman province) with the Via Augusta (Tarraconense Roman province). It was monumentalised through the so called Pompeius’ Trophy.

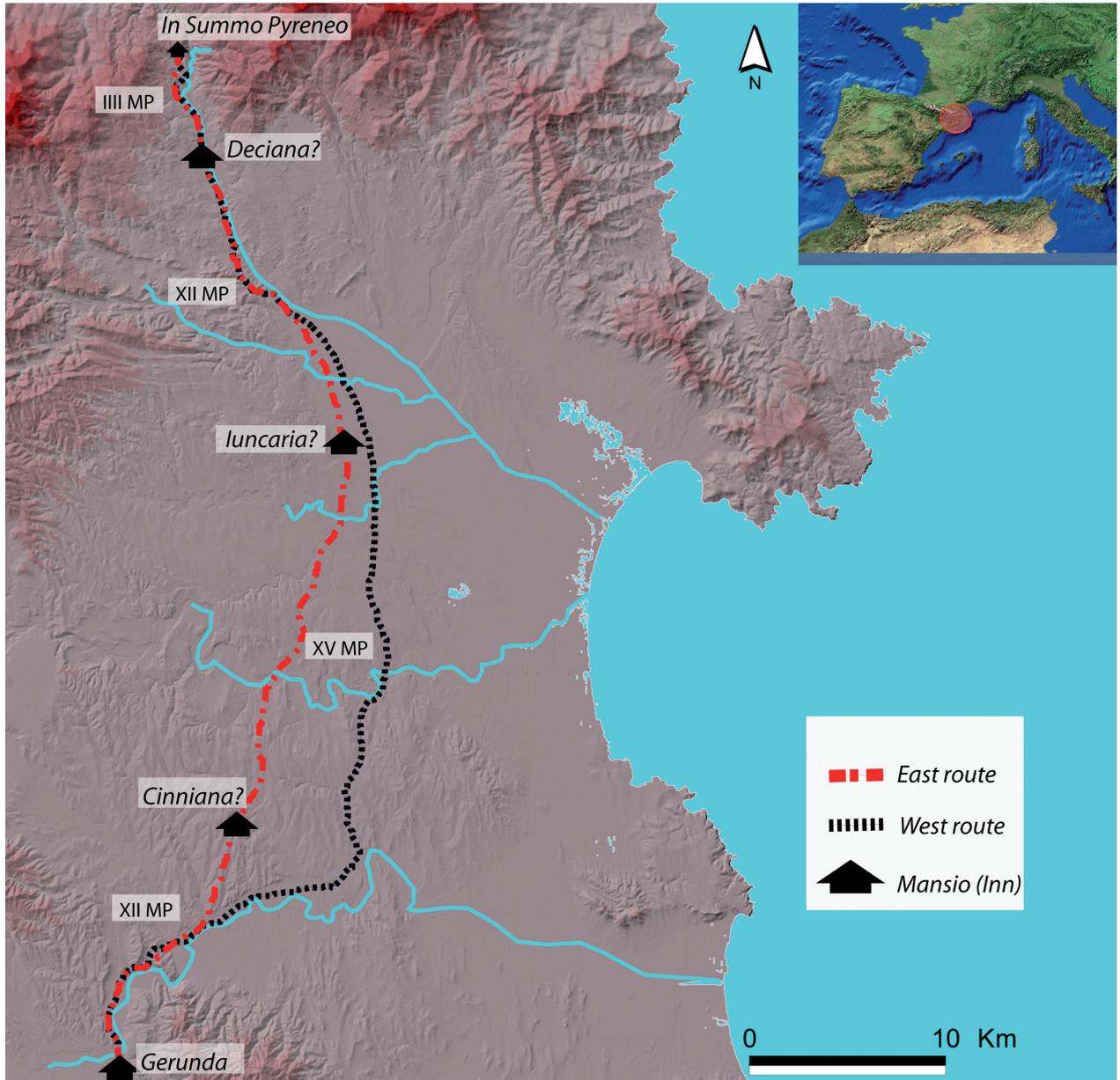


Fig. 1. Predicted routes using the hydrophobia model. The left route was developed increasing the flow accumulation values for this area.

they so closely resemble) it was decided to calculate the total distance between Summo Pyrenae and Gerunda as reported in Vicarello's Goblets and compare it to the LCR total distance.

Moreover, Vicarello's Goblets document the existence of five mansio (an official stopping place on a Roman road) in this stretch: Summo Pyrenae (Coll de Pannisars), Deciana (La Jonquera), Iuncaria (Figueras), Cinniana (unknown location), Gerunda (Girona), including the distance between each one of those mansio (Fig. 1).

The sum of the distance between all mansio favours the predicted west route as the one described in the Vicarello's Goblets. The location of

the mansio over the route, following the distances indicated in the goblets, produced interesting results, since Cinniana, the only unlocated mansio, coincided with a series of toponyms closely resembling that of Cinniana: Boscos de Cinyana (forests of Cinyana), Riera de Cinyanella (river of Cinyanella), Camps de Cinyana (fields of Cinyana). The suggested spot for Cinniana mansio was also very close (about 400 meters) to a series of important Roman archaeological sites among which a ceramic production centre is the most significant (MARTIN 1981).

Thus, in conclusion, the traditionally suggested west route is most probably the principal



Fig. 2. Francolí River flooding in 1994.

route, coinciding with that described in Vicarello's Goblets. Worth noting is also the importance of river level risings in the setting of communication routes, since the increment of flow accumulation values as a cost factor directed the LCR through the west route.

### Tarraco – Ilerda Route

The Tarraco-Ilerda route, quoted in the Antonine Itinerary as Ab Asturica Terracone, connects the coast with inner regions of the Iberian Peninsula. The stretch of road of interest to this study spans from Tarraco (modern Tarragona) to Montblanc. Old maps identify this route as an old Camí Ral. Ample archaeological evidence also supports this hypothesis: a miliarium from the third century AD and an inscription from a roads supervisor (*curator viae*) are both located on this pathway. Furthermore, this route connects some of the most important Roman villas of the province.

The "hydrophobia model" cost surface was developed and applied to this area. The resulting predicted LCR overall favours the old path connecting Tarragona and Montblanc rather than the modern road. Nonetheless, at some point the route devi-

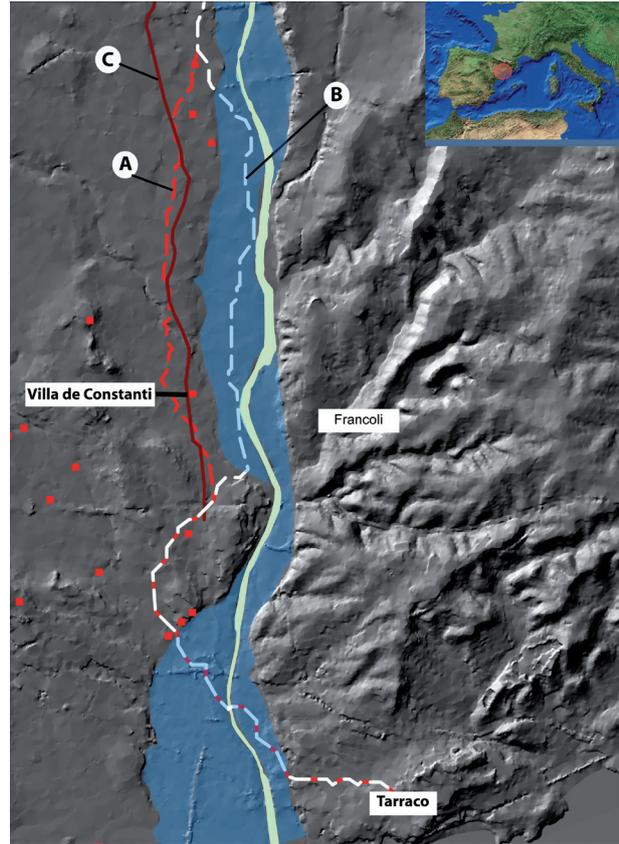


Fig. 3. Francolí River flooding model and the different predicted routes. Flooding area in dark blue, the normal volume of water in light blue. Roman sites represented as red dots.

ates from the old pathway to follow a flatter area close to Francolí riverbed (*Fig. 3, stretch B*). The old path was in a slightly steeper area away from the riverbed, probably due to the Francolí seasonal floods. Evidence for the floods exists in photographs taken in 1994 (*Fig. 2*), highlighting their importance and virulence/turbulence in this area. There is also written documentation of multiple repair works of the old stone bridge over River Francolí, granting access to Tarragona city. A simulation of the River Francolí flooding area was produced (*Fig. 3*), which was then added as an extra cost factor to the already developed cost surface. The new LCR almost coincided with Camí Ral (*Fig. 3, stretch A*) (max. difference of 250 meters) and passed through the Centcelles Villa; arguably the most important villa in the province. Furthermore, this flooding model provided some explanation for the location of those Roman sites near River Francolí, as they were all located at the edge of the flooding area, indicating the importance of seasonal river floods not only in the setting of roads but in all constructed archaeological features, with the possible exception of some related principally to cultivation.

### Conclusions

The methodological approaches suggested here are a first attempt to incorporate and combine multiple parameters in Roman route modelling in Mediterranean alluvial plains. The exploratory analysis presented here has the potential to contribute to better route models. Historical sources also appear to be an invaluable tool in the creation and evaluation of these models.

Although, the primary focus of the analysis was to develop a cost surface model adapted to the study areas' local character, this study led to a deeper understanding of the numerous factors involved not only in the planning of Roman roads but also in the distribution of habitation sites in the landscape. The hydrological proxy, and in particular seasonal flooding, proved to be an important factor in the choice of communication routes in Mediterranean alluvial plains, at least, during the Classical period. The development of this model was also useful in contrasting historical sources such as Vicarello's Goblets.

In accordance with these results, it becomes apparent that cost surface models and other types of GIS-based predictive analysis must always adapt to local particularities and seasonal variations, as straightforward application of general models or models created for different areas proved inadequate.

Least Cost Route analysis must be employed as an exploratory tool and never as an explanatory mechanism. Therefore, rather than offering a definitive answer the results presented here must be considered as a base to be further tested.

### Acknowledgements

The authors would like to thank Ana Ejarque (Catalan Institute of Classical Archaeology, Tarragona, Spain) and Dr. Mark Gillings (School of Archaeology & Ancient History, University of Leicester) for their comments and support.

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*Ignacio Fiz*

*Catalan Institute of Classical Archaeology  
Universitat Rovira i Virgili  
Pl. Rovellat, s/n.  
43003 Tarragona, Spain  
ifiz@icac.net*

*Hèctor A. Orengo*

*Catalan Institute of Classical Archaeology  
Universitat Rovira i Virgili  
Pl. Rovellat, s/n.  
43003 Tarragona, Spain  
horengo@icac.net*