How do we tie the transport information we need together and deliver it ?

M R Wigan

Chief Scientist
Australian Road Research Board

Abstract:

Small and large scale traffic and transport proposals could be handled in a more coherent manner by using Geographical Information Systems (GIS). GIS have a special importance for the management and monitoring of travel demand as they permit the spatial patterns of road and transport links to be handled on the same basis as the variables and administrative areas affecting demand, social and environmental impacts. Integrating land information and transport infrastructure enables better survey samples to be drawn, better transport data for monitoring, and less complex methods to integrate the use of different forms of traffic, land use, population and transport information.

Australian Road Research Board
P O Box 156
Nunawading Victoria 3131
Telephone: (03) 235 1567 Fax: (03) 233 8878

Introduction

This paper addresses the need to handle small and large scale traffic and transport proposals in a coherent manner, and specifies how geographical information systems in particular now offer the opportunity to do this effectively.

The community and professional needs for information correlation, synthesis, modelling, evaluation and consultation are specifically addressed: the shortfalls and the advantages are covered, and the specific tasks required by transport analysts to 'raise their game' are given.

The central feature of current organisational treatment of land traffic and transport is that it overlaps all too many boundaries. This creates difficulties in putting coherent policies together, and in formulating how the different measures fit. The impacts of different policies and aspects are also quite awkward to coordinate, and the demand for disparate sources of information to be fitted together quickly is growing.

The central feature which ties all these issues together is the location of the roads and transport links, and the relative locations and numbers of the vehicles, people, residents and environmental effects. All these come together as different views of the same location.

The skills to combine such information in a usable manner have long been held by cartographers, who have also been the beneficiaries of the digital location thrust of the last decade. Land information is now a reality, and the tools to combine descriptions of what is on the ground (in terms of terrain models, locations of infrastructure, topographic features, buildings and the like) with the activities and influences that can now be combined and applied to a map of the same area.

The basic concept is that of layers. For any given area there are huge numbers of different possible maps, made up of the boundaries of particular factors of interest to specific groups, and the levels, characteristics and intensities of the various items of information of special concern to them. Although the boundaries will rarely coincide (even in transport planning it is a major task to keep the zonal boundaries stable - or even cross referable - over time), each and every map can be overlaid on the basic topographic map. Making sense of the resulting visual mess would not be easy, as the confusion of information will make it impossible to use the single combined result. However, if we could hold the details of each boundary in a form that could be merged with others, and had suitable methods for dealing with boundary overlaps and reconciliation of the differences in variables of extent or intensity, then we could automatically create maps to show how widely differing selections of variables and areas of influence combined to affect different areas.

This fairly abstract specification has been implemented in a family of specialised databases called Geographical Information Systems (GIS). They have a special importance for the management and monitoring of travel demand as they permit the spatial patterns of road and transport links to be handled on the same basis as the variables and administrative areas that affect demand and social and environmental impact.

This paper explores some of the gaps in our present ability to monitor and manage transport and the related land use activity systems, and identifies where GIS and other available tools can be used more effectively to make better use of the available information, and reduce the overheads otherwise involved. As transport increasingly requires fast response and monitoring capacity, sharing the load of updating the common parts of the land use and transport database is now a necessity.

GIS systems are not new, in a technical sense, but have now achieved a fair measure of penetration into practise and the locational data required for their efficient use is now becoming widespread. Newer techniques (such as object oriented database) will not reach this stage for 5 or more years, but the critical phase is now, as cadastral data collection and dissemination reaches a critical level.

GIS Applications

The major initial application of GIS systems has been to permit land information systems to be built up with some real flexibility in the manner in which various forms of areal and point information can be extracted to build specialised and informative maps, quickly and accurately. This requires that a wide range of overlapping areas be reconciled, as few characteristics of land or environment are all based on the same zoning systems or boundaries. The best known GIS in wide use for land information purposes is probably ARCINFO (Moorhouse 1986), which has now been developed to a stage where ARCINFO databases can be distributed over networks, linked to databases such as ORACLE, and has Hypercard front ends created for it. It is however no longer quite at the vanguard of the subject, and a wave of more advanced and powerful systems are beginning to appear.

GIS systems have recently moved from being simply advanced map creation and land use parcel databases to a considerably more active role. The route finding algorithms of early GIS systems have now been built upon with full equilibrium assignment and gravity models (Caliper Corp. 1989), and the links have been opened for land use and population and travel demand projection procedures, and require only an Intel 80386-based system to run effectively. Cartographic GIS systems such as MapGrafix (Comgrafix Inc. 1987) have also been available on small machines (in this case the Apple Macintosh) for quite some time. Consequently GIS extensibility and availability on popular small machines have both now arrived.

These developments are important for transport and road analyses of any type, as the visual management and presentation of such complex data visibly enhances the credibility and usefulness of planning and operational information. The public and professional need to monitor and communicate the results of transport policies on the ground highlights the need for different forms of information and feedback, and that much of the information required to monitor and influence travel demand generation and location (and its impacts) are not yet readily available.

Just combining census data and road and transport links yields movement+people+effects in a simple manner, and does it **quickly**. It is becoming clear that a wide range of interest groups exist that have a major concern with Travel Demand Management (TDM) measures, and that they need a common base on which to communicate their operational and implementation needs.

A major TDM-specific application is to be able to address the congestion, safety and environmental issues in an integrated manner, and to make direct connections between the people and the locations where travel is generated, and the other monitoring and updated transport, safety and land use information required to make sense of it.

The hierarchy of models currently in use for traffic and transport analysis have two major gaps in the spectrum.

The first clearly-visible gap in the spectrum is at the middle level, where areas larger than a local area traffic control district yet smaller than a full scale corridor study are of interest. The costs of building up the input data for most types of models become quite large for such areas, as the effort is much the same as for a full corridor study yet the are is much smaller. GIS data bases provide a practical method of bridging this gap, and making such meso-level models practical and economic.

The second is at the largest scale, where the behaviour of full metropolitan areas are of interest over time, the land use information once again becomes a very expensive resource to create. The need to continually update this resource has previously made the use of such analysis methods prohibitive in cost. The adoption of land information databases (and their direct utilisation by GIS systems) fundamentally improve the economics. At the same time, the cartographic foundations of GIS designs opens the way to more effective environmental and social impact assessments.

While it is clear that metropolitan-scale models with the ability to trace the development of land use and transport changes over time are now and essential tool for the assessment of many of the possible large scale travel demand management strategies, the need to be able to manage the process as a whole requires monitoring and links between different types of database and modelling/forecasting systems. Consequently, links between such metropolitan-scale models and GIS systems need to be constructed and subsequently exploited.

Vehicle guidance

Perhaps the largest current effort in traffic and transport research in several countries is the concentrated work on advanced technologies, their exploitation and their effects. The major European programs are DRIVE (coordinated by the EEC) and PROMETHEUS (mainly led by the vehicle and electronics manufacturing sectors). Details of both programs are given from a traffic standpoint by Gillan (1989). The US has several smaller, but similar, programs such as PATH (Kanifani and Parsons 1989). Most of them are aimed at improved travel safety, control, and management of the road and vehicle system. These acronyms stand for:

1. **PRO**gra**M** for **E**uropean **T**raffic with the **H**ighest **E**fficiency and **U**nprecedented **S**afety

- a pre-competitive initiative by eleven car manufacturers wishing to explore the potential of advanced computing and electronic systems in vehicles, and supported within the nineteen European ministries of industrial research and development: a series of programs referred to as EUREKA. Prometheus includes a substantial vehicle navigation, communication and guidance component, and has generated a practical need for GIS links for location and navigation.

2. Dedicated Road Infrastructure for Vehicles in Europe

- initiated by the European Community, with broadly similar objectives. Drive also includes a major vehicle guidance and information component Its prime objective is to produce a cumulative effect which will make a major improvement to road and vehicle travel performance and reduce their safety and environmental impacts. A complete specification of the program elements is given by the CEE (1988), and of the projects finally approved (CEE 1989). The EUROTOPP series of projects extends from the user activity pattern analysis to broad spatial modelling, and it is difficult to see GIS links being omitted as this overall review and overhaul of integrated models proceeds.

3. Program on Advanced Technology for the Highway

- initiated by the California Department of Transportation, the Institute for Transportation Studies at University of California at Berkeley and the US Government: a major part of this program is dedicated to vehicle navigation, using the ETAK dead reckoning systems in the first instance. A major problem with ETAK has been the volatility of the detailed data, and the expense of improving on the US Bureau of the Census locational adjuncts to the population census files.

The potential capacity or efficiency gains from vehicle guidance have been estimated to range for 5 to 20% (Jeffrey 1981; Outram and Thompson 1978; Rakha et al 1989) and the communication aspects are a major potential tool for travel demand management and control.

Vehicle guidance requires an efficient and detailed geographical database of the road system, and the need to produce such databases on a large scale is a massive undertaking. The US community is fortunate to have the TIGER and DIME small area geographical location files in the public domain as a standardised locational extension of their census data sets, yet even these excellent basic datasets are proving to be inadequate. One of the reasons is the lack of regular updating (a message that must eventually be grasped by more of the bodies involved in the land use and transport management task), and another is need to specify activity locations with a considerably greater precision and detail.

While the DIME and TIGER files, are in the public domain (Government funded data and programs are required to be released and accessible in this manner in the US, unlike other countries such as Australia where such basic data is sold by the central agencies).

One of the problems with on-board navigation systems is the need to hold all this data in the form of a CD Rom or other mass storage device, which is by its nature not continuously updatable. Even so, a detailed database must be built and maintained by the navigation system supplier (ETAK in the case of some of the PATH project work). The characteristics of this database are remarkably similar to the land use and development records that are slowly being created by many local government and planning agencies - and most of these bodies are now using GIS tools to do it.

Pavement management systems

The rapid developments in road Pavement Management Systems (PMS) have paralleled that of GIS systems, with which they share many common characteristics. The first generation of pavement information systems were essentially road information systems, and as such were precisely the same as GIS systems in the first stage of application as they could generate excellent graphical and spatial information from the database, but did not do much management resource allocation or projection (Kenyon and Wigan 1986; Wigan 1989). Subsequently a considerably greater level of appreciation of the tight and beneficial links between cadastral land mapping databases and databases on roads and road characteristics and expenditures has led to active programs to add graphical interfaces to PMS systems, and to exploit the databases and facilities available in the GIS data bases being built by both land use planners and utility service organisations for their own purposes

Transport planning and surveys

The steady growth in the importance of small and medium scale networks in transport and traffic analysis has been matched by a tightening in the funds available for undertaking surveys, and, particularly, in the effort available to maintain and provide response to the users of such data once created. This has come at a time when the importance of monitoring and performance measurement has become widespread at the management levels of public and private enterprise.

The use of GIS systems as an intrinsic component of both travel survey design and the subsequent maintenance, monitoring and usage of the results has been proposed by both Taylor et al (1989) and Wigan and Groenhout (1990). These reports were both results of systematic reviews of the utility of transport survey information and more effective methods of obtaining and using the results.

The relevance of GIS as a 'glue' between different requirements arose in two different ways: the first was as a clear-cut cost-effectiveness measure in survey design and coding. Drawing samples from a geographical data base could be of material assistance in the design phase, and the levels of detail available in a GIS created for land information is quite substantial. The links to the population census are potentially excellent, but the constraints of privacy and non-identification have yet to be fully satisfied. However, a really efficient geocoded transport survey would present problems in non-disclosure that would require careful design of the data extraction facilities to be applied: the security of the respondents has been based substantially on the anonymity of the record describing the household, and the large area to which the household location has been encoded.

If the precision of the geocoding is to be to a few metres (typical of GIS systems), then the identification of the respondent is very nearly complete if a single dwelling is at that location. On the other side of the coin, the collation of many of the land use and related variables will normally be available at the same level of locational detail, and save a great deal of coding effort thereby.

The utility of travel survey information is greatly enhanced by increasing its accessibility. The use of GIS databases by other bodies can help substantially, as the ability to aggregate to unforeseen zones and groupings is greatly eased (and thereby also answers many of the confidentiality problems).

The application of travel survey data to environmental impact estimation is also made much easier, as this is precisely what GIS systems were originally designed to achieve by McHarg. Producing maps of impacts of various types is straightforward in a GIS framework, as it was designed for this type of task.

There are other hidden benefits to transport and travel analysts in a GIS framework, as most good GIS systems have shortest route finding and other simple models built in, and hooks on which to hang others. The availability of fine grained geographical location is particularly helpful when microsimulation models are being built. These types of models provide a considerably more sensitive framework for activity readjustment models, and for complex location and travel issues (Mackett 1990).

The growing concern for an improved ability to assess, forecast and evaluate travel demand management measures places increasing stress on these features.

Why make the effort to link up the different forms of travel and infrastructure data?

The scale of transport networks is very large, and the effort now being devoted to creating comprehensive land information systems (usually in a GIS framework) is equally substantial. The national efforts to create a cadastral location database for all types of land use and utility categories are beginning to make real headway, and the ability to link variable administrative, technical and analysis ranges in a single framework is therefore highly desirable. Why recode it all simply for the use of a single authority? Even more to the point: who could afford to maintain such data bases if the effort were not to be shared?

The ability to extract information about a road or transport movement network at many different levels of detail is one that is now in demand: small scale and strategic analyses both require fast response - and graphical interpretation- to service a more sophisticated public's hunger for information and active consultation. These growing user requirements do not allow for the time consuming one-off coding schemes of the past.

Perhaps the most important need for linking up the land use, utility and travel information systems in a GIS framework is the pressing need to be able to assess long and short term responses to policies to condition, channel and manage travel demand. Few of these policies can be pursued without tracking the effects over time, and it is this need to work with a mutually updated land use and activity database that completes the case in favour of a GIS path to coordinate the land use, transport and travel data holdings of public authorities.

The ability to link models within a GIS framework provides a further valuable potential for improvement in communications, as the cartographic and environmental roots of GIS systems ensure effective graphical and mapping outputs become a **standard** method of providing the results of even exploratory analytical and forecasting investigations.

It is clear that images (and computer retrievable storage and presentation of images) are a highly desirable component of land use and transport databases. GIS systems provide a mature and proven method for achieving this capacity, and the links between GIS and RDBMS (Relational DataBase Management Systems) have already been drawn by ESRI and others.

Looking forward, most of the ideas built into GIS systems are now nearly a decade old, and the new generation of concepts and tools beginning to arrive are the Object Oriented Databases by Ontologic and others. These enable images, vectors, data and text to be integrated smoothly from the start, and have enormous potential - but will once again take most of a decade to become widespread enough to be of practical appeal to the audience for this applied paper.

Conclusions

Location is the key to tying land use, transport and travel information together effectively, and this can be done through Geographical Information Systems.

1) GIS **methods** are a key contribution to demand assessment, monitoring and management.

2) GIS capabilities are needed to bring together the types of **data** needed for demand management assessments.

3) GIS databases provide a long-needed common **basis** for linking and integrating the many different levels of traffic and transport models.

4) GIS databases are **required** to make more effective use of the potential for vehicle guidance

5) GIS databases **provide** an efficient basis for improving the accessibility and utility of accident data.

The integration of land information and infrastructure and facilities will enable better samples to be drawn, better use of transport data for monitoring, and smoother and less complex methods of assuring mutual usage of different forms of traffic, land use, population and transport information. The improved economics of maintaining an updated land use and travel database obtainable by using GIS as a linking glue offer the opportunity of undertaking more effective monitoring of the transport system, and more responsive and open access to the information held in the system.

The essence of management of a system is having timely monitoring information, and good communications. The major theme example used here (of vehicle navigation and guidance) is only one of the rapidly developing areas where these lessons can be illustrated, and others exist across the planning and transport spectrum.

Acknowledgements

This paper is given by permission of the Executive Director of the Australian Road Research Board. The opinions expressed in this paper are those of the author.

References

Caliper Corporation (1989). *TransCAD*. Newton, Mass.

Claussen, H., Lichtner, W., Heres, L., Lahaije, P. and Siebold, J. (1989). *GDF: A proposed standard for digital road maps to be used in car navigation systems*. pp. 324-330 of Reekie, D., Case, E and Tsai, J. [Eds.] *Proc 1st Conf. Vehicle and navigation and information systems*. Piscataway: IEEE.

Comgrafix Inc. (1987). *MapGrafix Users manual.* Clearwater, Florida.

Comission of the European Communities (1988). *DRIVE Workplan.* DG 13 Report No. DRI 100. EEC: Brussels.

Comission of the European Communities (1988). *DRIVE '89: The DRIVE programme in 1989.* DG 13 Report No. DRI 200. EEC: Brussels.

Gillan, W.J. (1989). PROMETHEUS and DRIVE: *Their implications for traffic managers.* pp. 237-243 of Reekie, D., Case, E and Tsai, J. [Eds.]. *Proc. 1st Conf. Vehicle and navigation and information systems.* Piscataway: IEEE.

Jeffery, D.J. (1981). *The potential benefits of route guidance.* TRRL Report LR 997. Crowthorne: Transport and Road Research Laboratory.

Kamijo, S., Okumura, K. and Kitamura, A. (1989). *Digital road map data base for vehicle navigation and road information systems.* pp. 319-323 of Reekie, D., Case, E and Tsai, J. [Eds.]. *Proc. 1st Conf. Vehicle and navigation and information systems.* Piscataway: IEEE.

Kanifani, A and Parsons, R.E. (1989). *Program on advanced technology for the highway: vehicle/highway research and development.* pp. 270-272 of Reekie, D., Case, E and Tsai, J. [Eds.]. *Proc. 1st Conf. Vehicle and navigation and information systems.* Piscataway: IEEE.

Kenyon, J.A. and Wigan M.R. (1986). *Pavement Management Systems.* Internal Report AIR 439-2. Vermont: Australian Road Research Board.

Lee, S.T., Karimi, H.A. and Krakiwsly, E.J. (1989). *Road information systems: impact of geographic information systems technology to automatic vehicle navigation and guidance.* pp. 347-352 of Reekie, D., Case, E and Tsai, J. [Eds.]. *Proc. 1st Conf. Vehicle and navigation and information systems.* Piscataway: IEEE.

Mackett, R.L. (1990). *Exploratory analysis of long term travel demand using micro-analytical simulation.* In JONES, P. [Ed.]. *Developments in dynamics and activity based approaches to travel.* Aldershot: Avebery.

Marsh, D.C. (1989). *Database design, development, and access considerations for automotive navigation.* pp. 337-340 of Reekie, D., Case, E and Tsai, J. [Eds.]. *Proc. 1st Conf. Vehicle and navigation and information systems.* Piscataway: IEEE.

Moorhouse, S. (1986). *ARCINFO: A georelational model for spatial information.* Proc. AutoCarto 7, Washington DC pp 388-397.

Outram, V.E. and Thompson, E. (1978). *Drivers perceived cost in route choice*. pp. 226-257 of *Transportation models. Seminar L. Proc. Annual Summer Meeting*. PTRC: London.

Rakha,H., Van Aerde, M. and Ugge, A. (1989). *Evaluating the benefits and interactions of route guidance and traffic control strategies using simulation*. pp. 296-303 of Reekie, D., Case, E and Tsai, J. [Eds.]. *Proc. 1st Conf. Vehicle and navigation and information systems*. Piscataway: IEEE.

Smith, A.B. (1989). *Prototyping a navigation database of road network attributes (PANDORA)* pp. 331-335 of Reekie, D., Case, E and Tsai, J. [Eds.]. *Proc. 1st Conf. Vehicle and navigation and information systems*. Piscataway: IEEE.

Taylor, M., Young, W., Ogden, K. and Wigan, M. (1989). *Melbourne transportation research project [MTSRP]*. Reports nos 1, 2, 3. *Department of Civil Engineering Working Paper* CEWP 89/T12. Clayton: Monash University.

Wigan, M.R. (1989). *The use of prototyping and graphics methods for road information systems. Microcomputers in Transportation Conf. Proc. ASCE* (4). [In Press]

________ (1990). *Emergent roles for optical media in transport engineering. Transportation Research Record*. [In Press]

________ and Groenhout, R. (1990). *How much is it worth to have strategic travel and transport demand information?* Proc. 15th ARRB Conf. 15(6), pp 127-146. [In Press]