ESPECIAL

TRANSPORTATION PLANNING AND THE USE OF TRANSCAD

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ABSTRACT

Transportation planning consists of a variety of activities that can be supported by Geographical Information Systems (GIS). This kind of system offers many functions that can be used for both spatial and transportation analyses. TransCAD is a GIS-package with specific transportation analysis tools. This package offers different functions for network analysis, transportation modelling, route analysis and traffic assignment.

This paper describes the role of GIS for transportation planning which will be illustrated by several research projects. Special attention is given to the functions TransCAD offers for transportation analysis purposes. Three projects conducted by the Urban Planning Group of the Eindhoven University of Technology illustrate some of these functions in more detail. The projects concern the simulation of activity patterns, the evaluation of planning scenarios, and the simulation of parking behaviour.

Experiences from several research projects show that TransCAD is very useful for transportation planning activities. The open architecture that makes it possible to implement any self-made procedure in the TransCAD environment, appears to be one of the most important characteristics of this software. Also the amount of network analyses such as shortest path finding and traffic assignment makes the package valuable. Still, improvements are desirable, for example a better structured users' manual, more advanced options for presentation and for modelling and statistical fitting of distribution. Some of these requests are implemented in the new Windows version of TransCAD 3.0.

1. INTRODUCTION

Nowadays, Geographical Information Systems (GIS) have found their way into the field of transportation planning. Many planning agencies and institutions are introducing GIS to support their transportation planning activities. The introduction of GIS in an organisation consists of several actions such as identifying available databases and maps, surveying problems and data requirements, identifying existing hardware and software, etc. In most cases, organisations start with some kind of case study to get insight into the pros and cons of introducing GIS.

GIS allows to assemble and process data from a diversity of sources and present it in an easily understandable graphical format (NCHRP, 1991). According to NCHRP, this capability will permit the assimilation, integration, and presentation of data collected and stored by transportation agencies. However, there might be problems when using the general purpose GIS in the context of transportation planning. There are some specific requirements for using GIS in case of transportation planning (*GIS-T*): for example, special data structure and topology relationships, both for effective network representation and for efficient transportation algorithm processing.

There are also several specific facilities required for GIS applications to transportation. Which include: ability to handle linear location referencing methods, origin plus offset along a line; dynamic segmentation; path construction and path naming; network construction; special kinds of transportation 'objects' like overpass and merges' network overlay; network analysis; ability to support various transportation modelling techniques (e.g., assignment modelling) and time slicing. Suggested additional needs for GIS-T are: improvement of linkages between CAD and GIS-T, and between GIS-T and transportation planning models; three and four dimensional network representation; investigation of computer-aided software engineering applications; improvement of off-the-shelf networking technology; linkages to multimedia and integration of advanced data collection technology and GIS-T. However, the question is *'Which GIS-software package has all or most of the requirements and has possibilities to develop new procedures in the future?'* Because of the rapid developments of GIS-software, it is very hard to answer this question in general. This paper illustrates the functions of a specific GIS-software package named TransCAD, which might be considered as one of the most promising packages for transportation applications.

Transportation GIS-software TransCAD (Caliper, 1990 & 1992) was developed as a GIS-T. TransCAD offers a variety of tools that can be used in transportation planning. The versions 2.0 and 2.1 of the package have been used for several years by the Urban Planning Group of Eindhoven University of Technology for different types of research projects. The main purpose of these projects is the implementation of specific planning tools and approaches into a GIS useful to planners. During the project different *functions* of TransCAD *were* used and tested. TransCAD was chosen for the following reasons: the number of specialized tools, the open architecture, the ease to learn, and the pc-based platform (see also Meyer & Sarasua, 1992).

The aim of this paper is *to give an overview of the functions that TransCAD offers for transportation planning and to illustrate this by means of several examples.* Some of the projects are conducted by the Eindhoven Urban Planning Group. These projects concern the simulation of activity patterns, the evaluation of planning scenarios on the use of the urban transportation network and the development of a parking simulation model.

First, the role of GIS-T in transportation planning activities is discussed and the functions of GIS-T are illustrated. Next, the major transportation functions of TransCAD are described. The next section describes three research projects of the Eindhoven Urban Planning Group that are based on TransCAD. The paper ends with some concluding comments concerning the use and new developments in TransCAD.

2. TRANSPORTATION PLANNING AND GIS-T

Transportation planning concerns activities related to managing and maintaining the existing transportation system and anticipating future problems regarding transportation infrastructure (Meyer, 1986). Different activities require different types of analyses such as: studies of individual traffic generators (e.g., universities), major land-use projects (e.g., urban revitalization projects), subarea studies (e.g., terminal areas), corridor studies (e.g., performance of transit), transportation plans (e.g., multimodal plan for transportation service), dedicated studies (e.g., parking studies), and transportation management.

GIS-T can be seen as an integrator of all types of transportation planning activities (NCHRP, 1993). As data integrator: 'GIS-T does not create a single integrated database, rather it creates a mechanism for integration at will to assist in solving whatever problem is at hand'. As systems and process integrator: 'GIS-T provides mechanisms for data conflation and data aggregation'. Potential GIS-T applications can be found at different stages of the infrastructure lifecycle:

a. *the planning stage*: transportation planning, travel demand analysis, road surface management, air quality analysis, etc;

b. *the preliminary design stage*: environmental investigation, right-of-way acquisition, etc;

c. *the construction stage*: detour routing, site management, etc;

d. *the operations and maintenance stages*: accident analysis, traffic monitoring, hazardous waste routing, etc.

For all kinds of applications, different tools must be available in GIS-T. How GIS-T is used in the different transportation planning activities and what kind of tools it requires, will be illustrated with some examples.

Shaw (1993) discusses the use of GIS for *urban travel demand analysis*. He argues that a GIS must have the following requirements for such application. First, there must be some requirements on GIS data support such as high-order topology, cross-layer referencing, and flexible data formats. Also, some requirements on analysis procedures must be available such as spatial, statistical and mathematical analysis.

GIS-T is widely used for *road surface management* (Johnson & Demetsky, 1994) where GIS-T provides the framework for the management system. In this case, GIS-T will need to identify current road surface conditions and trends, and to forecast when and where major maintenance action will be needed. GIS-T application development involves bringing all pieces of the management system together: the establishment of the geographic base map, of the thematic, or attribute, database and of the geographic referencing scheme.

Another field application in transport, concerns *building Traffic Analysis Zones: TAZ*, (Ding, Choi & Kim, 1993; Bennison & O'Neill, 1994; Kim, 1995). The main contribution of GIS-T in this context is the building of databases, establishing the link between spatial and attribute databases, building topological relationships among spatial elements, and displaying results

(Kim, 1995). Bennison and O'Neill use GIS-T for addressing homogeneity and shape criteria for developing TAZ, according to specific criteria established in the traffic theory.

Also in *transit planning* a number of GIS-T applications are being initiated. Schweiger (1992) found five major areas of application: transit analysis (transit ridership forecasting, service planning and market analysis), map design and publishing, facilities/land management, telephone-based costumer information services and transit scheduling and run-cutting.

Table 1: *Transportation network analysis and analytical functions for spatial relations via transportation networks*

ANALYSIS / FUNCTION	POSSIBILITIES	SPECIAL OPTIONS
Shortest path finding		impedance from segment length impedance from attribute table one-way streets turntables partial segments correction for distance to network
Special routes	travelling salesman chinese postman sequence mapping	
Network allocation	districting distance zoning Hitchcock Transportation problem	distance limit capacity constraint isochrone maps
Distance Matrices	square matrix based on network nodes rectangular matrices based on network nodes matrices based on locations outside the network	
Interaction analysis	flow data storage flow data display spatial aggregation based on flow data flow data estimation	
Combining distance and flow data	mean travel distance double constrained gravity model single constrained gravity model	

Jong and Ritsema van Eck (1991) made a comparison of GIS packages on different transportation network analyses and analytical functions related to distances between different locations. To get an idea of relevant analyses and functions in this respect, Table 1 presents a short overview without reference to specific GIS-packages.

3. TransCAD's functionalities for transportation planning

TransCAD is announced as 'a Geographical Information System software package for planning, management, operation, and analysis of transportation systems and facilities' (Caliper, 1990). The package can be used for many different applications including highway or transit planning and operations, facility management and inventory systems, accident reporting and analysis, road surface management, maintenance planning, demand modelling and forecasting, market analysis, environmental impact assessment, regulatory and policy analysis, distribution planning, routing and scheduling, and emergency management. For all these applications different procedures and tools available are summarised below. TransCAD incorporates various modules for data handling (entry, storage, analysis, and presentation). It also allows the implementation of one's own procedures as part of it's environment.

DATA ENTRY AND STORAGE

Both spatial and non-spatial data can be entered by digitizing, by keyboard as well as by importing from different types of data files (DXF, PCX, HPGL, dBase, ASCII, ArcINFO, TIGER). For data storage, TransCAD uses line, point and area databases. *Point databases* contain the coordinates and attributes for a set of points. An *area database* is made up of areas or regions that are surrounded by boundaries. *Line databases* are segments starting at one point and ending at another. They can be used to build transportation networks with turn parameters, representing turn penalties which can be used to simulate turn restrictions, or to indicate the delay involved in making a left or right turn. To connect areas and points to the transportation network in the line database, TransCAD offers an automatic connection option. This technique can be used to link centroids of traffic analysis zones (or other points such as buildings), to a road network.

Dynamic segmentation is a special data managing tool for partitioning lines in a database in order to reflect underlying attributes. The technique can be used to define an abstract line element (the route), with arbitrary start and ending points, and then link attribute data to this segment or section within the route (Uiterwijk & Holsmuller, 1991). TransCAD offers a procedure DYNASEG that creates a line database which is dynamically segmented based upon a set of attributes chosen from attribute tables.

DATA AND NETWORK ANALYSIS

An important data-analysis technique offered by TransCAD is the shortest path algorithms from Dial and Dijkstra (Dial, 1979), with the opportunity to use transfer penalties between different link types and the earlier mentioned turn tables. TransCAD also offers the possibility to calibrate and evaluate single and double-constrained gravity (entropy) models, binary logit models and multiple linear regression models. Further, TransCAD offers a variety of traffic assignment routines to estimate traffic flow on a network (e.g. All-or-Nothing, Stochastic Loading, Incremental Assignment and Capacity Restraint). Most of the assignment algorithms offer an option to take turning penalties into account when performing traffic assignment.

Various transportation planning applications use TransCAD's utilities such as buffer analysis (Silva & Kawamoto, 1995; Silva, Filho & Raia Jr, 1995), traffic assignment and travelling salesman analysis (Bailey & Lewis, 1992).

Data presentation

TransCad offers a variety of presentation possibilities. Most important are the map presentations: thematic maps, maps with pie charts, and maps with different line width representing attribute values of one or more variables. It also offers possibilities of presenting attributes in tables.

Procedure toolbox

The procedure toolbox can be used to implement self-made procedures. It can make use of values in ASCII-files, TransCAD databases, network files and table files. The toolkit contains a variety of statements (command directives) that are processed before or after a procedure is executed. Command directives can be used to check the current settings in TransCAD, to pass information or parameters to a procedure, or to control processing of a solution file.

4. SPECIFIC TRANSPORTATION APPLICATIONS WITH TRANSCAD

In this section, transportation planning applications with TransCAD conducted by the Eindhoven Urban Planning Group are described. Different functionalities of TransCAD were used in the projects.

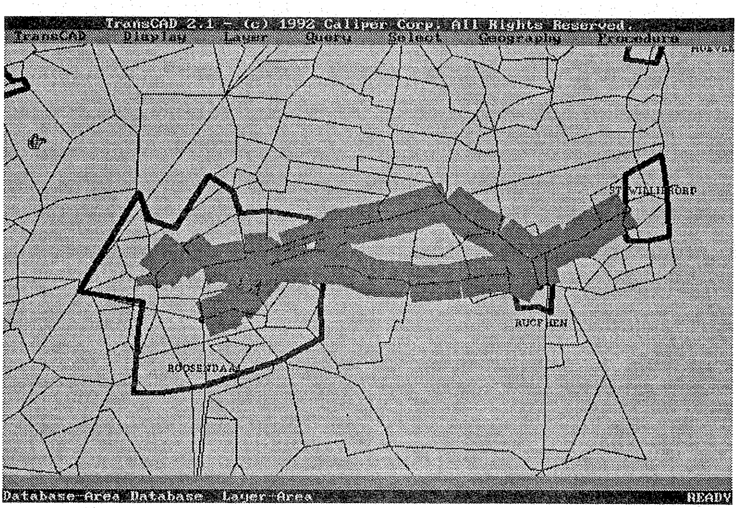

Figure 1: *Presentation of traffic assignment results based on activity patterns*

EVALUATION OF PLANNING SCENARIOS

TransCAD was used in this project to determine the effects of different planning scenarios on the use of the urban transportation network.

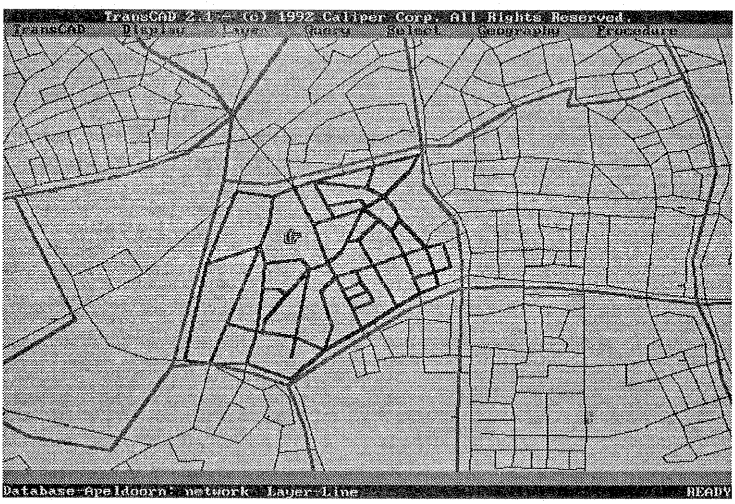

Figure 2: *Selection of network links based on traffic analysis zones*

For this purpose, an area and a line database were built with several attribute values. Using multivariate least-squares regression, a trip generation function was estimated using observed number of trips and characteristics of defined traffic analysis zones. An estimated trip distribution matrix was imported into TransCAD as a database matrix. The incremental assignment method was used to assign the estimated trips to the network. An external procedure allowed for the calculation of the so called Total System Costs (TSC) and Area System Costs (ASC), representing the number of car kilometres driven in an area (TSC for the city and ASC for each neighbourhood of the city). In order to assign the links of the network to the defined traffic analysis zones, TransCAD procedure 'select by vicinity' was used (Figure 2). It selects entities based on their spatial relationship to entities in another geographic layer.

Parking Simulation Model

In order to conduct a simulation of motorists' parking behaviour, TransCAD was used as a data handling and data analysis environment. Several databases (for origin zones, destination zones, parking lots, and road network) and table files (for distances between origin and destination zones, and between parking lots and destination zones) were built. The parking simulation model was implemented as an external procedure (Figure 3) that uses information from TransCAD databases and table files and writes information to these files.

```
set execution condition screen save off;

verify layer base2 warning "Layer has to be the Parking Layer";


choose file table prompt "Choose Parking Distance table ...";
choose file table prompt "Choose O-P Location table ...";
choose file table prompt "Choose O-D Distance table ...";



dump selected attributes to "parkin.dat" 8"
ID" "#places" "Dtoshop" "Pprice" "Ncars" "Pdur" "Orate"
"Tover";


run procedure "psm01\psim";


import file "parkres.asc";
```

Figure 3: *Command directive file for the Parking Simulation Program*

Figure 3 shows an example of a command directive file. The first command directive in this file determines whether the graphics display is saved before a procedure is run and restored after the procedure is completed. The command directive **Verify** is used to check if the type of the current layer is 'area'. To identify the different table files that will be used by the simulation, the **Choose** command directive is called. The file names are stored in an ASCII file (solution.tmp). The attribute values of eight relevant variables (necessary for the evaluation of the simulation model and the calculation of some statistics), are exported from the databases to an ASCII file (parkin.dat) with the command directive **Dump**. The external procedure is started with the command directive **Run**. After running the simulation, some results are imported from an ASCII file (parkres.asc) into the database with the command directive **Import**.

5. CONCLUSION

In this paper, it is argued that GIS can be very useful for various transportation planning activities. The way a GIS can be used, depends on the availability of network analyses and analytical functions. The GIS-software TransCAD offers a variety of analyses and functions that can give support to transportation planning. This paper gives an overview of some of these possibilities. Three examples (research projects conducted by the Eindhoven Urban Planning Group) are given: a simulation model for activity patterns, an evaluation of planning scenarios, and a simulation model for parking behaviour.

In TransCAD, many network analyses and several options are available, such as shortest path finding, route finding and optimal location finding. TransCAD also offers different analytical functions, such as traffic assignment and estimation of the gravity model. A major characteristic of TransCAD is the open architecture which makes the implementation of external procedures or programs very easy. Still, some improvements have been suggested by TransCAD users. Although some of them will be implemented in the new version, it is useful to mention them here. The most important problem users face, concerns the quality of the manual: it is very comprehensive and differs many times from the menu structure or description of the program. This makes it hard to conduct several procedures such as polygon overlay and dynamic segmentation. Useful features/ possibilities that are not available in the package are legend editing, north arrow, storage of data formulae, and switching from miles to kilometres.

More advanced shortcomings are: fitting of distribution functions, generating random numbers (Van der Waerden & Timmermans, 1994); estimation and evaluation of Multinomial Logit models, macro language for building applications based on standard GIS procedures, for example in case of the Urban Transportation Modelling System (Van der Waerden & Timmermans, 1993); limited geographical display and visual power, and the limitation of trip-purpose (one purpose only) (Hartgen, Li & Alexiou, 1993).

During the writing of this paper the Windows version of TransCAD (Caliper, 1995) became available which offers many new possibilities. A quick view showed that there are more advanced drawing facilities available for legends, labels and freehand drawings. Also the Data Formula possibility is improved in the way that a formula can be stored in a so called 'formula field'. Another important change concerns the editing of geographic files. In the new version, edits are not automatically saved; it occurs after giving TransCAD 'green light'.

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