Studying Pedestrian Movements in Central Shopping and Business Areas with a Dedicated Geographical Information System

Peter van der Waerden¹ and Robert van de Voort²
¹Faculty of Building and Architecture
²Faculty of Technology Management
Eindhoven University of Technology
PO Box 513, 5600 MB Eindhoven
The Netherlands

Antônio Nélson Rodrigues da Silva
Department of Transportation
University of São Paulo
Av. Trabalhador São-carlense 400
13566-590 São Carlos, Brasil

ABSTRACT

This paper pays attention to pedestrians’ route choice behaviour in central shopping and business areas, and the various ways this behaviour can be investigated. One of the tools available to carry out this kind of analysis is currently offered by the GIS-software TransCAD. This dedicated GIS software offers a route system routine that is suitable to store and examine in details pedestrians’ movements. In order to deeply explore the potential of these tools, they are used to investigate pedestrians’ movements in the central shopping and business area of Montreal (Canada). More than 360 individual routes have been entered in the route system. These observed routes were compared with (shortest path) routes generated by TransCAD using different network settings. The first network was based on the length of links. A second network was based on both the length of links and the fact that a link was an underground link or not. The final network was based on the length of links in combination with several characteristics of the links (such as presence of shops, presence of restaurants, presence of offices, and located in Old Montreal). The investigation shows that it is very easy to generate alternative routes based on different network settings. The routes generated with the network based on several characteristics of the network links correspond best with the observed routes. This network is used to generate routes after some planning measures (opening of new network links and renewal of some existing network links) are implemented. The result of this exercise is presented in a map.

1 INTRODUCTION

Central shopping and business areas have to deal with continuous transformations such as the opening of new shops, remodelling of existing shops and their façades, and reconstruction of shopping streets. All these changes might influence pedestrians’ movements in the shopping area (e.g., Borgers & Timmermans, 1986a) and, in addition, the performance of the stores from an economic point of view (e.g., Timmermans & Van der Waerden, 1992). To get insight into the effects of changes in the structure of shopping and business areas on pedestrian flows, several route choice models have been developed. Most route choice models are based on the minimisation of walking distance or walking time between successive stops or between starting and ending point (Borgers & Timmermans, 1986b). This minimising behaviour was confirmed in a laboratory setting by Hayes-Roth & Hayes-Roth (1979). It appears that
it is more difficult to support this type of behaviour with empirical data (Gärling & Gärling, 1988).

These research findings indicate that there is still a lack of knowledge concerning pedestrians’ movements in central shopping and business areas. This paper aims to contribute to the discussion concerning the distance and time minimising behaviour of pedestrians. The study described in the paper tries to find out if pedestrians in the central shopping area of Montreal (Canada) follow the shortest path principle between two successive stops (including start and end point of a route). The study also explores the possibilities that Geographical Information Systems offer to store and analyse routes and related data. Recently, some dedicated GIS, like TransCAD (Caliper, 1999), started to offer specific tools to investigate pedestrians’ movements. Pedestrians’ routes and accompanying stops can be recorded as parts of a specific route system, which also includes routines to generate shortest paths between successive stops. These possibilities provide a basic framework to investigate the differences between observed routes and automatically generated routes.

The paper is organised as follows. First, pedestrians’ movements in shopping centres will be described shortly. Next, attention is paid to the possibilities of the special tool of the route system module of TransCAD. This section is followed by a short description of the study area. Next, the basic analyses are described, followed by a description of the best fitting network. This network is then used to illustrate the effects of changes in the pedestrian network and in land use. The paper ends with some concluding remarks concerning the use of GIS for this kind of analyses.

2 PEDESTRIANS’ MOVEMENTS IN SHOPPING CENTRES

In general, pedestrians move through a shopping centre to visit various destinations like shops, restaurants, and offices. The pedestrians use a variety of movements (Figure 1). Most pedestrians’ movements within shopping centres start at parking lots, bus stops, metro stations, or bike stands (Borgers & Timmermans, 1986a). From these so-called entry points, the visitors go to the first shop they have planned to visit. Next, the visitors go to one or more other shops or return to the entry point. The routes might lead through different streets and cross various squares of the shopping centre and, as mentioned in section 1, follow the most optimal path, which is mostly the shortest path (e.g., Dijkstra, Jesserun & Timmermans, 2002; Daamen & Hoogendoorn, 2002).

It appears, however, that pedestrians’ route choice behaviour is not only influenced by walk distance or time (e.g., Naderi & Raman, 2002). Also other elements of the environment (e.g., pavement, vegetation, and shopping fronts) and characteristics of the transport system (e.g., traffic flows and traffic lights) might play a role in this context. To study this influence, the availability of tools to store and analyse routes and calculate the values of these elements, is essential. A dedicated GIS, like TransCAD, might offer these tools.
3 GENERATION OF ROUTES

The definition of routes and the handling of route related data in a dedicated GIS have been discussed before in Van der Waerden, Timmermans and Borgers (1996). The underlying paper focuses on a specific tool in the route system of the selected GIS software TransCAD: the route generation tool.

The GIS-software TransCAD is a ‘full-featured geographical information system designed specifically for planning, managing, and analysing the characteristics of transportation systems and facilities’. One set of available tools deals with routes in a transportation network. TransCAD stores these routes in a so-called Route System module, which is a set of map layers that contains a collection of routes with accompanying stops (see for more details Caliper, 1999). In TransCAD, the routes are made up of a series of links, which are the line objects of a line database. Routes can be stored continuously, with all the links connected to each other or with gaps or spaces in it. Every route in the system can have data associated with it, such as: type of pavement, percentage of the route covered by a roof, number of crossings with traffic signals, etc. Route systems can also contain information about stops that are made along a route, such as kind of stop (shopping, waiting, resting, etc.) and length of stay at the stop.

The part of the route system module that is the most interesting for the underlying application is the ability of the route system to create shortest routes given a table of stops (Figure 2). The table has to contain the list of nodes the route will
visit. Based on the line layer and the accompanying network file, the shortest route can be generated automatically.

Figure 2: Creating shortest routes from stop table

4 THE CASE OF MONTREAL

The data used in this paper were collected in the city of Montreal (Canada, Quebec). The research area (Figure 3) is strategically located between the Central Business District, Old Montreal - which is one of the city’s major tourist and recreational areas, and Chinatown. The presence of large office towers, a convention centre, a metro system, lots of retailing, and a variety of restaurants, makes the environment very complex.

The more specific subject, the case study, deals with the urban renewal plans of Montreal’s international business district. This district consists, among others, of a world trade centre, a stock exchange, a large office tower, a convention centre, and some large hotels. The major part of the urban renewal plans is the expansion of the Montreal convention centre with 10,000 m$^2$ of space. Since the convention centre is a major facility in Montreal, its expansion will have a catalyst effect on the development of the neighbourhood, the international business district. To reinforce this effect, the local government proposed the realisation of some new indoor pedestrian walkways, and even suggested a connection with 'The Underground City'. Also, the revitalization of public streets, public squares, and the planning of some new hotel facilities, is part of these urban renewal plans.

A great part of this research deals with a pre-evaluation of the upcoming urban renewal plans of Montreal’s international business district. This evaluation will be based on observed spatial behaviour of the most important users of the environment, the pedestrians. Therefore, spatial ‘lunch time’ behaviour data of the users (mainly office-workers and conventioneers) has been gathered, since between noon and 2pm
(peak around 1pm) the highest number of people patronizing shops and restaurants, can be found.

![Map of Montreal’s Central Business Area](image)

**Figure 3: Map of Montreal’s Central Business Area**

In March, April, and May 2000, the routes of 362 pedestrians were observed by means of tracking. Tracking methods, following those developed in other case studies (e.g., Zacharias, 1993), essentially involve mapping detailed spatial behaviour through observation at a discreet distance. The tracking data has been collected during lunchtime over three months of the year. Pedestrians were selected randomly at one of the entrances of the shopping area or exits of offices. Next, pedestrians were followed during their stay in the shopping area. This means that both the route and the successive stops were administered. Also, some additional information was gathered, such as date, age, gender, and weather conditions.

Data-analysis, by using a GIS (TransCAD), will provide for a very specific and detailed understanding of the actual spatial use of the international business district. This knowledge will finally also be applied for making some predictions about the future use of the soon to be renewed environment. Figure 4 shows the different layers (buildings and road network) for the study.

5 PEDESTRIANS’ MOVEMENTS INVESTIGATED

To investigate the routes of the pedestrians, all 362 routes and accompanying stops are entered in the route system of TransCAD (Figure 5).
The routes are stored in the route file with route name and route length (Figure 6). The stops are stored in the stop file with link code, node code and the distances between successive stops.

Figure 4: **Study area in TransCAD**

Figure 5: **Observed routes in the route system module of TransCAD**
The comparison of the observed and generated routes was elaborated at the level of distances walked per route. Therefore, three different road networks were built based on the characteristics of the network links. The first network was only based on the length of links (simple network). The second network was based both on the length of links and the fact that a link was an underground link or not (ground level network).

The length of a link was weighted with 1 for underground or with 2 for ground level. The final network (complex network) was based on the length of links in combination with several characteristics of the links (such as availability of shops, availability of restaurants, availability of offices, and located in Old Montreal). The lengths of the links were adapted according to the following formula. The weights of the variables are extracted from another (modelling) part of the research.

\[ L_i^* = 16 \times L_i + 58 \times S_i + 30 \times R_i + 64 \times O_i + 30 \times OM_i \]

Where,

- \( L_i^* \) is the adapted length of link \( i \);
- \( S_i \) is the presence of shops at link \( i \) (1=yes, 0=no);
- \( R_i \) is the presence of restaurants at link \( i \) (1=yes, 0=no);
- \( O_i \) is the presence of offices at link \( i \) (1=yes, 0=no);
- \( OM_i \) is the location of link \( i \) in Old Montreal (1=yes, 0=no).

The average distances of two series of distances (observed routes with generated routes using one of the networks) are compared using a paired sample t-test. The size of the t-value (more than 1.96, at conventional level: \( \alpha=0.05 \)) shows the existence of a difference between the average distances of the two networks that are compared.
From table 1, it can be concluded that the routes that are generated with the network based on the various characteristics of the network links (the complex network) are most similar to the observed routes.

6 PREDICTION OF PEDESTRIANS’ MOVEMENT

The network based on the characteristics of the network links was used to generate new routes after some planning measures were implemented (Figure 7).

![Figure 7: Old (left) and new (right) network in the study area of Montreal](image)

The planning measures consisted of the opening of several new network links and the renewal (e.g., the opening of shops) of some existing network links. We have to notice that we assumed that the destination choice (or location of stops) did not change after the implementation of the measures. Figure 8 shows the pedestrian volume per link based on the observed (left) and generated (right) routes. The figure shows clearly where the changes in pedestrian volumes appear. In figure 9, the differences in pedestrians’ volumes are presented in a more detailed view. The dark grey colour indicates that there is an increase in pedestrian volumes in relation to the initial
volumes, while the light grey colour indicates that there is a decrease in pedestrian volumes.

Figure 8: Pedestrians’ flows in the before (left) and after (right) situation

Figure 9: Difference in pedestrians’ volumes after the implementation of several planning measures
7 CONCLUSIONS

This paper describes an investigation of pedestrians’ movements in the central shopping area of Montreal, Canada. To get insight into these movements a specific tool of the GIS-software TransCAD has been explored. The aim of the paper is to contribute to the insights into pedestrians’ movements in shopping areas and into the possibilities TransCAD offers to study these movements.

It appears that the effects of the changes in the road network on the number of pedestrians per network link could be easily presented in the GIS. The analyses show that the observed behaviour can be described best with a network that is based on the length of links in combination with the following characteristics of the links: presence of shops, presence of restaurants, presence of offices, and the fact that a link is located in Old Montreal. The network is used to predict new routes after some planning measures were implemented. This prediction shows a good view of the impact of a set of planning measures on the pedestrian volumes.

Of course, attention has to be paid to the effects of the planning measures on other choices like the destination and parking choice of the pedestrians. This will be certainly an issue of future research. Further research will also imply a search for the exact influence of the characteristics of the network links.

8 REFERENCES


