

# MODELLING ACCESSIBILITY FOR PUBLIC TRANSPORT IN AN URBAN CONTEXT

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## PREFACE

The paper is a revised version of a paper presented to the European Regional Science Association, thirty-seventh European Congress, Rome, Italy, August 26-29, 1997.

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The paper is developed on basis of Eivind Aase's master thesis from Department of Town and Regional Planning, Norwegian University of Science and Technology.

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## 1 INTRODUCTION

Sustainable development is increasingly focused in urban planning. In that perspective planning might contribute by organizing land-use in a way that reduces the demand for transport of people and goods, and by improving the conditions for sustainable transport patterns, such as walking, bicycling and public transport.

If public transport is to be competitive it ought to provide good standard of accessibility for its users to different parts of the urban scene. This has also to do with efficiency in circulation of people and goods, which is an important aspect of master planning (Harvey 1996).

Professional planners in Norway are paying attention to the Dutch inspired ABC approach in urban land-use and transportation planning (Engebretsen & Hansen 1994, Asplan 1996, Myrene 1996). In this policy approach, the emphasis is on locating industry to sites based on accessibility to land by considering the demand for mobility by different branches of industry (Van Huut 1991, Hilbers & Verroen 1992, 1993, Verroen & Jansen 1992). A-locations are characterized by high standard of accessibility by public transport and low standard of accessibility by car. Opposite to that, are C-locations identified by good standard in accessibility by car, or maybe poor accessibility by public transport. Mobility in this approach

is defined by the number of work places per unit floor space related to industrial activities, the patterns of attraction in relationship to visitors/customers, and the characteristic of goods transport.

A-locations in this approach will be reserved for industry that are characterized by high density of workplaces per unit floor space, and/or activities attracting many visitors. Typical land use in the first case is office buildings, and shopping centres in the second case. Manufacturing enterprises are typically a C-location activity by relatively few workplaces per unit floor space and dependent on high standard of accessibility by trucks for goods transport.

Using the ABC-approach, or other methods, it is important for urban planners to have access to methods that allow calculation of accessibility by different modes of transport in a fast and straight forward way for different alternative land-use patterns. Geographical Information System (GIS) based network models appear to be promising in that respect. In addition to include mathematical models for calculation as in non-spatial models, the geography is integrated in a transparent way. The GIS-based network models might thus represent significant improved tools and techniques for approaches to comprehensive land-use and transportation planning.

Our paper deals with modelling accessibility for public transport by GIS. It builds on, and develop the arguments in a master thesis in town and regional planning (Aase 1996). The reason why we are addressing public transport is because this mode of transport is particularly challenging to conceptualise for accessibility evaluations, since it lacks the flexibility of other modes related to the road infrastructure, several routes might operate on the same roads, and is operated by time schedules. Just to mention a few attributes that differ from other modes. Public transport by bus service is addressed, but this is in our perspective not very different from other modes of public transport, for instance those operated on rail. The different modes of land based public transport might also be integrated in the same network.

## **2 THE NETWORK CONCEPT**

The network concept in our terminology is comprised by links and nodes made up of points identified by geographical coordinates (vector-GIS). When simulating a road network, lines are intersected by nodes in cross-roads, or elsewhere we have differences in quality aspects or where we from a reason or other want to split up roads in smaller parts. In links we might attach attributes as distance and average travel distance and identify busroutes, while we in nodes store attributes as bus stop, frequency of bus service, and rules for turning. In a GIS-based network file geographical data are stored by topological structure, which mean all nodes and links are identified by unique numbers and which nodes and links that are connected. Such a structure allows us to keep track of direction, and thus for instance associate speed to direction of travel, which can be useful when modelling differences due to congestion or to topography.

Basic geographical sources of data for the analysis discussed in the paper are a roadnetwork and networks reserved for walking and bicycling. The networks refer to the centreline of the real phenomena at which we pretend to simulate the social activity. Other data is presented for the reader as we develop the examples below. The applied data is from Trondheim, which is a town of 143.000 inhabitants in the middle of Norway.

In this study we have applied TransCAD, version 3.0, which is a software solution from Caliper Corporation (1996) specialised on transport and logistics. The shortest path algorithm is frequently applied in the analysis related to the examples outlined below.

### 3 CALCULATIONS EXAMPLES

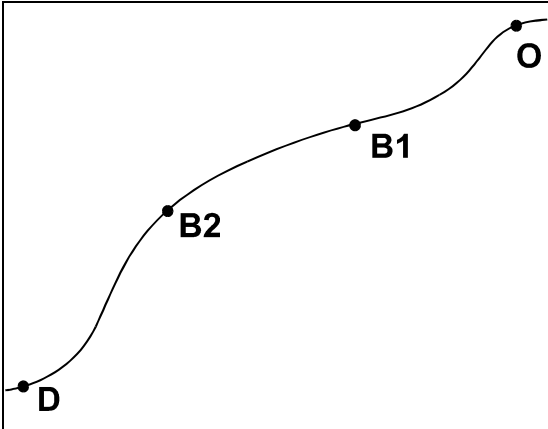


Figure 1

Our first example is simply to find the accessibility from busstop "O" to "D" as illustrated in Figure 1. It is assumed that only one bus route is operating the distance. In that simple case it is not even necessary to select shortest path, and the traveltime and accessibility to D from O can simply be found by summing up the driving time stored on each link in the path and by adding stipulated stop time at each bus stop on the path. The shortest path algorithm is, however, applied. The calculation is carried out by just activating the right function and by pointing with the mouse to O and D on the monitor map, which is the general technique for the end user.

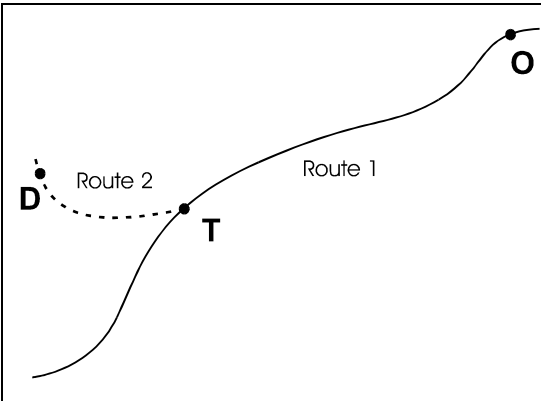


Figure 2

In the next example bus riders from "O" to "D" have to make a transfer at "T" from route 1 to route 2, which is illustrated in Figure 2. It is not assumed any other changes of complexity compared to the first example.

In this case the software has to handle the time table for two routes at the transferstop "T" in order to calculate waiting time. The software allows the end user to establish a specific

transfer table at each bus stop to define which transfers might occur and associated attributes. In addition to the waiting time derived from the differences in timetables, the accessibility calculation includes the transfer time, which is the time it takes to change from one bus to another. Moreover it is possible to handle explicit situations where there are walking distances between the place of stop for different routes. That is useful since such data is likely to be specific for each point of transfer in the network, while the transfer time might be global. In this case the accessibility is made up of calculated driving time by function of distance, time for ordinary stop, waiting time, transfer time and by possible walking time included in the transfer operation.

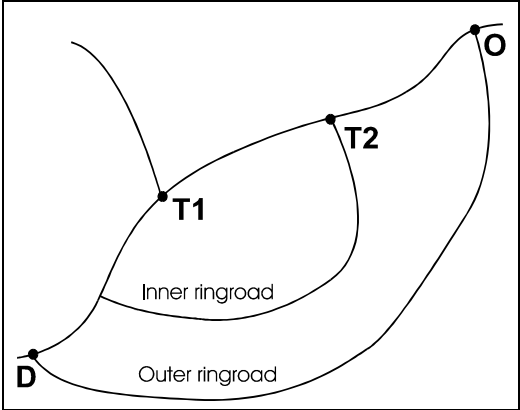


Figure 3

The example in Figure 2 might be expanded by alternative routes that drive different paths from the terminal of origin "O" or from the place of transfer "T". The only principal difference is that the software has to calculate the shortest path measured in travel time. In Figure 3 this situation is illustrated with three routes to choice among to get from "O" to "D", which are the route operating on the outer ringroad, make a transfer in T2 and follow the inner ring road or by travelling through the city centre and make the transfer at "T1".

The point of transfer in the previous example might be a central busterminal as it is in our primary data from the city of Trondheim. It is likely to be several routes to choose among from such a terminal. A way to solve this is to operate with fictional routes in the busnetwork made up by adding routes that operate on the same road links to one. The travellers are assumed to choose the departure from the point of transfer that brings them to the destination. Route 2 in Figure 2 can thus for instance be replaced by a fictional route. The only difference in calculation is that the travellers are likely to achieve less waiting time and thus improved accessibility. The principle for generating fictional routes is illustrated in Figure 4.

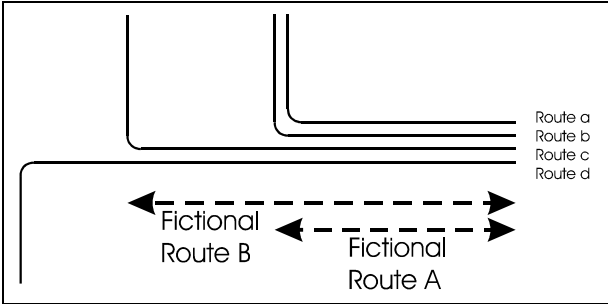
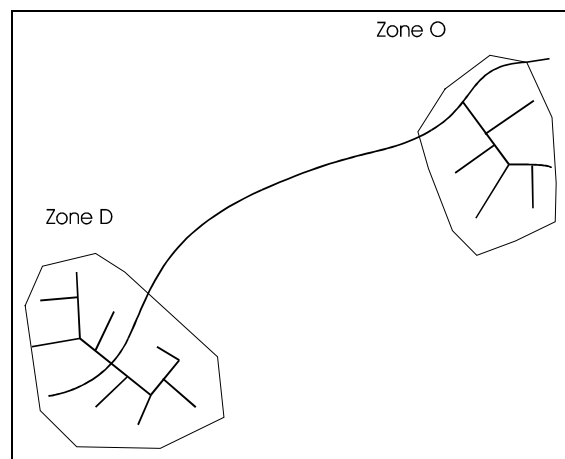


Figure 4

A likely behaviour by passengers is to give preference to routes without transfers. However, if there are significant differences in travel time many travellers would likely prefer to transfer to a faster route. This can, for instance, be the case when local routes are corresponding with express routes or where the differences are derived from geographical distance (driving different paths). With a lack of empirical data, 5 minutes was selected as the transfer cost in the underlying calculations. The value of the variable does not matter as the study focuses on techniques and methods, but it would probably be more realistic in the social context of Trondheim if 10 - 15 minutes was applied.

The examples above can be extended by the number of transfers, bus stops, alternative routes and by driven distance, which mean to expand the calculations quantitatively, not qualitatively. It expands, however, the work for the planners responsible for preparing and updating the affiliated data base.

In urban planning it is of interest to calculate accessibility to certain points in the city from housing areas and, for instance, to workplaces. We thus move the point of origin "O" and destination "D" from the bus terminals to a residence area and work place area respectively, for instance an office complex. The accessibility calculations have then to be expanded by time for access and egress in relation to places of origin and destination. A traditional way to solve comparable challenges in non-spatial transportation models is to operate with a fixed geographical structure of zones and calculate the travel between pair of zones. Such procedures are also supported by TransCAD, which software offers full four steps analyse opportunities for transportation planning. The zone-to-zone situation is illustrated in Figure 5.



**Figure 5**

The time for access and egress in this case is the average time needed to achieve access from the different housing units in zone "O" to the actual bus stop, and likewise the average time of egress to the different workplaces in zone "D". In traditional transport analysis (four step analysis carried out by non-spatial models) the access and egress factors are added by rough assumptions, but in TransCAD, and other GIS-based network applications (Kalsaas & Oterholm 1993), these time factors might be calculated automatically, if we have access to appropriate data.

In the study underlying the paper we have developed geographical point data associated with ownership of urban land and addresses. The geographical points are placed at the centre of the associated buildings, or group of buildings, for each parcel of land. It is a one-to-many relationship between ownership of land and addresses in order to cover phenomena like

shopping centres in this respect, which are made up by several individual shops, and blocks of flats, etc. The applied set of data has actually been created by linking subset of two national data bases, one for ownership of land and one for addresses.

Using TransCAD, the file containing geographical property locations was integrated with the geographical network file, which is illustrated in Figure 6. The left illustration in the figure is the point of departure, and in the right picture the result after the merging procedures have been accomplished. To fulfil these operations, the end user has to add nodes as demonstrated in the figure. That is because the software is linking the geographical points to the nearest node. The attributes of the point data, after the "merging" with the network, are automatically accessible as resources for the simulation of activities in networks. The user should, however, take care to secure that the merging is completed according to the concrete situation. It can for instance occur that a point of resources will be linked incorrectly across barriers as rivers and railway tracks.

With a geographical fixed structure of zones it is then easy to calculate the access and egress time in relationship to a bus stop, which is represented by one of the nodes in the network. We simply calculate the travel time to the bus stop for each located address by the shortest path algorithm based on, for instance, the average speed of walking, and divide the accumulated access/egress time with the number of addresses.

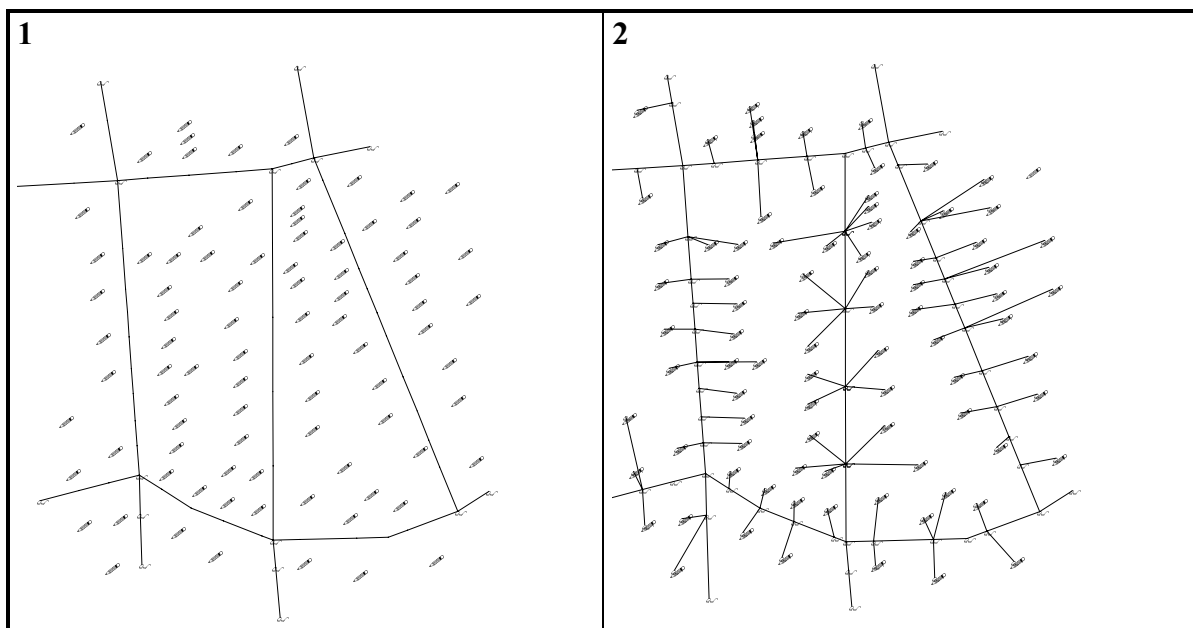


Figure 6

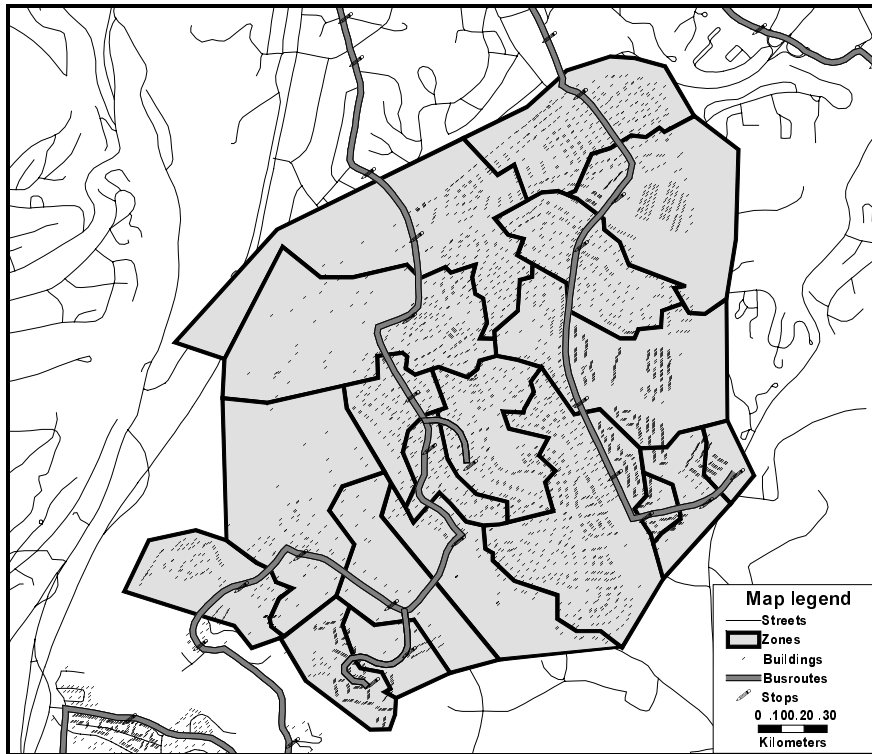


Figure 7

The software has, however, more analytical power than to limit planners to work with a fixed structure of zones. It makes it possible to generate a structure of zones based on the shortest path method, which is carried out in the analysis underlying the illustration in Figure 5. The only principal difference in technique, compared to the fixed zone structure case, is that we must apply full data set of bus stops and allocate the located addresses to the nearest point of bus service, which is illustrated in Figure 7. The boundaries of the set of buildings allocated to the same bus stops make up the generated zone structure.

An urban residential area might have different public transport opportunities. It could be different bus routes that operate on different roads or both bus service and train service. Regarding the generation of zones, it may not be appropriate to use specific zones for each as they overlap. The aspect of geographical overlapping is certainly increased when there is a different frequency of service between the alternatives. A high standard of frequency may outweigh the cost of walking a longer distance. Practically we might eliminate the problem by first generating zones for each point of service, and thereafter merge adjacent zones

Public transport services are in most cases timetabled, which affects the accessibility as touched upon. When the service is operated with a frequency of 15 minutes, 30 minutes or beyond this, the accessibility is affected sufficiently that users ought to plan their journey. They are not free to travel when they want, which might be the case for car drivers, bicycle riders and pedestrians. In the calculation of accessibility we might add a fixed waiting time at the bus stops where the trip has its origin, but the aspect of flexibility remains different between these groups of transport.

Our set of point data representing buildings and addresses does not let us know how many persons that are located at each address, and not even if it is housing addresses. For practical planning purposes it would thus be of interest to expand the attributes connected to each property of land and address. However, legally restricted, Norwegian census statistics make it

possible to connect our set of data to subset of the national data bases for buildings, data for population and industry. We can thus, by property or address, identifies type of activity, such as housing, retail, manufacturing, administration, etc., the number of residents, their age and sex, and the number of employees in different categories of industry. Methodically such a qualitative improvement in data makes little difference to the techniques being focused in this paper.

One important extension following from an improvement in the data to accessibility needs to be mentioned, however. When calculating accessibility in urban planning we are not only interested in the travel time by different modes of transport from "O" to "D", we want to know the number of persons who have what kind of access to different locations. That is for instance the case when carrying out location analysis informed by the ABC-approach, or in efforts to improve the overall accessibility by manipulating organization of land use and policy of transport.

#### **4 THE MOST SOPHISTICATED METHOD OF CALCULATING ACCESSIBILITY FAILED**

It was also an aim in the underlying study to see if it was possible to calculate the travel time between two geographical located addresses without involving any zone specific average time variable for access and egress as demonstrated above (Aase 1996) ^ .

In order to handle address-to-address calculation in a logically straightforward way the software should be able to cope with different layers of networks, in this case one for the bus network and one for walking and bicycling. Conceptually this could be solved by connecting the networks in shared nodes simulating terminals for public transport. This is in principle how a layer of point data is integrated to a network layer, which is discussed above.

The TransCAD-software can, however, only involve network calculations at one layer at time, and the "best" solution is not available, according to our findings. It is necessary to fool the system in one way or another in order to reach the aim. Such alternative approaches to the mentioned principal method are discussed below.

We might expand the network for public transport by links for pedestrians. It is, however, to our knowledge not possible to operate with the logical operators "and" and "or" regarding link types. That means a link is either a link for public transport or for pedestrians/bicycle riders. We know that this is not true in real life. To avoid the main problem we can add parallel links where our modes of transport share roads. That will enlarge the set of data considerably, but is closer to a real situation when the road space is divided between driving and walking/bicycling. However, in residential areas the modes of transport in question frequently share the road space in the Norwegian context. Another challenge arises by this approach. That is how we should avoid that the public transport service in the model starts to operate on the network reserved for walking and bicycling. A principal solution could be to force the different modes to keep to associated links by applying different speeds in the network, which is ought to be done anyway. A conceptual parallel is found in the TransCAD-solution developed to hinder unwanted transfers between different busroutes, where a global factor of cost is related to making transfers.



Another solution to our problem might be to pretend that the address specific calculated access and egress time is the average time applied for zone-to-zone calculation, which is similar to making a zone out of every building in the set of data. In the zone-to-zone calculations the access and egress times are calculated and stored as an attribute to the respective point of service. Thus it is easily conceived that the set of data will expand by making a zone out of each building. The conversion of a point layer to a polygon layer should be no obstacle in the applied GIS-software, which is a necessary operation if each building is chosen to represent a zone.

## **5 CONCLUSION**

The results from applying the GIS-based network model TransCAD, for calculation of accessibility by public transport in an urban setting is considered to be very promising. It requires, however, relatively high skill regarding both the objects of study and the software to make successful analysis. The software is thus very much an expert tool. Moreover it would be useful if it was possible to operate with simultaneous calculation on more than one network at time. In the time available we did not succeed to calculate accessibility on the detailed address to address level. It might be necessary to do some development on the software in order to reach this. For this task the associated GIS Developers Kit might be used. The layer concept for storing data in the software, which is so commonly applied in GIS might, however, be an obstacle.

When applying the notion of accessibility in this paper we have focused on technical matters and the system, which are socially contingent. It is thus also socially aspects that have to be considered in practical planning and analysis of accessibility (Sayer 1993, Kalsaas 1995). What is, for example, the influence of the fares? Can all inhabitants afford to demand public transport?

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