

Public transport travel time simulation

Tomáš CHLEBNICAN, Jiří ČTYROKY, Marek ZDERADICKA

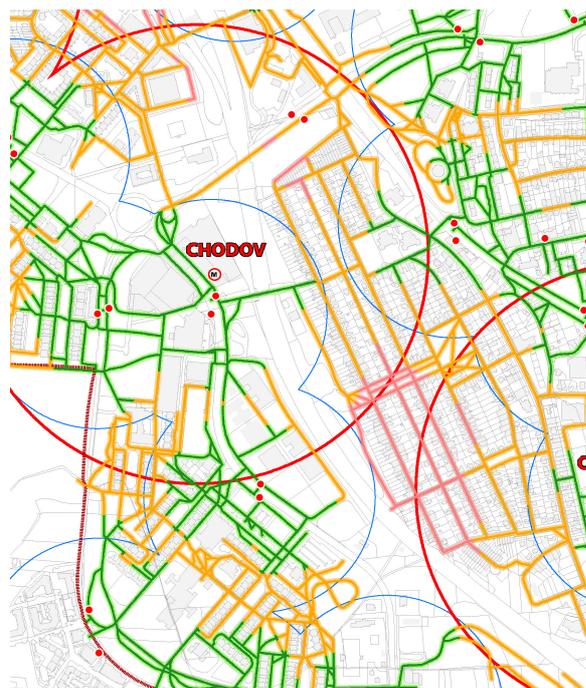
(Mgr. Jiří ČTYROKÝ, Útvar rozvoje hl. m. Prahy, Vyšehradská 57, Prague 2, 128 00, ctYROKY@urm.mepnet.cz)
 (Ing. Marek ZDĚRADIČKA, Útvar rozvoje hl. m. Prahy, Vyšehradská 57, Prague 2, 128 00, zderadicka@urm.mepnet.cz)
 (ing. Tomáš CHLEBNIČAN, CHAPS spol. s r.o., Bráfova 1617/21, Brno, 616 00, tchlebnican@chaps.cz)

1 INTRODUCTION

Information on reliable time based travel distances within the urban areas is of increasing importance for management of today cities struggling with congested traffic and limited opportunities for reduction of traffic demand. The public transport promotion is for many European cities the only way to tackle the situation.

The quality of public transport (PT) is closely connected with the real time accessibility of the area by public transport means. Generally observed indicator of quality of the PT system is **Total Travel Time** defined as total time spent on journey from any place to the final PT stop including walking from origin to the nearest PT stop and average travel time spent on travelling with PT system. Both determines attractiveness of the PT service on a local or global level .

As a support tool for town and transport planning activities City Development Authority of Prague uses analysis based on modelling of the time accessibility in both levels. These analyses provide town planners more realistic information about time accessibility of particular areas as an assessment tool of them for both urban development and development of the public transport system.



Pic 1: Case study revealed need of footbridge over the motorway in order to improve accessibility of metro station and local shopping centre. At the same time there is clearly showed differences between theoretical isochrones (circles) and due to GIS simulated close-to-real walking distances (lines).

On the local (micro) level **Walking access time** from the site to the nearest public transport stops coming out of real footpaths is being evaluated based on GIS technologies. This level helps to reveal barriers in the area and to optimise location of stops and stations.

Other outputs are catchments areas or so called PT stops service areas. This output is used for comparison of calculated close-to-reality walking accessibility with theoretical concentric ring isochrones that are traditionally used for description service area of PT stops without taking into account the townscape.

Beside it, planners and PT managers put their focus on time accessibility of the city centre, usually (due to the highest concentration of workplaces) or to other points of interest in a global, let us say citywide view. The indicator is **Average travel time** and shows us the quality of the PT service from the time point of view.

2 CALCULATION OF THE AVERAGE TRAVEL TIME

The key output of the analysis is Average travel time. This time index is composed from Average waiting time and Average connection time. Calculation of **Average waiting time T_c** on each stop for services of PT is come from connections that run within the pre-selected period of a day (e.g. morning peak from 7:00 until 9:00) with the proviso that there were sought two connection at least.

Fehler! Es ist nicht möglich, durch die Bearbeitung von Feldfunktionen Objekte zu erstellen. (fig 1), where

t_1 ... departure time of the first connection

t_n ... departure time of the last connection

n ... number of connections

Average connection time T_s is defined as sum of connection times $T_{1,2,3,\dots}$ (time that is spent on the board of the public transport means and on transfers between them) divided by number of connections.

$$T_s = \frac{\sum T_{1,2,\dots,n}}{n} \text{ (fig. 2), where}$$

$T_{1,2,\dots,n}$... connection time of the 1st, 2nd up to n^{th} connection

n ... number of connections

Average travel time T_p is the sum of Average waiting time T_c and Average connection time T_s .

$$T_p = T_c + T_s \text{ (fig. 3)}$$

3 AVERAGE TRAVEL TIME APPLICATION (ATTA)

Traditionally, data about average travel time were collected and counted manually (using Excel tables), the data for this calculation was acquired from common journey planner available on the Internet. This approach is naturally very time-consuming, its variability and flexibility is low and regular update complicated. In order to facilitate this assessment, City Development Authority of Prague in collaboration with company CHAPS spol s.r.o. that has been authorized by the Ministry of Transport of the Czech Republic to run The National Information System of the public line passenger transport timetables, developed the application for automatic statistical analyses of time table information. The project is called Average Travel Time Application (ATTA). The results of ATTA evaluation are combined with the GIS based walking distances evaluation outputs, giving us complex and very close to real information. What's more the ATTA works with regularly upgraded real timetable of the Prague Integrated Transport (PID).

4 PHILOSOPHY OF THE ATTA

Average Travel Time Application works in following steps. First, origin or more origins and destination or destinations along with period of the day are defined. On this basis possible PT connections are searched and comparison and selection of strategies and sequent calculation of average travel time is then provided.

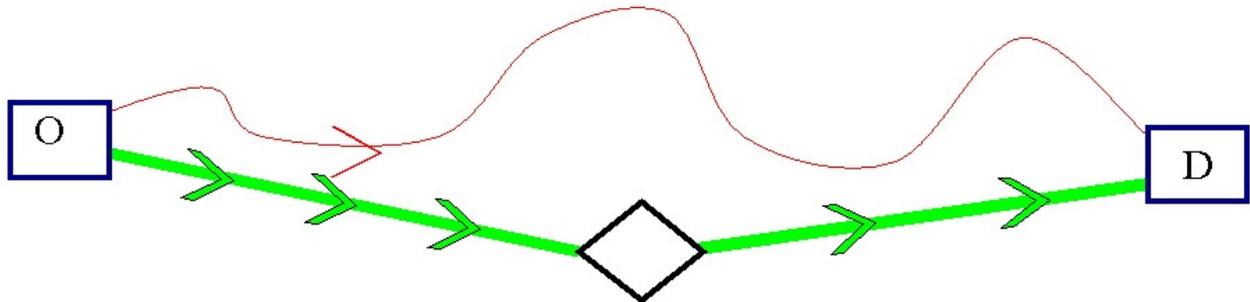
The data sources are timetables of Prague Integrated Transport (PID), providing the real data and schedules of all integrated transport means (metro, tramways, bus lines, suburban bus lines and trains, ...) that are incorporated into the metropolitan passenger transport system. The same database serves as the data source for for the Journey Planner for public (available on the Internet). Connection search engine for ATTA has been derived form the Journey Planner web application.

The crucial issue that was considered during the development of the ATTA was how to set up the seeking strategy of the application in order to get outputs close-to-real behaving of passengers. Application works with two different strategies to search connections from the origin/origins to the destination/destinations:

Strategy 1 – there are concerned all possible connection with very various routes in the meaning of time, frequency and numbers of transfers (e.g. much longer non-transfer connection with low frequency vs. shorter connection with transfer and higher frequency). This strategy covers all possibilities but some of them were evaluated as unlikely for everyday use during the testing operation. It affects the results of calculation significantly as well (large dispersion of sought connection times that are average out).

Strategy 2 - there are preferred connections with higher frequency of operation with same or similar transfer points and transport means. Results are more homogenous and they were evaluated as more acceptable for calculation. On the other hand there are cut off all other possibilities of travelling.

Scheme of strategies



Pic 2: Strategy 1 use red and green types of connections while strategy 2 use only green type of connections

Both strategies have its advantages and disadvantages. In order to avoid the biased results the application use **comparison method** and define the preferable result. The strategy where the longest searched connection time is shorter (out of both strategies) is taken into account. Beside this there are possibilities of manual settings selection.

Thanks to cooperation with Prague Integrated Transport Coordinator (ROPID) we are able to simulate also planned lines of PT for which ROPID is able to create fictitious timetables with the view of comparing changes and assessment of the time accessibility.

5 WALK DISTANCE CALCULATION

Image of near-real accessibility of the area by the PT may be improved considerably by taking the walking distances to the PT stops into consideration. The goal is, usually, to calculate the isochrones to the nearest stop within the area taking into account the layout of pedestrian route network (footpaths) or, in the wider concept, all “walkable” surfaces within the area. Along with this calculation, boundaries of PT stops service areas are also defined.

The nearest stop calculation can be provided by several GIS based methods according to the selected data model. Due to the relative simplicity of input data preparation and good calculation performance the grid model analysis has been chosen. The principle of the calculation is based on the creation of grid model of footpaths as the input matrix. The matrix cell values domain consists normally of two values 0 (non-walkable area) and 1 (footpath). The more complex models may, however, take into account also the surface and slope characteristics influencing the walking speed. If the additive vertical or horizontal factors are to be taken into calculation, new separate grids must be used.

It is important to ensure all stops must lie on the footpath. The calculation of walking distance is based on simple Euclidean distance and shortest cumulative path cost distance. The principle of cost distance is calculation of “cost” (i.e. measurable time, distance, fuel, etc.) which must be spent for one-unit move on the surface. In case of normal rectangular grid it two cases have to be taken into consideration. The cost of vertical or horizontal move across the grid from cell A to B is described by the formula:

$$C = \frac{C_a + C_b}{2} \text{ (fig.4), where}$$

C_a ... cost of move on cell A,

C_b ... cost of move on cell B

The cost of diagonal moves is represented by the different expression:

$$C = \frac{\sqrt{2}(C_a + C_b)}{2} \text{ (fig.5), where}$$

C_a ... cost of move on cell A,

C_b ... cost of move on cell B

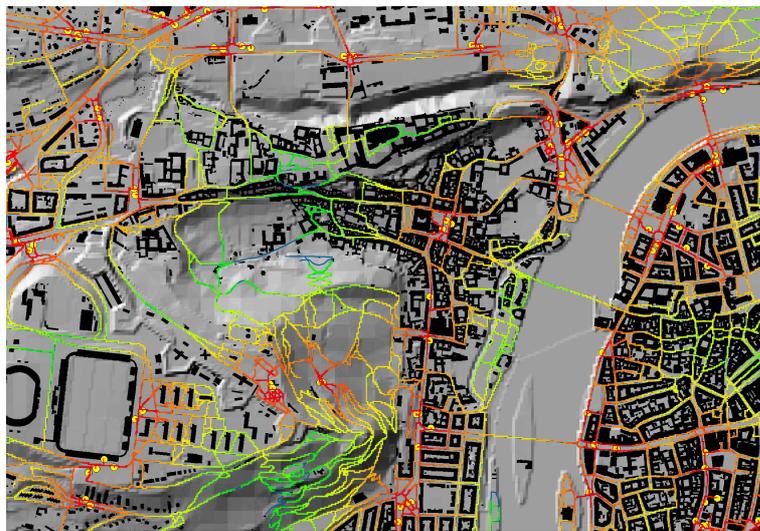
The cumulative cost path from source cell to destination is then calculated as the minimal sum of all possible cost paths :

$$C_{CP} = \sum \min(C_{AB}) \text{ (fig. 6), where}$$

C_{CP} ... total cost of move from source to destination

C_{AB} ... cost of move between two neighbouring cells on the path

The total cost path depends, however, on the grid resolution. Final cost sum must be multiplied by the value of grid resolution in distance unit if the cost grid resolution does not equal to the distance unit. For the purpose of walking distance modelling in Prague 1m grid resolution is being used. The value may be interpreted as the real geographic distance or time distance in seconds as the speed 1 m/s well corresponds with average walking speed (3.6 km/h). This simplification may be, however, used only if no terrain factors are taken into consideration.



Pic 3: Cost distances to stops on the walking network

6 TERRAIN FACTORS

Calculation of cost path as described above provides very acceptable results when the modelled area is flat-shaped and/or if the result should be figured out in the distance units only. In case of rugged topography the vertical factors influence the real cost distance in two ways. First, the real distance on the sloped link is bigger than the distance on the horizontal footprint of the link (surface factor), second the difficulty of moving on the terrain varies with the slope and the move direction (vertical factors). The difficulty is then reflected on the moving speed, fuel consumption and related factors. If the surface and vertical factors are taken into calculation, the total cost algorithm from move from cell A to B is then extended:

$$C_s = D_s \cdot VF \cdot C \text{ (fig. 7), where}$$

C_s ... the cost from move from cell A to B,

D_s ... the surface distance,

VF ... the vertical factor,

C ... the horizontal cost according to the fig. 1 or 2 respectively

Surface distance D_s is calculated as the actual ground distance between cells A and B. The distance calculation is based on definition of right triangle with the one side has the length equal to the grid resolution and second side length is the difference between height (Z value) of the cell A and height of the cell B. The third side (the surface distance) is then calculated using the Pythagorean theorem:

$$D_s = \sqrt{R^2 + (Z_a - Z_b)^2} \text{ (fig. 8), where}$$

D_s ... the surface distance,

R ... the grid resolution,

Z_a, Z_b ... the height of cell A or B respectively

The positive or negative influence of the slope on the move depends very much on the units used for cost measurement and mode of transport. There can be defined several functions for the description of the dependence of the move costs on the terrain slope. The detail research on the best fit function has not been undertaken so far, thus, the basic inverse linear function for the walk distance calculation is used for practical purposes. The figure that influence the moving cost dependently on the actual moving angle from cell A to B is called the vertical factor:

$$VF = \frac{1}{1 + VRMA \cdot SM} \text{ (fig. 8), where}$$

VF ... the vertical factor,

VRMA ... the vertical relative moving angle from cell A to B,

SM ... the slope modifier variable

The value of SM influences the steepness of the vertical factor curve, for the calculation purposes is set to $1/45^\circ$ (45° slope is the limit for common walking in both up and down directions).

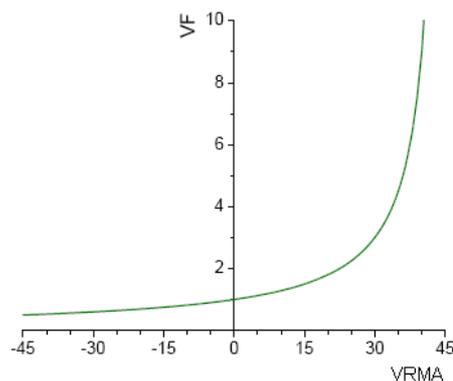


fig. 10: vertical factor function curve

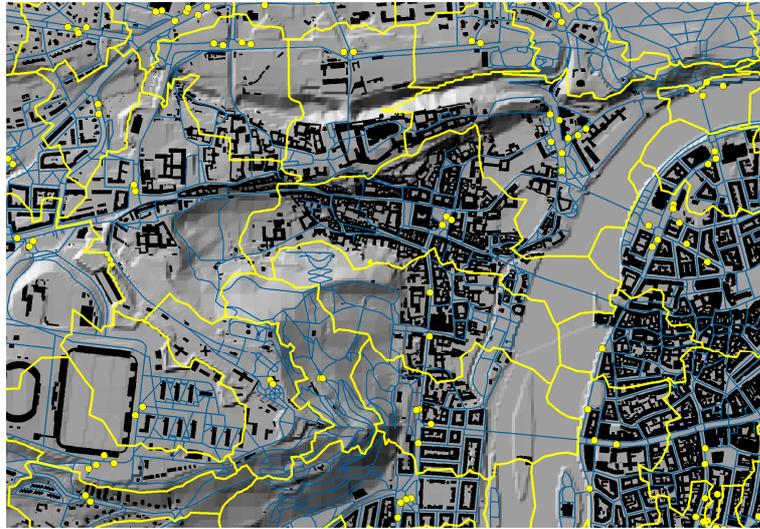


Pic 4: Demonstration of terrain factors influence (from left): a) 5 minutes isochrones without terrain factors calculation, b) after surface distance implementation, c) after surface and vertical factors – downhill move direction, d) after surface and vertical factors – uphill move direction

7 PT STOPS SERVICE AREAS

So far, we have discussed the way how to calculate the walking distance cost (time) from stops along the pedestrian network. Now we will try to match the results from the time-table analysis and the walking distance analysis. The task is to find for each cell on the network such combination of walking route to the stop and consequent PT travel cost from this stop to the destination, where the cumulative cost for both trips is minimal.

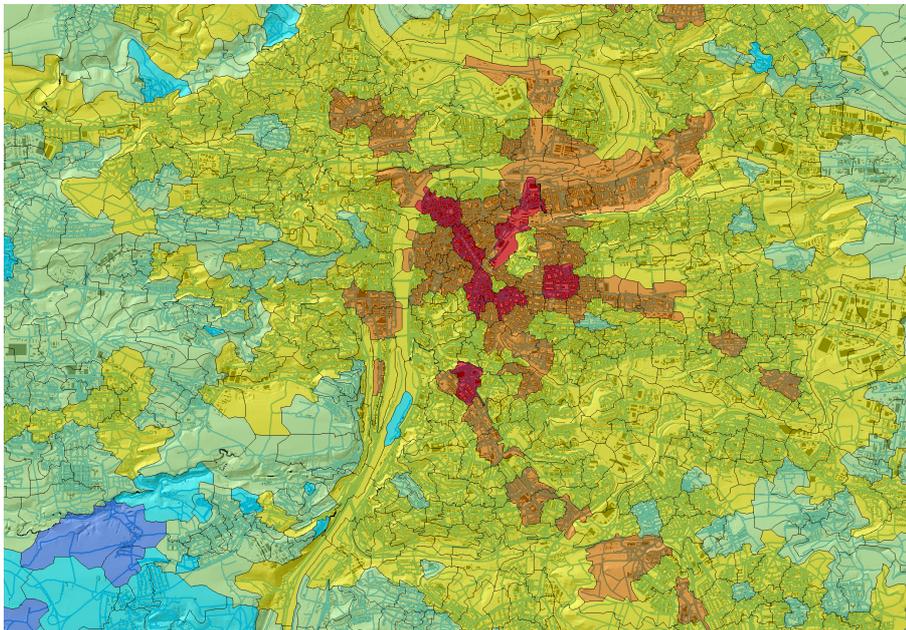
The algorithm is based on selection of the set of PT stops within pre-set proximity; for each stop the total travel cost than may be calculated. On this basis the optimal service stop is selected. In practice, this approach has not been so far applied. Instead of it service areas have been defined on the traditional static allocation basis – as the areas with the common closest stop according to the walking costs.



Pic 5: PT stops service areas

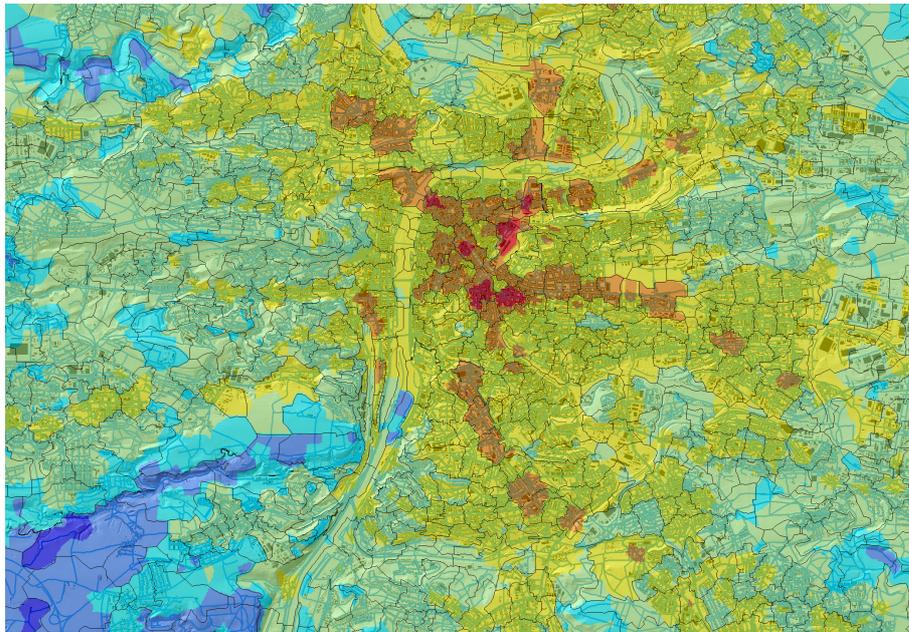
8 TOTAL TRAVEL TIME

After definition of service areas the travel costs expressed as time needed for moving from the source to the destination using the PT in connection with walk can be summarised. To each service the PT travel time of the corresponding stop is matched and then it is added to the walking distance values of each cell.



Pic 6: PT travel time allocated to the service areas (isochrones 5, 15, 30, 45 and 60 minutes)

It is useful to visualise the result time on the map through isochrones, mostly for the easy understanding and good comprehension. The isochrones can be generated from the total travel time grid values (only walking network grid cells carry the value) by interpolation. Interpolation method used in our case is Inverse Distance Weighted Method, taking into account 12 point neighbourhood and power 2 for calculation of the weight of each point value.



Pic 7: Total travel time, isochrones 5, 15, 30, 45 and 60 minutes

9 CONCLUSIONS

For cities with high share of public transport on the modal split the public transport accessibility is the crucial factor deeply influencing the commercial attraction of particular city areas. Good knowledge of near-real accessibility makes possible to provide better city management and planning through optimisation of public transport lines routing, tuning up the timetable scenarios, better location of stops and also improving the walking network within the city. The practical example clearly revealed the importance of walking distances for the total accessibility values, as well as the important role of terrain factors for the walking distance model.

The further study should be focused on the dynamic definition of the public transport stop service areas which extent in fact varies with the changes of the destination place. Also, better understanding of vertical factor influence to the walking cost should be beneficiary for the further development of the model.

10 EXAMPLE

Demonstration of the public transport accessibility shown in this paper was provided for the Prague area. The objective of evaluation was to calculate near real-time accessibility to the city centre (Wenceslas Square). The destination stops were Muzeum or Můstek, the better (shorter) total travel time of these two was considered. The time period used for time table statistical evaluation (ATTA) was Monday, 3.9.2007 from 6:30 to 9:00. Walking distances were calculated using by ESRI ArcGIS and Spatial Analyst Extension. The resolution of the grid was 6790 x 4935 the cell size is 5 meters.

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