Design and Plan of Travel Time Surveys on Slovene Road Network

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Abstract: The paper gives the overview of the possible methods of travel time data collection. The overview of the possible methods is elaborated on the basis of the analysis of foreign literature. Based on domestic and foreign experiences and the available equipment some methods of collecting and analysing data were checked in a pilot study, and the results were mutually compared. Based on the comparison of the results it was found out that beside the classical travelling observer method, for our conditions also the application of the ABC ETC system and the method of extrapolation of local measurements of speed can conditionally be used.

Key-Words: Travel times, Survey, Roads, ETC

1 Introduction

Travel time is one of the basic parameters of the traffic flow. It is used not only by traffic engineers and designers for their studies, but it is also a generally known term used by transport organisations and dispatching systems to help them make their decisions, and, last but not least, also by the users of transport services – drivers and passengers in public transportation.

Despite the important role of this parameter, there is no fixed system of travel time data collection in Slovenia. The data on operative speeds, kept in the bank of road data (BRD), are to a large extent of older origin and need to be updated.

The present paper gives the main results of the development and research project financed by the Directorate of the Republic Slovenia for Roads (DRSC). The purpose of the project was to propose a system of travel time data collection. It gives the overview of the possible methods of travel time data collection, from the travelling observer method, through the license plate matching technique to the application of local speed measurements for the estimation of travel times. Some methods were then re-checked in the practice in a pilot study.

2 Definitions of travel time and speed

Travel time is defined as “time, necessary to drive the distance between two points”. It consists of driving time and additional time (the time when the vehicle stands or drives slower than 8km/h).

In certain cases travel time can also be estimated by presuming that the average speed measured at a certain cross-section is constant. This presumption is appropriate especially for those sections where traffic flow is unimpeded (freeways and expressways). In this case travel time can be calculated using the following equation:

$$t = \frac{l}{V_t} \qquad \ldots(1)$$

where:

t is estimated travel time
l is section length
V_t is average speed in the time period – arithmetic mean of speeds of all vehicles driving through a cross-section in a certain time period and calculated by

$$V_t = \frac{\sum v_i}{n} \qquad \ldots(2)$$

where:

V_t is average speed in the time period
v_i is vehicle speed i in the cross-section
N is the number of vehicles driving through the cross-section in the time period

3 Preparation of the data collecting plan

The typical procedure of travel time data collection is as follows:

- defining objective and the purpose
- identifying users
- defining the area of study
- selecting methods and techniques
- defining schedule
- conducting training
- pilot collection of data
- data collection
- data analysing and control

The first step at the elaboration of the plan of collecting data is to define the purposes that the collected data should serve. Often the data are collected for several purposes with the main objective to establish a database on the present traffic condition in the roads. It is necessary to identify all the users and to check if the collected data suffice the minimum demands for all the users.

When defining the scope of data collection, the following questions need to be answered:

- Where to collect the data? (geographical area)
- On what roads? (road types)
- When to collect the data? (time periods)

The geographical area, where the data are to be collected, can be:

- short road section near the planned or introduced measure (e.g. before-after study)
- corridor between two points, which can include a freeway, access roads, parallel roads (e.g. justification study)
- several corridors leading to a certain centre of activity
- all main corridors within a certain zone or area

In the case that the geographical area is limited to only a few corridors or roads, travel times will probably be collected in each section (no sampling). However, if a geographical area extends over a whole region or a country, sampling will be used and thus the costs of data collection will be substantially lower. In this respect only the data for a certain sample of sections will be collected, with the presumption that the characteristics are similar also at the rest of the roadway system. Sampling is most applicable for the needs of planning, where the required data accuracy is less than that required for design and operation analyses.

When preparing the plan of data collection, the following time factors need to be considered:

- traffic fluctuation during the year
- traffic fluctuation during the week
- traffic fluctuation during the day

The data on travel times should present the typical or average annual conditions, thus they should be collected in those months when the traffic load is approximately the same as in average conditions. To determine the average month we normally use the data collected by automatic traffic meters. Normally the most appropriate month is May.

The data are generally collected on Tuesday, Wednesday or Thursday. In the case data of higher accuracy are required and there are sufficient funds at disposal, the measurements can be carried out in all workdays of the week. On Saturdays and Sundays the measurements are carried out only in the case that the main purpose is to collect data on recreational and tourist trips.

When preparing a plan for data collection, holidays, changes in school timetables (e.g. vacations) and especially to such events as big sporting events, entertainment festivals, etc., need to be avoided.

The data are normally collected in the following hours of the day:

morning peak period	normally between 6.00 and 9.00
off-peak period	normally between 10.00 and 12.00, and 18.00 and 20.00
afternoon peak period	normally between 13.00 and 17.00

The time periods need to be adjusted to the local conditions, as it is normal that in large towns peak hours last longer, while in smaller towns they can last even less than one hour. When defining peak hours once again automatic traffic meters can be helpful.

There are several methods at disposal to collect data on travel times. A single method or a combination of several methods can be used.

When choosing a method, first any existing sources of travel time or speed data need to be found (e.g. automatic traffic meters, ITS centres, etc). Then the methods of supplementary data collection are to be selected. When selecting these methods, financial limitations and the limitations of the available equipment and personnel need to be considered.

For the comparison of the methods of data collection the following criteria are used:

- <u>initial costs</u>: costs of equipment needed for data collection
- <u>efficiency</u>: relative costs of data collection per data unit
- <u>necessary knowledge</u>: necessary knowledge of the data collecting personnel
- <u>data analysis</u>: time and costs needed for transcription and data editing
- <u>flexibility</u>: possibility of using equipment at different sections
- <u>precision</u>: precision compared to the actual average travel time

- sample according to time: possibility of frequent data collection
- sample according to space: possibility of data collection at several nearby locations
- sample according to vehicle; possibility of data collection according to different vehicle typesand behaviour of different drivers

Once the scope and methods of data collection have been set, the schedule of the activities needs to be determined. Beside time and location the schedule also needs to include data on the personnel and equipment to be used.

The attitude towards work and knowledge of the data collecting personnel are very important factors influencing the quality of the collected data. The conduct training of the personnel needs to include the following items:

- familiarising with the purpose of data collection
- detailed description of the data collection procedure
- procedure of removing difficulties in the equipment malfunctioning
- procedure of suspending data collection in the case of poor weather conditions, traffic accidents or equipment failure

Before the actual data collection starts, pilot data collection needs to be carried out. Pilot data collection is carried out at a sample of sections (5-10%) to be included in the actual collection. The purpose of pilot data collection is:

- to get a detailed insight into the data collection method
- to get familiar with the corridors where the data are to be collected
- to measure precise section lengths
- to identify problems or necessary equipment in the early stage

The data collected in the pilot data collection can also be used to calculate or adjust the necessary sample sizes.

4 Defining section sample

The next step is to define the types of roads or functional classes of roads where the data on travel times are to be collected. The types of roads depend to a large extend on the objectives and purpose of the study. Normally the classification of sections into categories changes depending on the purpose of use: e.g. the classification for planning differs from the one for the optimisation of operation.

When classifying sections full attention needs to be paid to the fact that at the sections of the same class the same or similar traffic conditions are valid. This enables the use of what is called stratified sampling.

When stratified sampling is used, the following steps need to be taken:

- defining categories
- defining sections
- dividing sections to subsections with similar traffic conditions and geometrical characteristics.
- calculating the necessary sample size within each category. The necessary sample size depends on the following variables:

variation coefficient – relative measure of variation, defined as standard deviation divided by average value. Variation coefficient can be calculated from the existing data, or default following values (depending on traffic load) can be used:

- freeways/expressways 15-25%
- arteries 20-25%

Variation coefficient is calculated using the following equations:

$$cv = \frac{\sigma}{\mu} \approx \frac{S}{\overline{X}} \qquad \ldots(3)$$

where:

σ is standard deviation of the whole population
μ is mean value of the whole population
S standard deviation of a sample
$\overline{X}$ is mean value of a sample

Z-statistics (or t-statistics for samples < 30) – the function of the desired confidence level (e.g. 95% confidence level) for the average value. For the stratified sampling normally the levels of confidence between 80 and 95% are used, depending on budgetary limitations.

Table 1: Confidence level / Z-statistics

Desired confidence level	Z-statistics
99%	2,575
95%	1,960
90%	1,845
85%	1,440
80%	1,282

Permitted relative error – expressed as a percentage, is one half of the interval of the desired confidence level for the average sample value (e.g.±5%)

Normally the following values are used:
$\pm 5\%$ for design and operation optimisation
$\pm$ 10% for planning

Sample size is calculated using the following equation:

$$n' = \frac{cv^2 \times z^2}{e^2} \qquad \ldots(4)$$

where:
z is z-statistics for the selected confidence level
e is relative permitted error (%)

for finitely large populations the following corrected estimation is used:

$$n = \frac{n'}{1 + \frac{n'}{N}} \qquad \ldots(5)$$

where:
n' is non-corrected sample size
N population size

- selection of sections within each category.

As a rule random stratified sampling should be used. When this kind of sampling is used, the sections that are to be measured are normally scattered throughout the studied area, which makes the data collection quite expensive. As an alternative to random stratified sampling we use what is called priority sampling. In this case travel times are measured at 10-20% of the most critical sections, while at the rest 80-90% sections random sampling is used. To determine the priority (critical state) of sections, the following criteria can be used:
- bottlenecks and the congested locations
- percentage of change in the levels of concentration
- average daily traffic per lane
- average annual daily traffic

5 Travelling observer method

The travelling observer method has been used to collect data on travel times since the late twenties. With this method the observer in a vehicle, driving in the traffic flow, records the cumulative travel times at the predefined checkpoints along the route. These data are then converted into travel time, speed and delays for each section along the route. There are several different techniques for the execution of this manner of data collection, depending on the vehicle equipment and instructions to the driver. This method is also known as active test vehicle method.

According to the equipment of the vehicle the following techniques can be classified:
- manual – fellow passenger in the test vehicle records the times of crossing the checkpoint on a paper, tape recorder or in a computer.
- EDM (electronic distance meter) – establishing travel times with the help of speed and distance meter inside the vehicle
- GPS (global positioning system) – establishing location and speed of the vehicle with the help of satellite signal

According to the manner of driving the following methods can be classified:
- average vehicle – the driver estimates the average traffic flow speed and drives at this speed
- floating vehicle – the driver tries to pass safely the same number of vehicles as the number of those that have passed the test vehicle
- maximum vehicle – the driver drives at maximum allowed speed, except when the traffic-safety conditions do not allow it

Normally floating vehicle method is used, and often also the combination of floating and average vehicle.
The demands for the sample size dictate the number of drives in a section that a test vehicle needs to carry out in the observed time. The use of the minimum prescribed number of drives ensures that the measured average travel time of the test vehicle differs from the actual average travel time of all vehicles by less than the selected permitted error.

The necessary number of passings can be calculated from:

$$n = \left(\frac{t \times s}{\varepsilon}\right)^2 = \left(\frac{t \times (cv \times \bar{x})}{(e \times \bar{x})}\right)^2 = \left(\frac{t \times cv}{e}\right)^2 \ldots(6)$$

where:
t is t-statistics from the Student t distribution for the specified confidence level
s is standard deviation of travel time

ε is maximum permitted error

cv is variation coefficient $cv = \frac{s}{x}$

$\overline{x}$ is average travel time

e is relative error $e = \frac{\varepsilon}{x}$

When the sample size approaches 30, which is not customary for test vehicles, instead of the Student t distribution also normal distribution can be used. In this case the following equation can be used:

$$n = \left(\frac{z \times cv}{e} \right)^2 \qquad \ldots (7)$$

As can be seen, minimum sample size depends on three parameters:

- T-statistics - value t from the Student t distribution for (n-1) values of freedom. T-statistics depend upon the specified confidence level in the estimation of travel time. Since the value of freedom depends on the sample size, it has to be calculated iteratively.
- Variation coefficient - relative changeability of travel time expressed as a percentage. It can be calculated from empirical data using the above formulae, or the approximate value between 9 and 17% can be used.
- Relative permitted error (e) - is permitted error in the estimation of travel time expressed as a percentage. It depends on the purpose of use of data. For the needs of planning, normally the values with $\pm 10\%$ error suffice.

Table 2: Variation coefficients at freeways and arteries

Freeways		Arteries	
average daily traffic per lane	average variation coefficient	traffic lights density	average variation coefficient
<15,000	9	<3	9
15-20,000	11	3-6	12
>20,000	17	>6	15

Table 3: Sample sizes at freeways

average daily traffic per lane	average variation coefficient	sample size		
		90% ±10%	95% ±10%	95% ±5%
<15,000	9	5	6	15
15-20,000	11	6	8	21
>20,000	17	10	14	47

Table 4: Samples sizes at arteries

density of signals (No./mile)	average variation coefficient	sample size		
		90% ±10%	95% ±10%	95% ±5%
<3	9	5	6	15
3-6	12	6	8	25
>6	15	9	12	37

After the necessary number of passings is defined, they need to be distributed through the whole time period in which the data are collected.

6 License plate matching method

With this method license plates and their passings are being recorded at several successive locations. Travel times are then calculated from the differences in the times of their arrivals to successive locations. According to the manner of recording license plates there the following techniques can be classified:

- Manual

With this technique the observers register license plates and the times of their passings on a paper and later on transcribe them manually into a computer

- Transportable computer

The observers transcribe license plates directly into a computer; the time of passing is recorded automatically

- Video with manual transcription into computer

Vehicles are recorded to a video cassette and later on license plates are manually transcribed into a computer.

- Video with automatic recording into computer

Vehicles are recorded to a video cassette and then these tapes are processed using special software for automatic identification of signs.

As the number of the vehicles registered by the matching license plates method is large, the sample size is not of primary importance. The sample size needs to be greater compared to the travelling observer method, since also the variability of the captured times is greater. The reason it is greater is in the fact that with this method different types of vehicles and different driving styles are recorded.

The necessary minimum sample size can be calculated from the following equation:

$$n = \left(\frac{t \times cv}{e}\right)^2 \approx \left(\frac{z \times cv}{e}\right)^2 \quad \ldots (8)$$

if the estimated sample size is greater than 30

Table 5: Typical values of sample sizes for certain levels of confidence and selected allowed relative errors.

traffic	period	average cv	sample size		
confidence level permitted error			90% ±10%	95% ±10%	95% ±5%
low/medium	15-30min	10	4	5	18
low/medium	1-2 h	20	12	18	62
dense	15-20 min	25	18	27	96
dense	2 h	35	34	48	189

Based on foreign experiences it can be concluded that for the needs of planning 50 matching license plates are sufficient sample size.

The number of registered license plates can be estimated from the percentage of plates found in successive locations. This percentage can vary between 5 and 20% and depends upon:

- the distance between two successive checkpoints
- the number of intersections between two successive checkpoints
- percentage of transit traffic and mean travelling length

7 Application of the ITS systems for travel time data collection

It is typical for the methods of travel time data collection using ITS systems that they use those systems where the primary purpose is not travel time data collection but for example operation control, automatic detection of incidents, etc.

This chapter presents five different techniques of using ITS systems for travel time data collection. These are:

- Automatic Vehicle Locating (AVL) based on the roadside transmitters – this method is most frequently used in public traffic. Vehicles from public traffic communicate with transmitters placed along the routes of public transportation.
- Automatic Vehicle Identification (AVI) – test vehicles are equipped with onboard units communicating with roadside antennas. With the analysis of data on passings of onboard units by individual antennas the data on travel times can be obtained.
- Navigation with the help of radio communication – it is normally used in public transportation or at navigating a fleet of trucks. The data are collected with the help of radio connection between the vehicle and a radio transmitter.
- Locating with the help of the GSM system – the location of a vehicle can be obtained with the help of following applications of the GSM telephone number in individual cells of the GSM system.
- Locating with the help of the GPS system – vehicles are equipped with the GPS receivers; with the help of GSM or radio connection the current location is communicated to the control centre.

8 Testing some of the methods in a pilot study

Based on the study of foreign literature and knowledge of domestic conditions we decided to test some of the methods in a pilot study (8 sections at the national roadway system). Tested were the travelling observer method, the use of ITS systems (ABC) and local measurements. When selecting locations our objective was to cover different road categories.

8.1 Application of the data of the ITS systems

To test the applicability of the data of the ITS systems we chose the Slovenian electronic toll collection system ABC. The system enables to calculate travel times from the differences in the times of passing through two successive tolling plazas.

8.2 Local speed measurements

The next tested method was the application of local speed measurements to estimate travel time. The data on the local speed measurements were obtained from vehicle meters, which enable also speed measurements. On one destination the speed was measured with the analysis of video picture. For the data acquisition and treatment the Autoscope system was used. For the analysis of the measured data average speeds at the measured cross-section were calculated.

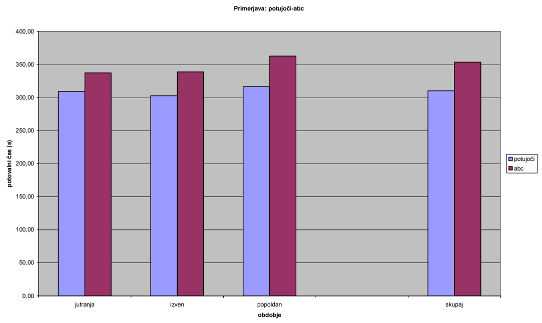
8.3 Travelling observer

The next tested method was the travelling observer method, which served us to collect data on travel times in all the selected destinations.

9 Comparison of results obtained by different methods

When comparing the data obtained from the ABC (Slovenian ETC) system and with those from the travelling observer method, it can be seen that the average travel times as obtained from the ABC system are by 12% (43 seconds) greater. The reason for the difference is in the fact that with the travelling observer method the time was measured from the beginning of the acceleration lane at the entrance to the end of the braking lane at the exit, whereas the ABC system is based on the exact transaction times.

Fig 1: Travel time obstained form ETC and travelling observer method.



The data of the ABC system are therefore useful for the estimation of travel times at traffic sections, taking into account that travel time needs to be reduced by the time that a vehicle, using ABC, needs from the beginning of the braking lane to the antenna and from the antenna to the beginning of the acceleration lane. In our case the difference is even greater because of the fact that there was no "fast" ABC lane at one of the selected tolling plazas.

By comparing the data acquired with the travelling observer method and the extrapolation of local measurements it can be concluded that travel times obtained by the travelling observer method are still greater than those obtained by the extrapolation of local speed meters. The deviations at freeways and expressways do not exceed 15%, while at main roads they were rather large. These deviations appear when the location of the meter is outside a settlement, and the greater part of the section is inside a settlement.

10 Conclusion

The paper gives the overview of the possible methods of travel time data collection. The overview of the possible methods is elaborated on the basis of the analysis of foreign literature. Based on domestic experiences and available equipment some methods of collecting and analysing data were checked also in a pilot study, and the results were mutually compared. Based on the comparison of the results it was concluded that beside the classical travelling observer method also the application of the ETC system and the extrapolation method of local speed measurements are conditionally appropriate for our circumstances.

In the case that the ABC system is used, one has to pay attention to the fact that the times obtained from the ABC system are longer than those obtained by the travelling observer method (due to different locations of the section beginnings and ends). Depending on the location and equipment of a tolling plaza (fast lane) we propose that in the case that a tolling plaza is equipped by a fast lane, 15 seconds are subtracted from the time obtained by the ABC (for the driving time through the ramp), and in the case there is no fast lane, 30 seconds (for the drive through the ramp and waiting in line).

The results obtained by the extrapolation of local speed measurements can be used directly only in the case of freeways and expressways. With other roads one has to pay attention to the course of the section and the meter location. In the case that the meter location is outside a settlement and the whole section is also outside the settlement, it can be concluded with a large degree of certainty that the method is useful. In other cases, however, it is better to divide the traffic section into smaller sections and use the data obtained by this method only in that part that is in the same environment as the meter (inside or outside the settlement).

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