TURN SPECIFIC VS. LINK BASED TRAVEL TIMES CALCULATED FROM FLOATING CAR DATA

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ABSTRACT

Floating car data (FCD) meanwhile is a widely available and affordable data source. The given GPS data – delivered in frequencies of some seconds or sometimes only a few minutes – are typically matched to some digital road network and mainly the traffic variables travel time or travel speed are calculated out of it, yielding current values for each link in the road network with at least one observed GPS position.
With regard to route planners or navigation systems for example, the information could be even more precise as there is typically no distinction drawn between different turning directions at intersections. Taking the according and presumably varying travel times into account might result in improved navigation solutions.
This contribution quantifies the travel time variations regarding different driving directions at several junctions in the German city of Berlin. For this purpose, GPS positions delivered by a fleet of about 4000 taxis covering some months of data are used. Traffic data are decomposed and the resulting turn specific travel times are compared.

Keywords: traffic data collection, floating car data, probe vehicle data, travel times, travel speeds, turn-dependence

INTRODUCTION

Reliable traffic information is a basic prerequisite for nearly all innovative ITS applications. Area-wide knowledge about current and former traffic states is needed for many tasks in planning and control of traffic. With regard to route guidance and navigation, floating car data (FCD) has been established during the past years as an important technology to provide the necessary travel time information which, for example, can be used to dynamically compute optimal routes for a given road network (cf. Schäfer et al., 2002; Lorkowski et al., 2005; Cohn and Rutten, 2009).

In this context, current travel times for a specific stretch of road are typically calculated as time-aggregated, probably also space-aggregated or time-weighted values based on data delivered by a couple of floating cars which passed there in recent time. Often the values are adjusted to some daily variation curves which represent the expected travel time behaviour for that stretch of road at the specific time.

But the way the traffic variables are commonly calculated is by now not as precise as it could be. For example, the journey time estimation for a given route driving on an arterial road straight on at each intersection towards the city center should incorporate only those floating car data which represent a car driven straight on, too, at the junction of interest.

Despite that, today all data available for a given link form a single aggregated and/or weighted travel time value for that link. Thus, floating cars turning left at an intersection, for instance, may negatively affect the estimated current speeds for routes driving straight on. This effect is at first due to left turners waiting for oncoming traffic. Then, the straight direction in reality is often not influenced by that as vehicles driving straight on can pass by. On the other hand, queues for left turners might be so long that not only turning lanes but also (multilane) links far away from the intersection are covered by the queue. Of course, this would influence the calculation of journey times for routes in straight direction, too.

Although such effects obviously have a significant practical meaning, there are only very few publications in the literature dealing with this topic (Liu and Mizuta, 2008; Liu et al., 2009). Systematic studies in real-life conditions with sufficient large data sets are – to our knowledge – completely missing.

Therefore, the following chapters describe an approach to quantify the effects of varying travel times due to different turning directions at road intersections by analyzing a data set consisting of some million GPS positions delivered by a taxi fleet of about 4000 taxis in the German city of Berlin during about four months in 2010. The analysis focuses on selected intersections for which meaningful results could be obtained.

APPROACH

Problem description

For purposes of route navigation and provision of Real Time Traffic Information (RTTI), especially travel time information, nowadays different data sources, often based on the FCD technology are used as a basis. The GPS-positions of vehicles delivering data are matched to some digital road network, the traffic information is created and can be used by services.

The traffic information is typically generated only for some stretch of a road (e.g. TMC-segment), and routing services take these - travel times for example – to deliver optimal/quickest routes. To take travel time losses at intersections into account, often some extra-time is added if turning left or right. This extra-time may be dependent on the intersection type and the different street types which meet at a crossing.

The basic assumption is that left-turns cost the most extra time and right-turns a bit less. The problem is that for individual intersections this may probably be a bad assumption. For example if the traffic volume on the segment straight on is very high resulting in longer travel times and a long left-turn lane is available with low traffic volume, this will be the opposite effect. Thus, Real Time Traffic information should be provided not only as one value for a stretch of road, but probably for three values with turn-specific travel times. This will result in a more accurate travel time provision enhancing optimal route finding, especially if based on Real Time Traffic Information.

Approach for solution

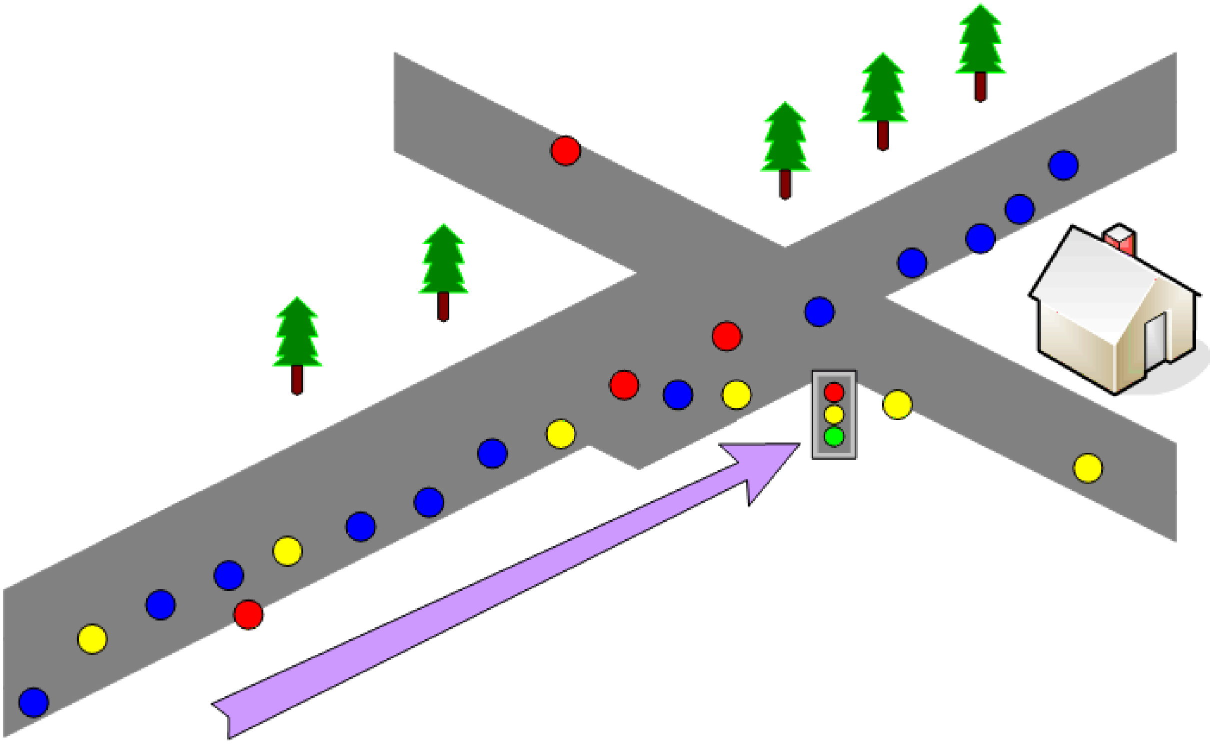

Figure 1 – Principle of the decomposition of the GPS-data for the inflow-segment (blue dots: vehicles driving straight on, yellow dots: vehicles turning right, red dots: vehicles turning left)

The approach is to decompose the data turn-specific as shown in figure 1. For this one takes an inflow segment leading to a crossing. All the available GPS data points related to this segment are typically put together to gain an average value for speed or travel time. This is probably not the best solution because some vehicles turning left at the next crossing may stuck in a jam or have to give way for oncoming traffic. Vehicles turning right may have to give way to pedestrians or bicycles. Thus, if a route is calculated going straight over the crossing these potentially waiting times of the turning vehicles may increase the calculated travel time.

To decompose these data in the inflow segment to a crossing there could be some possibilities to do this. Nowadays digital roadmaps inherit the information about all lanes and connections to all other lanes to where a change is possible. With the width of a lane in cities of about 2,75 m or a bit more, the localisation of a lane is possible with an accuracy of about 1 m. This is for the static data base of a digital road map. The problem is the inaccuracy of the GPS signal which in parts is about 1 m, but especially in cities it often diverts. Thus, it is not possible to match a GPS-point exactly to a lane, which of course would be the best. The information about speed and travel time could be directly calculated in the quickest way. Another possibility for decomposition – and this is what this paper suggests – is the referencing of the GPS data nearby the crossing not until then the according vehicles passed the crossing, the driving direction is clear then and thus (in the normal case) the lane where it drove on the inflow segment.

The analyses are done by collecting all available travel time data for each inflow segment over the whole time period the data are available. The data are aggregated then by daytime-intervalls of 15 minutes and the median value is taken for each of these intervals. The resulting daily variation curves of the median values are then smoothed by taking the median of the interval itself, the interval before and the interval after it. The resulting turn-dependent median curves are then compared to each other by building difference curves.

DATA-SET

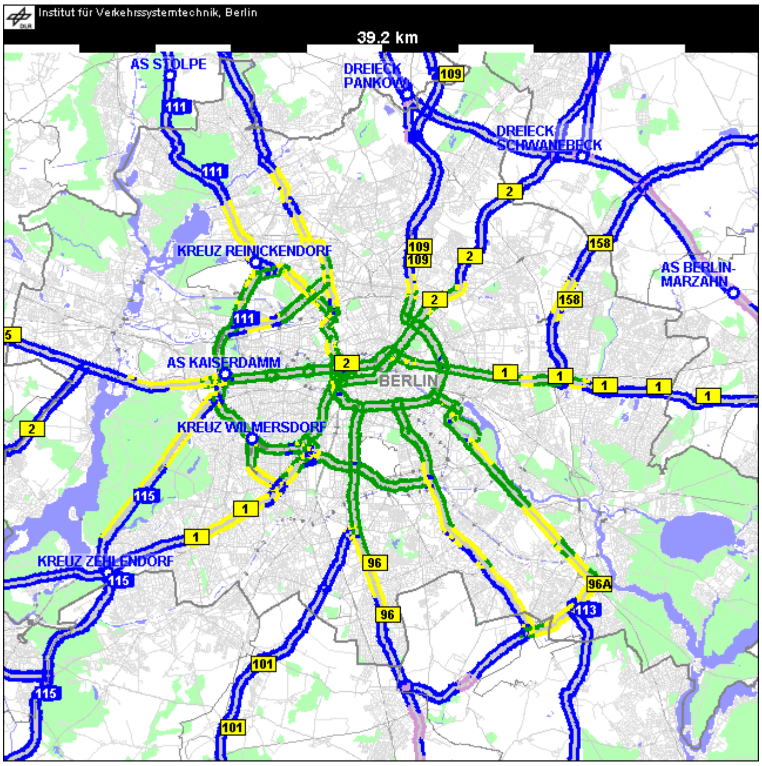

Figure 2 – GPS data density delivered by the taxi fleet on the main road network of Berlin (green: > 1 vehicle per 10 min, yellow: > 1 vehicle per 20 min, blue: <= 1 vehicle per 20 min)

The data set the results are calculated from are delivered by a taxi fleet in Berlin with about 4300 vehicles. Data from 16 weeks (08.01.2010 till 30.04.2010) were taken for the studies. Figure 2 shows the average data density on the main road network of Berlin over sample period of one month. It can be seen that the coverage is really good for most of the arterials connecting the city center to the outskirts with GPS data available more often than every 10 minutes. More to the outskirts the data base becomes a bit thinner with values more often than every 20 Minutes. Data on two arterials and two additional crossings were taken for the analyses. About 20 intersections on the main road network have been analysed of which the results for 5 crossings with a sufficient data basis, thus meaningful results and different number of inflow sections are presented in the following.

RESULTS

Crossing 1

Figure 3 – Map and sketch of road network with inflows from all directions

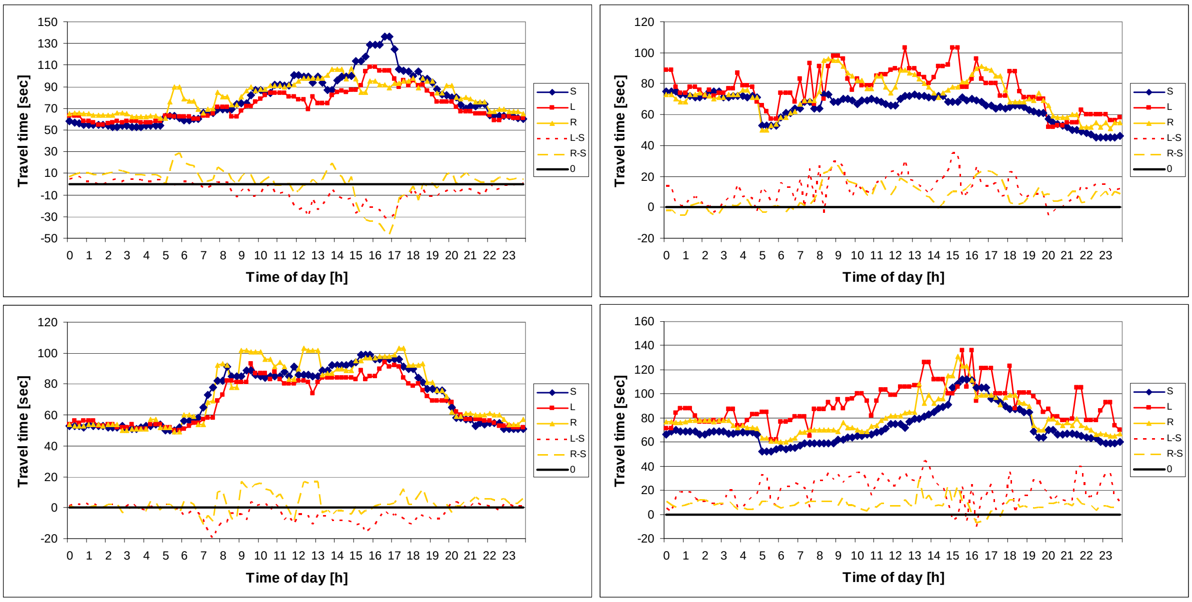

Figure 4 – Daily variation curves for driving straight on (S), left-turn (L), right-turn (R) and difference curves L-S and R-S (top-left: inflow from south-east, top-right: inflow from north-west, bottom-left: inflow from north-west, bottom-right: inflow from south-west)

For crossing 1 the inflows from all directions are analysed as shown in figure 3. Figure 4-top-left shows the decomposed travel time curves related to the inflow-section coming from south-east. Typical daily variation curves with peak hours in the afternoon can be seen for this direction, which is an arterial coming from the city center. For low traffic volumes left- as well as right-turners have up to 10 seconds additional travel time, but this changes with increasing traffic flow at the day resulting in lower travel times up to 25 seconds especially during the peak hours. This may be because of separate turning lanes for each direction and a generally high traffic volume on the straight direction. The opposite direction (bottom-left) has no differences in the night time, but from about 7 o'clock to 19 o'clock a relative constantly high traffic volume with varying advantages up to 15 seconds for the left-turners and disadvantages up to 18 seconds for the right turners. The curves for the direction from north-east (top-right) show relatively small fluctuations for direction straight on, but relatively heavy fluctuations for left- and right-turners with up to 30 seconds additionally. For direction from south-east the daily variation interestingly shows a similar picture as for direction from south-east even though this is not an arterial coming from the city center. The effects for the turners seem to be classical with a few seconds additionally for the right-turners and up to 40 seconds for the left-turners. But remarkably is here again that the additional travel times for the turners decrease to nearly no difference during the peak hours from about 15-18 o'clock. Additionally noticeable are transitions in the travel times especially for the straight directions in both Figures 4-right at 5 and 19 o'clock. An assumption is that this may be caused by the traffic signal plan which changes the phase program at this crossing substantially at these times, probably because of the tram lane which can be seen in figure 3-left driving on relation north-east <-> south-west.

Crossing 2

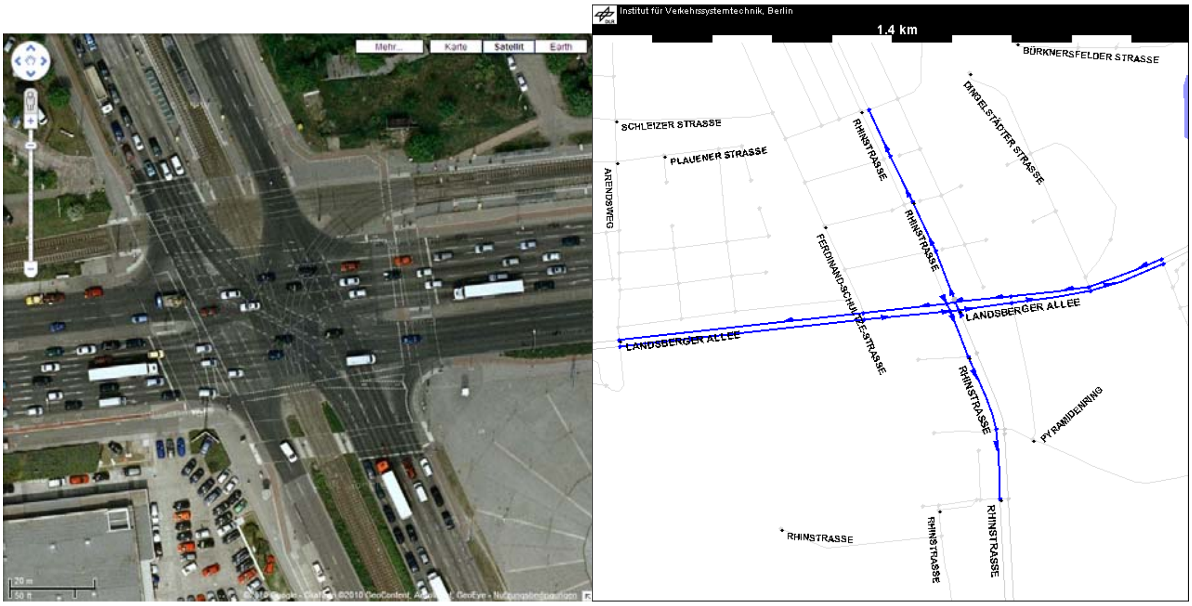

Figure 5 – Map and sketch of road network with inflows from east and west

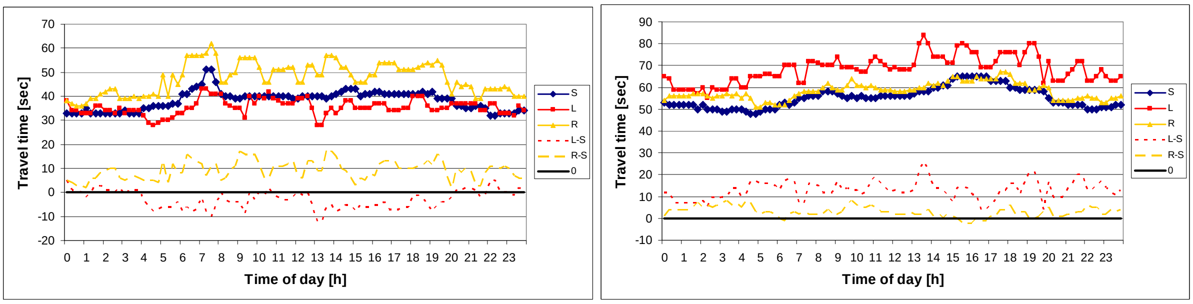

Figure 6 – Daily variation curves for driving straight on (S), left-turn (L), right-turn (R) and difference curves L-S and R-S (left: inflow from east, right: inflow from west)

For crossing 2 the inflows from all directions are analysed as shown in figure 5. Figure 6-left shows the decomposed travel time curves related to the inflow-section coming from east direction. It shows a small morning peak for all directions as it is an arterial towards the city center. Right-turners relative constantly have additional travel times of about 5-18 seconds, but left-turners often do not differ to the straight direction or even save travel times up to 11 seconds. For the inflow from west direction (away from city center) typical daily variations can be observed with some seconds additionally for right-turners and permanently significant additional seconds up to 24 for left-turners.

Crossing 3

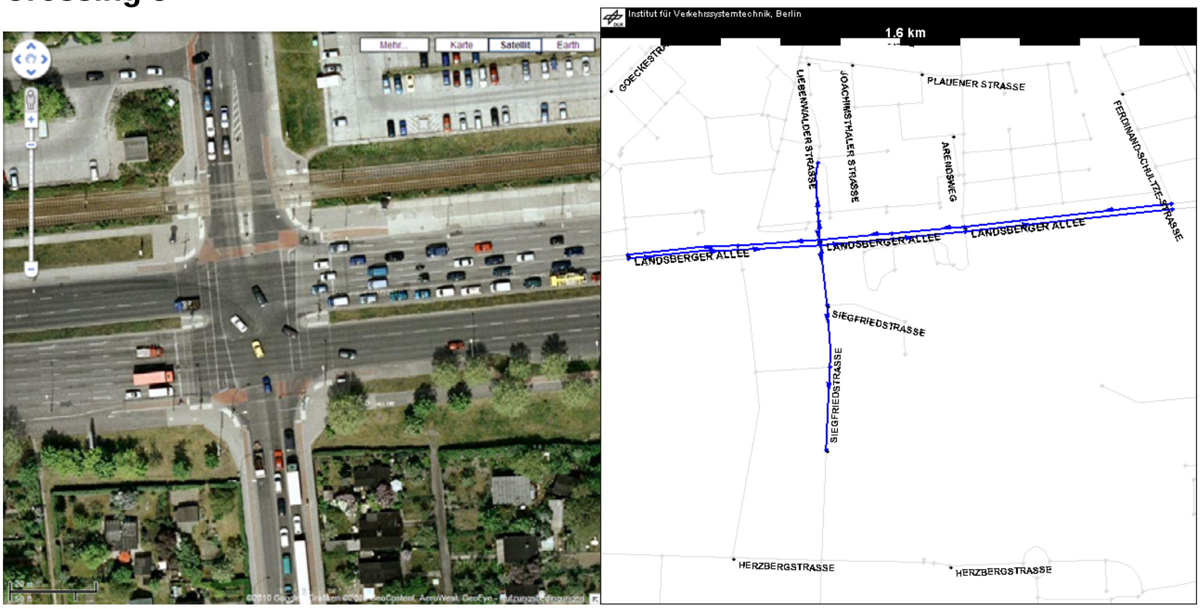

Figure 7 – Map and sketch of road network with inflows from east and west

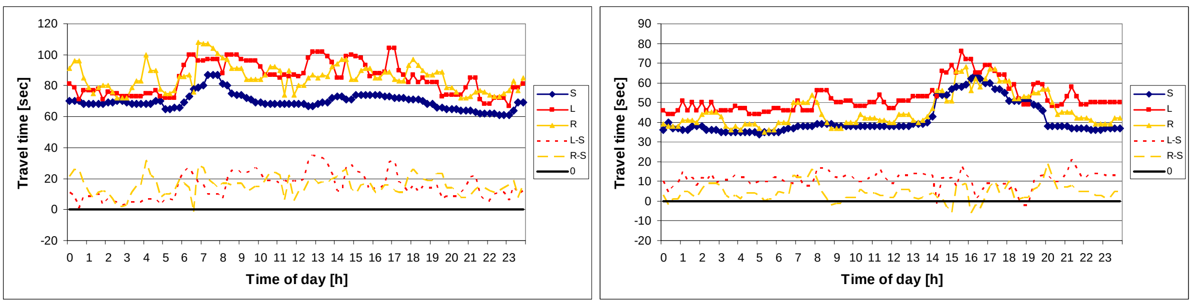

Figure 8 – Daily variation curves for driving straight on (S), left-turn (L), right-turn (R) and difference curves L-S and R-S (left: inflow from east, right: inflow from west)

For crossing 3 the inflows from east and west are analysed as shown in figure 7. Figure 8-left shows for the straight direction coming from the east a peak in the morning and a smooth peak in the afternoon. The left-turners as well as the right-turners need in average need about 20 – fluctuating from 0 to 38 – seconds additionally. The inflow from the west direction (Figure 8-right) shows a clear peak in the afternoon as it is the direction away from the city center. The right-turners take about 5 seconds additionally in comparison to the straight direction with fluctuating values. The left-turners I average have got about 9-10 seconds additional travel time.

Crossing 4

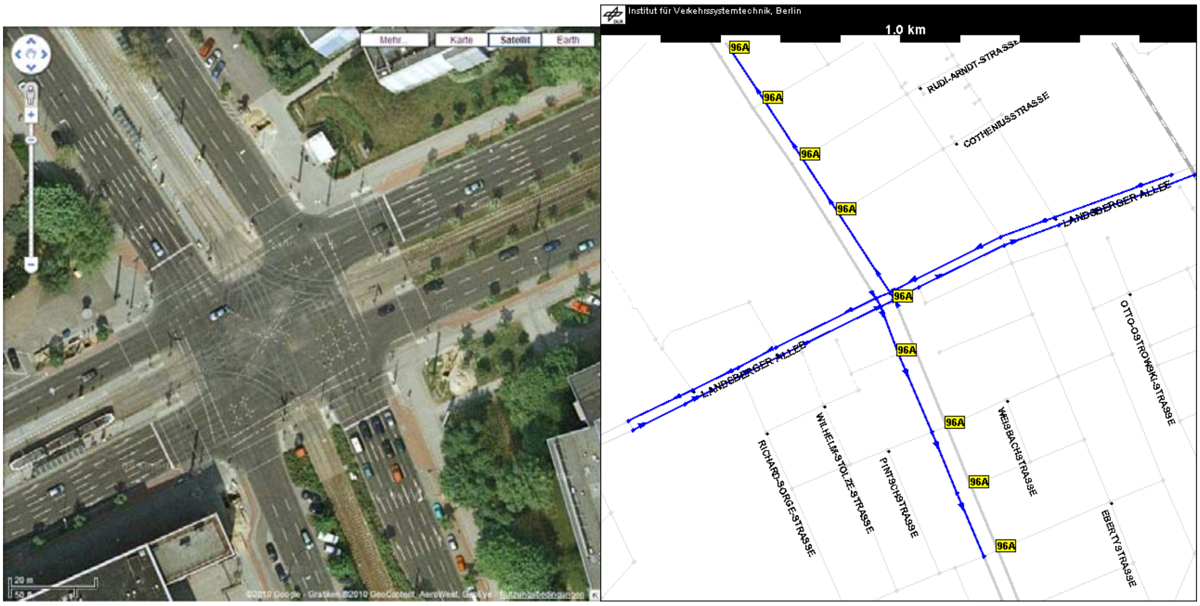

Figure 9 – Map and sketch of road network with inflows from north-east and south-west

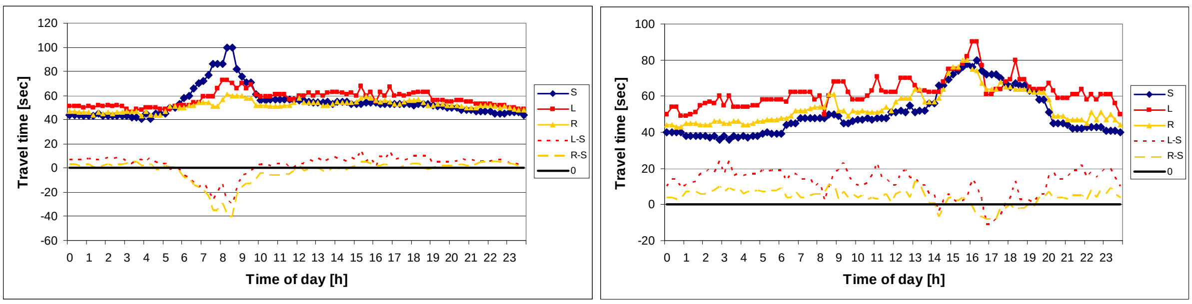

Figure 10 – Daily variation curves for driving straight on (S), left-turn (L), right-turn (R) and difference curves L-S and R-S (left: inflow from north-east, right: inflow from south-west)

For crossing 4 the inflows from north-east and south-west are analysed as shown in figure 9. Figure 10-left shows for the straight direction coming from the east a clear peak in the morning for the straight direction as it is the direction to the city center. In general the left- as well as the right-turners take some seconds additionally, but during the morning peak lower travel times up to 40 seconds are obtained. This might be because of the relatively high demand in straight direction and additionally because of existing long left- and right-turn lanes which let the turners easily flow downstream. For the inflow coming from the west direction (Figure 10-right) a clear wide afternoon peak is can be observed. In general the right-turners take about 8 seconds additionally and left-turners a bit more with 10 up to 20 additional seconds. As seen already for crossing 1 for two inflows, during the peak hours the curves decrease and turners may be quicker than vehicles driving straight on.

Crossing 5

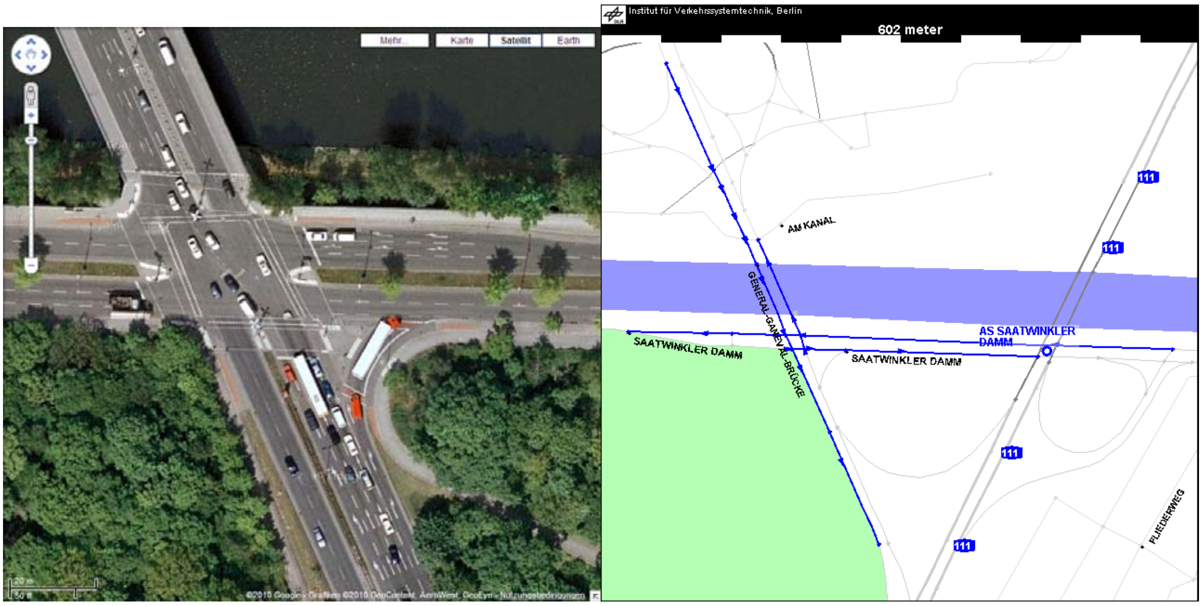

Figure 11 – Map and sketch of road network with inflows from north and east

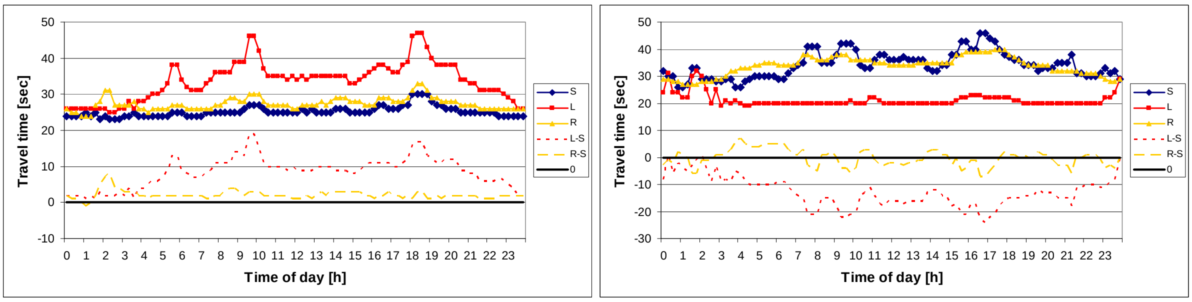

Figure 12 – Daily variation curves for driving straight on (S), left-turn (L), right-turn (R) and difference curves L-S and R-S (left: inflow from north, right: inflow from east)

For crossing 5 the inflows from north (long left turn lane) and east (long right turn lane) are analysed as shown in figure 11. In the north part of the map an airport is located which of course results in heavy taxi activity on these relations. Figure 12-left shows a relatively smooth daily variation curve for vehicles driving straight on. Right-turners take 1-5 seconds additionally over the whole day, but for left-turners a clear daily variation curve can be seen with few additional seconds in the night but additional travel times up to 20 seconds for the median values. The variation of the curve is defined by the activity at the airport where the vehicles come from.

Figure 12-right shows a more pronounced daily variation curve for vehicles driving straight on, to which the curve of the right-turners follows with fluctuations of about 8 seconds additional to about 8 seconds less travel time. Remarkably here is that the left-turners take a relatively constant travel time of 20 seconds for the inflow section, which results in lower travel times of 10 to 25 seconds in comparison to vehicles driving straight on. This may be

because of a relatively low traffic volume on the left-turn direction (which is not towards the airport) at this intersection with the effect that left-turn vehicles may halt not at all or only once at the traffic signal.

CONCLUSION AND FUTURE RESEARCH

The results show that the turning-dependent decomposition of the traffic information data will be usefull in many cases and should be performed probably for each big intersection. For routing purposes a simple assumption for additional travel times for left-/right-turners based on some assumption about the street types which meet at an intersection seem to be imprecise. The results for the distinction of different turning directions may be manifold. Furthermore the effects may be dependent on the daily variation of traffic flows and thus additionally on the traffic volume itself. Of importance may be traffic signal plans as well as number of pedestrians or bicycles turning vehicles have to wait for. Of course, the downstream congestion state as well as the oncoming traffic letting left-turners wait can have an important effect, too.
For further research in this field a structured analysis concerning the exact reasons for the effects which can be seen in the data has to be done. A further systematisation especially concerning intersection design (separate left-/right-turn turn lanes and their length as well as separate traffic signal phases) will be of big interest. Finally analyses separating the results for different weekdays are of importance.

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