Proceedings of the 14th International Conference "Reliability and Statistics in Transportation and Communication" (RelStat'14), 15-18 October 2014, Riga, Latvia, p. 25. ISBN 978-9984-818-70-2
Transport and Telecommunication Institute, Lomonosova 1, LV-1019, Riga, Latvia

THE IMPACT OF ACCESSIBILITY ON TRANSPORT INFRASTRUCTURE WITHIN COMMERCIAL SITE

Nadezhda Zenina [1], Yuri Merkuryev [2]

[1]Riga Technical university
Riga, Latvia, 1 Kalku Street
nadezda.zenina@inbox.lv

[2]Riga Technical university
Riga, Latvia, 1 Kalku Street
merkur@itl.rtu.lv

In the traffic impact studies (micro level) accessibility is affected by different activities within a commercial, office or residential land. Activities include pedestrian and bicycle conditions, transport infrastructure changes, network capacity, level of service within a site. The aim of this paper is to provide better understanding of how transportation infrastructure changes within the commercial site influence on car-based trip generation rates at micro level. Transportation changes include development of new connections to the site: signalized and unsignalized intersections with different allowed traffic movements. Three parameters: demand, supply and readiness were considered and analyzed.

Readiness (the number of traffic flows at the connections after changes in geometrical parameters) was determined by Synchro / Simtraffic 6.0 simulation tool with assumption that the level of service of the site connection should be better than D / E. Verification and validation of simulation model were performed. Demand for commercial site was calculated based on ITE trip generation rates (ITE, 2010) taking into account "smart growth" criteria for local conditions (Zenina and Borisovs, 2013). Supply including existing incoming and outcoming traffic flows for the commercial site was observed by the survey (Solvers, 2013).

Keywords: Accessibility, simulation, trip generation, traffic impact studies.

Introduction

Accessibility by Litman (2011) is defined as the ability to reach destination or activity and can include different transportation modes such as motorized and non-motorized.

Land use patterns have significant impacts on transportation and accessibility at the macroscopic, mesoscopic and microscopic scales. Development of big commercial centres around cities, tend to increase the travel time, distance and congestion in the area.

There are many ways how to improve accessibility connected to destination land use pattern (Abley, 2012), but mostly all of them are connected to possibility to reduce distance, travel time or costs between two points. Some of the ways include improvements in transportation, for example, changing traffic organization, reducing congestions, developing new roads and connections, in mobility, for example, improving public transport service, pedestrian and cycling routes or reducing distance between destinations.

Another way in evaluating accessibility lies in understanding of individuals' perceptions proximity to urban businesses and associated measurement issues (Krizek, Horning, El-Geneidy, 2012). The results of research have showed that in areas where landscape is very complex with a lot of elements and without smooth way to destination, individuals will perceive distances as longer.

In the study by Geurs and Wee (2004) four ways of how to identify accessibility measures were considered: infrastructure-based, location-based, person-based and utility-based measures. All these measures are interrelated and are focused on how to reduce travel time or distance travelled by motorized and non-motorized modes and improve walking, cycling and public transport facilities.

In this study accessibility is considered with the aim to get better understanding of how transportation infrastructure changes within the commercial site influence on car-based trip generation rates at micro level. Two main things were evaluated: 1) how to measure accessibility for motorized modes on condition that existing access to the commercial site will be redeveloped. Four variants of access organization to the commercial site were analysed: unsignalized access, signalized access with and without allowed left turns and development of new access. 2) how to change the incoming traffic flows to the commercial site after improvements in existing accesses?.

Accessibility evaluation

Reducing travel time or distance to the destination improves accessibility. From this point of view does it mean that, for example, if travel time or distance to commercial site will reduce, the number of incoming traffic flow will increase? And how to change incoming flows if new transport accesses will be developed? To check this hypothesis the accessibility was considered as a function of three parameters (1): demand, supply and readiness.

$$\text{Accessibility} = f(D, S, R) \quad (1)$$

where accessibility – relative measure, that describes an increasing or reducing number of incoming traffic flows to commercial centre based on transport demand, supply and readiness.

D (demand) – the number of incoming traffic flow calculated by rate method based on ITE trip generation model and additionally evaluated with "smart growth" tools to increase the accuracy of generated trip calculations with mixed-land use and transport infrastructure availability (public transport, pedestrians).

S (supply) – the number of incoming traffic flow observed by survey.

R (readiness) – the number of incoming traffic flows that come to the commercial site based on traffic organization scheme, road capacity, signal timing, pedestrian and bicycling flow at intersection and level of service.

The next chapters describe in details how each of parameters were calculated and evaluated.

1.1. Incoming traffic flow demand and supply to the commercial site

Number of incoming traffic flow demand depends on purpose of trip destination, land use pattern, social – demographic factors and personal behaviour.

Incoming traffic flow demand for commercial site was calculated based on ITE trip generation rates (ITE, 2010) taking into account "smart growth" criteria for local conditions (Zenina and Borisovs, 2013).

ITE trip generation rates method based on linear regression equations (2) and is one of the most frequently used for traffic impact studies (at micro scale). The number of generated trips (incoming and outcoming traffic flows) is expressed as the number of trips per unit X, where X – describes the activity of land use, the gross leasable area is used for commercial site.

$$Y = a + b_1 x_1 + b_2 x_2 + \ldots + b_n x_n \quad (2)$$

where Y – the dependent variable (trips/household).

x_1, x_2 .. – independent variables (population, number of apartments, gross leasable area).

b_1, b_2..b_n – regression coefficients that show to what extent Y changes, if xn variable increases.

All ITE rates are based on historical data that are provided for isolated areas and does not take into account public transport services and pedestrian routes availability. To correct number of incoming traffic flows to commercial site, additional corrections by Urbemis (urban emissions) program (2005) were evaluated for local conditions. Corrections took into account information about public transport, pedestrian activity and available number of parking places around and within the commercial site.

The ITE linear regression equation used in this study for evening Saturday peak hour is showed in (3) for the commercial site.

$$Y = e^{0.65 * LN(10.76X) + 3.78} \quad (3)$$

where Y – number of incoming and outcoming traffic flow.

X – gross leasable area of the commercial site.

Incoming traffic flow supply including existing incoming and outcoming traffic flows for the commercial site was observed by the survey (Solvers, 2012). Survey was conducted on regular Saturday basis (in this day there were not any events or city holydays) in the time period from 15:00 till 20:00. Respondents were drivers coming to the commercial site parking and the main questions included the time spent in car to get to the site, number of person in the car, name of origin and destination point and name of road direction from/where respondents are coming. All received data firstly were pre-processed, noisy and unrealistic data were cleaned. Secondly data were processed with the aim to distribute the number of incoming traffic flow to the commercial site by city's directions and to understand how many vehicles come to the site by the each street road.

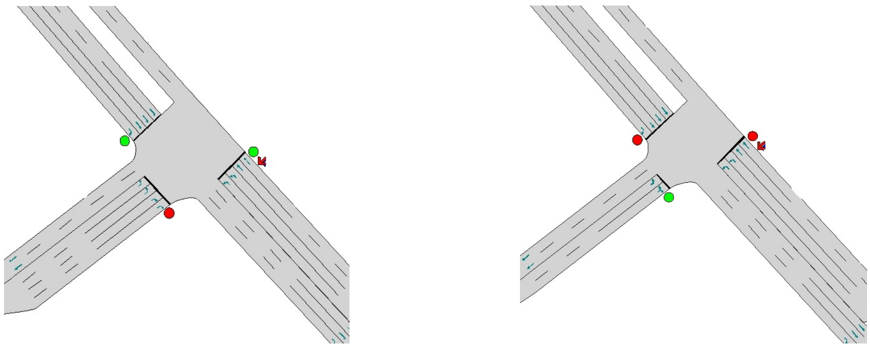
1.2. Incoming traffic flow readiness to the commercial site

The readiness was used as third parameter of accessibility evaluation. These parameters were introduced to evaluate the number of incoming traffic flows to the commercial site that depend on traffic scheme organization. It means that for signalized intersection with only one incoming lane to the site, 80 seconds cycle of signal timing at access, volume to capacity more than one at this access and demand of 2 000 vehicles per hour, the maximum supply will be in the range of 700 – 900 vehicles per hour based on road type. And readiness will be at level of 400 – 600 vehicles per hour taking into account signal timing, congestion and level of service within a site. To improve the readiness or to increase the number of incoming traffic flow to the commercial site it will be necessary to improve conditions of transport organization around the site and site access.

Readiness or the number of traffic flows at the accesses before and after changes in traffic organization scheme was determined by the following steps:

Five variants of traffic scheme organization for the transport access to the commercial site were considered. Variants were developed based on business requires.

Variants included unsignalized access, signalized access with allowed left turns and two outcoming lanes, signalized access with allowed left turns and four outcoming lanes, signalized access with allowed left turns and two outcoming lanes plus development of new access, and unsignalized access and development of new access. Variants with signalized access with allowed left turns and two or four outcoming lanes are showed in Figure 1.



a) signalized access with allowed left turns and 4-out lanes b) signalized access with allowed left turns and 2-out lanes

Figure 1. Examples of traffic scheme organization for the transport access to the commercial site

Simulation model for each variant was developed based on collected data from survey. Percent of public transport and truck volumes was 9% from total traffic flows at network based on survey data. Synchro/Simtraffic 6.0 simulation tool was used for this purpose.

Simtraffic simulation tool was designed as modelling and optimisation software for traffic flow and signal timing. It is a microscopic simulation tool that uses the outputs of the Synchro (macroscopic level) to model street networks (modelling travel through signalised and unsignalised intersections and arterial networks, as well as freeway sections, with cars, trucks, pedestrians and buses). Most of the inputs are entered through the Synchro program, but some parameters, such as driver and vehicle characteristics are modified through SimTraffic specifically (Zenina, Merkuryev, 2009).

Verification and validation of simulation model were done.

The level of service of the site access was calculated based on HCM 2010 methodology. It was assumed that level of service at site access should be better than D / E (traffic volumes are near the capacity of roads, drivers have little freedom to manoeuvres and in some cases for short time periods, traffic flow is unstable).

For the existing situation (without traffic scheme changes in transport accesses) it was assumed that readiness is equal to incoming traffic flow supply.

Verification and validation of simulation model and method for level of service calculation are described later in this section.

Verification and validation of simulation model

Verification and validation of simulation model were carried out by calculating number of multiple runs of the simulation model, calculation the root mean square and compares the incoming traffic flow to the commercial centre from simulation model with observed volumes from transport data survey. The verification process of simulation model is shown in Figure 2.

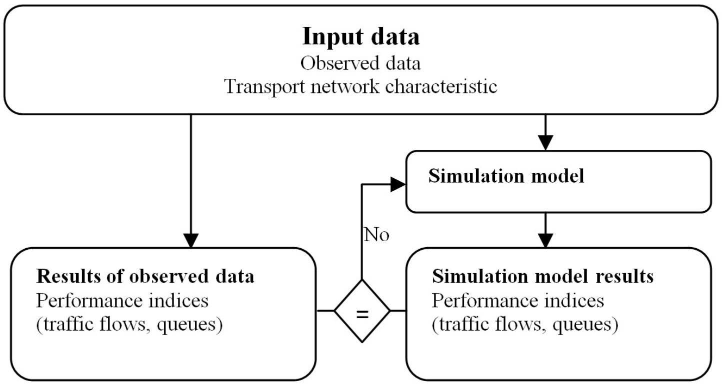


Figure 2. Verification process of simulation model

Number of simulation model runs is one of the steps to receive acceptable simulation results. Run is the performance of singleness simulation model program, in which model time monotonically increases. Because of variation of simulation model results multiple run can provide more accurate calculations of performance indices. Accuracy depends on multiple runs number of model. To reach the β accuracy at the reliability level α, it is necessary to perform n runs of the simulation model and calculate confidence interval, average values and variance (3).

$$\overline{X}(n) \pm t_{n-1,1-\alpha/2}\sqrt{\frac{S^2(n)}{n}} \tag{3}$$

where $\overline{X}(n)$ - average value of n observation.

$t_{n-1,1-\alpha/2}$ - the critical value of t-distribution. (for n=10, α =0.05, t=1.833).

$S^2(n)$ – the deviation between simulation results and initial values of the parameter.

In the next step root mean error (4) was calculated to measure distance between observes incoming traffic lows and evaluated from simulation models.

$$RMS_i = \sqrt{\frac{1}{n}\sum_{j=1}^{n}(w_{ij} - v_{ij})^2} \tag{4}$$

The plot of the incoming traffic flow to the commercial site for estimated and real traffic flows is shown in Figure 3. Comparison of estimated incoming traffic flows and surveys has shown acceptable results, the root mean square was 14% for existing traffic organization variant with unsignalized transport access. The number of multiple runs was chosen 10 that match up 95% confidence interval.

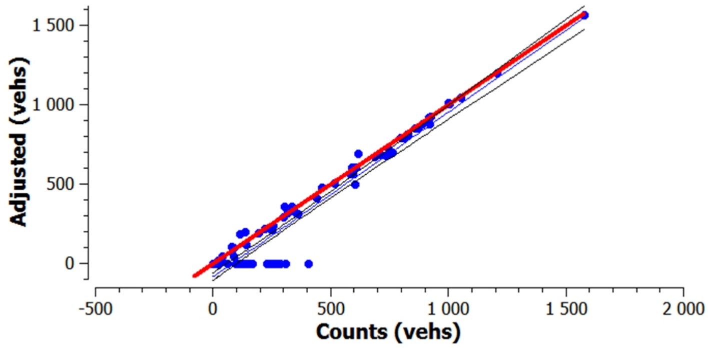


Figure 3. Results of simulation model verification

Level of service calculation and evaluation

Evaluation and comparison of different traffic organization variants were performed based on average control delay calculation according to Highway capacity manual 2010 for analyzed time period. Average control delay is expressed in seconds and includes time spent on acceleration and deceleration at signalized intersection.

$$d = d_1 \cdot pf + d_2 + d_3 \tag{5}$$

where d – control delay per vehicle expressed in seconds (seconds/veh).

d_1 – uniform delay (seconds/veh).

d_2 – incremental delay (seconds/veh).

d_3 – initial queue delay (seconds/veh).

pf – progression adjustment factor, that affects uniform delay (*d1*) and shows the correlation between vehicles arriving during green time and effective green-time ratio.

Uniform delay estimates the time that driver has spent to come to the intersection taking into account presence or lack of vehicle queue.

$$d_1 = \frac{0.5C\left(1 - \frac{g}{C}\right)^2}{1 - \left[\min(1, X)\frac{g}{C}\right]} \tag{6}$$

where C – the length of the cycle (seconds).

g – effective green time for lane group (seconds).

X – volume to capacity (v/c) ratio for the lane group.

Incremental delay (7) evaluates the incremental delay due to nonuniform traffic arrivals to the intersection.

$$d_2 = 900T\left[(X-1) + \sqrt{(X-1)^2 + \frac{8klX}{cT}}\right] \tag{7}$$

where T – duration of analysis period expressed in hours.

k – incremental delay adjustment for the actuated control (κ=0.5 according to HCM 2010);

c – capacity of lane group (veh/h).

Average control delay was calculated for all five traffic organization variants providing that Level of service at intersections was D – E. It means that for variants with signalized access control delay should be in range of 35 – 80 seconds per vehicle and for variant with unsignalized intersection control delay time should be 25 – 50 seconds per vehicle. The level of service and control delay is shown in Table 2.

Table 2. Average control delay and level of service

Level of service		Delay (sec./vehicle)	
		Signalized intersection	Unsignalized intersection
A	Minimal delay	<= 10	<= 10
B		> 10 – 20	> 10 – 15
C		> 20 – 35	> 15 – 25
D	Acceptable delay	> 35 – 55	> 25 – 35
E		> 55 – 80	> 35 – 50
F	Demand exceeds capacity	> 80	> 50

Evaluation of accessibility indices

The incoming traffic flow demand, supply and readiness were calculated and evaluated according to the methods that were described above. The demand was calculated according to the ITE trip generation equations with correction to local conditions. Supply was observed from survey data. And readiness of the incoming traffic flow to the commercial site was evaluated from simulation model with assumption that level of service of considered traffic organization variants will be D – E.

The result of interrelation between transport infrastructure development and the incoming traffic flow to the commercial site is presented in Figure 4.

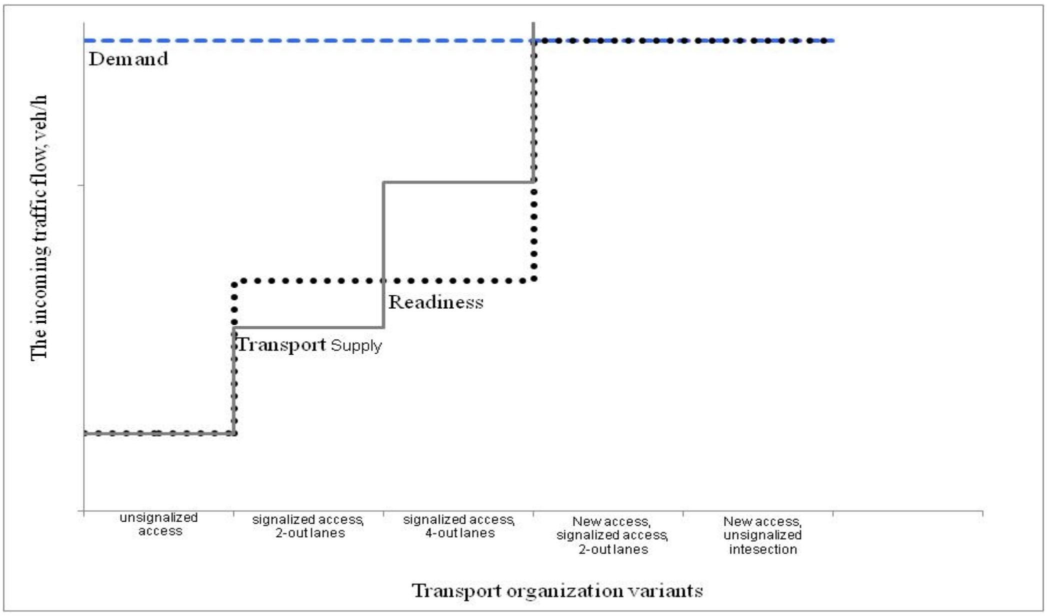


Figure 4. The incoming traffic flow and analysed transport organization variants

The demand of the incoming traffic flow to the commercial site is as an upper boundary, means that regardless of transport infrastructure around commercial site, different management measures, location of the site and its attraction, the number of incoming traffic flow could not exceed this level.

The transport supply for the existing situation with unsignalized access was observed from survey, for others transport organization variants that are not developed in the present, supply was evaluated according to “ideal” origin – destination pairs pattern (Solvers, 2013). Two patterns were used, one for pass-by trips and other for primary trips (Table 3).

Table 3. Origin destination pairs “ideal” pattern

Day of the week	OD pair for pass-by trips	OD pair for primary trips
Friday	7.8%	5.3%
Saturday	4.8%	10%

OD pair for pass-by trips– ratio of pass-by trips (without primary trips) to the background flow.

OD pair for primary trips – ratio of primary trips (without pass-by trips) to the background flow.

The results of supply calculation have shown that improving the traffic organization at the access, the number of incoming traffic flow will grow, but completely to reach demand is possible only with developing new access to the commercial site. It is important to mention that supply is the number of traffic flow that will come to the site in condition that around the site any congestion will not occur and road capacity will be acceptable in the distance of 800 – 1000m from the site.

And the readiness is the indices that show how much traffic will come to the commercial site according to the traffic organization variants at the access and taking into account the transportation situation around the site in the distance of 800 – 1000m.

From the Figure 4 it can been seen that in variant with signalized access and two outcoming lanes to the commercial site, the readiness is bigger then supply, which means that drivers would be ready to go to commercial site, but transport infrastructure is unacceptable for them. The situation can be improved with extension of two out coming lanes to four, but still it is impossible to reach the demand at this level. To reach the demand it is necessary to develop new access to the commercial site.

Conclusions

The accessibility expressed as the interrelation between transport infrastructure development and the incoming traffic flow to the commercial site was considered and transportation infrastructure changes within the commercial site influence on car-based trip generation rates at micro level was evaluated.

Three accessibility indices were analysed: demand, supply and readiness.

Results of this analysis can be used in traffic impact analysis, when it is necessary to determine if there is any possibility in the enlargement of square meters for the commercial sites and if it is possible to reach demand with existing traffic organization or maybe it is necessary to improve traffic organization at accesses before expanding commercial site.

The limitation of the research is due to the fact that pedestrian, bicycles and public transport flows were considered at intersections for level of service calculation. Future analysis and research should include the analysis of “ideal” origin and destination pattern.

Acknowledgements

This study was partially supported by Solvers Sia by providing transportation survey data for analysis.

References

1. Ort´uzar, J. D. and Willumsen, L. G. (2011) *Modelling Transport*, Fourth Edition. New York: John Wiley & Sons Inc. 606 p.
2. Geurs, K.T. and Wee, B. (2004) Accessibility evaluation of land-use and transport strategies: review and research directions. Transport Geography, 12, 127–140. doi:10.1016/j.jtrangeo.2003.10.005
3. Zenina, N. and Borisovs, A. (2013) Regression Analysis for Transport Trip Generation Evaluation. Information Technology and Management Science. Vol.16, 89-94. DOI:10.2478/itms-2013-0014.
4. Zenina, N. and Merkuryev, J. (2009) Analysis of Simulation input and output to compare simulation tools. *Mechanics Transport Communication*. Issue 3. pp V-4-V-10. ISSN 1312-3823
5. Victoria Transport Policy Institute. (2011) Measuring Transportation Traffic, Mobility and Accessibility. Todd Alexander Litman.
6. The Institute of Transportation Engineers. (2004) Trip Generation Handbook, 2nd ed. An ITE Recommended Practice, 2004.
7. Nelson\Nygaard Consulting Associates (2005) Adjusting Site-Level Vehicle Trip Generation Using URBEMIS. San Francisco. USA. (Tech. Rep. CA 94103).
8. Zenina, N. and Lopatenoks, V. (2013) Site access planning and on-site circulation. Riga: Solvers SIA (NO. TIA-KIPETRIVKA01).