Scientific Journal of Silesian University of Technology. Series Transport
Zeszyty Naukowe Politechniki Śląskiej. Seria Transport

Volume 92 **2016**

p-ISSN: 0209-3324

e-ISSN: 2450-1549

DOI: 10.20858/sjsutst.2016.92.4

Journal homepage: http://sjsutst.polsl.pl

Article citation information:
Dźwigoń, W. Analysis of transition times of pedestrians and passengers in an interchange node. *Scientific Journal of Silesian University of Technology. Series Transport*. 2016, **92**, 31-40. ISSN: 0209-3324. DOI: 10.20858/sjsutst.2016.92.4.

Wiesław DŹWIGOŃ[1]

ANALYSIS OF TRANSITION TIMES OF PEDESTRIANS AND PASSENGERS IN AN INTERCHANGE NODE

Summary. Accurate design of infrastructure for public transport is the basis for the efficient functioning of traffic and passenger transportation. The article presents an analysis of the availability of public transport stops. The measure of the availability relates to access times to certain stops from other stops and the surroundings of the transport hub. The article discusses the scope and the objective of measuring pedestrian and passenger traffic. It also presents an analysis of transition times for the passengers who change their means of transport and need to reach a stop. The provided measurements were carried out on a two-level interchange tram-bus hub. Thus they should be part of any assessment of the quality of passenger service in the hub.
Keywords: public transport; interchange node; transit time.

1. INTRODUCTION

Change is an important component of the journey undertaken by means of public transport. Some of the changes are performed in specially designed interchange nodes [1, 5]. They can have a considerable degree of complexity in terms of their infrastructure. Additionally, stops located at the interchange nodes offer services to passengers from the surrounding areas who wish to use public transport vehicles [4].

[1] Faculty of Civil Engineering, Cracow University of Technology, Warszawska 24 Street, 31-155 Cracow, Poland. E-mail: wdzwigon@pk.edu.pl.

There are a few methods that focus on the evaluation of interchange nodes [3, 6]. However, most often, a change is one of the components of a qualitative assessment of passenger service, be it a partial or a synthetic evaluation [7, 8]. The partial criteria present in such an assessment include:

- the time lost when changing the means of transport (transition between stops, waiting for the vehicle to arrive)
- the distance between stops
- the conditions when accessing stops (possibility of collision, ease of orientation, traffic lights, height differences, density of pedestrian traffic)
- the conditions when waiting at the bus stop (shelter, attractive surroundings, density of pedestrian traffic).

The paper focuses on the analysis of the transit times between stops localized at the interchange node. Measurements included the entire area of the interchange node, which also allowed for capturing the connections between the node and the surroundings, but only in the area of the interchange node. The results ought to be used to evaluate solutions that are formulated from the point of view of the passenger and pedestrian traffic.

2. CONDUCTING MEASUREMENTS

The aim of the measurements was to assess the usefulness of the method being used, as well as obtain data for the partial assessment of the functioning of the interchange. In this case, the transition time is a component of a fractional assessment.

For the analysis, a characteristic traffic hub was selected, namely, the Mogilskie roundabout in Kraków. It is situated on the border of the city's downtown area. Cross-town and tangential bus and tram lines run through it. It is also part of the second ring road, which generates intense traffic for the majority of connection types. The most important idea accompanying the reconstruction was to separate vehicle traffic from pedestrian traffic and public transport vehicles. The aim in doing so was to increase the efficiency of public transport and the improvement of safety. Finally, the completion of a two-level road junction was executed with the following specifications:

- there is traffic comprising cars and buses on the ground level (level 0)
- there is traffic comprising trams, pedestrians and cyclists on the lower level (level -1)

Figure 1 shows a diagram of this node. Five streets feed into the intersection (including four dual carriageways), while there is a bus stop at each exit from the roundabout. On the lower level, there are tram tracks, three of which lead to the street of the upper level and one to a tunnel. All pedestrian and bicycle traffic is performed on the lower level. This implies the need to overcome differences in height between the trams and bus stops, as well as between tram stops and the surroundings of the node (using ordinary stairs, escalators [2], ramps or lifts). Meanwhile, pedestrians passing among the surrounding buildings and passing through the node must be twice the difference in height between the levels. On the lower level next to the tram stops, there are three pedestrian crossings with traffic lights. Most pedestrians and interchange users have to use them, which could extend the transition times and times for any interchange. In addition, the trams passing through the lower level lose time due to waiting on these traffic lights. Bicycle traffic on the lower level generates a problem of having to make up the differences in terms of twice the height. The lack of collisions with car traffic is an advantage of this solution.

The lower node level is not symmetrical; it is far from the tram stops to the others stops and those buildings that are located on the northern side of the node. On the other hand, it is close to the southern direction. Many office buildings surrounding the node generate significant pedestrian traffic, which is directed to the stops. Additionally, they produce large flows of passengers who switch their means of transport when selecting connection options. Summing up, on the lower level, a surface with a large degree of pedestrian and cycling traffic was created, where everyone enters from different directions.

The specific objectives of measurement include:

- determining transition times in different types of connections in the node (among stops and between the stops and the surroundings)
- determining time losses for these types of connections
- determining the reasons for time losses (reasons for stoppages)

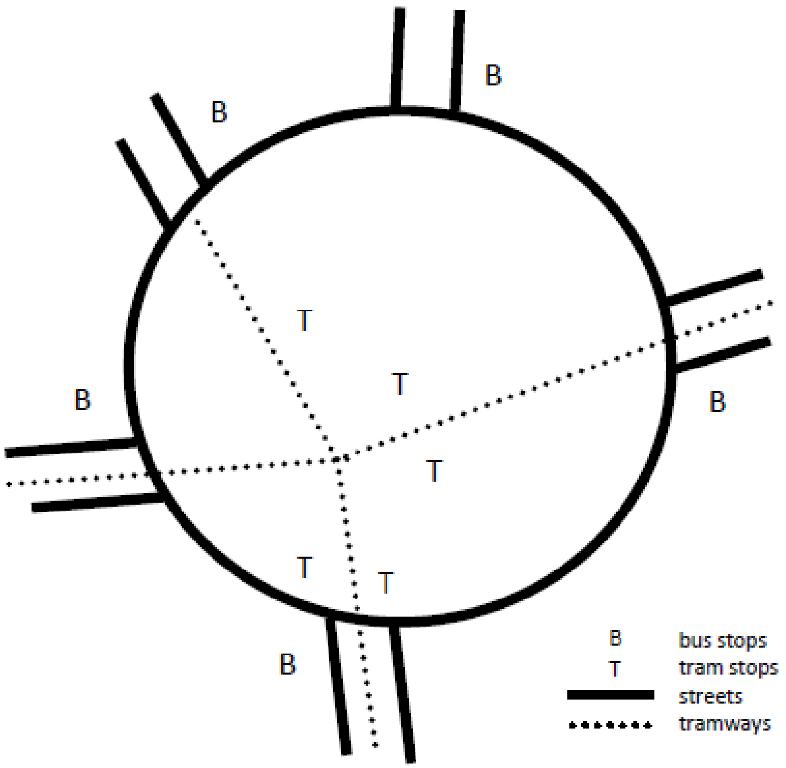

Fig. 1. Diagram of the analysed transport node

The survey was performed using a method of tracking a pedestrian or a transport passenger who appeared at the interchange node, came from the surrounding area or got off at a bus stop. The person taking the measurements recorded a variety of pedestrian behaviours. After one pedestrian left the node, the person taking the measurements randomly chose another person whose behaviour was to be measured. This kind of measurement method means that large flows of passengers (or pedestrians) can be measured many times, resulting in a large sample being obtained. Conversely, where small flows are involved, the sample will be small and unreliable. The analysis only included the area of the node (up to its borders) and was not related to any further connections between the node and its surroundings.

In the process of taking measurements, the following types of information were recorded:

- the places where a pedestrian appeared and left the node (stops of quarters building)
- the transition time between these points
- the places and reasons for stoppages (traffic lights, traffic conflict, small purchases, other)
- the time of stoppages
- the ways to overcome differences in height (ordinary stairs, escalators, ramps, elevator)

Finally, the actions of 531 individuals were measured and the structure of the measured dependencies is as follows:

- the movement of passengers between stops = 59%
- the movement of passengers between stops and the surroundings of the interchange node = 32%
- pedestrian traffic passing through the node = 9%

3. ANALYSIS OF THE RESULTS

The analysis firstly clustered the types of connections into several groups (for example, stop-stop or stop-surroundings), followed by types of connections between the individual stops. Those types of connections when only several measurements were obtained were skipped (between bus stops and from bus stops to the surroundings of the node). Figure 2 summarizes the average transition times. It is noteworthy that the shortest time between tram stops is 82 s. This is related to their location being on the lower level of the node and the short distance between them. All other types of connections clearly have longer transition times. This is related to three factors:

- the greater distance to a crossing
- the difference in height between the levels
- the necessity to go through pedestrian crossings, where some people lose time when waiting on traffic lights

The types of connections involving "tram stop-surroundings" require half the diameter of a node to be made, as well as the same difference in height, while the types of connections involving "bus-bus" and "surroundings-surroundings" require a full diameter of the node and twice the height difference. Table 1 lists more statistical parameters describing the analysed transition times: sample size, average, standard deviation, variation coefficient, and percentiles p_5 and p_{95}. Generally, transition times are characterized by high volatility. The variation coefficient ranges from 0.39 to 0.59 for different groups of connection types. This is connected with different distances between the stops within one group. What is also significant is the presence of traffic lights at pedestrian crossings. For example, in the types of connections between different tram stops, there are zero, one or two pedestrian crossings. This means that a passenger, while changing the means of transport, may lose between 0 and 80 s due to traffic lights, with an average walking time equal to 82 s. The consequence of this is high volatility in the transition time. In addition, the speed of passengers along the access passages to the stops is very volatile. When a passenger sees a tram at the stop, they speed up in order to catch the tram. Conversely, when seeing a stop with no vehicle, a passenger slows down, because there is no reason to hurry.

Tests of significance for two averages, carried out at a confidence level of 0.95, showed that:

- transition times in "tram stop-bus stop" and in the opposite direction do not differ significantly; while
- transition times in "tram stop-surroundings" and in the opposite direction do not differ either.

Therefore, they will be grouped in the subsequent analysis. For types of connections grouped in this way, the transition times were estimated. Table 2 summarizes the limits of confidence intervals.

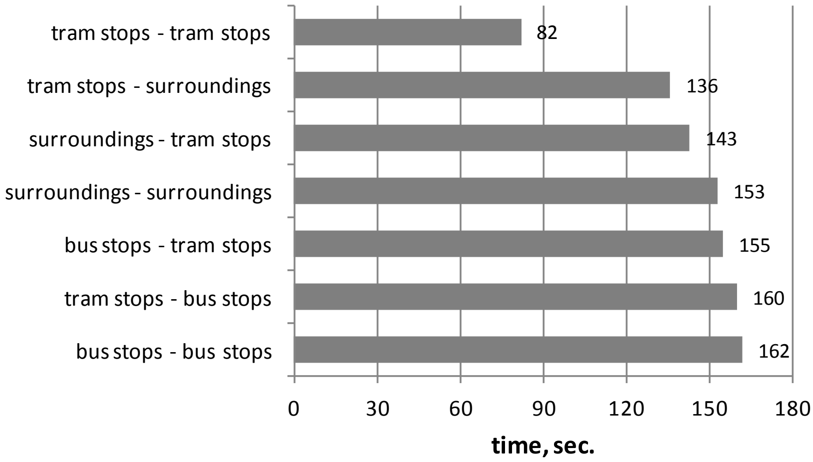

Fig. 2. Average transition times through the node for different groups (in s)

Table 1. Characteristics of transition times for different types of connection groups

Connection	Count	Average	Standard deviation	Variation coefficient	Percentile p_5	Percentile p_{95}
Tram stops-bus stops	36	160	68	0.42	77	263
Bus stops-tram stops	40	155	60	0.39	67	268
Bus stops-bus stops	12	162	69	0.43	90	275
Tram stops-tram stops	224	82	40	0.49	30	155
Tram stops-surroundings	104	136	61	0.45	54	273
Surroundings-tram stops	61	143	84	0.59	37	292
Surroundings-surroundings	45	153	66	0.43	66	254

The error in estimating the transition time for various types of connections is as follows:

- for the passage of pedestrians through a node = 12.5%
- between tram stops and the surroundings = 7.9%
- between tram stops and bus stops = 8.5%
- between tram stops = 6.4%
- between all the stops = 6.1%

Clearly, the error estimate decreases with an increase of the size of the measured sample.

Table 2. Characteristics of confidence intervals for different types of connections groups

Connection	Count	Lower limit	Average	Upper limit
Surroundings-surroundings	45	134	153	172
Tram stops-surroundings	163	126	137	148
Tram stops-bus stops	76	140	153	166
Tram stops-tram stops	224	77	82	87
All stops	312	96	102	108

The graphs in Figures 3, 4 and 5 show the distribution of transition times for various types of connections.

Clearly, the graph for the transition times between the tram and bus stops is most concentrated (the graph in Figure 3 is almost symmetrical), with the coefficient of variation only being 0.38. In two other cases, it amounts to 0.49 and 0.51. In Figures 4 and 5, approximately 10% of the measurements represent elongated transition times, which is mainly caused by the crossings with traffic lights.

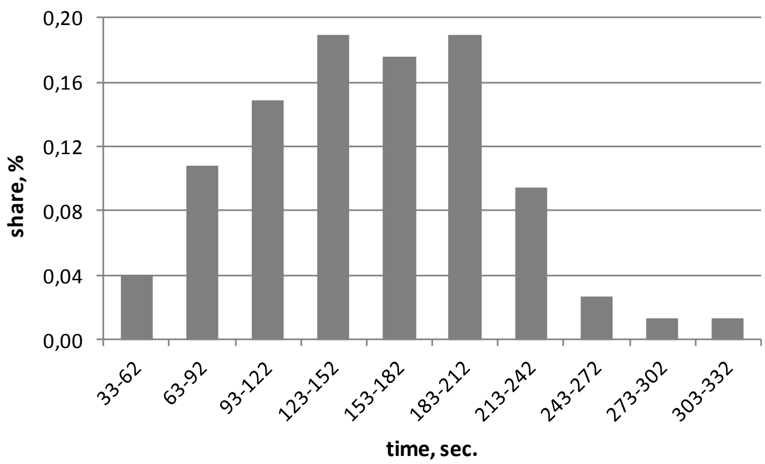

Fig. 3. Transition time between tram and bus stops

The graph in Figure 6 shows the time distribution functions of passage. The average transition time for changes between the closest situated tram stops is 82 s. Contemplating changes between tram-bus and bus-bus elongates the average transition time by up to 102 s. Distances to bus stops are bigger and there is a need to overcome the differences in height, which increases the transition times. Transition times are elongated by approximately 13%, starting from the p_{80} percentile.

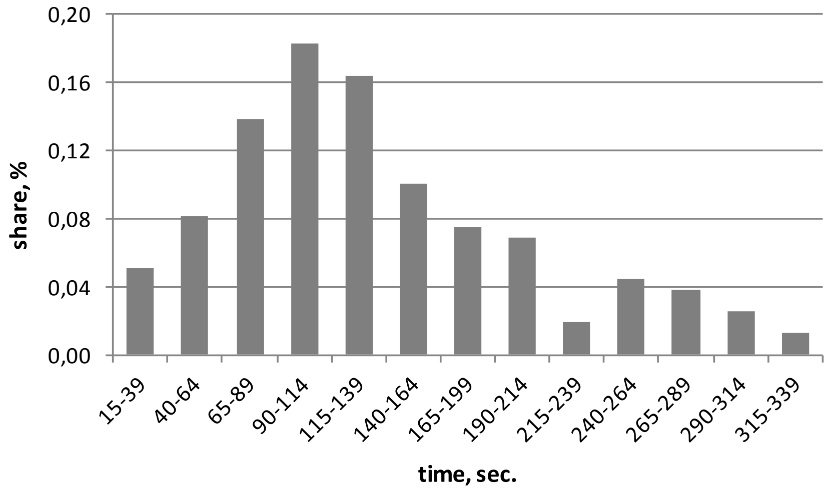

Fig. 4. Transition time between tram and bus stops

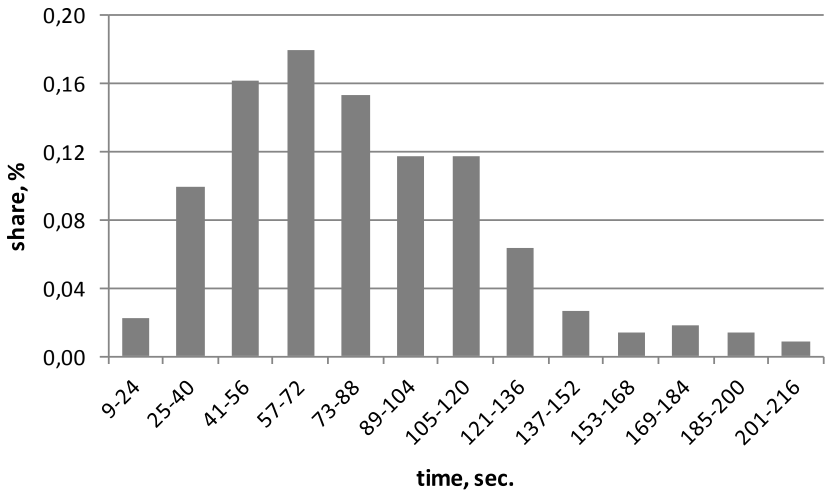

Fig. 5. Transition time between tram and bus stops

The final stage of the analysis is to determine the effect of the stoppages in relation to transition times. The structure of the measured passages is as follows:

- passages without detentions = 63.9%
- passages with one detention = 32.8%
- passages with two detentions = 4.3%

The average passage without detention lasts 103 s, although one detention extends it to 142 s and two detentions extends it by up to 244 s (which is more than 100% more). Table 3 summarizes the transition times for each types of connections (a very small sample size with less than seven measurements was omitted).

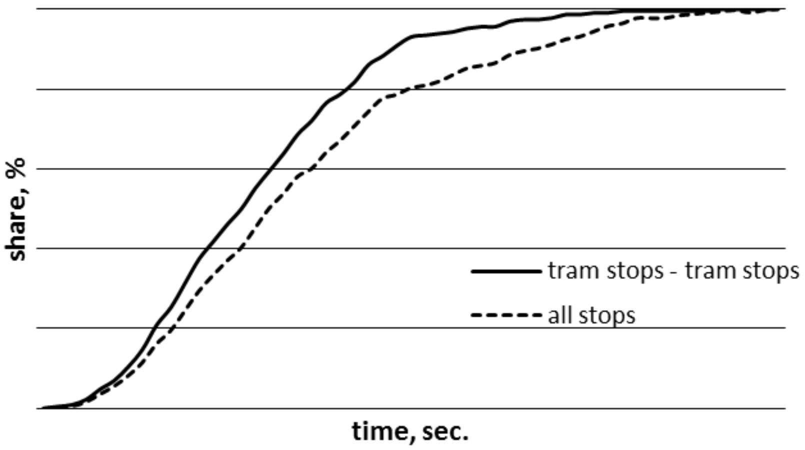

Fig. 6. Transition time of distribution functions between the tram stops (continuous line) and between all stops of the node (dotted line)

Table 3. Characteristics of transition times for certain types of connections in the node

Connection	Count	Average	Standard deviation	Variation coefficient	Pedestrian crossings
Surroundings-surroundings					
S1-S2	15	115	59	0.52	0
S2-S3	11	163	44	0.27	1
S2-S5	9	168	56	0.33	1
tram stops-bus stops					
T1-B2	7	128	30	0.23	0
T2-B2	7	135	24	0.18	0
T3-B2	15	170	50	0.29	1
T4-B2	7	150	75	0.50	1
T5-B2	7	219	48	0.22	2
Tram stops-surroundings					
S2-T1	18	120	54	0.44	0
S2-T2	15	128	68	0.53	0
S3-T3	13	85	35	0.41	0
S2-T3	35	144	57	0.40	1
S2-T5	19	225	69	0.31	2
Tram stops-tram stops					
T1-T2	44	65	42	0.65	0
T1-T3	58	68	29	0.42	1
T1-T4	15	96	32	0.33	1

T3-T5	46	97	41	0.43	1
T1-T5	16	123	48	0.39	2
T2-T5	21	98	29	0.30	2

T = tram stop; B = bus stop; S = surroundings

In each group of the type of connection (surroundings-surroundings, tram-tram etc.), it is evident that the shortest transition times are related to the types of connections, meaning that they are not vulnerable to any loss of time regarding red traffic lights. The need to pass through traffic lights, especially twice, clearly increases the transition time. This applies particularly to the types of connections between the lower and upper levels of the interchange node, meaning changes between a bus and a tram as well as walks from the surroundings of the hub to tram stops. The least accessible place is the T5 tram stop, which has the longest lead times between it and the surroundings, as well as from bus and tram stops. For many passengers, access to this stop requires overcoming two pedestrian crossings, each of which have traffic lights.

5. SUMMARY

The analysis enables the evaluation of the usefulness of the respective method of measurement in relation to the characteristics of pedestrian and passenger interchange behaviour. The method of tracking and manually recording behaviours of pedestrians is very accurate, as it allows for identifying the durations of different situations with an accuracy up to one second. The measurement form can be easily modified, for example, the one-level node where people cross at the red or green light can be recorded (instead of a method for overcoming the differences in height, which do not occur in this case).

Transition times are affected by the distance between the stops and the need to go through pedestrian crossings with traffic lights. In the case of the analysed infrastructure, the average transition time without stopping is 103 s. One stop increases it by 40%, while two stops increases it by more than 100%. Transition times are characterized by high volatility, which is associated with the behaviour of a pedestrian with regard to acceleration or deceleration, depending on the situation at the target stop, talking on a mobile phone etc. Such situations were not recorded.

The results may be useful when:

- performing a simulation analysis of the functioning of an interchange node, for example, using VISSIM software
- evaluating the interchange node
- designing other interchange nodes
- assessing the quality of a journey made by public transport.

References

1. Duda Urszula. 2015. Planowanie i projektowanie stref krótkiego parkowania (kiss and ride) jako elementu efektywnego węzła przesiadkowego. In *Współczesny stan wiedzy w inżynierii lądowej*, edited by Joanna Bzówka, 119-129. Gliwice: Wydawnictwo Politechniki Śląskiej. ISBN 978-83-7880-207-5. [In Polish: Planning and designing a short-term park zone (kiss and ride) as an element of an effective transport node. In *The Modern State of Knowledge in Civil Engineering*. Gliwice: Gliwice: Silesian University of Technology Publishing].
2. Dźwigoń Wiesław. 2014. "Efficiency of escalators in public transport". *Logistics* 4: 2781-2789. ISSN 1231-5478.
3. Dźwigoń Wiesław. 2012. "Kryterium oceny bezpieczeństwa w ocenie węzłów przesiadkowych". *Transport Miejski i Regionalny* 6: 13-18. ISSN 1732-5153. [In Polish: "Criterion for the safety of passengers in the evaluation of interchange nodes". *Urban and Regional Transport* 6: 13-18].
4. Gaca Stanisław, Wojciech Suchorzewski, Marian Tracz. 2008. *Inżynieria ruchu drogowego. Teoria i praktyka*. Warsaw: Wydawnictwa Komunikacji i Łączności. ISBN 978-83-206-1707-8. [In Polish: *Road traffic engineering. Theory and practice.* Warsaw: Transport and Communication Publishers].
5. Husarek Piotr, Wojciech Palus. 2005. "Analiza funkcjonowania węzłów przesiadkowych w transporcie zbiorowym". *Transport Miejski i Regionalny* 11: 2-8. ISSN 1732-5153. [In Polish: "Functional analysis of interchange nodes in public transport". *Urban and Regional Transport* 11: 2-8. ISSN 1732-5153].
6. Olszewski Piotr, Halina Krukowska, Piotr Krukowski. 2014. "Wskaźnikowa metoda oceny węzłów przesiadkowych transportu publicznego". *Transport Miejski i Regionalny* 6: 4-9. ISSN 1732-5153. [In Polish: "Indicator method for public transport interchange node evaluation". *Urban and Regional Transport* 6: 4-9].
7. Rudnicki Andrzej. 1999. *Jakość komunikacji miejskiej*. Cracow: Stowarzyszenie Inżynierów i Techników Komunikacji. ISSN 1231-9155. [In Polish: *Urban public transport quality*. Cracow: Polish Association of Transport Engineers and Technicians].
8. Starowicz Wiesław. 2007. *Jakość przewozów w miejskim transporcie zbiorowym*. Cracow: Wydawnictwo Politechniki Krakowskiej. ISBN 978-83-7242-427-3. [In Polish: *Quality of urban public transport*. Cracow: Cracow University of Technology Publishing].

Received 11.04.2016; accepted in revised form 25.07.2016