THE EVALUATION OF TRANSFER TIME IN PUBLIC PASSENGER TRANSPORT

Ing. Ján Ponický[1], Ing. Jana Lalinská, PhD.[1], doc. Ing. Martin Kendra, PhD.[1], Ing. Vladislav Zitrický, PhD.[1]
University of Žilina, The Faculty of Operation and Economics of Transport and Communications, Department of Railway Transport, Univerzitná 1, 010 26 Žilina, Slovakia[1]

jan.ponicky@fpedas.uniza.sk, jana.lalinska@fpedas.uniza.sk, martin.kendra@fpedas.uniza.sk, vladislav.zitricky@fpedas.uniza.sk

Abstract: *The segment of public passenger transport is a part of the everyday activities of the population. His task is to ensuring for the population commuting to work, at free time activity, shopping etc. The passengers must sometimes during of transport process to change of transport mode. The change is carried in the traffic hub, where the passenger can change the means of transport of the same transport mode or different transport modes. It is important to ensure continuity of public transport in the traffic hub. The current situation in the field of solving the problem has lack, not yet been to developed a complex assessment methodology. In practice this means, that all transfer times between different modes of transport are set from estimations coordinators integrated transport system. The changes of transfer times are performed operatively. In the contribution is set a new methodology of continuity public passenger transport in traffic hub.*

.**Keywords**: PUBLIC TRANSPORT, TRANSPORT HUB, PASSENGER TRANSPORT

1. Introduction

The transportation process is a sequence of consecutive sub-operations, which the passenger must during transportation take part. Passengers in many cases forced crossing passage the same or a different way of transportation. Crossing passage is negative for passenger. The optimal architectural arrangement and optimal setting time of continuity traffic line in traffic hub will significantly contribute to increase the attractiveness of public transport and help reduce growing share of individual transport.

The current situation in the field of solving the problem has lack, not yet been to developed a complex assessment methodology. In practice this means, that all transfer times between different modes of transport are set from estimations coordinators integrated transport system. The changes of transfer times are performed operatively. In the contribution is set a new methodology of continuity public passenger transport in traffic hub.

2. Characteristics of the transport chain

The transport chain in passenger transport can be characterized as a series of continuously sequential material and time actions. Appropriate optimization of partial operations can contribute to the creation of a functional transport system in public passenger transport. [1]

Appropriately chosen methodology of quantifying time elements can reveal the bottlenecks of the shipping process, which need to be modified in order to improve and make public transport more attractive. [1]

In a passenger transport system is a transport element an object that is not divided into smaller parts during the transport process. The transport requirements are imposed on the movement of persons, that is to say the object of transport is the passenger. [2]

All passenger transport systems can be characterized:

- places of arrival, exit and transfer of passengers - by transport hubs,
- sections between pairs of transport nodes, úsekmi medzi dvojicami dopravných uzlov, which are always overcome by the only means of transport,
- the common goal of fast, safe, convenient and reliable transportation [3].

3. The evaluation of the connections in the traffic junction

Traffic and transport processes that affect the linkage of the connections in the transport hub consist of the evaluation of partial indicators. Partial indicators can be divided into:

- time indicators of continuity evaluation,
- spatial arrangement of doped node.

Time indicators of follow-up evaluation

A temporal link connection processes the links between the train, bus and public transport. The result of the analysis is the number of joints, the interval between connections, the suitability and the inaccuracy of connections, and so on. [2]

Frequency connection (Fc) – an indicator that expresses the number of target, starting and direct connections of each type of public passenger transport (PPT) at the traffic hub. The formula for calculating this pointer is:

$$F_c = \sum_{i=1}^{n} F_i^{target\,.} + \sum_{i=1}^{n} F_i^{start\,.} + \sum_{i=1}^{n} F_i^{direct\,.} \quad (1)$$

[Number of public passenger transport connections]

where:

F_c	*number of connections PPT [number of connections PPT],*
$\sum_{i=1}^{n} F_i^{target\,.}$	*total number of target links PPT [number of connections PPT],*
$\sum_{i=1}^{n} F_i^{start\,.}$	*total number of starting links PPT [number of connections PPT],*
$\sum_{i=1}^{n} F_i^{direct\,.}$	*total number of direct links PPT [number of connections PPT],*
F_1, F_2, F_n	*connections of PPT [-].*

Interval between connections $\Delta(T)$ – expresses a difference Δ(T) arrivals or departures of connections PPT, i.e. denotes the difference between the arrival or departure of the second connection (Connection 2) PPT from/to the transport junction and the first connection (Connection 1) PPT form/to the transport junction (fig. 1). In the same way, it continues until the last PPT connection that has arrived or left the transport junction.

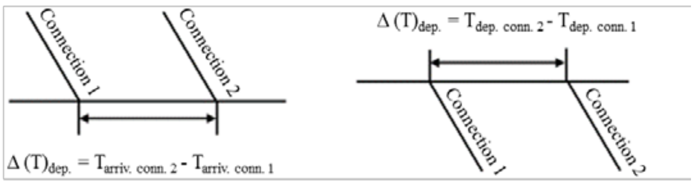

Fig. 1 – Graphical representation of the interval between connections

After determining the interval between individual connections, it is possible to determine the ***average interval between connections ($\bar{I}$)***. The calculation formula is:

$$\bar{I} = \frac{\Delta(T_{1,2})+\Delta(T_{2,3})+\cdots+\Delta(T_{n-1,n})}{n-1} \text{ [min.]} \qquad (2)$$

where:

$\bar{I}$	*average interval between connections PPT [min.],*
$\Delta_{(T1,2)}, \dots, \Delta_{(Tn-1,n)}$	*interval between incoming or outgoing connections PPT [min.],*
n	*total number of connections PPT [-].*

A ***suitable connection*** is considered to be the connection that departs for the minimum transfer time and the set maximum transmission time according to the PPT type.

$$T_{departure} - T_{arrival} > T; T \in < T\ min., \infty min. > \qquad (3)$$

An ***inappropriate connection*** is considered to be the connection that leaves before the minimum transfer time and after the specified maximum transfer time.

$$T_{departure} - T_{arrival} \le T; T \in (0\ min., T\ min. > \qquad (4)$$

where:

$T_{departure}$	*time of departure PPT [min.],*
$T_{arrival}$	*time of arrival PPT [min.],*
T	*maximum transmission time [min.].*

The direct link is the connection which, upon arrival at the transport node stops for the exit and the arrival of the passengers and leaves in one of the directions that are there.

Spatial arrangement of the transport junction

The need for relocation is one of the basic human needs. In many cases, the passenger is forced to change the means of transport of the same or different type of transport. The transport vehicle is changed in the transport node. The construction configuration of the transport hub should therefore comply with certain principles based on the legislative regulation of the European Union and national legislation. [4]

Building element in a transport junction	***Measures***
Parking spaces	location close to the entrance hall, a sufficient number of parking spaces for people with SHD card (severe health disability)
Access roads	connection of public spaces in the transport junction with the shortest way, alternative access routes for SHD, indication by visual means
Cashes for ticket sales	the sales area is separated by transparent glass, customization for people with SHD card, acoustic devices for better communication
Platforms	separating the danger zone by a visual and tactile indicator, the smallest platform width is 90 cm.
Other building elements	visual information devices and radio equipment for actual transport information,

4. The proposed assessment methodology of linking connections

The proposed methodology is based on:

- using network analysis,
- the calculation of partial indicator (modules).

Using network analysis

Network analysis (NA) - Is a special way of mathematically displaying a time or technological sequence of partial operations where the basic element is a ***network graph***. It serves as a graphical representation of individual partial operations and links between them. [5]

The generated network graph is both edge and vertices rated:

- ***evaluating the edges in the graph –*** the edges in the network graph are formed by orientated connections between the individual vertices (the operations of the passenger in the transition at the transport junction) and represent the access paths in the transport junction. Evaluating the graphs in the chart is the time ("t") that is needed to overcome the access roads to the passengers.
- ***evaluating the vertices in the graph –*** the vertices in the network chart are the carriers of the information on the duration of the individual activities at the transfer of the passenger at the transport hub (purchase of travel documents, exit from the vehicle, etc.).

Calculation of partial indicators – modules

This part of the methodology defines the partial operations of the passing traveler, which serve to evaluate the edges and the vertices of the traffic node network graph.

Evaluating network chart vertices

The vertices in the network chart carry the information on the duration of the individual activities at the transfer of the passenger at the transport junction. Partial indicators are:

- exit time from the vehicle,
- time of walking down the stairs,
- time transport of passengers by escalator,
- time of passenger transport in the lift,
- passenger time on mobile walkways,
- time required purchasing travel documents.

Exit time from the vehicle

The factors that affect the time of the passengers coming out of the vehicle are:

- ***the time of opening the door on the vehicle „t_{od}“-*** it is determined by measuring according to the design of the trigger mechanism and method for controlling doors,
- ***coefficient of design of the door on the vehicle „C_{dd}“- t***he design of a door on a public passenger transport vehicle (their design width) greatly affects the number, speed, time of entry and arrival of.
- ***loading the door on the vehicle „L_{dv}“ -*** the load on the vehicle is the ratio of the number of passengers outgoing to the number of doors on the vehicle. The more the door is on the vehicle, the faster (in shorter time) the passengers will get out because they are more evenly split in the door. On the contrary, with fewer doors on the vehicle, the time of exit is longer due to the increased use of individual doors on the vehicle.

- ***platform edge coefficient „C_{pe}“*** - this coefficient is determined on the basis of the platform edge design. The platform edge design is level where the edge of the platform is at the level of the floor of the vehicle from where the occupants will stand and the level of the platform where the edge of the platform is not at the floor of the vehicle. [4]
- ***Baggage handling coefficient „C_{gh}“-*** the luggage coefficient depends on its size, weight and volume.

The resulting relationship for calculating the time required to exit the vehicle is:

$$T_{lv} = t_{od} + \sum_{i=1}^{n} O_p * \sum_{i=1}^{\boldsymbol{Ldv}} Tep_i * C_{dd} * C_{pe} * C_{bh} \quad [s] \quad (5)$$

where:

T_{lv}	*time required to leave the vehicle [s],*
t_{od}	*time of opening the doors on the vehicle according to their design [s],*
O_p	*number of outgoing passengers [number of passengers].*
T_{epi}	*unit time of exit by type of passenger [s],*
C_{dv}	*door's coefficient on the vehicle [-],*
L_{dv}	*loading the door on the vehicle [-],*
C_{pe}	*coefficient of design of the platform edge [-],*
C_{bh}	*baggage handling coefficient [-].*

Time of walking down the stairs

The time required to walk the stairs is to be divided into:

- walk down the stairs,
- walk up the stairs.

The reason for dividing the time needed for the walking passengers on the stairs downward and upward steps are the fact that the speed of downward walkers is faster than the upward speed. The relationship for calculating the time of the passage of passengers on the stairs is:

$$T_{ws} = \frac{N_{s.}}{\emptyset_{w_{s_i}}} * C_{bh} \quad [s] \quad (6)$$

where:

T_{sch}	*walking time on stairs [s],*
N_s	*number of stairs down or up [-],*
$\emptyset_{w_{s_i}}$	*walking speed [m.s^{-1}]*
C_{bh}	*coefficient baggage handling [-].*

Time transport of passengers by escalator

The total transport time depends on the individual design of the escalator at the traffic junction, i.e. it conveyed speed and the escalator length.

In the case of calculating the total time of passenger transport to the escalator, it is necessary to calculate the number of passengers traveling simultaneously at the escalator.

Calculation of the passenger's time to the escalator:

- 1. passenger - $\boldsymbol{t_1}$
- 2. passenger - $\boldsymbol{t_1 + t_i}$
- 3. passenger - $\boldsymbol{t_1 + 2 * t_i}$
- n – th passenger - $\boldsymbol{t_1 + n * t_i}$

The time of the first passenger's journey ("t_1") to the escalator is determined by:

$$t_1 = \frac{L}{p_s} \quad [s] \quad (7)$$

where:

t_1	*time of one passenger's journey [s],*
l	*length of the escalator [m],*
p_s	*passenger speed [m.s^{-1}].*

In the case of the time of each other passenger's journey ("t_i"), account must be taken of the time of the first passenger's transport and the time of another passenger's transport. The relationship and calculation of the time of another passenger's journey is:

$$t_i = \frac{2*l_s}{p_s} \quad [s] \quad (8)$$

Time of passenger transport in the lift

The total transit time in the lift is dependent on the individual design solution used in the transport junction.

Time up passengers from the lift begins to run after the lifts stop on the relevant floor, it can be determined by:

$$T_{pgo} = t_{od} + \frac{\sum_{i=1}^{n} T_{pgo\ i} * N_p}{C_{de}} \quad [s] \quad (9)$$

where:

T_{pgoi}	*the unit time for the passengers to get out of the lift [s],*
t_{od}	*time of opening the lift door [s],*
N_p	*number of outgoing passengers [number of outgoing passengers],*
C_{de}	*the construction of the door to the elevator [-].*

The time at which passengers can enter the lift begins to run from the moment when all the passengers arrive can be determined by the relationship:

$$T_{ep} = \frac{\sum_{i=1}^{n} T_{EP\ i} * N_p}{C_{rdvv}} + t_{cld} \quad [s] \quad (10)$$

where:

T_{epi}	*unit time of passengers entering the lift [s],*
T_{cld}	*time to close the lift door [s],*

The total calculation time of transferring the passenger in the lift can be determined according to the relationship:

$$T_l = T_{pgo} + T_{ep} + \frac{d}{v} \quad [s] \quad (11)$$

where:

T_l	*total transit time in the lift [s],*
d	*distance travelled by lift [m],*
v	*conveyed lift speed [m.s^{-1}].*

Passenger time on mobile walkways

The mobile walkway is suitable for mass transit of people in shopping centers and transport hubs. In general, it is possible to determine the time of transport according to the relationship:

$$T_{mw} = \frac{L}{v} + N_{pc} \quad [s] \quad (12)$$

where:

T_{mw}	*total time on mobile walkways* [s],
L	*path of the mobile walkways [m],*
v	*transport speed of the mobile walkway [m.s^{-1}].*

WEB ISSN 2535-0307
PRINT ISSN 1313-5031

Time required purchasing travel documents

The place where a traveler can buy the necessary travel documents for his / her journey is a typical example of the THO (Theory of Mass Management). Places for the sale of travel documents consist of service lines and may consist of one or more service lines.

The basic THO model will be M / M / n / ∞ system in which n nodes are available or vending machines for the sale of travel documents. We assume that customer arrivals are described by a Poisson division with the λ frequency and the length of service time of one service line has an exponential distribution with an average operator time of 1/μ. All lines are mutually equal and equally powerful. Serving passengers are in the order in which they entered the system.

The total time spent in the system, i.e. the average total time spent in the system is the sum of the average time spent waiting in the queue for the service and the time of the operator:

$$E(R) = \frac{\pi}{n*\mu-\lambda} + \frac{1}{\mu} = \frac{\frac{\rho^n}{n!}*\frac{1}{1-\frac{\lambda}{n*\mu}}*p_0}{n*\mu-\lambda} + \frac{1}{\mu} \quad [min.] \qquad (13)$$

Edge evaluation in the network graph

Edges in the network graph are formed oriented link between the individual peaks (passenger operations at crossing the transport junction) and represent access roads to transport junction.

Time walking along the access road

Access roads should connect all public spaces at the traffic junction as quickly as possible. Another module for assessing linkages in public passenger transport is to determine the time needed to overcome these distances.

The relationship for calculating the walk access road is:

$$T_{wr} = \frac{d}{\emptyset v_{ws\,i}} * C_{bh} \quad [s] \qquad (14)$$

where:

T_{wr}	*walking time on access roads [s],*
d	*distance that passengers must overcome [m],*
$\emptyset v_{wsi}$	*the average walking speed by type of traveler [m.s^{-1}],*
C_{bh}	*coefficient baggage handling [-].*

In the case of a passenger coming out of a means of transport, the distance from the farthest door to the vehicle from which the passenger may exit can be counted. In this case, the relationship for walking time calculation will look like this:

$$T_{wr} = \frac{d_{max}}{\emptyset v_{ws\,i}} * C_{bh} \quad [s] \qquad (15)$$

where:

d_{max}	*the maximum distance that passengers must overcome after leaving the means of transport [m].*

The result of the application of a network graph at the transport junction and the calculation of individual time slots is to make a comprehensive assessment of linkage in public passenger transport for all combinations of edges and peaks that may occur.

Comparing calculations

The last part of the methodology compares the transit times of the passengers, which are determined on the basis of the network analysis of the transport node (time needed for the transfer) and the intersection interval between the connections. Based on the comparison, the following are set:

- appropriate connection,
- inappropriate connection,
- direct connection.

For a ***appropriate connection*** according to the relation (3), we consider the connection which leaves after the minimum transfer time and within the determined maximum transfer time according to the type of PPT.

For an ***inappropriate connection*** according to the relation (4) we consider the connection that leaves before the minimum transfer time and after the determined maximum transfer time.

The direct link is the link that upon arrival at the transport hub stops for loading and unloading passengers and goes to one of the directions that are out there mouths.

Conclusion

The presented methodology is based on a comprehensive analysis of the transport hub on the technical-construction site and the arrangement of the individual elements affecting the passengers' transition times. The proposed solution is based on the real situation, yet it provides a methodology suitable for different transport nodes with the potential to implement an integrated transport system.

This paper has been developed with support of the project "**Transfer of innovative knowledge and technology in logistics and transport processes**“, ITMS project code 26220220006, **University of Zilina**.

References

[1] Gasparik, J., Luptak, V., Mesko, P., in: New methodology for assessing transport connections depending on the integrated transport network. 3rd International Conference on Traffic and Transport Engineering (ICTTE) Location: Assoc Italiana Ingn Traffico Trasporti Res Ctr, Belgrade, SERBIA Date: NOV 24-25, 2016, pp. 388-392.

[2] Gasparik, J., Zitricky, V., in: A new approach to estimating the occupation time of the railway infrastructure. TRANSPORT. 2010. Vol: 25, Issue: 4, pp. 387-393.

[3] Cerna, L., Bukova, B., in: Supplier evaluation methodology in the logistics company. Proceedings of the 9th international scientific conference (Transbaltica 2015). 2016. Vilnius, Lithuania. Vol. 134, pp. 377-385.

[4] Dolinayova, A., Camaj, J., Danis, J., in: New approaches of strategic control in railway transport in the context of sustainable mobility and competitiveness. ICTTE. 2016. Belgrade, Serbia. Pp. 429-437.