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ORIGINAL RESEARCH PAPER

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SMART TERMINAL FOR MAKING TRANSFERS BETWEEN VARIOUS TRANSPORT MODES USED BY PASSENGERS WITH REDUCED MOBILITY

KEY WORDS: Terminal, accessible, reduced mobility, transfer time, public transport, Smart Cities

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ABSTRACT

In this article, the authors write about passengers' mobility in complex transport terminals. The issue is usually dealt with within the scope of information systems that inform the passengers on the optimal route and the time needed to complete the transfer. The authors developed a methodology to calculate the time needed for the transfer with various transport infrastructure components on the transfer route. The methodology accounts for various groups of passengers (i. g. wheelchair users, passengers with a pram, elderly passengers). Based on this methodology, the authors developed an algorithm to calculate transfer times. The algorithm accounts for combinations of transport infrastructure components for various groups of passengers. Accurate knowledge of the total time needed to complete a transfer can help to optimise making bus/train connections or it can be used in Smart Cities applications.

INTRODUCTION

In today's public transport solutions, a trend of building complex transfer terminals is noticeable. These transportation hubs interconnect various modes of public transport and passengers have to use them while using the public transport. Such complex terminals are being constructed at airports where the buses, trains, and air transport form a single complex transportation hub. Typically, such hubs are multi-level buildings and they cover large areas. The navigation around such complex hubs is considerably demanding even for passengers whose mobility is not reduced. For the passengers with reduced mobility, who cannot use certain components of the infrastructure (such as stairs), the navigation becomes even more difficult. Thus a well-laid orientation system helping to establish the optimal route from point A to point B is, at those complex hubs, necessary.

These are three key information points for every group of passengers:

- The path of the transfer (what way shall the passenger go)
- The length of the transfer (the distance in meters)
- The time needed for the transfer (min and max time)

DURATION OF THE TRANSFER IN RELATION TO THE COMPONENT OF TRANSPORT INFRASTRUCTURE AND THE GROUP OF PASSENGERS

Passengers with reduced mobility travel at different velocity in relation to the type of their handicap. The knowledge of their velocity while using different infrastructure components can be used while designing the hub or at traffic restrictions when a substitute mode of transport has to be introduced. The timetable ought to be set so, to allow enough time for the slowest group of passengers to complete their transfer.

Transport infrastructure components

The components of transport infrastructure within a transportation hub fall into these type groups:

- Corridors (a general component type that interlinks other transport components)
- Pedestrian crossing
- Lift, platform
- Stairway
- Inclined plane
- Escalator
- Travellator
- Indoor tram/train

Grouping passengers

In order to analyse the passengers' velocity in detail (and the time needed to complete transfers or to analyse the idle (extra needed) time), the authors categorised the passengers making a transfer into groups. Those groups cover both, the demographic progress of the Czech Republic, and the categories of people with reduced mobility. The authors used grouping as it is set by the regulation no 398/2009 Col. [1] that refers to the people with disability as to people with locomotion or special orientation impairment. This regulation categorises people as following: people with impaired mobility, visually impaired people, hard-of-hearing people, elderly people, people with mental disability, pregnant women, and people accompanying a child under three years or with a pram. [2]

This classification provided the authors with definitions that allowed for each measured person being in just one group. If a passenger falls into more than one group, then the group with higher C_{g1} value is used. Each group of passengers is assigned a coefficient (C_{g1}), which is a variable that quantifies how much is the passengers' mobility reduced. [4]

The coefficient C_{g2} is a variable that quantifies passengers' mobility reduction in respect of a particular transport infrastructure component.

TABLE - 1
COEFICIENTS C_{G1} AND C_{g2}

Group ID	Group description	Value	Value
1	Passenger without a disability	1,00	1
2	Visually impaired	1,38	1,1
3	Pregnant women	1,11	1,2
4	Passengers with heavy luggage	1,14	0
5	Elderly people	1,48	2
6	Passenger with a pram	1,09	0
7	Children under three years	1,58	1,3
8	Passenger with crotches	1,62	0
9	Electric wheelchair user	0,65	0
10	Wheelchair user without company	1,80	0
11	Wheelchair user accompanied	1,01	0

TRANSFER DURATION

The transfer duration time needs to be set for each transport infrastructure component.

Corridors or ramps

$$tp = \frac{l_P}{v_P} * C_{g1} * G_p * D_P \qquad (1)$$

tp Transfer duration time for corridor or inclined plane [s]
l_p *Corridor length [m]*

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v_P	Transfer velocity of a passenger without disability – 1,44 [m/s]
C_{g1}	Coefficient of group of passengers
G_p	Coefficient of the gradient of the corridor
D_P	Coefficient of traffic density in the corridor ($D_P = 1$ – off-peak time; $D_P = 1,3$ – rush hours)

Value G_p	Incline/gradient of the corridor or inclined plane
1	< -3% ; +3% >
1,1	< -6% ; -3%) OR (+3% ; 6% >
1,2	< -9% ; -6%) OR (+6% ; 9% >
1,3	< -11% ; -9%) OR (+9% ; 11% >
1,5	< -13% ; -11%) OR (+11% ; 13% >
1,7	> -13% OR > +13%

The total duration time of a transfer is calculated as a sum of duration times needed to clear individual infrastructure components. The total time of the transfer P along all the communications is calculated with formula (2).

$$P = \sum_{i=1}^{n} tp_i \qquad (2)$$

Where n is the total number of corridors at given route.

Pedestrian crossing

This infrastructure component requires a knowledge of its parameters and then it is necessary to measure the actual time needed to clear the crossing for each category of passengers. However, while calculating the total time needed to clear a pedestrian crossing, the time of waiting for the chance to cross must be addressed too. [6]

If there is a pedestrian crossing on the transfer route, then a modified formula (2), which allows for the waiting time, is used (3).

$$tc = \frac{l_P}{v_P} * C_{g1} * G_p * D_P + t_w \qquad (3)$$

tc	Transfer duration time for pedestrian crossing [s]
l_P	Corridor length [m]
v_P	Transfer velocity of a passenger without disability - 1,44 [m/s]
C_{g1}	Coefficient of group of passengers
G_p	Coefficient of the gradient of the corridor
t_w	Average time a passenger is waiting for the chance to cross [s]

The total time C needed to clear all the pedestrian crossings on the route is calculated with formula (4).

$$C = \sum_{i=1}^{n} tc_i \qquad (4)$$

Where n is the total number of pedestrian crossings on the transit route.

Lift, platform

$$tl = \frac{h}{v_v} * c_C \qquad (5)$$

t_l	The time needed to transport a passenger with a lift or a platform [s]
h	Vertical distance (lift) or the length of the path of a platform [m]
v_v	Lift/platform velocity
c_C	Capacity coefficient

Value C_c	Description
1,5	Off–peak hours – lift/platform (the lift/platform may be at a different floor)
3	Rush hours – lift/platform (passengers have to wait for the second run)

The total time *L* to clear all the lifts/platforms on the route is calculated with formula (6).

$$L = \sum_{i=1}^{n} tl_i \qquad (6)$$

Where *n* is the total number of lifts or platforms on the route.

Stairways

The calculation of the time needed to clear a stairway needs to account for several details. Firstly, it is the direction of travel (up or down). [5] Secondly, higher passenger flow density requires more time to avoid collisions with ongoing passengers. Furthermore, the velocity of passengers climbing more than 40 stairs decreases. There is a number of such details and all of them need to be recorded while measuring the idle times. Which, naturally, makes the measuring more demanding and time consuming (7).

$$ts = t_{step} * n_{step} * c_s * c_{g2} \qquad (7)$$

, where

ts	The time needed to clear a stairway [s]
t_{step}	The time needed to clear one step by a passenger without mobility impairment 0,54 [s]
n_{step}	Number of stairs
c_s	Coefficient of the stairway length (applicable only for the way up)
c_{g2}	Passenger group coefficient

Value C_s	Number of stairs
1	<1; 40>
1,3	(40; 60>
1,5	> 60

The total time S needed to clear all the stairways on the route is calculated with formula (8).

$$S = \sum_{i=1}^{n} ts_i \qquad (8)$$

Where *n* is the total number of stairways on the route.

Escalator

The infrastructure component escalator also requires two time components to calculate the time needed to clear it. It is the time spent on the escalator plus the time of waiting for the chance to use it (traffic density coefficient) (9).

$$te = \frac{1}{2} * \frac{n_{step} * d_{step}}{v_e} * D_e \qquad (9)$$

, where

te	The time needed to clear the escalator [s]
d_{step}	Tread/run of the stair
n_{step}	Number of stairs
v_e	Speed of the escalator (0,5 m/s)
D_e	Traffic (passengers flow) density coefficient ($D_e = 1$ – off-peak; $D_e = 1,5$ – rush hours)

The total time *E* needed to clear all the escalators on the route is calculated with formula (10).

$$E = \sum_{i=1}^{n} te_i \qquad (10)$$

Where n is the total number of escalators on the route.

Travellator (a moving walkway)

$$tt = \frac{l_t}{v_t} * D_t \qquad (11)$$

, where

tt	The time needed to clear the travellator [s]
l_t	The length of the travellator [m]
v_t	The speed of the travellator (0,5 m/s)
D_t	Traffic (passenger flow) density coefficient at the travellator ($D_m = 1$ - off-peak hours; $D_m = 1{,}3$ – rush hours)

The total TT time needed to clear all the travellators on the route is calculated with formula (12)

$$TT = \sum_{i=1}^{n} tt_i \qquad (12)$$

Where n is the total number of travellators on the route.

Indoor train/tram

$$tr = \frac{l_r}{v_r} + (S_r * Z_r) \qquad (13)$$

, where

tr	The time of train run [s]
l_r	The distance covered by the train [m]
v_r	Velocity of the train [m/s]
S_r	Number of stops
Z_r	Train wait time at each stop
tr	The time of train run [s]

The total time TR of indoor train run on the route is calculated with formula (14).

$$TR = \sum_{i=1}^{n} tr_i \qquad (14)$$

Where n is the total number of trains run on the route.

Total transfer time

Generally, the total transfer time equals the time needed to complete the transfer, which can be defined as idle time to clear all the traffic infrastructure components on the route.

The total transfer time T across all the traffic infrastructure components on the route is calculated as the sum of all transfer times for each component (15).

$$T = P + C + L + S + E + TT + TR \qquad (15)$$

The following factors also influence the process of transfer. Since those are highly individual, they cannot be accounted for in the formula. The factors affecting the speed of the transfer can be categorised:

- The fitness level of a passenger
- Technical parameters of any given infrastructure component (i. g. the quality of the surface of the communication)
- The passenger's knowledge of the transfer route

Better knowledge of the individual factors helps us understand the difference in the speed of individual passengers at individual components of the infrastructure and to understand the idle times.

TRANSFER ROUTE DETERMINATION

Transfer route:
a) the shortest path between two points
b) the fastest path between two points

Well known algorithms for finding the shortest paths between nodes in a graph (i. g. Dijkstra's, Floyd-Warshall, Bellman-Ford, A*, and self-organising migrating algorithms).

If there are stairways on the route ($S > 0$), the route is only suitable for a group of passengers with the coefficient

$$C_{g2} <> 0.$$

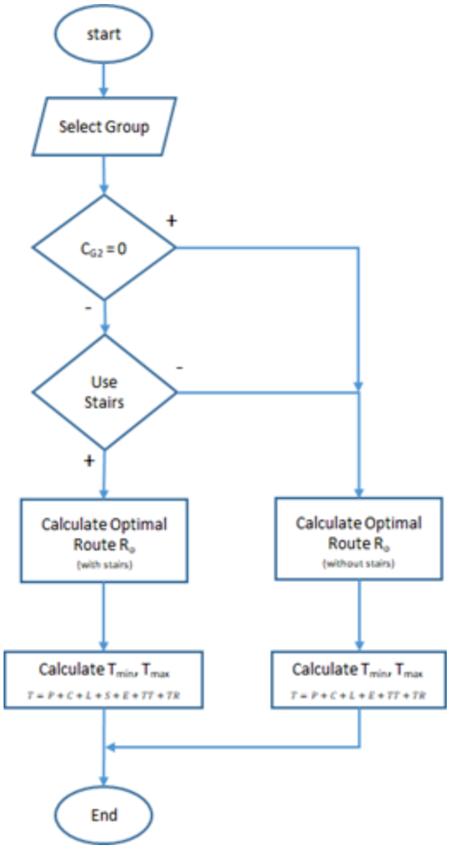

Figure 1 : Example flowchart for routing

In the case of transfer between two modes of transport, it is always the route between the exit and boarding terminal of the two modes. The route itself comprises of individual components of transport infrastructure. These components appear on the route in various numbers and order. Since there are different categories of passengers, same transfer may be completed on different routes. Thus, the array of infrastructure components differs

CONCLUSION

The article deals with the matters of transfer time needed to complete transfers between different modes of transport in respect of the possibility to use given (main) transfer route by particular group of passengers at complex transport terminals. Not always is the main route accessible, so certain passengers (wheelchair users) have to use alternative route. If we break the transfer route into individual traffic infrastructure components that make up the route, and if we know the idle time for each component, then it is possible to determine the total time needed to complete the transfer. The research not only mapped individual traffic infrastructure components in detail that make up the transfer route. I also measured the idle times that occur at (are needed to clear) individual infrastructure components in a broader context of i. g. wait time needed to enter/exit a lift or the density of passengers flow. The knowledge of transfer times in respect of different passenger groups has broad applications in transportation, logistics or, in particular, in Smart Cities applications.

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