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.e. 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.

This classification provided the authors with definitions of the groups that allowed for different measured persons being in just one group. If a passenger falls into more than one group, then the group with higher \( C_p \) value is used. Each group of passengers is assigned a coefficient \( C_p \), which is a variable that quantifies how much is the passengers' mobility reduced.

The coefficient \( C_p \) is a variable that quantifies passengers' mobility reduction in respect of a particular transport infrastructure component.

### TABLE - 1

<table>
<thead>
<tr>
<th>Group ID</th>
<th>Group description</th>
<th>( C_p )</th>
<th>( C_g1 )</th>
<th>( C_g2 )</th>
<th>( D_p )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Passenger without a disability</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>2</td>
<td>Visually impaired</td>
<td>1.38</td>
<td>1.38</td>
<td>1.38</td>
<td>1.38</td>
</tr>
<tr>
<td>3</td>
<td>Pregnant women</td>
<td>1.11</td>
<td>1.11</td>
<td>1.11</td>
<td>1.11</td>
</tr>
<tr>
<td>4</td>
<td>Passengers with heavy luggage</td>
<td>1.14</td>
<td>1.14</td>
<td>1.14</td>
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</tr>
<tr>
<td>5</td>
<td>Elderly people</td>
<td>1.48</td>
<td>1.48</td>
<td>1.48</td>
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</tr>
<tr>
<td>6</td>
<td>Passenger with a pram</td>
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<td>1.09</td>
<td>1.09</td>
<td>1.09</td>
</tr>
<tr>
<td>7</td>
<td>Children under three years</td>
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<td>1.58</td>
<td>1.58</td>
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</tr>
<tr>
<td>8</td>
<td>Passenger with crotches</td>
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<td>1.82</td>
<td>1.82</td>
<td>1.82</td>
</tr>
<tr>
<td>9</td>
<td>Electric wheelchair user</td>
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<td>0.65</td>
<td>0.65</td>
<td>0.65</td>
</tr>
<tr>
<td>10</td>
<td>Wheelchair user without company</td>
<td>1.80</td>
<td>1.80</td>
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<td>1.80</td>
</tr>
<tr>
<td>11</td>
<td>Wheelchair user accompanied</td>
<td>1.01</td>
<td>1.01</td>
<td>1.01</td>
<td>1.01</td>
</tr>
</tbody>
</table>

### TRANSFER DURATION

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

\[
tp = L_p \times C_{g1} \times C_{p} \times D_p
\]
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).

$$P = \sum_{i=1}^{n} t_{li}$$  \hspace{1cm} (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).

$$t_c = t_{vc} + C_{g1} * G_p + D_p + t_w$$  \hspace{1cm} (3)

$t_c$ 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).

$$C = \sum_{i=1}^{n} t_c_i$$  \hspace{1cm} (4)

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

**Lift, platform**

$$tl = \frac{h}{v_p} * c_c$$  \hspace{1cm} (5)

$tl$ 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]

$v_p$ Lift/platform velocity

$c_c$ Capacity coefficient

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

$$L = \sum_{i=1}^{n} t_{li}$$  \hspace{1cm} (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).

$$ts = t_{step} * n_{step} * c_s * c_{g2}$$  \hspace{1cm} (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

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

$$S = \sum_{i=1}^{n} t_s_i$$  \hspace{1cm} (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).

$$te = \frac{1}{2} * \frac{n_{step} * d_{step}}{v_e} * D_e$$  \hspace{1cm} (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).

$$E = \sum_{i=1}^{n} t_e_i$$  \hspace{1cm} (10)

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

**Travellator (a moving walkway)**
The total time needed to clear all the travellators on the route is calculated with formula (12)

\[ T \text{TT} = \sum_{i=1}^{n} t_{t_i} \]  

(12)

Where \( n \) is the total number of travellators on the route.

Indoor train/tram

\[ T \text{TR} = \frac{l_r}{v_r} + (S_r \cdot Z_r) \]  

(13)

Where

- \( t_{t_i} \) The time needed to clear the travellator [s]
- \( l_r \) The length of the travellator [m]
- \( v_r \) The speed of the travellator (0.5 m/s)
- \( D_t \) Traffic (passenger flow) density coefficient at the travellator \( (D_{m} = 1 - \text{off-peak hours}; D_{m} = 1.3 - \text{rush hours}) \)
- \( n \) is the total number of travellators on the route.

The total \( T \text{TR} \) of indoor train run on the route is calculated with formula (14).

\[ T \text{TR} = \sum_{i=1}^{n} t_{r_i} \]  

(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).

\[ T = P + C + L + S + E + TT + TR \]  

(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.e. 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.e. 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 \( C_{GD} \) \( \approx 0 \).

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, the 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.e. 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.

REFERENCES:

[4] Heindl M., Time loss in the movement of people with reduced mobility at...
