Chapter 4

Pedestrian route choice of vertical facilities at KLCC underground train station

Tee Xin Lei, Nur Sabahiah Abdul Sukor, Noorhazlinda Abd Rahman, Munzilah Md Rohani and Sitti Asmah Hassan

4.1 Introduction

Route choice is the pedestrian’s decision of optimal path between an origin and a destination among a set of alternatives. Pedestrian route choice is dissimilar with drivers’ route choice as the pedestrians have higher degree of freedom and randomness in choosing routes. Meanwhile drivers route choice always constraint of direction for maneuver, space of movement, fixed road and has restricted traffic rules. The understanding on pedestrian route choice behaviour is necessary for planning and design of pedestrian walking facilities especially in rail transit stations that serve thousands of daily ridership.

LRT Kelana Jaya Line has recorded the highest ridership among the existing rail transit in Klang Valley [1] and has the most direct impact from the Malaysia government with the effort of improving rail network system. Recent projects that have been launched include Light Rail Transit (LRT) Line Extension Project (LEP) connecting Ampang Line and Kelana Jaya Line by Putra Heights Station as interchange [2] as well as Klang Valley Mass Rapid Transit Project (KVMRT) which is MRT Line 1, Sungai Buloh to Kajang Line (SBK Line) [3]. Government’s initiative on public transport results in 12% of the overall daily ridership for existing urban rail in 2017 comparing to 2016 and even reached 30% after opening of MRT full line and the remarkable increment has happened at LRT Kelana Jaya Line with 26% increase of daily ridership [1]. In addition to that, Kelana Jaya Additional Vehicle (KLAV) project has added new generation trains to LRT Kelana Jaya Line to reduce the waiting time and increase passenger capacity by 20% [4].
Growing of ridership of LRT Kelana Jaya Line must be supported by efficient facilities in train station that meet the demand of riders to ensure fluent flow of pedestrians without any congestion at the bottlenecks. The stairway and escalator are the bottlenecks at underground platform level that determine a train station capacity due to their lowest capacity in the station [5]. If similar route is taken by pedestrians to egress from underground platform via vertical facility, this causes pedestrians crowded the entrance of vertical facility and results in congestion [6]. Pedestrians should be distributed over different routes in the station to optimize the efficiency of facilities and ensure the pedestrian comfort, therefore encouraging use of public transport.

KLCC underground train station that serves LRT Kelana Jaya Line is located beneath a shopping mall, Avenue K. This underground train station has a pedestrian subway connecting to Suria KLCC and to the rest of commercials, retails, business and financial centers, hence it has become one of the busiest train stations, serving more than 37,000 daily ridership according to the report provided by Prasarana Sdn. Bhd. The number of ridership at train station will increase if KLCC Convention Centre hold functions. In addition, MRT Line 2, Sungai Buloh-Serdang-Putrajaya Line (SSP Line) will commence service on July 2022 and one of its underground station, KLCC East MRT Station will be located a short distance from KLCC LRT underground train station [7]. It is believed to boost the ridership of KLCC LRT underground train station after its commencement of service. Hence, the existing facilities in KLCC LRT underground train station should be reviewed and evaluated.

The passengers composed of office workers and visitors has caused congestion at the underground platform level and the congestion situation is even worse during peak hours. The excessive demand of pedestrians to egress the underground station via vertical facilities caused these bottlenecks overflowing with pedestrians especially at the entrance of escalator. The route choice of pedestrians to egress could have contributed to the excessive demand on one of the vertical facilities at underground platform level. Therefore, the study on the route choice of pedestrians from each train door to the egressing vertical facilities should be conducted to review whether the existing layout of KLCC underground station influences the route choice of pedestrians.
The common route taken by the pedestrians causes overcrowding and leads to congestion which in turn incurring additional pedestrians’ walking costs at underground train station. Additional walking costs was stemmed from delay of pedestrians caused by reduced walking speeds due to high pedestrian densities [8]. Therefore, it is interested to investigate the delay time caused by the route choice of pedestrians to egress via vertical facilities during peak hours and non-peak hours.

In a nutshell, the investigation of the route choice of pedestrians to egress the underground platform level via vertical facilities can review the existing layout of KLCC LRT underground train station and help the station operators to have better understanding of pedestrian behaviours inside underground station.

4.2 Methodology

The Pedestrians Following Survey was carrying out from 12nd March to 15th March 2018 at peak hours and non-peak hours which were selected by referring to hourly ridership report provided by Prasarana Sdn. Bhd as shown in Table 1.

<table>
<thead>
<tr>
<th>Peak Hour</th>
<th>Time</th>
<th>Non-Peak Hour</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Morning</td>
<td>7.00 – 10.00 am</td>
<td>Morning</td>
<td>10.00 – 12.00 pm</td>
</tr>
<tr>
<td>Noon</td>
<td>12.00 – 2.00 pm</td>
<td>Afternoon</td>
<td>2.00 – 5.00 pm</td>
</tr>
<tr>
<td>Evening</td>
<td>5.00 – 8.00 pm</td>
<td></td>
<td>-</td>
</tr>
</tbody>
</table>

During surveying, the enumerators followed random pedestrian once the pedestrian alighted from the train until the pedestrian reached concourse level. Pedestrian route choice of using stairway and escalator as well as the walking path to facilities were observed and recorded during survey. The pedestrian’s travel times were measured by stopwatch and recorded into two sections which were the walking time between train door to the entrance of stairway or escalator and the walking time on the whole section of stairway or escalator. Hence, pedestrian proportion using
vertical facilities with respect to each of the train door and pedestrian
walking speed at platform and vertical facilities can be determined using
Equation (3) whereby the walking length of stairway and escalator were
calculated by Equations (1) and (2) respectively and walking length at
platform was determined from layout of platform level as exhibited in Fig.
1.

\[ L (m) = 2(l_s \cos 30^\circ) + l_L \]  

(1)

\[ L (m) = \frac{h}{\sin 30^\circ} + 2l_e \]  

(2)

\[ v (m/s) = \frac{L (m)}{t (s)} \]  

(3)

where \( L \) is distance travelled, \( l_s \) is length of stairway, \( l_L \) is the length of
landing, \( h \) is the difference in floor height, \( l_e \) is the length of horizontal
area at escalator, \( s \) is length of stairway, \( v \) is the pedestrian walking speed
and \( t \) is the time travelled.

Fig. 1 Layout of platform level

The calculated walking speeds at platform level and at vertical facilities
were used to construct cumulative frequency table for the input of desired
speed distribution, a main parameter in Viswalk.

The verification and validation of Viswalk to determine whether the
specific settings were required to reproduce the expected result that
agreed with the observations. Verification tests adopted from study of
Henningsson and Blomstrand Martén [9] and involved walking speeds at
platform level, stairway and escalator as well as delay time. Verification of escalator performed in two conditions: (1) pedestrians stood on moving escalator; (2) pedestrian walked with 0.5m/s with moving escalator. Cumulative mean from the results was calculated after each simulation run and the convergence measure was evaluated by two consecutive cumulative means as shown in Equation 4. CM was the cumulative mean and N was the number of simulation run. The criterion convergence should be 1% or less than 1% as these verification tests were to check any potential discrepancy in the results.

\[
\text{Convergence measure (\%)} = \left| \frac{CM_N - CM_{N-1}}{CM_N} \right|
\] (4)

Validation test was conducted by comparing the result of the simulation using default settings and specific settings to the real-life data which available from video footage recorded at KLCC underground station (27th to 29th Jan 2015) and hence test the accuracy of settings to represent the real situation in KLCC underground station. The simulation involved pedestrian alighting from train and egress to concourse level via vertical facilities. The method of determining number of simulation runs was similar with verification tests.

After validation tests had been done, the settings that able to obtain the most accurate results were used to simulate again to extract delay time of pedestrians when egressing. The delay time was extracted into 3 categories, which were overall delay time, delay time when walking at platform level as well as delay time when walking at vertical facilities. This simulation was performed to determine whether the route choice of pedestrians to egress would influence delay their travel time.

4.3 Results and discussion

4.3.1 Pedestrian proportion of using vertical facilities with respect to train doors at platform level

The great distance between entrances of escalators and stairways which was estimated 31.1m had promoted the use of stairways with approximately more than 45% of pedestrians were recorded choosing
stairways to ascend. During data collection at train station, pedestrians would not switch their choice of vertical facility when the entrance of facility was congested, they just queued and waited for boarding to facility. The results showed that pedestrians at the underground train station preferred to use the vertical facility that is nearer to their respective train doors due to the shortest path, except the passengers that alighted from the middle section of train and tended to egress with escalators over stairways as shown in Fig. 2. This resulted in the percentage usage of escalators (52.3%) was higher than stairways (47.7%). Effort of climbing stairs might have demoted the pedestrians to use stairways as the floor difference of train station was 4.9m which considerably high.

None of the doors had almost similar pedestrians proportion of using stairways and escalators as doors B3 of Platform 1 and C1 of Platform 2 as shown in Fig. 2. One of the reasons might due to the narrow passage leading to the facility with less than 4m width which need to cater large numbers of arrival pedestrians, it was faster, easier and efficient for the pedestrians following crowd movement egressing platform instead of countering the massive flow going to another vertical facility which could take more time to egress. Hence, this suggested that pedestrians flow in passage between the platform edge and vertical facility had restricted the freedom of pedestrian route choice to egress. The locations of doors B3 of Platform 1 and C1 of Platform 2 were near to the middle hallway of platform which reserved them amber space to decide which crowd they can follow. In addition, there was no movement flow to stairways after doors B3 of Platform 1 and C1 of Platform 2 as they all went for escalators. Hence, the pedestrians can freely choose the path to ascend.
(a) Morning peak hours (7.00 am – 10.00 am)

(b) Morning non-peak hours (10.00 am – 12.00 pm)
(c) Afternoon peak hours (12.00 pm – 2.00 pm)

(d) Afternoon non-peak hours (2.00 pm – 5.00 pm)
Fig. 2 Proportion of pedestrians using vertical facilities during peak hours: (a) Morning peak hours; (b) Afternoon non-peak hours; (c) Afternoon peak hours; (d) Afternoon non-peak hours; (e) Evening peak hours

Overall, the route choice of pedestrians was similar during all survey time except morning non-peak and afternoon peak hours. This could be the sample size collected was small due to the low frequency of train during these two survey times. In the other hand, high frequency trains occurred during morning peak and evening peak hours, thus larger sample size was collected and more representable as pedestrian route choice at KLCC underground train station.

4.3.2 Verification and Validation

The result of verification tests — walking speed at platform level, stairway and escalator were shown in Table 2 and Table 3. The simulation ran 10 times only as the convergence measure maintained below 1% and hence showed that no discrepancy in the result. In short, Viswalk able to reproduce and maintain the pedestrian walking speed along the walking facilities.
Table 2 Result of verification test

<table>
<thead>
<tr>
<th>Verification test</th>
<th>Defined walking speed</th>
<th>Mean simulation speed (m/s)</th>
<th>Percentage of difference (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Walking speed at platform level</td>
<td>1.85</td>
<td>1.83</td>
<td>1.08</td>
</tr>
</tbody>
</table>

Table 3 Result of verification test

<table>
<thead>
<tr>
<th>Verification test</th>
<th>Expected travel time (s)</th>
<th>Mean travel time (s)</th>
<th>Percentage of difference (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Walking speed at stairway</td>
<td>18.48</td>
<td>18.54</td>
<td>0.87</td>
</tr>
<tr>
<td>Walking speed at escalator - pedestrian stationary</td>
<td>23.90</td>
<td>23.77</td>
<td>0.54</td>
</tr>
<tr>
<td>- pedestrian walked</td>
<td>11.87</td>
<td>11.95</td>
<td>0.67</td>
</tr>
</tbody>
</table>

Verification test – delay time was conducted to examine the ability of Viswalk to simulate pedestrian behaviour when the pedestrian density was high. The result that showed in Fig. 3 indicating pedestrians reduced in speed and incurred delay in time that determined from the difference between actual speed and assigned speed. The pedestrian walked ahead of the pedestrian group experienced less or no delay whereas the last pedestrian walked behind the pedestrian group had the maximum delay time, 21.7s. In conclusion, Viswalk able to simulate the interaction of high density pedestrians which caused decrease in delay time.

Validation was performed for both platforms for all survey times. Default settings used the standard settings of Viswalk whereas specific settings involved adjustment of parameters and defined walking speed according to data collected. However, it was found that walking speed during peak hours unable to represent the pedestrian behaviours in KLCC underground station, therefore non-peak hours walking speed was used.
instead. The result of validation is shown in Table 4. The specific settings produced the most accurate results were used to obtain the pedestrian delay time.

![Fig. 2 Histogram of delay time](image)

**Table 4 Result of validation test**

<table>
<thead>
<tr>
<th>Validation test</th>
<th>Percentage Difference (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input settings</td>
<td>Total time egress via stairway</td>
</tr>
<tr>
<td>Default</td>
<td>4.86 - 36.72</td>
</tr>
<tr>
<td>Specific</td>
<td>1.86 – 9.55</td>
</tr>
</tbody>
</table>

### 4.3.3 Delay Time of Pedestrian when Egressing via Vertical Facilities

Delay is loss of time due to traffic congestion. The entrance of escalator was always observed to have crowded with pedestrians even during non-peak hours, however, the average total delay time experienced by pedestrian did not much longer than pedestrians egressed with stairway as shown in Fig. 3. Therefore, the total delay time should be further analysed and divided into delay time experienced at platform level and at vertical facilities.
Fig. 3 Average pedestrians total delay time during peak and non-peak hours

Fig. 4 indicated pedestrians moved towards escalators experienced more delay time than moved towards stairways at platform level. This result was explainable with the congestion happened at the entrance of escalators as more than half of the pedestrians preferred to use escalator to egress platform level. Some of pedestrians choose to stand on left side of escalator and the right side was the walking pedestrians. The stationary pedestrians decreased the efficiency of escalator transferring people to concourse level and even consequently caused the pedestrians at the upstream queued and congested at entrance, hence, delay was incurred. This implied similar route choice of vertical facility incurred high delay in time.

However, Fig. 5 depicted pedestrians walked at stairways experience higher delay time those used escalators that had uniform operating speed. At stairways, the pedestrians walked at the downstream of the group hindered the pedestrians at upstream from walking with desired speed. The average delay time at stairways for other survey times was even higher than morning peak hours which the ascending pedestrians number was the highest. During morning peak hours, the pedestrians tended to occupy to both stairways to faster ascend, thus distributed almost equally number of pedestrians to both stairways. In contrast, when the pedestrian density was low, the pedestrians likely to use stairway nearer them, therefore one of the stairways would be occupied with more pedestrians, the other
stairway could be just few pedestrians or even no pedestrians. Therefore, the average delay time for the stairways occupied with more pedestrians was similar and even higher than the morning peak hours as the pedestrian density could probably alike.

Fig. 4 Average pedestrians delay time at platform level during peak and non-peak hours

Fig. 5 Average pedestrians delay time at vertical facilities during peak and non-peak hours
In conclusion, the delay time at stairways dictated the total delay time of pedestrians using stairways while delay time walking towards escalators governed the total delay time of pedestrians using escalators. Similar pedestrian route choice of vertical facility caused pedestrians crowded at entrance of facility and incurred higher delay time when pedestrians walking at platform level.

4.4 Conclusion

This study simulated the route choice behaviour of pedestrians to egress via stairways and escalators at KLCC underground train station to obtain delay time experience by pedestrians.

Pedestrians of KLCC train station preferred to egress with nearer vertical facilities due to shortest path. The pedestrians alighted from train doors located at middle of platform hall chose between stairways and escalators, thus overall 47.7% of the pedestrians using stairways and 52.2% of pedestrians choosing escalators. The passage leading to entrance of vertical stairways had suspected to have restricted the freedom of pedestrians choosing further vertical facility as they had to encounter the massive pedestrians flow in this limited space.

Verification tests proved the ability of Viswalk to reproduce the defined settings and simulate the pedestrian interaction with large number of pedestrians. The result showed no discrepancy. Validation tests was performed before carrying out simulation. The specific settings with adjustment of walking speed and walking behaviour in Viswalk produced results which is the closest with the real total egress time of pedestrians at KLCC train station with difference ranging from 1.59% to 9.55%. The non-peak hours walking speed was used to replace peak hours walking speed as influence of social force model used in Viswalk caused the peak hours speed even slower.

The delay time extracted from simulation discovered that the route choice of pedestrians to egress giving impact to the delay time of pedestrians when walking at platform level. Average delay time experienced by pedestrians walking towards escalator was longer than walking towards stairways for all survey times as more than half of pedestrians chose
escalator to egress. However, route choice of pedestrians did not influence on total delay time pedestrians experience when egressing from platform level.

This dissertation focused on the route choice egressing the platform level via vertical facilities and its impact which represented as delay time experienced by pedestrians. Future study could focus on study of route choice of pedestrians egress the concourse level via faregates and route choice of pedestrians entering via faregates as well as descending via vertical facilities at KLCC underground train station, therefore whole train station can be simulated and study the effectiveness of existing facilities as well as can be used as renovation planning tool.

References


