Determinants for Bus Stop Performance in Penang Island

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Abstract. Less dependency on public transport has caused a high reliance on private vehicles. This is due to several factors including a comfortable aspect, safety, and inconvenient infrastructure and facilities at the bus stop. This paper attempts to identify the significant determinants affecting the bus stop performance by evaluating 123 bus stops based on the developed indicators within maximum walking distance to transit stations along the proposed alignment of Light Rail Transit (LRT) stations. The indicators were adapted from Transport Assessment Indicators and suited with local guidelines which were subsequently developed into Transport Assessment Checklist. 13 indicators in the audit checklist were significantly reduced to five factors containing 12 significant indicators (factor loadings greater than 0.5) through Factor Analysis and Principal Components Analysis (PCA). These indicators were identified to give an effect on bus stop performance. The findings can help solve the low dependency on public transport by emphasizing the significant determinants at the bus stop for future improvement.

1. Introduction
The rapid development and technology in these recent years have caused people to be highly dependent on private automobiles especially cars [1]. The alarming rate of private vehicles triggers concern for its adverse consequences in terms of congestion and pollution [2-3]. The Malaysia Automotive Association (MAA) has reported that up to June 2017, the total number of vehicles exceeds 28 million with more than 13 million registered cars and 12 million and more for motorcycles [4]. Even though demand in cars is positively contributing to automobile development and industry, it depletes the environmental health and sustainability by causing air pollution due to various carbon remittances [5].

According to the recent report from the Malaysian Automotive Association [6], in 2017, Penang was reported to have 1,126,618 registered private motor vehicles. Despite its small area, Penang owned more vehicles compared to other countries. Furthermore, Penang’s increasing population rate also contributed to the increasing demand for private vehicle ownership. Adding to that, the average daily traffic (ADT) was reported high with more than 60 000 vehicles per day exceeding ADT in other countries [7]. The increment of private vehicle usage was claimed to be associated with poor public transport systems [8] which cause people to shift to private vehicles. Rohani et al [9] listed the external and internal factors affecting bus ridership which includes design of the route, service schedules, and frequency, reliability, accessibility, and parking availability. Furthermore, Bernal [10] claimed that integration with other types of user facilities will also give a comfortable travel experience. Chakour and Eluru [11] stated that an equitable public transport service and accessibility can produce an efficient public transportation system. Lack of facilities and infrastructure will cause users to feel uncomfortable and insecure. Hence, shifting to private vehicles will be the first option. An infrastructure that connects to the bus stop such as, the pedestrian walkway is also significant to facilitate and ease the movement of users from their origins to
the bus stop [12]. Hess [13] added that the decision to ride public transit is affected by good access. In other words, the built environment is vital to give comfort to the users and encourage transit use [14-15]. A study made by Eboli and Mazulla [16] found that bus stop furniture was statistically significant towards users’ satisfaction on bus service. Furthermore, the well-equipped bus stop will give an effect on the efficiency of transit and traffic operation as well [17]. Previous studies often touch on reliability services [18-20] and poor bus service without discussing much on the detail of infrastructure and facilities that also affect the bus performance. Thus, this study came out with the micro-aspects of design that influence interest to access the bus stop.

2. Methodology

2.1. Data Collection

The data collection was conducted at 123 bus stops (Table 1) detected within the 800-meter walking distance from the proposed Light Rail Transit (LRT) stations (Figure 1). There are 19 LRT stations (exclude 8 stations on the 3 future reclaimed islands) on the island proposed in Penang Transport Master Plan (PTMP) [21].

The bus stops were evaluated based on the Transport Assessment Indicators Checklist created based on the literature review of transport assessment guidelines and active mode criteria for walkability and cycling. These indicators were filtered based on the most highlighted criteria by previous scholars and subsequently adapted with the local guidelines. Table 2 shows the final indicators of the Transport Assessment Indicators Checklist. The bus stops were evaluated with three categories; Available and
following the guideline (/); Available and not following the guideline (X); Not available/not existed (0). The evaluation was given a standardized coding; (/=3); (X=2); (0=1) for data computation in SPSS. Figure 2 shows the procedure of data collection.

Table 1. List of 123 Selected Bus Stops from 19 Zones.

| Site Zones                  | Number of Bus Stops |
|-----------------------------|---------------------|
| 1. Komtar Zone (KMZ)        | 23                  |
| 2. Macallum Zone (MZ)       | 9                   |
| 3. Bandar Sri Pinang Zone (BSPZ) | 8            |
| 4. Skycab Zone (SKYZ)       | 7                   |
| 5. East Jelutong Zone (EJZ) | 6                   |
| 6. The Light Zone (TLZ)     | 7                   |
| 7. Gelugor Zone (GZ)        | 3                   |
| 8. USM Zone (USMZ)          | 2                   |
| 9. Batu Uban Zone (BUZ)     | 9                   |
| 10. Pesta Zone (PZ)         | 9                   |
| 11. Sg. Nibong Zone (SNZ)   | 7                   |
| 12. Bukit Jambul Zone (BJZ) | 3                   |
| 13. SPICE Zone (SZ)         | 8                   |
| 14. Jalan Tengah Zone (JTZ) | 8                   |
| 15. FIZ North Zone (FNZ)    | 2                   |
| 16. FIZ South Zone (FSZ)    | 1                   |
| 17. Sg Tiram Zone (STZ)     | 2                   |
| 18. Penang Airport Zone (PAZ) | 7          |
| 19. Permatang Damar Laut Zone (PDLZ) | 2       |

Table 2. The Final Indicators of Transport Assessment Indicators Checklist

INDICATORS

a) Accessible

The bus stop is accessible with no obstructions within 400 meters from/to main attractions/public offices/residential area [22], [23], [24]
Distance between bus stops is 200 to 400 meters [22], [23], [24]
Accessible for people with disabilities or elders by providing smooth and same level curb with the bus door [22], [23], [24]

b) Safety

Bus stop should be a minimum of 60 meters from road intersection/junction [25], [26]
Bus stop is located close (15meters) to a pedestrian crossing [25], [26]
Bus stop is provided between 2 to 5 lighting sources [25], [26]
Provision of bus laybys (if provided) with a minimum width of 4.0meters and 12.0 meters length is not placed within 60 meters from road intersection/junction [25], [26]

c) Comfort

Provision of shelters that enclosed at three sides for weather protection [24], [27]
Shelters are well-maintained in good condition (not broken) [24], [27]
Provision of the same level curb with the bus floor [24], [27]
Provision of real-time information of bus time schedule at the bus stop [24], [27]
The parking area is prohibited near stops and stations by providing “no parking” signage [24], [27]

d) Universal design

Bus stop is designed with dropped curbs and tactile paving for disabled people, elders, and strollers [27]
2.2. Statistical Analysis
In this case, factor analysis was performed using IBM Statistic SPSS 22 to reduce the number of indicators and detect structures in the relationships between the indicators. The overall 13 indicators for evaluating bus stop performance were extracted by the maximum likelihood method and varimax rotated was implied.

3. Results and Discussions
3.1. Identifying significant determinants using Factor Analysis
By following the requirements for factor analysis, the indicators had been reduced from 13 to 10 as the eliminated indicators were identified to be not significant due to the low value of communalities. Based on Table 3, the Kaiser-Meyer-Olkin (KMO) measure of adequacy for indicator affecting bus stop’s performance was 0.640, trespassing the minimum threshold value of 0.6 [28] which means the indicators are adequate to be further analysed. Bartlett’s Test of Sphericity shows significant value ($\chi^2(78) = 311.657$, $p$-value = 0.000) indicating the correlation matrix is significantly different from an identity matrix, which makes the correlations between all indicators are zero. The significance level is small enough to reject the null hypothesis.

| Table 3. KMO and Bartlett’s Test. |
|-----------------------------------|
| Kaiser-Meyer-Olkin Measure of Sampling Adequacy. | .640 |
| Approx. Chi-Square | 311.657 |
| Bartlett's Test of Sphericity | df | 78 |
| | Sig. | .000 |

Nevertheless, the indicators should possess the value of communalities greater than 0.4. From the results in Table 4, indicator PT42; “Parking area is prohibited near stops and stations by providing “no parking” signage” does not influence the bus stop performance since the communalities value is lower than the threshold value (0.295). In other words, 29.5% of the variance ‘Parking area is prohibited near stops and stations by providing “no parking” signage’ is accounted for. Thus, indicator PT42 was removed for further analysis. PT39; “shelters are well-maintained in good condition” possessed the highest value of communalities (0.817) which means this indicator correlates with the bus stop performance and retained for further analysis.

Based on Table 5, the indicators with a value of more than 0.5 are categorized as indicators with high correlations. Five components (factors) were generated with an eigenvalue of > 1 as showed in Table 7. This explained 63% of the variance in the data. Thus, Table 6 summarized the factors with the respective indicators.
### Table 4. List of Indicators with Communalities Value.

| Indicators Description                                                                 | Indicator Abbreviation | Communalities | KMO   |
|---------------------------------------------------------------------------------------|------------------------|---------------|-------|
| Variable: PUBLIC TRANSPORT                                                            | PT31                   | 0.699         | 0.640 |
| The bus stop is accessible with no obstructions within 400 meters from/to main attractions/public offices/residential area |                        |               |       |
| Distance between bus stops is 200 to 400 meters                                        | PT32                   | 0.417         |       |
| Accessible for people with disabilities or elders by providing smooth and same level curb with the bus door | PT33                   | 0.677         |       |
| Bus stop should be a minimum of 60 meters from road intersection/junction              | PT34                   | 0.813         |       |
| Bus stop is located close (15 meters) to the pedestrian crossing                      | PT35                   | 0.471         |       |
| Bus stop is provided between 2 to 5 lighting sources                                    | PT36                   | 0.551         |       |
| Provision of bus laybys (if provided) with a minimum width of 4.0 meters and 12.0 meters length is not placed within 60 meters from road intersection/junction | PT37                   | 0.673         |       |
| Provision of shelters that enclosed at three sides for weather protection              | PT38                   | 0.807         |       |
| **Shelters are well-maintained in good condition (not broken)**                       | PT39                   | **0.817**     |       |
| Provision of the same level curb with bus floor                                        | PT40                   | 0.714         |       |
| Provision of real-time information of bus time schedule at the bus stop               | PT41                   | 0.751         |       |
| **Parking area is prohibited near stops and stations by providing “no parking” signage** | PT42                   | **0.295**     |       |
| Bus stop is designed with dropped curbs and tactile paving for disabled people, elders and strollers | PT43                   | 0.524         |       |

**Extraction Method:** Principal Component Analysis.

**Rotation Method:** Varimax with Kaiser Normalization.

a. Rotation converged in 8 iterations.

### Table 5. Rotated Component Matrix for The Retained Indicators.

| Component | 1   | 2   | 3   | 4   | 5   |
|-----------|-----|-----|-----|-----|-----|
| PUBLIC TRANSPORT 31 | .784 |     |     |     |     |
| PUBLIC TRANSPORT 36 | .634 |     |     |     |     |
| PUBLIC TRANSPORT 35 | .607 |     |     |     |     |
| PUBLIC TRANSPORT 32 | .602 |     |     |     |     |
| PUBLIC TRANSPORT 39 |     | .880 |     |     |     |
| PUBLIC TRANSPORT 38 |     | .876 |     |     |     |
| PUBLIC TRANSPORT 40 |     |     | .752 |     |     |
| PUBLIC TRANSPORT 33 |     |     | .709 |     |     |
| PUBLIC TRANSPORT 41 |     |     |     | .756 |     |
| PUBLIC TRANSPORT 43 |     |     |     |     | .922 |

**Extraction Method:** Principal Component Analysis.

**Rotation Method:** Varimax with Kaiser Normalization.

a. Rotation converged in 8 iterations.
Table 6. Descriptive Statistics of the Five-Factor Scores.

| Factor     | Proposed factor name         | Mean  | Standard Deviation |
|------------|------------------------------|-------|--------------------|
| Factor 1   | Proximity and vicinity       | 2.63  | 0.572              |
| Factor 2   | Well-maintained shelters     | 2.63  | 0.637              |
| Factor 3   | Provision of curbs           | 2.55  | 0.626              |
| Factor 4   | Bus information and facilities | 1.87  | 0.879              |
| Factor 5   | Location near road intersection | 2.90  | 0.324              |

Table 7. Eigenvalues and Sums of Squared Loadings.

| Component | Initial Eigenvalues | Extraction Sums of Squared Loadings | Rotation Sums of Squared Loadings |
|-----------|---------------------|-------------------------------------|----------------------------------|
| Total     | % of Variance       | Cumulative                          | %                                | % of Variance       | Cumulative                          | %                                |
| 1         | 3.036               | 23.355                              | 23.355                           | 23.355              | 2.196                               | 16.891                           |
| 2         | 1.681               | 12.927                              | 36.282                           | 12.927              | 1.889                               | 14.533                           |
| 3         | 1.300               | 10.004                              | 46.285                           | 10.004              | 1.651                               | 12.697                           |
| 4         | 1.117               | 8.590                               | 54.875                           | 8.590               | 1.365                               | 10.501                           |
| 5         | 1.075               | 8.272                               | 63.147                           | 8.272               | 1.108                               | 8.525                            |
| 6         | .942                | 7.242                               | 70.389                           |                     |                                     |                                  |
| 7         | .840                | 6.464                               | 76.853                           |                     |                                     |                                  |
| 8         | .757                | 5.823                               | 82.676                           |                     |                                     |                                  |
| 9         | .614                | 4.727                               | 87.403                           |                     |                                     |                                  |
| 10        | .557                | 4.286                               | 91.689                           |                     |                                     |                                  |
| 11        | .468                | 3.597                               | 95.286                           |                     |                                     |                                  |
| 12        | .361                | 2.779                               | 98.065                           |                     |                                     |                                  |

Extraction Method: Principal Component Analysis.

From Table 7, these components show a high correlation compared to the other indicators which means these indicators are significant for bus stop performance. This is related to the study made by Fitzpatrick et al. [29] where they stated that curbside elements have an impact on comfort, convenience and safety of the bus stop. Apart from that, proximity, bus shelters and time table information were among the demands made by the users for bus service quality improvement [9]. Previous studies mostly claimed that physical attributes such as accessibility, cleanliness, seat and space [30,31] significantly affected the satisfaction level of passengers regarding public bus ridership. The location of a bus stop near to the road intersection was mathematically proven to have a relationship with traffic delay as it involves the bus stopping and bus flow [32].

4. Conclusion

From the factor analysis, 13 indicators were reduced to 12 indicators consisting: PT31, PT32, PT33, PT34, PT35, PT36, PT37, PT38, PT39, PT40, PT41, and PT43. The indicators formed five components which are proximity and vicinity, well-maintained shelters, provision of curbs, bus information and facilities and location near road intersection were detected to have an impact on bus performance based on the satisfy the value of factor loadings and eigenvalues of principle component analysis. These indicators can be a reference for urban practitioners and transport engineers to improve the condition of the bus stop in the future. A well-equipped and good condition of the bus stop will attract and convince people to shift to public transport. Therefore, bus stop infrastructure and facilities should be given more attention to encourage dependency on public transport.
5. References

[1] Anable J 2005 Complacent car addicts’ or ‘aspiring environmentalists’? Identifying travel behaviour segments using attitude theory Transport policy 12(1) 65-78
[2] Khodeir M, Shamy M, Alghamdi M, Zhong M, Sun H, Costa M, Chen L C and Maciejczyk P 2012 Source apportionment and elemental composition of PM2.5 and PM10 in Jeddah City, Saudi Arabia, Atmospheric Pollution Research 3(3) 331-340
[3] Hoornweg D, Freire M 2013 Building Sustainability in an Urbanizing World: A Data Compendium for the World’s 100 Largest Urban Areas. World Bank, Washington, DC. Retrieved on 21 May 2015 from https://openknowledge.worldbank.org/handle/10986/18866
[4] Lee J 2017 Vehicle registrations in Malaysia hit 28.2 million units. Retrieved on September 1, 2019 from https://paultan.org/2017/10/03/vehicle-registrations-in-malaysia-hit-28-2-million-units/
[5] Ertugrul H M, Cetin M, Seker F and Dogan E 2016 The impact of trade openness on global carbon dioxide emissions: Evidence from the top ten emitters among developing countries Ecological Indicators 67 543-555
[6] Malaysia Motor Vehicles Registration 2017. Retrieved on August 22, 2019, from https://www.ceicdata.com/en/malaysia/motor-vehicles-registration?page=5
[7] Ministry of Transport Malaysia (MOT). Transport Statistics Malaysia 2017. Retrieved July 2, 2019, from http://www.mot.gov.my/en/Statistik%20Tahunan%20Pengangkutan/Transport%20Statistics%20Malaysia%202017.pdf.
[8] Shariff N M 2012 Private vehicle ownership and transportation planning in Malaysia. International Conference on Traffic and Transportation Engineering 64 68
[9] Rohani M M, Wijeyesekera D C and Karim A T A 2013 Bus operation, quality service and the role of bus provider and driver Procedia Engineering 53 167-178
[10] Bernal L M M D 2016 Basic parameters for the design of intermodal public transport infrastructures Transportation Research Procedia 14 499-508
[11] Chakour V and Eluru N 2013 Examining the influence of urban form and land use on bus ridership in Montreal Procedia-Social and Behavioral Sciences 104 875-884
[12] Hess P, A Vernez-Moudon, and Matlick J 2004 Pedestrian safety in transit corridors J. of Public Transportation 7(2) 73–93
[13] Hess D B 2009 Access to public transit and its influence on ridership for older adults in two US cities J. of Transport and Land Use 2(1) 3-27
[14] Estupiñán N and Rodríguez D 2008 The relationship between urban form and station boardings for Bogotá’s BRT Transportation Research Part A: Policy and Practice 42(2) 296-306
[15] Demetsky M J and Bin-Mau Lin B 1982 Bus stop location and design. Transportation Engineering Journal of ASCE 108(4) 313-327
[16] Eboli L and Mazzulla G 2007 Service quality attributes affecting customer satisfaction for bus transit J. of public transportation 10(3) 21-34
[17] Ruan M and Lin J 2009 An investigation of bus headway regularity and service performance in Chicago bus transit system. Proceedings of the 2007 Transportation Land-Use Planning, and Air Quality Conference (Orlando, Florida) Vol. 14 (Reston: American Society of Civil Engineers)
[18] Yaakub N and Napiah M 2011 Public Transport: Punctuality Index for Bus Operation World Academy of Science, Engineering and Technology 60 857-862
[19] Diab E, Bertini R and El-Geneidy A 2016 Bus transit service reliability: Understanding the impacts of overlapping bus service on headway delays and determinants of bus bunching. In the 95th annual meeting of the Transportation Research Board, Washington, DC
[20] Minhans A, Shahid S and Hassan S A 2015 Assessment of bus service-quality using passengers’ perceptions Jurnal Teknologi 73(4)
[21] Pelan Induk Pengangkutan 2013 Penang Transport Master Plan, Retrieved February 22, 2017 from http://pgmasterplan.penang.gov.my/index.php/ms/2016-02-26-03-12-57
[22] Chhavi Dhingra 2011 Measuring Public Transport Performance, Lessons for Developing Cities, Sustainable Urban Transport Technical Document. (Eschborn: Federal Ministry for Economic and Development)

[23] Murray A T, Davis R, Stimson R J and Ferreira L 1998 Public transportation access. Transportation Research Part D: Transport and Environment 3(5) 319-328

[24] Kementrian Perumahan Dan Kerajaan Tempatan 2012 Garis Panduan Perancangan Kejiranan Hijau (Kuala Lumpur: Jabatan Perancangan Bandar Dan Desa Semenanjung Malaysia)

[25] Jabatan Kerja Raya 1986 A Guide on Geometric Design of Roads (Arahan Teknik Jalan 8/86)

[26] Institute of Transportation Engineers 2010 Designing Walkable Urban Thoroughfares: A Context Sensitive Approach, (Washington: Institute of Transportation Engineers)

[27] West Sussex County Council Transport Assessment Methodology 2007 West Sussex County Council

[28] Field A 2009. Discovering statistics using SPSS. Sage publications.

[29] Fitzpatrick K, Perkinson D and Hall K 1997 Findings from a survey on bus stop design J. of Public Transportation 1(3) 2

[30] Foote P J and D G Stuart 1998 Customer Satisfaction Contrasts: Express Versus Local Bus Service in Chicago's North J. of the Transportation Research Board: Transportation Research Record 1618(1) 143 – 152

[31] Bureau of Transport Statitics, 2011 Transport Customer Survey Train, Bus and Ferry. 2 (New South Wales Government) pp. 28

[32] Yang X G, XU H, Long K J and Tan Z X 2009 The Effects of Bus Stops on Capacity of Neighboring Lanes J. Systems Engineering 8

[33] Loukaitou-Sideris A 1999 Hot spots of bus stop crime: The importance of environmental attributes J. of the American Planning association 65(4) 395-411

[34] Kwami A V, Kuan Y X and Zhi X 2009 Effect of bus bays on capacity of curb lanes J. of American Science 5(2) 107-118

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