The school bus route development using supply-demand competition based accessibility: Surabaya case study

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Abstract. Research has shown that educational transportation can worsen congestion to 5.85%. In Surabaya, 88% of school trips are of automobiles. The school bus is among one of the bus-pooled strategies have made to reduce this automobile dependence. However, the limited bus coverage area and routes limited the services; thus, the buses’ modal share is low. The purpose of this research is to formulate the development guidelines of school bus service routes as the recommendation to improve the school bus services in Surabaya. A supply-demand competition based accessibility to school bus services was used as the main method of analysis. This research found that there are 167 schools in Surabaya that can be served by the school bus services. Furthermore, this research formulates eight new routes of school bus services in Surabaya which can enhance the school bus services’ coverage up to 52% out of the total number of schools, an increase of 19% from the current route services level.

1. Introduction

Education trips in urban areas consisted of home-based trips to and from schools or campuses, to everyone aged between 5 to 22 years. In developing countries, the number of population in within that range is 85% of total population. There are some factors, which influence the education trips⁴:

- The availability of technology, such as the automobiles.
- The expectation of parents that their children could get a good education, even though they need to travel longer.
- Time budget or limitation, in which people will choose to make a shorter travel due to time limitation,
- The potential risks to children in their education trips.

The school location determines its easiness to reach, i.e. the accessibility. According to [1], schools are not only responsible to educate students properly, but also to help the parents in students’ mobility by providing a good school’s transportation system. The aim of the school’s transportation services is to deliver effective and efficient services to all students due distance, making a spatial separation between students and schools (Atkinson in [2]). In the regulation of the Director General of Land Transportation No. SK.967 / AJ.202/ DRJD2007: in delivering effective and efficient transportation services to schools, factors to consider consisted of the distance and travel time, the production and attraction trips to and from schools, and the road classes that serve schools.

⁴ LPM – ITB, 1996
Furthermore, mode choices in education trips had been perceived to closely related with distance and travel time. Therefore, the accessibility to the school determines the mode choices [3]. Accessibility is referred to the easiness or convenience that a location of land use is interacted with one another, through the transportation infrastructure [4]. Accessibility measures consisted of travel time, costs, and all transportation efforts between areas in an urban system [5]. Accessibility means an easiness to get or reach goods, services, activities, and destination. They may be called opportunities, i.e. the potential in interaction and trade off [6].

The number of network or network density in a location determines the accessibility level. The denser the network and the easier a location can be reached, the higher the accessibility [7]. Some factors influence accessibility [8] included:

- Transport demand
- Mobility
- Transport options
- User information
- Integration among the transport system links and the modes
- Affordability
- Mobility substitution, such as telecommunication and delivery services
- Land uses
- Transport network connectivity
- Transport management
- Prioritization

The accessibility determinant in the education trips consisted of: distance, the transportation system, and the travel ground [9]. Accessibility measures consisted of distance, travel time, cost of travel, public transport availability, land uses, and average speed ([10], [11]).

The mode share of education trips in Surabaya consisted of 88% automobiles and 12% public transport [12]. Surabaya provided the school bus services as part of the Transport Demand Management (TDM), recently operating with five car buses, encompassing four routes and carrying around 150 students daily. (See figure 1: bus route services).

Studies showed that the provision of school buses affected congestion, such as in Jakarta; it can reduce the congestion level up to 5.85% [13]. Meanwhile, the interests of students to use this service, especially in Surabaya, is 57% out of students being surveyed [14]. However, the limited route
coverage of school buses constraints the benefit of this service to urban area. This study aims to extend the potential school bus routes in Surabaya, using an accessibility criterion, based on the supply-demand competition.

2. Research Method

The method used in this study followed the supply-demand competition based accessibility in [15]. To understand the demand and supply of school bus services, a primary survey on current school bus services characteristics was carried out. The primary survey used a saturated sampling, i.e. all 3 routes being sampled, with a total of 67 students. From this survey, the distances and travel times of school bus services were measured, the number of schools being served was recorded, the road classes and the catchment of route services were identified. To measure demand and supply, the interaction between the origin (residential zones in all districts) and the destination (school zones in all districts) were identified, based on the distances and travel times between origins and destinations in all districts, resulted in matrix of origin-destination travel impedances. The demographic data of all the districts was collected from Biro Pusat Statistik or BPS Surabaya; meanwhile, the number of students in each school was collected from Department of Education, Surabaya.

2.1. Identification of schools

The regulation of the Director General of Land Transportation No. SK.967 / AJ.202/ DRJD2007 (the technical guidance of the School Buses Service Delivery, Department of Transportation, 2007) was used to determine which schools were eligible into which the school bus routes can serve. The criteria of schools that are eligible for bus school service are: the schools that are located on the road with at least an IIIB road class with the road function is collector. ArcGIS was used to measure the distance between the school points and the nearest IIIB roads. Based on the 400 meters catchment [16], the buffering technique was used, in which the points of schools inside the buffer were identified (167 schools, figure 2) and were choose as case studies.

2.2. Identification of Demand of School Bus Services

Identification of demand of school bus services followed equation 1 [17]. ArcGIS was used to measure the area of residential that can be served by bus services, i.e. the residential areas served by collector and arterial roads. Buffering these areas based on 400 meters from road services produced a
catchment of potential bus school services according to [16]. The demand was then calculated based on this equation. The process of analysis is illustrated in figure 4.

\[
S_{\text{load}} = \sum_{i} N \left( \frac{A_{\text{load}}}{A_{\text{load}} + S_{\text{load}}} \right)
\]

**Public Transport Supply Index Formula**  
*Source: Currie (2010)*

- **Input**:  
  - Sub – district residential area  
  - The total residential area covered by roads  
  - The population of school aged resident

- **T**  
  - Transportation area that can be served by bus service in sub – district i (400m buffer area from roads used by the base service)  
  - The total residential area in sub – district i  
  - The population of school aged resident in sub – district i

- **SL**  
  - Service Level Measure

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**Figure 3. Transport Demand Level Formula**  
*Source: Adaptation from [17]*

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**Figure 4. Spatial analysis process on identifying residential area inside the bus services coverage**

### 2.3. Identification of Supply of School Bus Services

Identification of supply of school bus services followed equation [15]. The responds from the primary survey was used to set the maximum Travel time or \( T_{\text{max}} \) that the student has experienced to reach school from their home. The number of school capacity was calculated based on the travel impedence matrices, with buffering technique in ArcGIS. The process of analysis is illustrated in figure 6.
Figure 5. Transport Supply Level Formula
Source: Adaptation from [15]

\[ A_{\text{Jobs}_i} (T \leq T_{\text{max}}) = \sum_{j=1}^{n} \frac{\text{Jobs}_j}{T_{ij}} \]

**Accessibility Formula**

Source: van Wee (2001)

**Transport Supply Level**

\[ \text{Transport Supply Level } i (T \leq T_{\text{max}}) = \sum_{j=1}^{n} \frac{\text{Jobs}_j}{T_{ij}} \]

**Transport Supply Level Formula**

Source: Adaptation from van Wee (2001)

Note:
- \( A_{\text{Jobs}_i} \) = The accessibility of jobs within a certain time \( T_{\text{max}} \) from zone \( i \).
- \( n \) = All zones \( j \) within \( T_{\text{max}} \) from zone \( i \).
- \( \text{Jobs}_j \) = The number of jobs in zone \( j \).
- \( T_{ij} \) = The travel time between zones \( i \) and \( j \).

**Input:**
- Student capacity from every schools
- Travel Distance between the center of sub district and School node

**Figure 6. Identifying the maximum travel distance for one educational trip**

2.4. The Supply-Demand Competition Based Accessibility of bus school route extension

The results from the previous analyses were used as the main input for this stage. The method followed equation [15]. The route prioritization was identified at this stage. The equation and illustration of the analysis is described in figure of equation 3 and map process in figure 8.
3. Results and Discussion

The analysis was started by determining the maximum distance of bus school services. It was found that the school bus travelled to serve 25 km routes at maximum. Based on the existing services, the average speed of bus school services was about 40 km per hour, in which the in-vehicle travel times was around 45 minutes.

The demand analysis reported three districts with the highest demand for bus services were: Semampir, Wonocolo and Wonokromo district. To determine the starting point of the new alternative...
route services, Semampir and Wonokromo districts were chosen, since the Wonocolo district was already served by the existing bus school services (Figure 9).

![Figure 9. Accessibility of Sub – Districts Demand Level Map](image1)

The results of the supply analysis gave direction on where to these route extension to be developed. The analysis found three districts with the highest potential of bus school services, i.e. Genteng, Tegalsari and Simokerto district. (Figure 10).

![Figure 10. Accessibility of Sub – Districts Supply Level Map](image2)
The alternative route extension was determined by considering the road segment and road class, the number of schools (school capacity) in within the buffer of supply of bus service catchment, and whether or not the roads are already served by the existing services. The final results found eight new routes to serve 87 new schools in addition to the existing 31 schools, accounting in total 71% of bus school service coverages.

**Figure 11.** Illustration of selecting starting point process, by considering the sub-districts with the highest educational trip demand level

**Figure 12.** Illustration of route development process, by considering the highest supply level of educational trip

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As the sub-district with the highest demand level, Wonomerto and Seranggren is selected as the school bus departure place. Both of the sub-district also located in the middle of the city, with high route development potential.
Figure 13. Alternative route map recommendation
To determine the prioritization among these new 8 alternative routes, the total accessibility value was measured based on the competition based of accessibility criterion. The results is reported in Table 1.

| Route ID | Priority | Accessibility value | The number of school served | The % of bus school service coverage improved |
|----------|----------|----------------------|------------------------------|---------------------------------------------|
| 3        | 1        | 246.8                | 42                           | 32 (19%)                                    |
| 6        | 2        | 242.1                | 34                           | 29 (17%)                                    |
| 5        | 3        | 208.1                | 39                           | 29 (17%)                                    |
| Existing route c | n/a | 180.3                | 20                           | n/a                                         |
| 4        | 4        | 156.5                | 37                           | 27 (16%)                                    |
| 7        | 5        | 135.0                | 39                           | 34 (20%)                                    |
| 8        | 6        | 124.6                | 31                           | 27 (16%)                                    |
| 2        | 7        | 123.2                | 21                           | 21 (13%)                                    |
| Existing route a | n/a | 121.0                | 13                           | n/a                                         |
| 1        | 8        | 111.8                | 22                           | 22 (13%)                                    |
| Existing route b | n/a | 21.0                 | 11                           | n/a                                         |

4. Conclusion
This study found among the 650 schools, 167 schools could be served by school bus services. Considering the area of residential land use, the size of the school age population, and the road network distribution, high demand for bus school services found in the following districts: Semampir, Wonocolo, Wonokromo, Krembangan, Genteng, Bubutan, Sukomanunggal, Tambaksari, Gubeng, Sukolilo, dan Sawahan. Further, considering the school capacity and the distance of bus services or catchment area, high supply for bus school services found in the following districts: Genteng, Tegalsari, Simokerto, Tambaksari, Bubutan, Genteng, Sawahan, Wonokromo, Pabean Cantian, Krembangan, dan Sukomanunggal. Considering the level of these demand and supply and the maximum route services at 25 km, 8 (eight) new school bus routes were recommended. These new services will increase the total services for 87 potential schools, thus extend the bus school service coverage by 52% in Surabaya City.

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