The factors influencing the modal choice for home-to-school trips based on neighborhood unit typology towards Surakarta as a child-friendly city

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Abstract. The children movement in accessing elementary school as social facilities on the neighborhood unit (NU) level should not contribute to CO₂ gas emissions. Yet, in 2017, these movements produced an average emission of 0.15% of the total emissions of the transportation sector in Surakarta. The higher degree of conformity of the NU with the criteria of the child-friendly city (CFC), the greater the chances of children being able to access elementary school without using motorized modes of transportation. This article aims to uncover the factors that affect children’s transportation modal choice to access elementary schools in supporting Surakarta to become a CFC. The study uses four stages: (1) NU's conformity to the criteria of CFC; (2) children’s modal choice to access elementary school; (3) the characteristics of factors that influence modal choice in accessing elementary school; and (4) the factors of modal choices to access elementary school. The study found two distinct categories of modal choice priorities based on the NU typologies which must be considered in efforts to establish Surakarta as a CFC. In one category the transportation system dictates priorities while user characteristics and movement characteristics affect modal choices in the second category of neighborhood units.

1. Introduction
Neighborhood units are the smallest residential units in the city. As such, the inability of neighborhood units to serve the needs of its population - including the social needs of the children - would disrupt the overall development of the city [1]. Therefore, the availability of child-friendly social facilities at the scale of the neighborhood unit (NU) is an important criterion in realizing a child-friendly city. This is the case because children have limited ability of independent movement compared to adults [2].

Elementary schools are social facilities for children that must be available in a neighborhood unit because children attend elementary schools daily. In the concept of the ideal neighborhood unit, the elementary school is the central unit of the neighborhood. It is the basis for determining the size of the neighborhood unit as this size is based on the distance a child can walk to school [3-5]. The availability of elementary schools in each neighborhood unit allows children to access basic education
services independently on foot. Conversely, when elementary schools are unavailable, children rely on transportation modes to access education services, in turn creating a rise in daily motorized movement [6]. Transportation produces air pollutants such as CO₂ and NO₂. The emission of these greenhouse gases is one of the triggers of climate change [7]. Neighborhood units need to meet certain criteria for children to be able to access elementary schools as a social facility in the context of the child-friendly city. These criteria include (1) the capacity of elementary schools to provide services to the population of the neighborhood unit, (2) security and enjoyment for in accessing schools, and (3) the opportunity for all children including with disabilities to access elementary schools [2, 8-10].

Surakarta was one of the cities that ranked in the highest category for child-friendly cities in 2017. The city had 263 elementary schools comprising public schools, private schools, Madrasah Ibtidaiyah (MIIs), and schools for children with disabilities (SLB). However, sixty-seven percent of elementary school children in Surakarta attend schools outside their neighborhood unit. In addition, forty percent of the elementary school children attending school inside their own neighborhood unit used motorized vehicles to go to school [11]. This indicates that the majority of children attended schools outside their neighborhood unit and used motorized vehicles to access their schools although elementary school facilities were available within their neighborhood units. As a result, the children’s movement in accessing elementary schools that should not contribute to CO₂ gas emissions, in fact, produced an average emission of 1,463 tons/day or 0.15% of the total emissions of the transportation sector in Surakarta [11].

In addition to compliance with the criteria of child-friendly neighborhood units, there were other factors that influence the choice of mode of transportation to access elementary schools [11]. Based on the concepts of demand and supply of transportation and children’s decision making, there are twenty-one factors that influence the children’s modal choice in accessing elementary schools, comprising (1) parents’ vehicle ownership; (2) parents’ driving license ownership; (3) family size; (4) household structure; (5) parents’ job; (6) parents’ income; (7) parents’ age; (8) parents’ gender; (9) number of workers in the family; (10) parents’ destination of journey; (11) time of trip to school; (12) distance to school; (13) travel time to school; (14) travel cost to school; (15) modal pleasure according to parent experience; (16) modal safety according to parent experience; (17) modal reliability and regularity according to parent experience; (18) parking facilities at schools; (19) time efficiency of traveling to school; (20) separation of pedestrian paths and motor vehicles according to parental knowledge; and (21) children’s safety crossing the road according to parental knowledge [12-22]. It is important to identify the factors that influence the modal choice in accessing elementary school for each type of neighborhood unit in Surakarta, as a foundation for developing Surakarta as a child-friendly city.

2. Methods

This article aims to find out the factors that affect children’s transportation modal choices in accessing elementary schools to realize the goal of Surakarta as a child-friendly city. To achieve this objective, the research for this paper followed four stages: (1) identifying neighborhood units’ conformity to the criteria of child-friendly city; (2) identifying children’s modal choice to access elementary school; (3) identifying of the characteristics of factors that influence modal choice in accessing elementary school; and (4) factor analysis of modal choices to access elementary school. The analysis techniques to uncover this information consist of superimposed map analysis techniques, scoring, and factor analysis. The study used primary data derived from field observations and questionnaires. The respondents were the parents, which assume that the decision of the children in choosing the elementary school and their transportation modal choice was depended on their parents. A total of 168 samples were obtained using the Slovin formula and divided by proportionate random sampling in each classified NU typology. The literature states that the size of neighborhood units is based on the distance from elementary schools [3-5]. Therefore, this paper determines the neighborhood units in Surakarta as the buffer area around elementary school services with a number of citizens equal to that in the Rukun Warga based on Indonesian government regulations.
2.1. The suitability of the neighborhood unit with the criteria of a child-friendly city
The neighborhood unit typology refers to neighborhood unit characteristics based on the criteria of the child-friendly city, covering the capacity of elementary schools to provide services to the population of the neighborhood unit (C1), safety and enjoyment for children in accessing social infrastructure (C2), and the ability to access elementary schools by all children including those with disabilities (C3) (See Table 1) [11]. The analytical techniques used to develop the neighborhood unit typology were superimposed maps and scoring.

Table 1. Neighborhood unit typology formulation.

| Criteria 1 (C1) | Criteria 2 (C2) | Criteria 3 (C3) | Typology Classification |
|----------------|-----------------|-----------------|-------------------------|
| NS             | NS              | NS              | 1                       |
| S              | NS              | NS              | 2                       |
| NS             | S               | NS              | 3                       |
| NS             | NS              | S               | 4                       |
| S              | S               | NS              | 5                       |
| S              | NS              | S               | 6                       |
| NS             | S               | S               | 7                       |
| S              | S               | S               | 8                       |

S = suitable, NS = not suitable

2.2. The preferences of children’s modal choice in accessing elementary schools in each neighborhood unit typology
The preference for the modal choice is identified based on the tendency of transportation modal used by children in accessing elementary school. The transportation modes are classified into two types: motorized vehicles (motorcycles, public transportation, gasoline-fueled cars, and diesel-fueled cars) and non-motorized modes of transportation (walking, bicycle, and pedicab) [11].

2.3. The characteristics of modal choice factors in accessing elementary schools
The aim is to uncover the characteristics of the factors that influence the modal choice in accessing elementary schools in each neighborhood unit typology. The study identifies twenty-one factors that influence the children’s modal choice in accessing elementary schools, as mentioned in introduction section above.

2.4. The priority factor for modal choice in accessing elementary schools to establish Surakarta as a child-friendly city
The study uses factor analysis with SPSS software to determine the factor of children’s transportation modal choice in accessing elementary schools in each NU typology. Factor analysis is a multivariate statistical technique used to reduce and summarize all dependent and interdependent variables [23].

3. Results and discussion
3.1. The suitability of the neighborhood unit with the criteria of the child-friendly city
Based on the three criteria of child-friendly neighborhood units as discussed in section 2.1, the neighborhood units in Surakarta can be classified into seven out of the eight possible NU typologies (See Figure 1) [11]. Only two neighborhood units (1.83%) in Surakarta fulfill all three criteria of child-friendly neighborhood units, while 44.95% (49 neighborhood units) does not meet all criteria. This indicates that the ideal situation of Surakarta as a child-friendly city has not been realized at the neighborhood unit level.
3.2. The preferences of children modal choice in accessing elementary school in each neighborhood unit typology

The use of motorized transportation modes, especially motorcycles, dominates preferences in accessing elementary schools in Surakarta. This is because not all areas of the city can accommodate elementary school-age children to access their schools on foot safely and comfortably according to their physical abilities [2]. Ironically, more than fifty percent of children of NU typology 8, which meets all criteria for child-friendly neighborhood units, use motorized vehicles to access elementary schools (See Figure 2) [11]. This phenomenon indicates that other factors influence the preference for motorized transportation modes in accessing elementary schools, in addition to the criteria for neighborhood units to be child-friendly.
3.3. The characteristics of modal choice factors in accessing primary schools

There are twenty-one factors that influence children’s modal choice in accessing elementary schools in Surakarta. The characteristics of each factor are derived from questionnaires with the children’s parents, as the study assumes that the decision of choosing the elementary school and choice of mode of transportation depends on the parents. The characteristics of the twenty-one factors in the neighborhood units of Surakarta are as follows:

- **Parents’ vehicle ownership.** Almost all parents of elementary school children own motorized vehicles, except in NU typology 1. Only four percent of parents do not have motorized vehicles. This will increase the likelihood of children accessing elementary schools using motorized vehicles.

- **Parents’ driving license ownership.** Most parents have a driving license, at eighty-one percent. The ability to legally drive a motorized vehicle based on having a driving license can encourage the choice of using a motorized vehicle mode to bring children to school.

- **Family size.** Family size varies from three to six people, with most families numbering four or five family members. The greater number of children will increase the preference for using motorized vehicles to access schools because parents drop off and pick up several children at once. Families in Indonesia generally prefer to use motorized vehicles regardless family size. Although not all families have a car that can accommodate all family members if the family size is large, most families have more than one motorcycle because of the convenience of this mode of transportation.

- **Household structure.** The family structure is dominated by the nuclear family; ninety-three percent of households consist of a father, mother, and two children. A complete family structure allows one parent to bring the child to school.

- **Parents’ job.** More than fifty percent of the parents of elementary school children work as laborers or private employees. Jobs that have regular work hours and workdays that start at almost the same time as school hours can encourage parents to drop off and/or pick up children when they go to work or are on their way home from work.

- **Parents’ income.** Most parents’ income is in the range of IDR 1,500,000 - IDR 3,000,000 which is higher than the minimum wage in Surakarta. This enables for each family to allocate a budget for motorized vehicle ownership.

- **Parents’ age.** The largest percentage of parents’ age ranges between 31-40 and 41-50 years. At this age range, parents are still working actively, so it is possible to take their child to school during a trip to work.

- **Parents’ gender.** There is a balance between fathers and mothers in taking their children to school. This is because in most families both parents work, so travel to and from school can be done simultaneously with trips to work.

- **Number of workers in the family.** In most families, two people work, namely the father and mother. This is in line with the characteristics of the parents who take the role of taking the child to elementary school.

- **Parents’ destination of journey.** There is a balance between children traveling to and from elementary school between concurrent or travel not with their parents. This indicates that some of the children use motorized vehicles in accessing schools during single trips that contribute to CO₂ emissions.

- **Time of trip to school.** The majority of trips to school occur from 06:00-07:00 while the time of returning from school varies depending on the grade level of the child. On the way to school it is possible to go to school at the same time as parents' trip to work, while at the time of going home, the opportunity for a single movement is greater.

- **Distance to school.** The average distance to school for children who attend schools in their neighborhood unit is 283 meters (category 200-300 meters), while children who attend an elementary school outside their neighborhood unit need to travel 1587 meters to school on
average (category >800 meters). In this case, sixty-seven percent of children who attend schools outside of the neighborhood unit where they live cannot reach their school on foot, thus increasing the preference for using motorized vehicles.

- **Travel time to school.** The travel time for most children to access elementary school is in the categories of 0-5 minutes and 6-10 minutes. This travel time is calculated by respondents who use different modes of transportation (motorized and non-motorized). As such, this indicator does not identify the maximum time that children are able to walk to reach their school.

- **Travel cost to school.** The travel cost of accessing elementary schools incurred is generally between IDR 0 - IDR 2000. This is the case for both non-motorized (walking and bicycle) or motorized transportation, which is calculated from the cost of fuel. This fee is considered cheap and can encourage the use of motorized vehicles in accessing elementary schools.

- **Modal pleasure according to parent experience.** Over ninety percent of parents in each NU typology feel comfortable with the choice of motorized vehicle modes in accessing primary schools.

- **Modal safety according to parent experience.** More than eighty percent of parents consider the mode used by their children to access elementary school to be safe. They consider the mode of transportation both safe from accidents and free from crime, including for children who go to school using motorized vehicles.

- **Modal reliability and regularity according to parent experience.** Important factors that influence the modal choice are the availability of the modes of transportation at any time and the ability to reach schools in a short time. Over eighty percent of parents in Surakarta felt that the motorized vehicle used to take their children to school could fulfill these requirements.

- **Parking facilities at schools.** Almost all elementary schools in Surakarta provide parking facilities for students, teachers, and employees, as well as for dropping off and picking up children.

- **Time efficiency of traveling to school.** Time efficiency refers to the timeliness of the mode of transportation to access school. More than eighty-five percent of respondents in each typology state that the mode used to access elementary schools is time-efficient.

- **Separation of pedestrian paths and motor vehicles according to parental knowledge, and children's safety crossing the road according to parental knowledge.** Based on the questionnaire, more than seventy percent of all of the neighborhood units in Surakarta fulfill both factors, so it can be interpreted that the majority of the road network can provide safety and comfort for children to walk. However, this is contrary to observations that found that only six out of 109 neighborhood units meet the criteria for safety and comfort for children in accessing elementary school. This indicates that parents lack sufficient knowledge about the road network that connects homes and primary schools, as well as the criteria of children’s safety and comfort in accessing schools.

3.4. The prior factor for modal choice in accessing elementary schools to establish Surakarta as a child-friendly city

The difference in factors that affect each neighborhood unit typology is influenced by each characteristic of the neighborhood unit typology. Table 2 shows various groups of factors formed in each typology (see Component column) based on factor analysis. The number of factors is based on the Initial Eigenvalue of more than 1 (see Total column), Group Factor 1 (showed by component 1 from each NU typology) with the highest value of data diversity is the prior factor that influences modal choice in accessing primary schools in Surakarta (see Table 3).
Table 2. Summary of total variance explained for each NU typology

| Typology | Component | Initial Eigenvalues | Typology | Component |
|----------|-----------|---------------------|----------|-----------|
|          |           | Total               | % of Variance | Cumulative % |          |           | Total               | % of Variance | Cumulative % |
| 1        | 1         | 4.511               | 16.707 | 16.707 | 1        | 5.254               | 21.018 | 21.018 |
|          | 2         | 2.452               | 9.080  | 25.787 | 2        | 3.454               | 13.814 | 34.832 |
|          | 3         | 2.230               | 8.260  | 34.047 | 3        | 2.846               | 11.384 | 46.216 |
|          | 4         | 2.099               | 7.773  | 41.820 | 4        | 2.293               | 9.174  | 55.390 |
|          | 5         | 1.742               | 6.452  | 48.272 | 5        | 2.015               | 8.061  | 63.451 |
|          | 6         | 1.506               | 5.578  | 53.851 | 6        | 1.760               | 7.039  | 70.490 |
|          | 7         | 1.387               | 5.135  | 58.986 | 7        | 1.508               | 6.033  | 76.523 |
|          | 8         | 1.220               | 4.917  | 63.503 | 8        | 1.117               | 4.467  | 80.990 |
|          | 9         | 1.144               | 4.517  | 67.739 | 9        | 1.075               | 4.301  | 85.292 |
|          | 10        | 1.069               | 4.517  | 71.699 | 10       | 1.024               | 4.301  | 85.292 |
| 2        | 1         | 5.297               | 20.375 | 20.375 | 1        | 5.614               | 22.457 | 22.457 |
|          | 2         | 2.988               | 11.493 | 31.868 | 2        | 3.216               | 12.863 | 35.320 |
|          | 3         | 2.620               | 10.078 | 41.946 | 3        | 2.921               | 11.686 | 47.006 |
|          | 4         | 1.965               | 7.559  | 49.505 | 4        | 2.700               | 10.799 | 57.804 |
|          | 5         | 1.866               | 7.178  | 56.683 | 5        | 2.272               | 9.089  | 66.894 |
|          | 6         | 1.681               | 6.465  | 63.148 | 6        | 1.846               | 7.383  | 74.277 |
|          | 7         | 1.485               | 5.711  | 68.859 | 7        | 1.570               | 6.281  | 80.558 |
|          | 8         | 1.194               | 4.594  | 73.452 | 8        | 1.241               | 4.965  | 85.523 |
| 3        | 1         | 12.000              | 100.000| 100.000| 1        | 10.000              | 100.000| 100.000|

* Taken from the SPSS Output Table

There are two categories of NU typologies in Surakarta that have similarities related to the prior factor selection in accessing elementary schools. The first category is of NU typologies 1, 2, 4, and 6. Priority factors that influence modal choices in accessing elementary schools include the travel cost to school; distance of travel to school; time of trip to school; modal safety; modal pleasure; time efficiency of traveling to school; and modal reliability and regularity. This means that the modal choice preferences in accessing elementary schools in the NU typologies 1, 2, 4, and 6 are mostly influenced by the characteristics of the transportation system. This finding is in line with the theory that the quantitative and qualitative characteristics of the transportation system influence modal choices [16-17]. Quantitative factors include travel time, travel costs, and accessibility index. The use of motorized vehicles, especially motorbikes is considered capable of reducing travel time, travel costs, and providing ease of accessibility in accessing elementary schools. This is because more than sixty percent of children attend an elementary school outside their neighborhood unit, with an average distance of more than 1.6 km [11]. In addition, the qualitative factors of the transportation system, namely safety, comfort, reliability and regularity of modes, are prior factors, where motorized vehicles are considered to best meet these criteria in accessing elementary schools at an average distance of 1.6 km.

Judging from the characteristics of NU typologies 1, 2, 4, and 6 on the criteria for the child-friendly city, no neighborhood unit meets the criteria of safety and enjoyment for children in accessing social infrastructure (C2). Many studies, including research result of neighborhood unit in Malaysia, show that the propensity of the children to walk and cycle was significantly affected by how safe, enjoyable,
convenient, and pleasurable the experience of walking and cycling was [24]. Neighborhood design also plays a role in promoting community safety and might impacting parental fear [25]. This is one of the reasons why most children attend schools outside their neighborhood unit and use motorized vehicles to access elementary schools. The lack of safety and comfort for children to walk to elementary schools makes the availability of elementary schools within the neighborhood unit is no major factor that influences elementary school preferences. Parents will tend to choose schools that meet certain criteria, even if they are not within their child’s walking distance from school. This leads to children accessing schools that can only be reached using motorized vehicles. This finding is in line with the study by Saputri et al [26] that found that the fulfillment of child-friendly school criteria is a priority factor in selecting elementary schools in Surakarta, rather than location factors. If the child-friendly school criteria would be fulfilled, this could change walking preferences in accessing elementary schools. In fact, if all children attending elementary schools in the NU typologies 1, 2, 4, and 6 would walk to school in their own neighborhood unit, this could reduce CO₂ emissions generated by trips to school in Surakarta by 17.5% [11].

**Table 3.** The priority factor of modal choice preference in accessing elementary schools.

| Typology of Neighborhood Units (NU) | 1 | 2 | 3 | 4 | 5 | 6 | 8 |
|------------------------------------|---|---|---|---|---|---|---|
| **cost of travel to school;**      | distance to school; | parents’ driving license ownership; | modal number of workers in the family; | modal parents age; | parents’ age; | parents’ job; | travel time to school; |
| **modal safety;**                  | modal           | parents’ age;                  | modal safety;                    | modal parents age; | parents’ age; | travel time to school; | cost of travel to school; |
| **modal pleasure;**                | safe;           | parents’ job;                 | modal pleasure;                  | modal parents age; | parents’ age; | school;          | parents’ gender; |
| **time efficiency of traveling to** |            | parents’ income;              | time efficiency of traveling to school; | total income;       | travel time to school; | separation of pedestrian paths and motor vehicles according to parental knowledge; | separation of pedestrian paths and motor vehicles according to parental knowledge; |
| **school;**                        | modal           | time of trip to school;       | travel time to school;            | modal total income; | modal travel time to school; | cost of travel to school; | separation of pedestrian paths and motor vehicles according to parental knowledge; |
| **modal reliability and regularity**| reliability;    | efficiency of traveling to school; | modal reliability and regularity | modal time of trip to school; | modal reliability and regularity | cost of travel to school; | separation of pedestrian paths and motor vehicles according to parental knowledge; |
| **regularity**                     | efficiency of traveling to school; | parents’ gender; | separation of pedestrian paths and motor vehicles according to parental knowledge; | modal reliability and regularity | cost of travel to school; | parents’ gender; | separation of pedestrian paths and motor vehicles according to parental knowledge; |
| **prevalence**                     |                  | according to parental knowledge; | modal safety;                  | modal reliability and regularity | cost of travel to school; | parents’ gender; | separation of pedestrian paths and motor vehicles according to parental knowledge; |
| **parental knowledge**             |                  | parents’ destination of journey | modal reliability and regularity | cost of travel to school; | parents’ gender; | separation of pedestrian paths and motor vehicles according to parental knowledge; | separation of pedestrian paths and motor vehicles according to parental knowledge; |

The second category contains NU typologies 3, 5, and 8. The priority factors for modal choice preferences in this category are parents’ ownership of a driving license, age of parents, type of work of parents, total income, distance to school, time of trip to school, travel time to school, parents’ gender, separation of pedestrian paths and motor vehicles, vehicle safety, and parents’ travel destination. The linkage between the factors in this second category is the similarity of the characteristics of road users and the characteristics of the movement that affect the choice of motorized modes of children in accessing primary schools in Surakarta. This condition is in line with two of the four factors that influence modal choice preferences as proposed by Tamin [15].

The characteristics of parents and motor vehicle ownership greatly influence the modal choice in accessing elementary schools in Surakarta. The dominance of these two factors is the reason that the availability of primary schools is not a priority factor for determining modal choices within neighborhood units where children live within walking distance from school. This is indicated by the average distance that children need to travel to access schools in NU category 2 that is closer than in NU category 1, which is less than 1.5 km [11]. On the other hand, the use of motorized vehicles is higher in NU category 2.
The second NU category has higher suitability to the child-friendly city than NU category 1. All NUs meet the criteria for safety and enjoyment for children in accessing social infrastructure (C2). The high preference for the modal choice of motor vehicles, especially motorcycles, indicates that the factor of mode choice must be considered to establish Surakarta as a child-friendly city, in addition to compliance of neighborhood units with child-friendly criteria. The availability of motorized vehicles makes the distance factor in accessing elementary schools not a priority in modal choices. In this case, another factor is needed besides the child-friendly criteria of neighborhood units that can make parents select primary schools within a child's walking distance. As such, the use of motorized vehicles is not needed. The government must raise the quality of all elementary schools and ensure all neighborhood units fulfill child-friendly criteria. As such, if all children in NU typologies 3, 5, and 8 would walk to school in their own neighborhood unit, this could reduce CO₂ gas emissions generated by trips to school in Surakarta by 14.84% [11].

4. Conclusion
A high percentage of children's movements in accessing elementary schools use motorized vehicles, even in the NU typologies that meet the three criteria for child-friendly neighborhood units. This shows that the factor of modal choice must be considered in efforts to establish Surakarta as a child-friendly city. The neighborhood units can be divided into two distinct groups based on modal choice priorities. The transportation system is the priority factor for modal choice in the NU typologies 1, 2, 4, 6 with NU characteristics that are not supported by safe and comfortable accessibility for children. This indicates that the internal transportation system within neighborhood units must consider children's needs, in addition to providing good quality schools. In category 2, comprising the NU typologies 3, 5, and 8, the priority factors for modal choice are user characteristics and movement characteristics. Notably, the characteristics of parents and vehicle ownership strongly influence the use of motorized vehicles in accessing elementary schools, even though each neighborhood unit in this category meets the criteria of accessibility for children. Therefore, raising the quality of schools in each neighborhood unit could make the preference for elementary schools on walking distance from home as the main priority in selecting schools, so that the use of motorized vehicles is not needed. Changes in preferences for elementary schools on walking distance from home in each of the NU typologies will reduce the average CO₂ gas emissions by 16.18%.

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