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INTEGRATED NAVIGATOR TECHNOLOGY FOR ROUTE AND PUBLIC TRANSPORTATION IN RURAL AND UNDERDEVELOPED REGIONS

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Abstract. *Lack of public transportation access and availability is one cause of poverty in rural and underdeveloped regions. Well managed and integrated public transportation will be an important thing for achieving sustained economic growth and a reduction in rural poverty. Purpose of this study is to provide an application that can help people to access information of public transportation routes in rural and underdeveloped regions. In addition, people will also get information about cost and distance estimation. Methodology used in this study is Waterfall which consists of data collection, design and analysis, development, and evaluation. Result of this study is an application that provides public transportation routes shown on the map, so that users can reach the initial shuttle point from his/her current position to the destination point.*
Keywords: Navigator, Route, Public transportation, GPS, Rural region, Underdeveloped region

1. **Introduction.** Rural area is an area that is located outside towns and cities. Underdeveloped area is an undergone development area by government with lower intensity and degree of development than rural area. Both rural area and underdeveloped area are facing problems, such as poverty. The causes of its poverty are complex and multidimensional, such as policy, culture, climate, gender, market, and transportation [1]. Public transportation is one solution recognized as an important thing for achieving sustained economic growth and a reduction in rural poverty.

Public transportation is the vehicle provided to the community to meet their daily movement from one to another location [2]. There are many general types of public transportation such as buses, trains, boats, ships, and planes. By using public transportation, many benefits can be obtained by the society. It benefits people financially, reduces air pollution, increases fuel efficiency, reduces traffic congestion, saves the cost (money), increases mobility, frees up time, makes travel safer, and encourages healthier habits [3]. Problem that arises on public transport is the confusion to seek the route through which public transport (vehicle ID) is effective in reaching the destination. Lack of information about public transportation routes will make people tend to not use public transportation.

Previous researches have been also conducted to support public transportation for rural and underdeveloped regions. In 2015, Atuoye et al. found transportation service is a challenge in rural regions in Ghana [4]. By conducting a focus group discussion and combined with political ecology of health framework, he found that public transportation barrier is a problem in accessing maternity health care. As a result, pregnant women use

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risky vehicles such as bicycles or motorbikes and some turn to traditional medicines to get or access maternal health care services. In another research, Djurhuus et al. created a multimodal travel-time network model in Denmark [5]. It integrates bus, train, and ferry with walking or cycling stop points. The multimodal network model is using SQL (Structured Query Language) and GIS.

In 2017, McDaniels et al. found that people with disabilities have inadequate access to public transportation [6]. This causes limited access to get services and it affects their health and quality of life, such as limited opportunities for community engagement, participation, and employment. He presented strategies for collaboration between local, state, and federal transportation agencies and private companies to remove unnecessary transportation barriers for people with disabilities in rural regions.

In 2018, Wang and Wu provide a design of rural public transportation network for further development in integrating the urban and rural public transportation [7]. The proposed design is constructed by using search algorithm with space and time constraints. As far as many researches conducted, there are few proposed solutions for public transportation in rural and underdeveloped regions through application approach.

This study will propose an application that can provide public transportation routes and vehicle ID from initial to destination position in rural and underdeveloped regions. Application will run on the Android platform (native) and can provide transit information, rates, and estimated distance. This study is expected to help society in rural and underdeveloped regions to do their daily activities by using public transportation easily.

Step of this study is presented along this manuscript. The development methodology that consists of 4 main stages is explained in Chapter 2. The first two stages of the methodology (user requirement, analysis, and design) are explained in Chapter 3, the third stage (development and implementation) is in Chapter 4, and the last stage (evaluation) is in Chapter 5. The route search algorithm that is used in the development of the application is presented in Chapter 4. Last, the conclusions and future work of this study are presented in last chapter.

2. **Methodology.** The development methodology used in this study is Waterfall that consists of stages: user requirement; analysis and design; development and implementation; and evaluation.

a. User requirement

User requirement in this study consists of literature study and questionnaire.

i. Literature study

Literature study is conducted as an early stage before starting the research through collecting the theories from books and articles, and also the results of the previous researches.

ii. Questionnaire

Questionnaire is distributed to 130 people in some rural and underdeveloped regions in Indonesia to assist the process of implementing the application in accordance with their needs.

b. Analysis and design

Data gathered from user requirement stage are analyzed to get list of functionalities to be designed and developed. Modeling the system is by using Unified Modeling Language (UML) which includes class diagram and use case diagram.

i. Class diagram

Class diagram is used to describe the modeling structure of the built application's entities.

ii. Use case diagram

Use case diagram is used to describe which actor performs each activity related to the application, or to describe what application can do for the users.

c. Development and implementation
Development and implementation are done by using Android programming language. Application uses GPS technology, Google Maps, and route search algorithm.
d. Evaluation
The evaluation is conducted for performance. Application performance is obtained from the calculation of duration taken when the user starts the "Get direction" function until the application displays the map with the desired route. Besides that, evaluation is also done by taking questionnaire.

3. **User Requirement, Analysis, and Design.** Questionnaires are distributed to 130 people in working-age (15-60 years old) in some rural and underdeveloped regions in Indonesia. Most respondents are students (31%), employees and entrepreneurs (61%), and unemployed (8%). Results of questionnaire are:

a. 130 of 130 respondents (100%) have mobile phones.
b. 97 of 130 respondents (75%) use Android OS, 19 (14%) use monochrome, 10 (8%) use Blackberry OS, and 4 (3%) use Symbian.
c. 113 of 130 respondents (87%) use public transportation in their daily activities.
d. 84 of 113 respondents (74% from point c) have difficulty in determining vehicle number/ID to be used.
e. To overcome the difficulties (in point d), 66 of 84 respondents (79%) use applications (such as Waze or Google Maps), 40 respondents (48%) ask others, 23 respondents (27%) use maps (paper or online based map), and 4 respondents (5%) use other methods. A respondent can have multiple answers.
f. Based on 79% who use applications (in point e), 60 of 66 respondents (91%) use Google Maps, 10 respondents (15%) use Waze, and 7 respondents (11%) use other applications. A respondent can have multiple answers.
g. Based on 79% who use applications (point e), 49 of 66 respondents (74%) state that the information on the application is not complete (no tariff information), 22 respondents (33%) state that the application is difficult to use (too complex and many features), 12 respondents (19%) state that the application cost is high (in consuming bandwidth data), and 23 respondents (35%) have other constraints. A respondent can have multiple answers.
h. 124 of 130 respondents (95%) want to use an application that can help them to determine public transportation in their rural and underdeveloped regions.
i. 99 of 130 respondents (76%) want to know tariff information, 89 respondents (68%) want features for saving route and its vehicle ID, 84 respondents (65%) require vibrate notification, 80 respondents (62%) require text notification when they reach their destination, and 41 respondents (32%) require voice alert.

Based on questionnaire results, the proposed application will be developed with simple features (concern for rural and underdeveloped society), including tariff information, notification, shuttle and vehicle number/ID. Figure 1 and Figure 2 show the class and use case diagram for the proposed application to be developed.

4. **Development and Implementation.** Hardware specifications used in the development of the application are Dual-core @ 2.3 GHz processor, 4 GB RAM, 320 GB storage, Internet connection; and smartphone specifications are Android 9 OS (Pie), Dual-core 1.4 GHz processor, RAM 1 GB, and 16 GB storage. To store and calculate general transit routes, minimum server specifications required are Intel Xenon, Debian Linux OS, 4 GB ECC RAM, Apache Webserver, Qmail Mailserver, PHP, and MySQL database. Hardware specifications to use the application are displayed in Table 1.

In development and testing stage, application is implementing a city region to simulate the crowded transportation to check the algorithm. If the GPS or Internet is turned off,

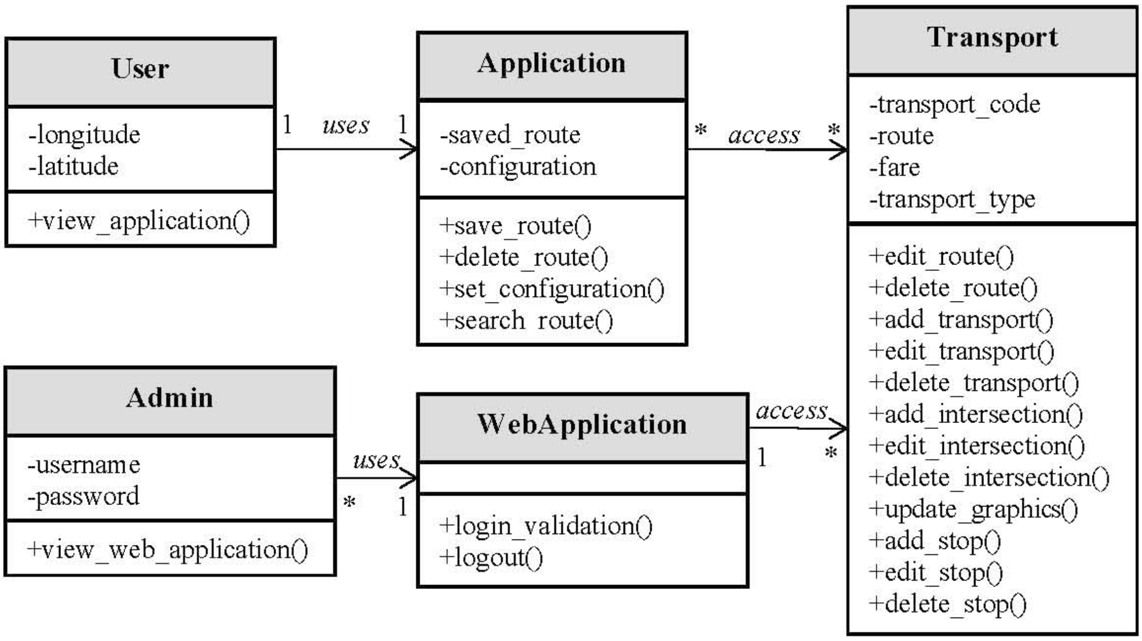


FIGURE 1. Class diagram

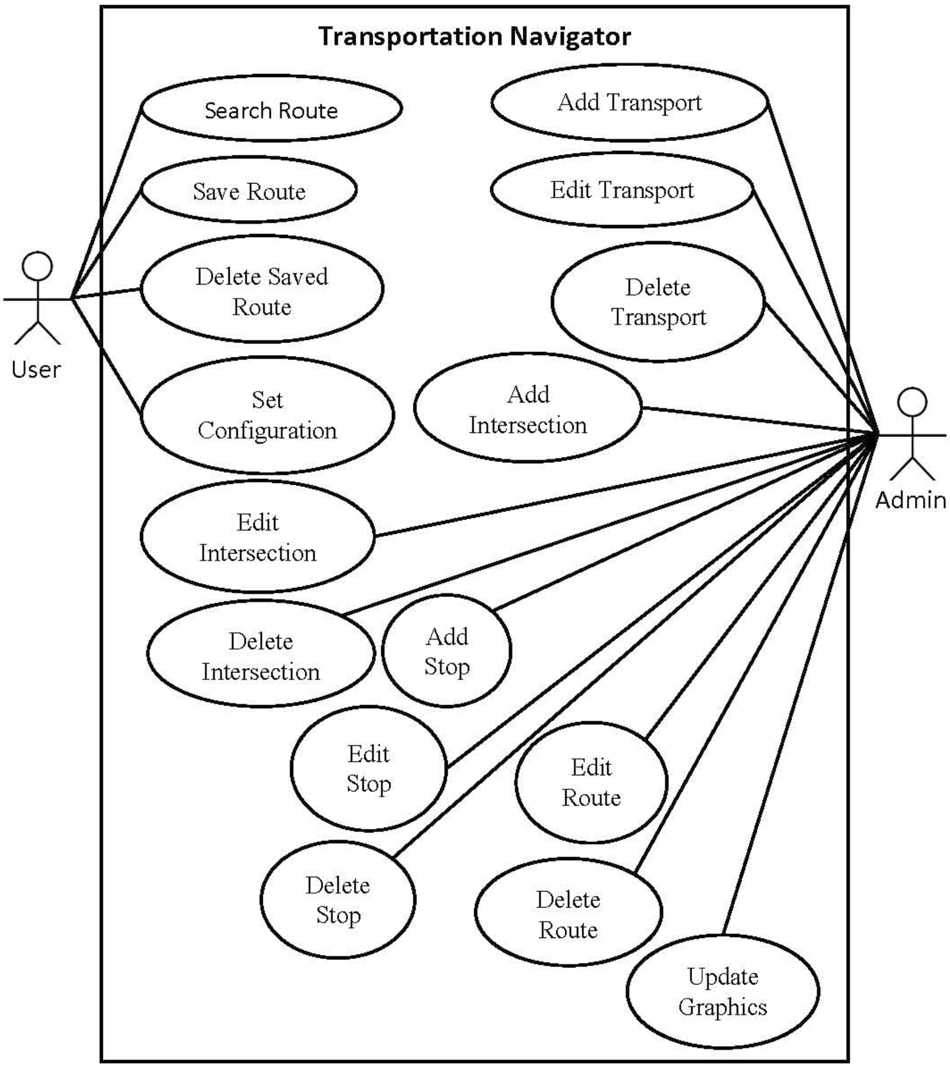
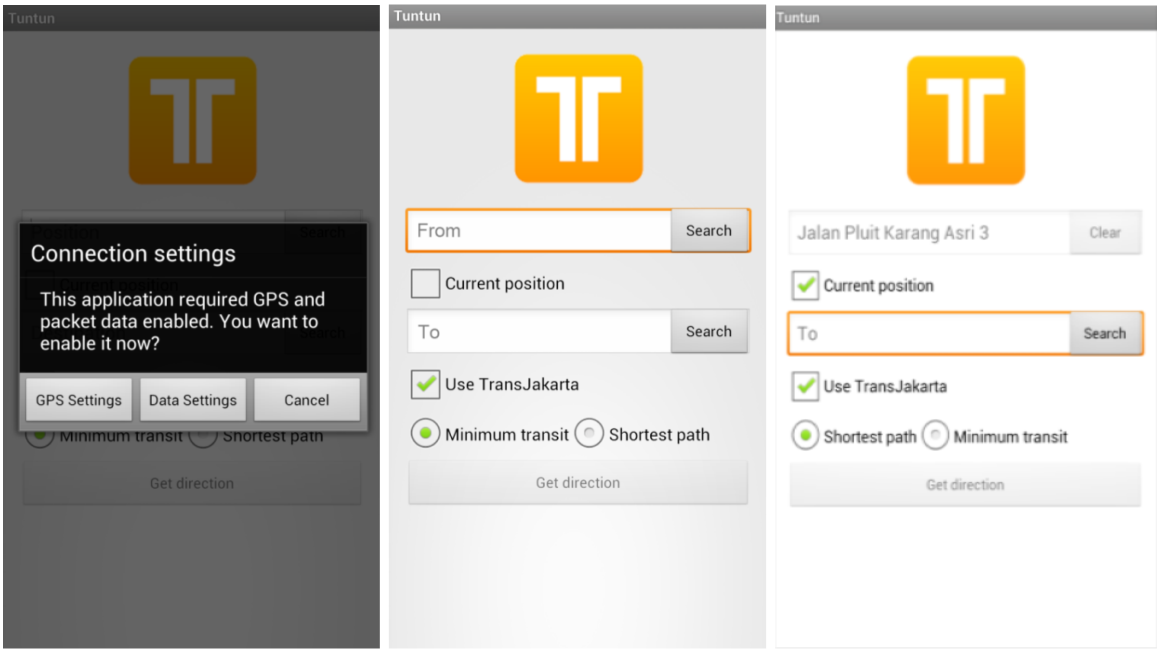


FIGURE 2. Use case diagram

Table 1. Hardware specification

Specification	Minimum	Recommended
OS	Android v4 Ice Cream Sandwich	Android v9 Pie
Processor	600 MHz	800 MHz
Storage	280 MB	512 MB
Memory	160 MB	160 MB



(a) (b) (c)

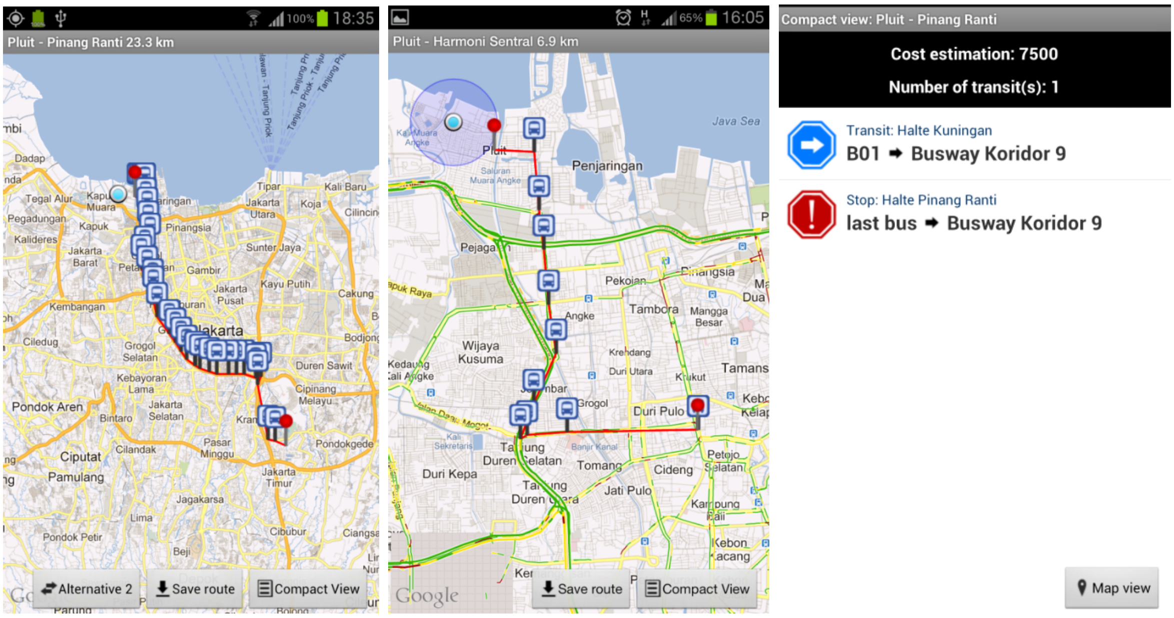
Figure 3. (a) Connection settings, (b) main page, and (c) initial and destination position

the application will show a message asking for turning on the GPS and Internet connection (Figure 3(a)). After it is turned on, application will redirect to the main page (Figure 3(b)).

On the main page, users must enter the initial position. It can be filled manually by typing the name of the desired place or by selecting the "Current position". After selecting the initial position, user can define the destination position by typing the desired destination location, then press the "Search" button to select. Users may choose to use local transportation (such as TransJakarta) by pressing the checkbox. Users can also choose the route based on the fastest route (Shortest path) or choose the route with the smallest transit path (Minimum transit) (Figure 3(c)).

After a user presses the "Get direction" button, the screen will redirect to the "Map view" page (Figure 4(a)). There is information from the initial and destination position and the traveled distance on the title bar. The circle symbol ( ) indicates the user's position. Two marker/pin symbols ( ) indicate the initial and destination position. The bus logo ( ) shows a stop or transit point that allows users to get off the shuttle. Application displays road congestion information (Figure 4(b)). The lighter-colored line (—) signifies a low level of congestion, and the dashed line (---) signifies a high level of congestion. This feature can be enabled or disabled on Settings menu.

The route taken is shown on the map with a bolder-colored line (—). Users can also save the route (Save route), calculate alternative route (Alternative), and display list of transit in text mode (Compact view). On "Compact view" menu, application views the



(a) (b) (c)

FIGURE 4. (color online) (a) Map view, (b) traffic, and (c) compact view

list of shuttles used by the user in a simple form (Figure 4(c)). Users can also view route information taken on the title bar, price estimation, the total number of transits, and the transport used to reach the destination.

The following are the types of information contained in “Compact view” (Table 2).

TABLE 2. Compact view information

Information	Notes
Transit: Halte Pluit **B01 ➡ Busway Koridor 9**	A user is required to transit. The name of the transit stop point will be displayed. If the name of the stop point is not available, the name of the nearest road will appear.
Internet connection required to show transit address. **Busway Koridor 9 ➡ Koridor 3**	A user is required to transit. Address (street name) for transit cannot be raised due to insufficient Internet connection.
Stop: Jalan Silang Merdeka Tenggara **last bus ➡ Koridor 2**	A user is requested to step down from the transport. If the name of the stop is not available, the name of the nearest road will appear.
Internet connection required to show transit address. **last bus ➡ Koridor 2**	A user is requested to step down from the transport. Address (street name) for transit cannot be raised due to insufficient Internet connection.

Route Search Algorithm. Mechanism of route search algorithm is described below.

a. The server receives a request from the application containing the data:
- Initial location (latitude, longitude)
- Destination location (latitude, longitude)
- Search method (shortest path/minimum transit)
- Using local transport route or not

- Radius (in meters)

b. The server connects each intersection between the transit points from database into a graph. The intersection is between two or more transit points and users can move it. Weight of the path is the distance from both points. The graph weight is affected by the selection of local transport (if selected) route usage. If the local transport route is not selected, the server will not count all intersections between local transport and other points into the graph.
c. The server looks for a list of shuttles that are within a walking radius of the initial location (referred as nearby-nodes) and the destination location (referred as nearby-nodes-goal).
d. For every transport included in nearby-nodes and nearby-nodes-goal, the server looks for all junctions owned by the transport and links it to the graph.
e. The server creates a start node and links it to each nearby-node with a weight of 0 (zero).
f. The server creates an end node and links it to each nearby-nodes-goal with a weight of 0 (zero).
g. Search by Djikstra algorithm is done from node start to node end.
h. The resulting route result is modified to replace the code for each point (described below).
i. The server sends the search result to the application in the form of a string with the format in Figure 5.

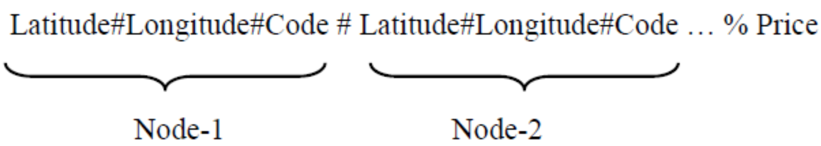


FIGURE 5. Code format (1)

The number of points sent corresponds to the length of the route required to reach the destination. The type of code sent indicates the type of point. The code format submitted is in Figure 6.

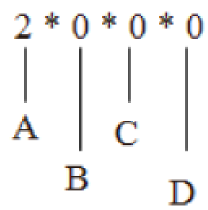


FIGURE 6. Code format (2)

Table 3 gives an explanation of the code format:

TABLE 3. Format code meaning

Code A	Meaning	Code B	Code C	Code D
0	Last point	0	0	Last point
1	Transit point	Transport 1 code	Transport 2 code	The name of the stop or transit position
2	Normal point	0	0	0

The exclamation point (!) will separate the first and alternative routes (if any). Sample string of server route search result: −6.1157955#106.7899954#2*0*0*0 # −6.2019521# 106.7999840#1*B01*Busway Koridor 9*−6.1673930&106.7885417 # −6.2025067#106.79 98874#2*0*0*0 # −6.2025067#106.7998874#0*0*Busway Koridor 9*−6.1675370&106.8 281633 % 3500 ! −6.1157955#106.7899954#2*0*0*0 # −6.2019521#106.7999840#1*B0 1*Busway Koridor 9*−6.1673930&106.7885417 # −6.2025067#106.7998874#2*0*0*0 # −6.2025067#106.7998874#0*0*Busway Koridor 9*−6.1675370&106.8281633 % 3500.

5. **Evaluation.** Evaluation is conducted by evaluating the performance. Evaluation results are obtained from the calculation of the length of time taken when the user presses the "Get direction" until the application displays the map with the desired route. The evaluation used the same route in the 1st trial until the 3rd trial. Table 4 displays the evaluation result.

Table 4. Application performance evaluation

Smartphone Type	**Android OS Version**	**Processor**	**Storage**	**Test**	**Internet (kB/s)**	**Searching Duration (sec)**			**Average**
						Rute	**Peta**	**Total**	
Samsung Galaxy Fit	v2.2 (Froyo)	600 MHz	280 MB	1	144.64	3.45	10.03	13.48	13.34
				2	148.48	3.06	9.64	12.7	
				3	126.72	3.52	10.33	13.85	
Samsung Galaxy Y	v2.3 (Gingerbread)	830 MHz	290 MB	1	144.64	3.55	9.89	13.44	13.36
				2	148.48	3.27	9.57	12.84	
				3	126.72	3.59	10.21	13.8	
Samsung Galaxy Note	v4.0 (Ice Cream Sandwich)	Dual Core 1.4 GHz	1 GB	1	144.64	3.41	9.95	13.36	13.40
				2	148.48	3.45	9.76	13.21	
				3	126.72	3.47	10.15	13.62	
Samsung Galaxy SIII	v4.1 (Jelly Bean)	Quad Core 1.4 GHz	1 GB	1	144.64	3.3	10.01	13.31	13.25
				2	148.48	3.01	9.72	12.73	
				3	126.72	3.51	10.2	13.71	

Evaluation of application performance shows that hardware does not show any significant impact on speed in displaying routes on the map, but Internet speed does. Application evaluation is also conducted by using questionnaire to 33 users who test to use it. Its results are as the following.

a. 100% respondents are satisfied with the application.
b. 32 of 33 respondents (97%) state that the UI looks good.
c. 100% respondents feel helped by the application.
d. 32 of 33 respondents state that the route displayed is easy to understand.
e. 31 of 33 respondents (94%) are satisfied with the duration to calculate the route.
f. 31 of 33 respondents do not face the difficulties in using it.
g. 100% respondents will recommend the application to their colleagues.

6. **Conclusions and Future Works.** Based on the implementation and evaluation that has been done, it can be concluded that application can be used to determine public transportation routes in rural and underdeveloped regions. It gives transit information, cost (price), and estimated distance required. Internet speed is influential in displaying routes on the map. Suggestions for further works are 1) feature addition to estimate time and alternative route to reach destination by considering congestion factor; 2) map-based picker to set initial and destination position; 3) integration with other public transportation such as train, ship, plane; and 4) development on other mobile operating systems such as iOS.

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