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OPERATIONAL EFFICIENCY OF PALEMBANG CITY TRANSPORTATION USING SAVING MATRIX METHOD

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Edi Kadarsa*, Melaewaty Agustien, Helmi Haki, Louis Alessandrobonaparte

Civil Engineering Department, Faculty of Engineering, Sriwijaya University, Indonesia

*Corresponding author
edikadarsa@ft.unsri.ac.id
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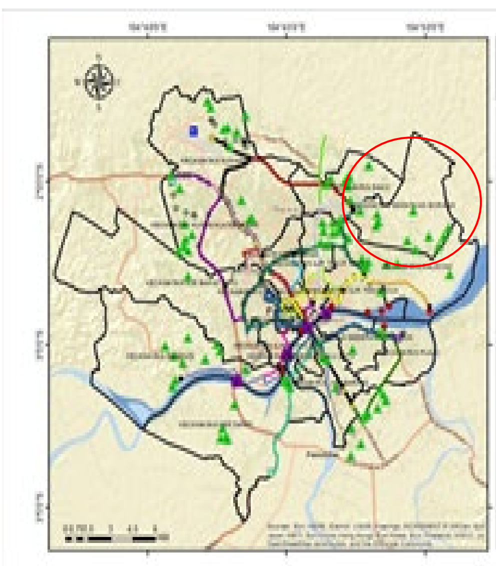
Graphical abstract



Abstract

Currently, housing development is actively carried out in Palembang City, especially in sub-districts with vast underutilized land with relatively cheap prices. People's preferences for private transport for movement may give rise to congestion on the roads leading to the housing estates due to narrow access roads. The Government of Palembang City has laid out a plan for feeder transportation connecting buses and LRTs. Going forward, the procurement and management for this feeder transportation will be handed over to the public (private sector). There needs to be a route plan that is efficient and easy to modify considering the low number of passengers outside of peak hours and the constantly-changing number at every point. The Saving Matrix was studied for its effectiveness in planning fast and efficient routes. The results of the study showed that calculations using the Saving Matrix method are easy to carry out and produces efficient routes.

Keywords: feeder, Saving Matrix Method, efficient route, outside of peak hours

1.0 INTRODUCTION

The city of Palembang is growing rapidly as evidenced by the large number of housings being built in sparsely populated sub-districts. The results of filed observations and in-depth interviews with informants from the Office of Public Works and Spatial Planning for Palembang City showed that developers have started to expand their business to several sub-districts with vast vacant land with relatively cheap prices, one of which is Sematang Borang Sub-District. However, based on the data from the Palembang City Office of Public Works and Highways, there are still quite a lot of narrow streets leading to housing locations, only about 4 meters wide, some are even 3 meters wide. In such situation, if people rely on private transport for mobility, traffic jams will occur on the access roads leading to these housing estates. Figure 1 describes the existing transportation infrastructure in Palembang city with the location given a red circle, namely the Sematang Borang sub-district.

At this time, the government of Palembang City has commenced the operation of modern transportation as feeders. This city transportation started operating in July 2022 through 2 corridors (routes), namely: Talang Kelapa – Talang Buruk and Asrama Haji – Sematang Borang. However, our observations show that although currently there is a significant increase in the number of city transport passengers, the number of passengers is still low outside peak hours. Going forward, the Palembang city transportation which functions as a feeder will be handed over to the public (private sector) for procurement and operation. It is necessary to consider that city transportation outside of peak hours can operate outside the official routes so that it can serve a wider range of community movements. However, it is necessary to plan the operation of this public transportation because the number of city transportation that is allowed to go off the route is limited and the pockets of demand are scattered at several points.

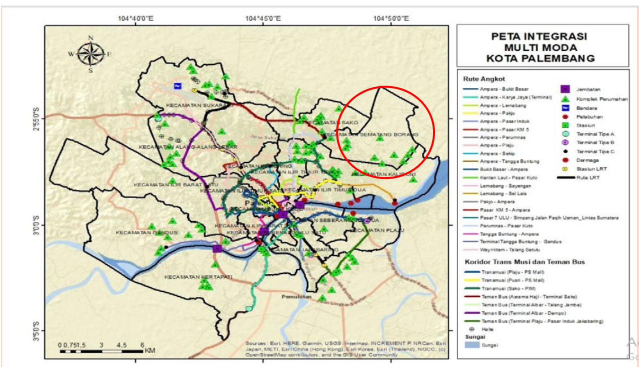


Figure 1. Map of Palembang City's Multi-Mode integration

The Saving Matrix method is used to solve transportation problems by determining efficient routes in order to minimize transportation costs [1]. This method is generally used to determine the route of distribution of goods or products [2,3,4,5,6,7,8,9]. However, with some adjustments, it can be used to determine urban transport routes. This method does not guarantee a globally optimal solution, meaning that there may still be other, better solutions. However, even though it may not be the best solution, the results are close to optimal and easy to execute, so that if there is a change in the number of passengers at the pick-up points, the recalculation can be done more easily and quickly. The Google Map application can be used to determine the distance between pick-up points and between pick-up points and depots [10,11,12] so that data can be obtained quickly and cheaply. There are several other heuristic methods to determine city transportation routes that might be better, for example the Genetic Algorithm or Particle Swarm Optimization which performs the process of finding the optimum value at several points simultaneously (one generation). Searching for the optimum value here by comparing a wider range of possibilities. However, these heuristic optimization methods should be used for main route planning, because they require more complicated data and calculations [13, 14, 15, 16]. For additional routes outside of peak hours, where the location of pockets and the amount of demand and distance tend to change, the saving matrix method is easier to implement

As a pilot study, this study only used the basic Saving Matrix method to study whether the method commonly used to determine freight transport routes can be used to determine more efficient public transport routes. This study does not discuss multiple depots, multiple trips and split delivery as research conducted by Dror and Trudeau (1989) and Evylin dkk (2016) [10,11] Because a simple method is thought to be sufficient to solve the problem in this research. However, they are recommended for further research.

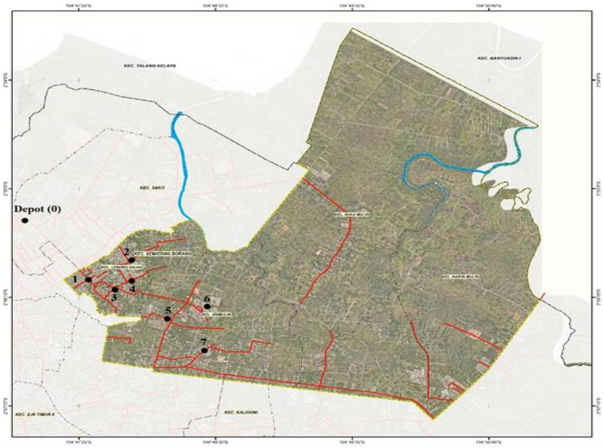
Based on the results of previous studies [2,3,4,5,6,7,8,9], efficiencies in the number of vehicles and mileage were observed that lead to lower transportation cost when the distribution routes were planed using the Saving Matrix method. However, all of the research discusses the network of freight transport routes with one depot (the point where the vehicle starts moving to drop off or pick up and return after all the goods have been delivered or picked up) with several drop off or pick up points. To our knowledge, there has been no study to determine the network of public transport routes such as angkot (city transportation) in Palembang City. City transportation is transportation from one place to another within one city area or district capital area by using public buses or public passenger cars tied to routes [17].

2.0 METHODOLOGY

According to Istantiningrum [18], the steps in the saving matrix method are as follows:

1. Defining the Distance Matrix. In this step, distance data between the company (depot) and locations and locations and other locations is needed.
2. Defining the Saving Matrix. After determining the overall distance between the company (depot) and locations and between locations and other locations, then in this step it is assumed that each location will be passed by one public transportation exclusively. That is, there will be several different routes that will be followed for each destination. Thus, savings will be achieved if there is a combination of routes that parallel other routes. To find the saving matrix, the following formula 1 can be used:
   $S(x,y) = \text{distance}\ (0,x) + \text{distance}\ (0,y) - \text{distance}\ (x,y)$
   (x,y) is distance saving resulting from combining route x and route y.
3. Allocating Vehicles and Routes Based on Locations. After the saving matrix is obtained, the next step is allocating locations to routes or vehicles. That is, in this step, new pick-up routes will be determined based on the route combination mentioned in step 2 above.
4. Ordering of Destination Locations in a Route. This step determines the order of trip. In this study, the method used to determine the order of trip was the Nearest Neighbor method. It determines trips by prioritizing the location with the closest distance to the last destination.

The location of the study is presented in Figure 2. The research location has not been traversed by city transport or feeders. The route network plan will pass through densely populated settlements with depots being converging locations between city transport (feeder) and onward transport.



Note:
●: Pick-up Point

Figure 2. Assumption of Pick-up Point Plan

If routes are determined through bus stops with distances between certain bus stops, then the bus stops must be determined in advance at one pick-up point, for example, if all stops on one road section will be part of the pick-up point x, then all the stops on the other section will be part of the other pick-up points (y, z, and so on). This research determines a new route if city transportation departs from the official route. Points 1,2, etc. show demand pockets which are pick-up points outside the official route, while point o is a depot, namely integration location between city transportation as a feeder and other public transportation, namely buses.

For information, at this time the government has inaugurated the operation of modern city transport as feeders for buses (teman bus) and LRT (Light Rail Transit) in Palembang City. The said city transport can carry a maximum of 9 passengers. They do not stop anywhere; only at the designated pick-up points or bus stops. In the future, the government will continue to improve the services of these public transportation based on the wishes of the community. Simultaneously with this research, a survey was conducted on public perceptions of improving public transportation services in Sematang Borang Sub-District. The survey results showed that people wanted CCTVs (Closed Circuit Television) to be installed at each pick-up point or bus stop and integration facility. CCTVs at every pick-up point allow city transport operators to determine the potential number of passengers at each pick-up point. Based on observations, the number of passengers on public transportation outside of peak hours on corridors that have been commissioned is typically less than 10 people. This information will serve as quantitative data for route determination with the Saving Matrix method. The number of passengers at each pick-up point was assumed for 2 different versions.

3.0 RESULTS AND DISCUSSION

The following tables contain the results of route calculation using the Saving Matrix mathod. Table 1 shows the distance from the depot to each pick-up point and the distance between pick-up points

Table 1 Distance Matrix

Spot	0	1	2	3	4	5	6	7
0	0	1.28	1.91	2.13	3.01	3.18	3.83	4.58
1		0	0.9	0.85	1.27	1.9	2.55	3.3
2			0	1.2	1.1	2.68	2.9	4.08
3				0	0.42	1.48	1.7	2.88
4					0	1.9	2.12	3.3
5						0	1	1.4
6							0	2.4
7								0

Point 0 is the depot which is the integration location between the city transport as a feeder and the main transportation. The distances in this table are symmetrical, meaning that a distance of 0.2 is equal to a distance of 2.0. Distance observation was carried out using GPS (Global Positioning System). Then determining the value of the saving matrix with the formula 1.

Example :

S(1,2) = distance (0,1) + distance (0,2) - distance (1,2)
= 1.28 + 1.91 - 0.9
= 2.29

S(5,7) = distance (0,5) + distance (0,7) - distance (5,7)
= 3.18 + 4.58 - 1.4
= 6.36

Calculations are carried out at all distances between points, so that a saving matrix is obtained as follows (Table 2):

Table 2 Saving Matrix

Spot	1	2	3	4	5	6	7
1		2.29	2.56	3.02	2.56	2.56	2.56
2			2.84	3.82	2.41	2.84	2.41
3				4.72	3.83	4.26	3.83
4					4.29	4.72	4.29
5						6.01	6.36
6							6.01

Table 3 The Order of Saving Matrix Values

No	Point	Saving Matrix	No	Point	Saving Matrix
1	(5,7)	6,36	12	(1,4)	3,02
2	(5,6)	6,01	13	(2,3)	2,84
3	(6,7)	6,01	14	(2,6)	2,84
4	(3,4)	4,72	15	(1,3)	2,56
5	(4,6)	4,72	16	(1,5)	2,56
6	(4,5)	4,29	17	(1,6)	2,56
7	(4,7)	4,29	18	(1,7)	2,56
8	(3,6)	4,26	19	(2,5)	2,41
9	(3,5)	3,83	20	(2,7)	2,41
10	(3,7)	3,83	21	(1,2)	2,29

No	Point	Saving Matrix	No	Point	Saving Matrix
11	(2,4)	3,82	-	-	-

Table 3 shows the order of saving matrix values from the highest one, point 5.7, with 6.36, to the lowest one, point 1.2, with 2.29. Assessment to determine the first pick-up point (from the depot) starts with the largest saving matrix value.

3.1 Assumption of the Number of Passengers at a Pick-Up Point

The research locations were roads previously not passed by city transport or feeders. Therefore, the number of passengers outside of peak hours was assumed based on data on the number of city transport passengers on routes that have been operating. There were 2 versions of the assumption of the number of passengers at each point to see whether the Saving Matrix method can be used to determine an efficient route easily and quickly when there is a change in the number of passengers at the pick-up points.

Table 4 The Number of Demands at Each Point

Assumption 1		Assumption 2	
Point	**Demand**	**Point**	**Demand**
1	6	1	1
2	3	2	4
3	5	3	6
4	1	4	3
5	4	5	3
6	3	6	3
7	3	7	5

3.2 Point Integration

Below is the route determination using the data on the number of demands at each point version 1. The integration points were obtained from the highest to the lowest saving matrix value, namely:

- Point (5,7), the number of demands: 4 + 3 = 7, did not exceed capacity (can be integrated).
- Point (5,6), point 5 was integrated with point 7, the number of demands: 7 + 3 = 10, exceeded capacity (cannot be integrated).
- Point (6,7), the number of demands: 3 + 7 = 10 (cannot be integrated)
- Point (3,4), the number of demands: 5 + 1 = 6 (can be integrated)
- Point (4,6), point 4 was integrated with point 3, thus, the number of demands: 6 + 3 = 9 (can be integrated). Because the value of demands has matched the passenger capacity, then integration related to points 3, 4 and 6 can be just ignored.
- Point (1,5), the number of demands: 6 + 7 = 13 (cannot be integrated)
- Point (1,7), the number of demands: 6 + 7 = 13 (cannot be integrated)
- Point (2,5), the number of demands: 3 + 7 = 10 (cannot be integrated)
- Point (2,7), the number of demands: 3 + 7 = 10 (cannot be integrated)
- Point (1,2), the number of demands: 6 + 3 = 9 (can be integrated)

Based on the point integration calculations, 3 routes were obtained, namely point (5,7), point (3,4,6) and point (1,2). Using similar method, point integration for the number of demands version 2 was also made, producing 3 routes, namely point (1,5,7), point (3,4) and point (2,6).

The calculation results for the 2 data versions showed differences in routes when a change in the number of demands occurred at each point. Route differences are meant to minimize the distance and maximize the number of passengers that can be carried.

3.3 Route Order with the Nearest Neighbor Method

Table 5 shows the comparison of calculation results using 2 different data assumptions on the number of demands at each point. If for the second version of data, routes version 1 were used, the number of passengers transported is not optimal, namely on route 0-5-7-0 there are 8 passengers transported, route 0-3-4-6-0 there are 9 passengers (the remaining 3 passengers are left behind due to maxed out vehicle capacity) and route 0-1-2-0 only 5 passengers. It is evident that not all passengers on route 0-3-4-6-0 can be carried, while other vehicles on other routes are short of passengers (less than 9 passengers).

Table 5 Route Order with the Nearest Neighbor Method

Versions of the Number of Demands	Point Integration Calculation Results	Distance from the Integrated Locations (Depot) to Points	Route Order	Total Distance (km)	The Number of Passengers
1	(5,7)	0-5 = 3,8 0-7 = 4,58	0-5-7-0	9,16	7
	(3,4,6)	0-3 = 2,13 0-4 = 3,01 0-6 = 3,83	0-3-4-6-0	8,5	9
	(1,2)	0-1 = 1,28 0-2 = 1,91	0-1-2-0	4,09	9
2	(1,5,7)	0-1 = 1,28 0-5 = 3,8 0-7 = 4,58	0-1-5-7-0	9,16	8
	(3,4)	0-3 = 2,13 0-4 = 3,01	0-3-4-0	5,56	9
	(2,6)	0-2 = 1,91 0-6 = 3,83	0-2-6-0	8,64	7

4.0 CONCLUSION

The Saving Matrix method can be used to determine new routes for city transport that depart from official routes efficiently. The calculations are relatively easy to perform, thus, in case of changes in the number of passengers at certain points, recalculations can be performed easily to generate new efficient routes. However, the method used in this study is basic and standard in nature. Future research should discuss a broader Saving Matrix method including time windows, split delivery, multiple depots and multiple trips. The Saving Matrix method can also be combined with other heuristic methods to improve results, namely more efficient routes.

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