Simulation Model for Scheduling Bus Rapid Transit

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Abstract. Trans Padang Bus is a Bus Rapid Transit in Padang which has operated 15 buses for one corridor along 39 km. The bus is a medium type which has 20 passenger seats capacity and 20 passenger standing capacity. Nowadays, the number of passengers Trans Padang Bus exceeds the passenger capacity causing the load factor of Trans Padang Bus can reach 170%. The load factor is one of the parameters that determine the performance of Trans Padang Bus is still not good. Improving performance of public transport operations can be done by redesigning operational scheduling by using simulation modelling. Based on the results of the research, the result of Trans Padang Bus scheduling design is more optimum than the previous schedule that determined by the load factor that is 107.5%. In the scheduling design, the number of Trans Padang Buses are 18 units, the number of trips are 5 trips and the inter departure time of the bus are 5 and 10 minutes.

1. Introduction
The Government has obligation to guarantee the availability of public transportation to transport persons and or goods, whether inter-city, inter-provincial, regency / municipal area [1],[2]. Public transportation is an alternative transportation in the city, especially for people who do not have their own private vehicles, so these facilities and infrastructure are needed in urban areas. Bus Rapid Transit (BRT) is one of the high-quality public transit systems based on fast, convenient, and low-cost transit system for urban mobility by providing pedestrian paths, infrastructure, fast and frequent service operations, and good service for customers [3]. There are 11 cities in Indonesia that have developed Bus Rapid Transit (BRT), one of the cities is Padang and the bus is called Bus Trans Padang.

The Trans Padang bus has officially operated on 14 February 2014. The Technical Implementation Unit of Trans Padang Bus has operated 15 buses for corridor I along 39 km from 5 planned corridors. Trans Padang bus is needed by the citizen of Padang because this mode of transportation is the only mass transit service for the route of Pasar Raya (Imam Bonjol) - Jl. Khatib Sulaiman - Air Tawar - Lubuk Buaya now, which has bus stops in every place located near public places such as Post Office, School, University, Governor's Office, DPRD Offices, Hospitals, Banks, Mall and so on.

The Trans Padang bus is a medium bus type that has 20 passenger seats capacity and 20 passengers standing capacity. Nowadays, there is still a problem in the operation performance of the Trans Padang bus which is the number of passenger’s bus exceed the available capacity of passengers. Overcapacity of passengers on the Trans Padang bus can be seen from the value of load factor of the Trans Padang bus. Load factor is a comparison between the passenger’s capacity and capacity available for one trip expressed in percent (%) which is one of the parameters can be used to see the effectiveness and
efficiency the operation of public transportation. One is the ideal value of public transportation load factor. Some observations have been done on August 1, 2016 to August 2, 2016 on six buses for 32 trips to determine the load factor of Trans Padang at this time. The observations data of Trans Padang bus load factor can be seen that there are some times when the load factor of Trans Padang bus is more than 100%. The load factor of Trans Padang bus that is more than 100% is one of parameters that determine the performance of Trans Padang Bus at this time is still not good. Improving the performance of public transportation can be done by redesigning the schedule of public transport. The load factor of Trans Padang bus can be reduced by redesigning the Trans Padang bus schedule using simulation modeling.

Simulation is one kind of decision making that imitates the true situation of a real-world life system without having to experience it in real situation [4]. By using simulation, the cost of research is cheaper because it is not using the real materials or equipment. The time of research is shorter than the time required in real experiment. The results of real experiments that takes time in a few months can be obtained in the form of simulation results that lasted a few seconds. The risk of simulation is not fatal and does not cause costs because the damage of virtual components to the operation of the system in virtual space does not cause real costs and fatal accidents [5][6].

Currently, there has been a lot of research on transportation using the concept of simulation. Research by A. Manis and S.T.S. Hutami is a research on simulation modelling for the University of Andalas Transportation system [7]. While Maulida Boru Butar Butar and Mohamad Yamin did research by using simulation computer to solve transportation problem, the object in this research is Bus Rapid Transit in Yogyakarta [8].

Both of those researches have some similarities with this research. The method of both of those researches are simulation computer using ARENA software. The output of A. Manis and S.T.S. Hutami research only resulted the number of operated buses while this research is to design the Trans Padang bus simulation model to get the optimum schedule of Trans Padang bus by changing the number of operated buses, time between departure of buses, and the number of buses trips. Both of those researches only modeled one direction bus trips, while this research will model two direction bus trips. Correct repair of the optimal Trans Padang bus operation with the change of time between bus departure, the addition of bus number and the addition or reduction of the number of trips rit bus. In addition, the two studies only model bus trips in one direction, while the study will model bus trips in both directions.

2. Research Methodology

Simulation modelling is a complicated activity that combines art and science. Nevertheless, from a high-level standpoint, one can distinguish the following major steps those are problem analysis and information collection, data collection, model construction, model verification, model validation, designing and conducting simulation experiments, output analysis, and final recommendations [9]. Data collection in this research will be used to construct the simulation model. The data collections consist of primary data and secondary data. Primary data collection was done on workday from Monday to Thursday for one month from April 3, 2017 to April 27, 2017. Primary data collection was done by direct observation. Secondary data collection was collected from Department of Transportation, Communication, and Information of Padang and Technical Implementation Unit of Trans Padang bus. The primary and secondary data of the data collection are then used as input data in the simulation model constructing.

Model construction is based on the real system of Trans Padang bus currently operation using a programming language for simulation that is ARENA 14.0 software. Model construction in this research uses ARENA software because this software is specialized to solve discrete system simulation problems. ARENA also has statistical data processing capabilities and has a good level of compatibility. Verification model aims to make sure there is no error in the model so it can run. Verification model is done by debugging the computer simulation model by activating the Check (✓) in ARENA software. If there is an error (error message) that occurred in the model, repair the model and do debugging again until a message stating that no errors in the model.
Model validation aims to confirm model is an accurate representation of the real system. Model validation in this research is done by using paired t-test statistics. Paired t-test statistic is used to output data from simulation model compared with real system data by using software SPSS 16.0. When the model is valid, it can be continued by designing and running a simulated experiment to estimate model performance and solve the problems of Trans Padang Bus. In this research some scenarios of Trans Padang bus operation are redesigned and then executed. Several scenarios of Trans Padang Bus operation scheduling can be designed by increasing the number of operated Trans Padang bus, increasing the number of trips of Trans Padang bus and changing time between departures of Trans Padang Bus. The next stage is output analysis of the simulation running results. Based on the output analysis is obtained which one is the proposed Trans Padang simulation scenario is relatively better. Proposed Trans Padang simulation scenarios that is selected is a simulation scenario of Trans Padang Bus operating system which has the most load factor value close to 100%. The formulation to determine the load factor according to Department of Transportation is comparison between the sold capacity and available capacity in one trip, it is stated in percentage.

The final step is using output analysis to get the final recommendations to Trans Padang Bus operating system. Based on the best scenario simulation suggestion, the most optimal Trans Padang bus operation schedule is obtained.

3. Results and Discussion
Model construction of the Trans Padang Bus is done by using special programming language for simulation that is ARENA 14.0 software. ARENA is one of the specialized simulation software to solve discrete system simulation problems. ARENA also has statistical data processing capabilities and has a good level of compatibility. ARENA software is object oriented and has the ability to be used in any application field. Before constructing the simulation model, entities and performance measurement are determined. There are two entities in this research object, Trans Padang Bus and passengers. The performance measure on this object is load factor of Trans Padang Bus passengers. The value of load factor is expected close to 1 or 100%.

There are three logics and one animation in this simulation model. The logic are logic - create passengers to create passenger entities into the system, logic - create bus to crate bus into the system, and logic - passenger departure to remove the passenger entity from the system. The animation on this simulation can be seen in Figure 1.

![Figure 1. Animation of Trans Padang Bus Simulation Model](image)

Simulation model of logic-create bus can be seen in Figure 2. In this logic there are 72 submodels those are two submodels of bus scheduling and 70 submodels of bus stops.
For bus stop 2 to bus stop 35 and bus stop 37 to bus stop 69 have the same logic, but for logic of bus stop 1, bus stop 36 and bus stop 70 are different. Logic of bus stop 1, bus stop 2, bus stop 36 and bus stop 70 can be seen in Figure 3.

Figure 3. Submodel Logic – Bus Stop

The logic of the scheduling submodel from Pasar Raya (Imam Bonjol) is made based on the scheduling of the Trans Padang Bus at this time by using the bus departure time input, can be seen in Figure 4. The logic of the scheduling submodel from Lubuk Buaya is made based on the scheduling of the Trans Padang Bus at this time by using the bus departure time input, can be seen in Figure 5.
In logic create passengers, the entity is passenger at each bus stop. In the module, input of create that used is the arrival schedule of passengers every 30 minutes. Logic - passenger departure can be seen in Figure 6. In this logic, the passengers will exit the system.

Model verification is done to the model and there is no error appears in the model, which means that the logic in the simulation model is correct. Validation is done to confirm the simulation model that is created has represented the real system. The first stage of validation is done by performing a preliminary simulation performed with a verified simulation running model. Based on the results of the simulation model that has been previously verified, obtained output of average and maximum number of passengers at each stop.

Model validation is done to make sure the elements in the simulation model are the same as the elements in the real system. Model validation is done by comparing the results of simulation model with data from the real system. The average bus passenger and maximum number of passengers at each stop in the simulation is compared with the average bus passenger and maximum number of passengers in the real system. This comparison of passengers is performed using paired t-test statistics, the paired t-test statistics can compare the mean of variables for a single sample group. Paired t-test statistical generally test the difference between two observations as done on subjects tested for pre- and post-

Figure 4. Submodel Logic – Bus Schedule from Imam Bonjol

Figure 5. Submodel Logic – Bus Schedule from Lubuk Buaya

Figure 6. Logic – Passenger Departure
process situations or paired or similar subjects. So paired t-test statistics can be done to validate the output of the simulation result with the actual situation.

SPSS output for the average passenger in the output the results of sig (2-tailed) value is 0.153, which is greater than α value at 95% confidence interval that is 0.05. Based on that, the initial hypothesis can be accepted that average passenger on the output simulation model results can represent the average passenger in the actual system. SPSS output for maximum number of passengers in the output the results of sig (2-tailed) value is 0.063, which is greater than α value at 95% confidence interval that is 0.05. Based on that, the initial hypothesis can be accepted that maximum number of passengers on the output simulation model results can represent maximum number of passengers in the actual system. Based on paired t-test statistic that compared the average passenger and the maximum number of passengers on the output of simulation model and real system, it is concluded that simulation model is valid.

Trans Padang bus transportation system model that has been constructed is a representation of the real system. Then, this model is used as a tool to conduct experiments on the system in order to find an alternative proposed transportation system that is expected to improve the performance of Trans Padang bus system. Parameter of system performance in this research is load factor of Trans Padang bus. The improvements of Trans Padang bus scheduling can affect the load factor of Trans Padang bus. These schedules can be designed by increasing the number of buses, changing the time between bus departures and adding the number of bus travel trips. Trans Padang bus schedule currently can be seen in Table 1, based on the simulation model result, the maximum load factor of Bus Trans Padang is 1.7.

Table 1. Actual Schedule of Trans Padang Bus

| Number | Origin of Departure | Number of Bus |
|--------|---------------------|---------------|
| Trip 1 | Lubuk Buaya         | 5.30, 5.40, 5.50, 6.00, 6.10, 6.15, 6.20, 6.25, 6.30, 6.40, 6.50 |
| Trip 2 | Imam Bonjol         | 6.00, 6.10, 6.20, 6.30, 6.40, 6.50, 7.00, 7.05, 7.10, 7.15, 7.20, 7.25, 7.30, 7.35, 7.40, 7.45 |
| Trip 3 | Lubuk Buaya         | 7.00, 7.10, 7.20, 7.30, 7.40, 7.50, 8.00, 8.10, 8.20, 8.30, 8.40, 8.50, 9.00, 9.10, 9.20 |
| Trip 4 | Imam Bonjol         | 8.00, 8.10, 8.20, 8.30, 8.40, 8.50, 9.00, 9.10, 9.20, 9.30, 9.40, 9.50, 10.00, 10.10, 10.20 |
| Trip 5 | Lubuk Buaya         | 9.30, 9.35, 9.40, 9.45, 9.50, 9.55, 10.00, 10.10, 10.20, 10.30, 10.40, 10.50, 11.00, 11.10, 11.20, 11.30, 11.40, 11.50, 12.00, 12.10, 12.20 |
| Trip 6 | Imam Bonjol         | 10.30, 10.35, 10.40, 10.45, 10.50, 10.55, 11.00, 11.10, 11.20, 11.30, 11.40, 11.50, 12.00, 12.10, 12.20 |
| Trip 7 | Lubuk Buaya         | 11.30, 11.40, 11.50, 12.00, 12.05, 12.10, 12.15, 12.20, 12.25, 12.30, 12.40, 12.50, 13.00, 13.10, 13.20 |
| Trip 8 | Imam Bonjol         | 12.30, 12.40, 12.50, 13.00, 13.05, 13.10, 13.15, 13.20, 13.25, 13.30, 13.40, 13.50, 14.00, 14.10, 14.20 |
| Trip 9 | Lubuk Buaya         | 13.30, 13.40, 13.50, 14.00, 14.05, 14.10, 14.15, 14.20, 14.25, 14.30, 14.40, 14.50, 15.00, 15.10, 15.20 |
| Trip 10| Imam Bonjol         | 14.30, 14.40, 14.50, 15.00, 15.05, 15.10, 15.15, 15.20, 15.25, 15.30, 15.40, 15.50, 16.00, 16.10, 16.20 |
| Trip 11| Lubuk Buaya         | 15.30, 15.40, 15.50, 16.00, 16.05, 16.10, 16.15, 16.20, 16.25, 16.30, 16.40, 16.50, 17.00, 17.10, 17.20 |
| Trip 12| Imam Bonjol         | 16.30, 16.40, 16.50, 17.00, 17.05, 17.10, 17.15, 17.20, 17.25, 17.30, 17.40, 17.50, 18.00, 18.10, 18.20 |
| Trip 13| Lubuk Buaya         | 17.30, 17.40, 17.50, 18.00, 18.05, 18.10, 18.15, 18.20, 18.25, 18.30, 18.40, 18.50, 19.00, 19.10, 19.20 |
| Trip 14| Imam Bonjol         | 18.30, 18.40, 18.50, 19.00, 19.05, 19.10, 19.15, 19.20, 19.25, 19.30, 19.40, 19.50, 20.00, 20.10, 20.20 |
| Trip 15| Lubuk Buaya         | 19.30, 19.45, 20.00 |

There are some limitations when designing the proposals schedule of Bus Trans Padang schedule, first the Trans Padang bus starts to operate at 05:30 AM, then the Trans Padang bus stops to operate after 08.00. PM, last the duration of Trans Padang bus travel is assumed for 60 minutes or 1 hour. The departure time of Bus Trans Padang on the proposal schedule is used as input on the simulation model that has been built. The load factor of each schedules can be determined which one is the best proposal schedule. The comparison of actual load factor and the result of proposal schedules of Trans Padang bus can be seen in Table 2.

Table 2. The Comparison of Actual And The Result of Proposal Schedules of Trans Padang Bus

| Schedule                  | Number of Bus | Time Between Departure | Number of Trips | Load Factor |
|---------------------------|---------------|------------------------|----------------|-------------|
| Actual Schedule           | 15            | 5, 10, and 15 minutes  | 14             | 1.700       |
| Schedule of Scenario 1    | 16            | 5 days 10 minutes      | 15             | 1.625       |
| Schedule of Scenario 2    | 17            | 5 days 10 minutes      | 15             | 1.400       |
| Schedule of Scenario 3    | 18            | 5 days 10 minutes      | 15             | 1.075       |
| Schedule of Scenario 4    | 19            | 5 days 10 minutes      | 15             | 0.825       |

Based on the Director General of Land Transportation, the load factor can be used to analyse the performance of the operation of public transport. The optimum load factor value of public transport...
should be close to 1 or close to 100%. The value of public transport load factor which is more than 100% can disturb comfort and safety of the public transport passenger. While the value of public transport load factor is less than one can be interpreted that performance of the operation of public transport is not optimum.

4. Conclusion

The closest value of load factor to one based on Table 5 is the load factor of schedule of scenario 3, which is 1.075 so that the 3rd schedule scenario is the most optimum schedule for Trans Padang bus schedule. The schedule can be seen in Table 3.

**Table 3. The Most Optimum Schedule of Trans Padang Bus**

| Number of Trip | Origin of Departure | Number of Bus |
|---------------|---------------------|---------------|
| Trip 1        | Imam Bonjol        | Bus 01        |
| Trip 2        | Imam Bonjol        | Bus 02        |
| Trip 3        | Imam Bonjol        | Bus 03        |
| Trip 4        | Imam Bonjol        | Bus 04        |
| Trip 5        | Imam Bonjol        | Bus 05        |
| Trip 6        | Imam Bonjol        | Bus 06        |
| Trip 7        | Imam Bonjol        | Bus 07        |
| Trip 8        | Imam Bonjol        | Bus 08        |
| Trip 9        | Imam Bonjol        | Bus 09        |
| Trip 10       | Imam Bonjol        | Bus 10        |
| Trip 11       | Imam Bonjol        | Bus 11        |
| Trip 12       | Imam Bonjol        | Bus 12        |
| Trip 13       | Imam Bonjol        | Bus 13        |
| Trip 14       | Imam Bonjol        | Bus 14        |
| Trip 15       | Imam Bonjol        | Bus 15        |
| Trip 16       | Imam Bonjol        | Bus 16        |
| Trip 17       | Imam Bonjol        | Bus 17        |
| Trip 18       | Imam Bonjol        | Bus 18        |

Based on the result of research, the schedule of Trans Padang Bus that is redesigned is more optimum than the actual schedule, determined by the load factor value that is 1,075. The optimum schedule of Bus Trans Padang can be seen in table 5.3. In that schedule the number of Trans Padang buses operated are 18 units, the number of trips are 15 trips and time between bus departures are 5 and 10 minutes.

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