

Article

## Application of Simulation Technique for Bus Stops Arrangement

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**Abstract:** This study uses simulation to improve efficiency of The Chiang Mai Municipality bus no. 2 (Arcade - Chiang Mai airport route). The target is to achieve the travel time from the starting station to the destination station within 1 hour and 45 minutes. The content of the research will present guidelines for the improvement and design of the Chiang Mai Municipality bus service by using simulation software Arena. In order to use the data obtained from the simulation to analyze and improve the service process of the Chiang Mai Municipality bus to be more efficient. From the simulation by reduce the number of stations. Chiang Mai Municipality bus will be able to provide the service as targeted for only 1 hour 45 minutes and reduce travel time up to 13:46 minutes or accounting for 11.01%. In conclusion, Chiang Mai Municipality bus service has a long traveling time causing passengers to wait a long time. The results of simulation found that Chiang Mai Municipality should reduce the number of stations.

**Keywords:** arena; simulation; public transportation; bus stops; Chiang Mai municipal.



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### 1. Introduction

Chiang Mai, THAILAND is one of the important city in the northern region, is the location of educational institutions, businesses, and important tourist attractions (Sensang et al., 2022). Chiang Mai has many populations and tourists. Therefore, public transport is very important (Caulfield & O'Mahony, 2007; Costa & Markellos, 1997; van Exel & Rietveld, 2001). Currently, there are only a few types of public transportation within this city. Type of public transportation in this city are as follows:

- Tricycle (Old town)
- Motorbike taxi (Only available in the bus terminal )
- Tuk Tuk (Downtown)
- Red car (Downtown)
- Blue car (Chiang Mai – Lam Phun)
- White car (Chiang Mai - Mae Taeng)
- Yellow car (Chiang Mai - Chom Thong)
- Orange car (Chiang Mai - Fang)

- Green car (Chiang Mai - Mae Jo)
- Dark red car (Chiang Mai – Phrao)
- Taxi Service call (GRAB)
- Taxi meter
- Public bus

Currently, the public bus in Chiang Mai available by 2 organizations are RTC Chiang Mai smart bus and Chiang Mai Municipality. After surveying the Chiang Mai Municipality bus service found that there is a small amount in each day. As there are many service stations (Up to 49 stations). Some stations have a few of passenger, some stations do not have passenger. But that bus is necessary to travel through all stations, resulting in a long traveling time and has a waiting period for bus (Johnson, 2003; Levinson et al., 2002). The problem in waiting is one reason that people do not choose to use public transport (Chen & Kitingern, 2020). In 2011, Cheevapattananuwong (2021) said that ambiguity regarding the details of the bus schedule details for each route provided, ambiguity of the bus stops are also the reason for the decision to use private cars as well. Thus, the provider need to improve bus systems to be more efficient in terms of their travel time and reliability (Agarwal & Singh, 2010). As described earlier the study aims to increase efficiency for the Chiang Mai Municipality bus service by using knowledge of simulation. The simulation is study of activity flows in various forms and collect data analyzing for the correct format by software to improve existing processes (Kelton et al., 2003). In order to lead solutions to the transportation problems with the results of the experiment applied in the service process of the Chiang Mai Municipality Bus in the future.

## 2. Materials and Methods

The researcher collected data on the routes of the Chiang Mai Municipality bus no. 2 (Arcade - Chiang Mai airport route). Record data using a stopwatch. The recorded data consists of:

- ***The number of passengers who get in the bus at each station.***

This information comes from calculate the number of passengers who get in the bus at station n to find the frequency of passengers at station n to calculate the proportion of the number of passengers to get in the bus at this station. From collecting the statistical data, it is found that the number of passengers get in the bus at station A1 as follows: 0 passenger at 9 times, 1 passenger at 9 times, 2 passengers at 10 times, 3 passengers at 10 times, 4 passengers at 5 times, 5 passengers at 3 times, 6 passengers at 3 times and 7 passengers at 1 times. From the data, it can be calculated that at this station A1, there is opportunity that passengers get in the bus is 0 the passenger is 18%, 1 passenger is 18%, 2 passenger is 20%, 3 passenger is 20%, 4 passenger is 10%, 5 passenger is 6%, 6 passenger is 6% and 7 passenger is 2%.

- ***The number of passengers who get off the bus at each station.***

This information comes from calculate the number of passengers who get off the bus at station n and calculate the averaged from the total of the sample of passengers who get off the current station n to the destination station .To find the distribution that passengers will have the opportunity to get off at the current station to the destination station. For example from collecting the statistical data, it's found that the number of passengers, who get in the bus at station 24 have the opportunity to get off at the next station are as follows: the passengers who want to get off at station 25 has 16.4%, at station 26 has 16.4%, at station 27 has 2.3%, at station 28 has 0 %, at station 29 has 0 %, at station 30 has 1 %, at station 31 has 0 %, at station 32 has 1.3 %, at station 33 has 0 %, at station 34 has 3 %, at station 35 has 2.7 %, at station 36 has 0.3 %, at station 37 has 0.3 %,at station 38 has 3.7 %, at station 39 has 2.3 %, at station 40 has 3 %, at station 41 has 0 %, at station 42 has 0.3 %,at station 43 has 2 %, at station 44 has 0.3 %, at station 45 has 1.75 %, at station 46 has 4.35 %, at station 47 has 3.75 %,at station 48 has 0 %, at station 40 has 34.85 %.

- ***The amount of time each passenger get in the bus at each station.***

This information comes from calculate the distribution of time each passenger to get in the bus and use that information to calculate the average per person. The information will be analyzed by Arena's input analyzer to find the distribution of the amount of time passenger to get in the bus at station n. After analyzing the data, it was found that the data is Lognormal distribution and expression is  $1.75 + \text{LOGN}(0.612, 0.343)$ . The distributions of the amount for time passenger to get in the bus at station n is given in Figure 1 below.

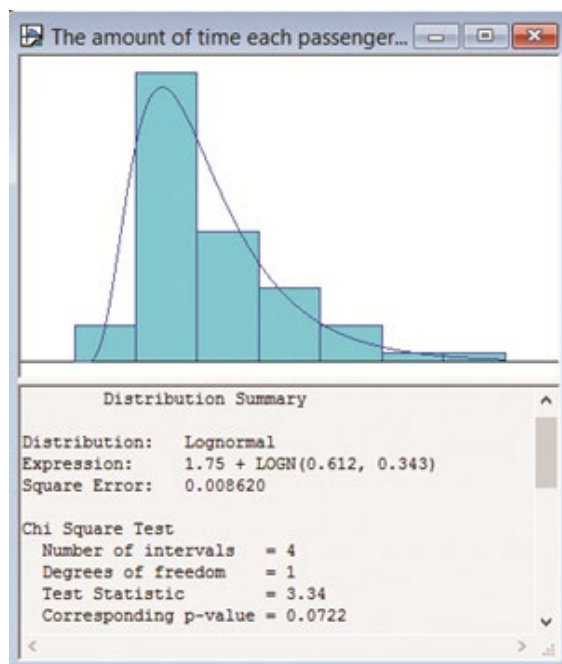


Figure 1. Plotting distributions for time passenger to get in the bus at station.

- **The amount of time that passengers get off the bus each station.**

This information comes from calculate the distribution of time each passenger to get off the bus and use that information to calculate the average per person. The information will be analyzed by Arena's input analyzer to find the distribution of the amount of time passenger to get off the bus at station n. After analyzing the data, it was found that the data is Erlang distribution and expression is  $1.13 + \text{ERLA}(0.0648, 20)$  and plot in the following figure.

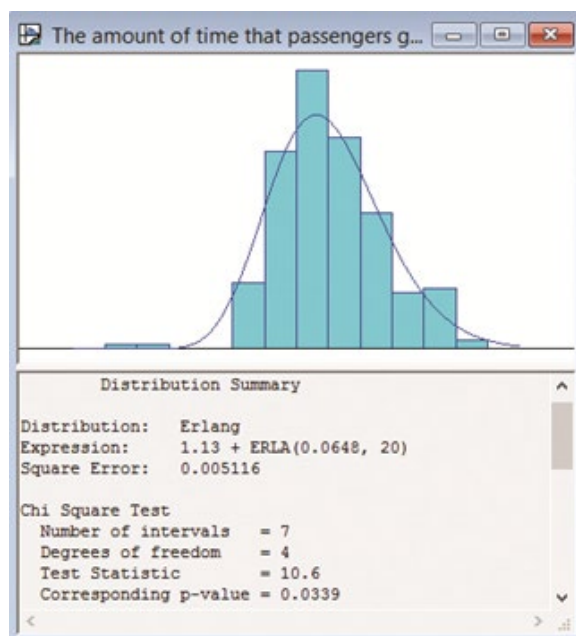


Figure 2. Plotting distributions for time passenger to get off the bus at station.

- **The duration of the bus movement from the current station to the next station.**

In this section data collector use the stopwatch by starting the timer after the bus door closes and starts moving until the delay before parking at the next station. After that, minimum time, mode time and maximum time of each station will be determined to be used in the simulation model. For example, the

travel time from the station 3 to the station 4 has minimum time is 0:02:14 minutes, mode time is 0:02:41 minutes and maximum time is 0:03:02 minutes.

• **The amount of time the bus slows down before reaching the station.**

As the bus cannot park immediately because if parking immediately may cause an accident. Researcher will use the stopwatch and starting the timer for start counting the period of the delay bus before parking and stop counting when the bus stop at the station. The information will be **analyzed** by Arena's input analyzer to find the distribution of the amount of time the bus slows down before reaching the station. After analyzing the data, it was found that the data is Triangular distribution and expression is TRIA (0.53, 1.4, 2.41).

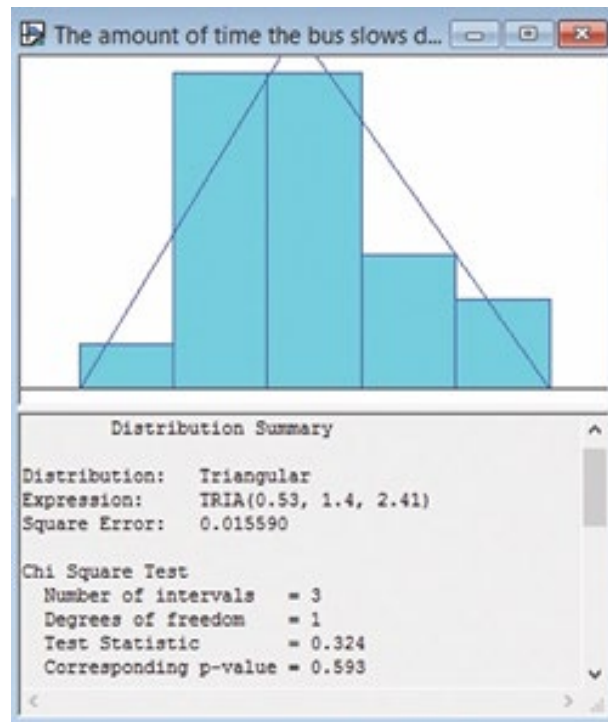


Figure 3. Plotting the amount of time for the bus slows down before reaching the station.

## 2.1. Simulation Model

Create a simulation model of the Chiang Mai Municipality bus no. 2 (Arcade - Chiang Mai airport route) 49 stations by using Arena Simulation Software version 14, copyright 2012 Rockwell Automation, Inc.

### 2.1.1. Building clocks for model

- Create bus: Assigned the bus get in the station at 40 minutes per car.
- Assign seat at start: Assigned that 1 bus can have 25 passengers and start counting traveling time.
- Assign at in n: Assigned the number of passengers to get in at station n by using the distribution of the total number of passengers to get in at station.
- Separate man at n: Assigned to separate passengers on the bus and the passengers to get in at the station.
- Assign seat for man n: Assigned the number of passengers to get off at station n by using the distribution of the passengers get to off at station.
- Hold man n: Assign the queue of the passenger to get in at the next station.
- Delay man at n: Assign the duration of the passengers to get off at station.
- Decide Pickup at n: The decision to locate the passengers to get in at the station.
- Pick up at n: Assigned the queue of passengers that will board at that station.
- Assign seat at n: Assigned the remaining seats of buses in station.

- Delay bus n to m: Set the travel time of the bus from the station n to the station m. determine the equation by using the minimum time, mode time, and maximum time of station n to station.
- Record bus n to m: Compile all duration statistics from the station n to the station.
- Assign bus start at m: Assigned to start counting the duration of traveling at the station.
- Search at m: Assigned for searching for passengers to get off at that station.
- Drop off at m: Assigned to drop off the passengers to that station.
- Assign seat after drop at m: Assigned to increase seats available after passengers to get off the bus at station.
- Record man at n: Compile statistics of all passengers at station.
- Separate at m: Separating passengers.
- Dispose at m: Exit the station.

When passenger to get off at station all, the model is calculated time for passenger, who need to get off the bus. After that, model will proceed with the same process. As Figure 4, it shows the simulation of moving the bus from the station to the next station.

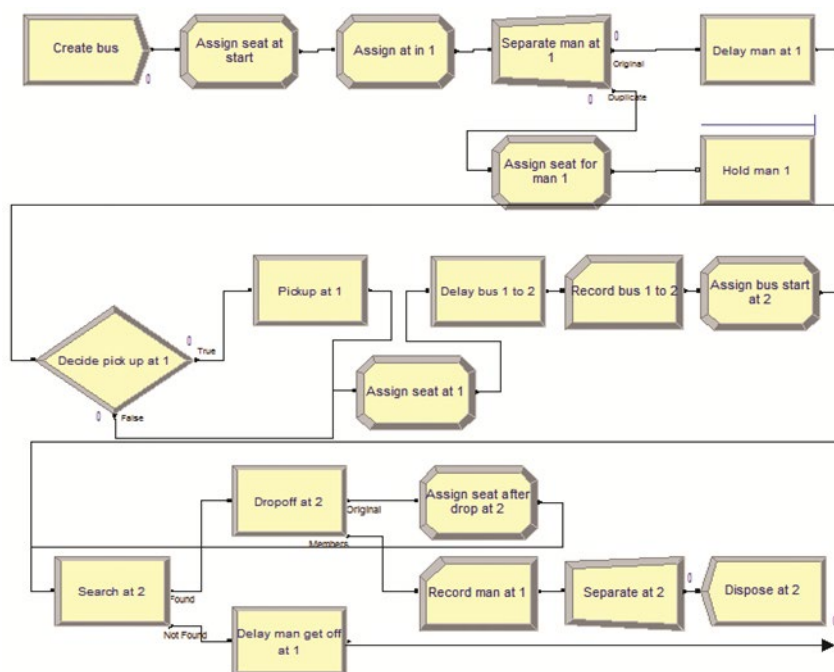


Figure 4. The simulation of moving the bus from the station to the next station.

## 2.2. Verification and Validation

From the validation of the bus simulation model according to table 1 found that the situation model can be analyzed to improve the efficiency of the bus because the result is in the range of acceptable when compared the travel time and average time in simulation model. By setting run setup number of replications is 7 times and confidence is 95%.

Table 1. Verification and Validation bus time.

Station	Travel Time (min)	Simulation Time (min)	Half Width
Bus 1 to 2	3.62	3.3898	0.55
Bus 2 to 3	1.93	1.9255	0.28
Bus 3 to 4	2.7	2.5750	0.16
Bus 4 to 5	1.57	1.5873	0.20
Bus 5 to 6	4.43	4.5075	0.52
Bus 6 to 7	2.01	2.2420	0.29

Bus 7 to 8	1.18	1.1376	0.16
Bus 8 to 9	2.35	2.3865	0.21
Bus 9 to 10	2.22	2.2752	0.20
Bus 10 to 11	1.87	2.1685	0.31
Bus 11 to 12	2.23	2.8185	0.07
Bus 12 to 13	1.52	1.7161	0.20
Bus 13 to 14	1.70	1.8178	0.19
Bus 14 to 15	1.88	1.9158	0.15
Bus 15 to 16	1.62	1.6980	0.13
Bus 16 to 17	2.22	2.1868	0.24
Bus 17 to 18	1.33	1.2151	0.16
Bus 18 to 19	1.62	1.5757	0.06
Bus 19 to 20	2.33	2.2758	0.35
Bus 20 to 21	2.47	2.5300	0.25
Bus 21 to 22	1.38	1.4510	0.19
Bus 22 to 23	1.62	1.6171	0.17
Bus 23 to 24	3.52	3.7082	0.22
Bus 24 to 25	5.35	4.9986	0.65
Bus 25 to 26	1.85	2.0739	0.23
Bus 26 to 27	5.32	5.3715	0.26
Bus 27 to 28	2.62	2.8360	0.25
Bus 28 to 29	1.67	1.6728	0.08
Station	Travel Time (min)	Simulation Time (min)	Half Width
Bus 29 to 30	1.95	2.0278	0.26
Bus 30 to 31	2.00	2.0234	0.28
Bus 31 to 32	1.92	2.0883	0.23
Bus 32 to 33	3.00	2.2534	0.48
Bus 33 to 34	2.23	2.1483	0.28
Bus 34 to 35	2.70	3.0499	0.35
Bus 35 to 36	2.89	2.9472	0.19
Bus 36 to 37	2.32	2.4390	0.26
Bus 37 to 38	1.68	1.7952	0.12
Bus 38 to 39	1.97	2.1400	0.27
Bus 39 to 40	2.23	2.4464	0.33
Bus 40 to 41	1.83	2.0156	0.23
Bus 41 to 42	1.92	2.0672	0.28
Bus 42 to 43	2.25	2.498	0.26
Bus 43 to 44	5.22	5.3718	0.37
Bus 44 to 45	3.17	2.8076	0.61
Bus 45 to 46	2.35	2.6926	0.45
Bus 46 to 47	2.75	2.5617	0.44
Bus 47 to 48	3.00	2.7500	0.71
Bus 48 to 49	2.68	2.9556	0.66

Although there is an increasing demand for the use of Artificial Intelligence (AI) for smart decision, it is often done manually in practice. Since, surgical scheduling is a complex problem, the application of mathematical programming is used as a solution technique for decision making in surgical scheduling system. This use of mathematical model could pave the way to AI for smart decision of surgical scheduling in hospitals and help improving performance opportunities of this challenging problem. In this study, the multi-period surgical scheduling problem with limited surgery capacity is addressed. The goal is to schedule a list of patients who must undergo various kinds of operations by different eligible hospitals. Two

objectives are considered in the proposed model; minimization of makespan and minimization of lease preference score of assigning patients to hospitals. The weighted sum approach is used to combine two objectives in a single objective. Then, an instance inspired by real treatments of cleft lip and palate patients is generated in order to conduct computational experiment for model analysis. The result shows that the model yield the correct assignment and operation sequence respected to all constraints. This, the proposed mathematical programming model has potential to bring significant improvements to practice.

Nevertheless, surgical scheduling problem is usually discussed under the assumptions that the surgery durations and capacity are deterministic variables, and only non-pre-emptive cases are considered. In practice, some of these assumptions are unrealistic. Hospital may be subjected to unpredictable conditions of their surgery capacity and surgery durations. Furthermore, arrival of emergency or urgent surgeries may occur and result in pre-emption's in the scheduling. Hence, the further research should be focused on stochastic modelling for handling the uncertainty in real-world practices.

### 3. Results and Discussion

From the designing a new bus stops arrangement simulation model by removing some stations. This showed that the new bus stops arrangement simulation model to reduce travel time up to 13:46 minutes or accounting for 11.01% and can service from the starting station to the destination station within 1 hour 45 minutes as targeted. Because those station had a few passenger ratios compared to other stations, some stations are located close to next station and the bus stop should have a station just 4-5 stations per 1 kilometer (Piriyawat, 2014). In which, removing some stations may cause inconvenience to passenger but can improve the efficiency of the bus service. Other than adjusting new bus stops, service provider should increase the frequency of bus services and has a clear schedule. As the bus service increases and has a clear schedule, it can help reduce the waiting time of passenger and can increase the efficiency in the bus service (Aurup & Cai, 2010).

**Table 2.** Comparison of travel time the original bus stops and the new bus stops.

Travel	Original Bus Stops (min)	New Bus Stops (min)	Difference (min)
Time	118.76	105.30	13.46

### 4. Conclusion

In conclusion, Chiang Mai Municipality bus service has a long traveling time causing passengers to wait a long time. Resulting in the simulation software Arena version 14 being used to increased efficiency and reduced travel time for the Chiang Mai municipality bus. The results of simulation found that Chiang Mai Municipality should reduce the number of stations. So, will be able to provide the service as targeted. The new bus stops arrangement offers only 31 stations from 49 stations, that number of stations will be able to provide services as the target of 1 hour 45 minutes and have a service efficiency of more than 11.01%.

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