A SIMULATION MODEL APPLICATION FOR CHIANG MAI UNIVERSITY MASS TRANSPORTATION SERVICE IMPROVEMENTS

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Introduction

Chiang Mai University (CMU), was founded in January 1964, being the first provincial institution of higher education in Thailand. CMU has confronted with a transportation problem such as air and noise pollution, energy costs, parking lots, etc. Thus, a CMU mass transport service project was established to solve the CMU transportation problem by operating electric-powered vehicles.

However, this project does not achieve expected results, including with unpunctuality, insufficiency of vehicles, inaccessibility of routes and unsatisfied services (Tsuda, 2003). Vehicle fleet routing and timetable setting are the fundamental focus of the transportation service system because they play an important role for increasing level of satisfaction. Moreover, the passenger trip demands, the operating constraints, the operating costs, maintenance and crew scheduling, have been considered in the transportation system (Yan and Chen, 2002).

The transportation problem is one of the planning problems with stochastic disturbances. Yan *et al* (2006) applied a simulation technique to solve the projected and actual daily passenger demand problem or stochastic disturbances. Simulation modelling is a common paradigm to experiment with the complex system such as improved system design, cost-benefit analysis, sensitivity to design parameters and so on (Altiok and Melamed (2010).

The purposes of this research are to analyze a problem of a mass transport service system in Chiang Mai University and propose efficient approaches for improving the logistics system. The rest of this research is organized as follows: In Section 2, related literatures are reviewed. In Section 3, a method for modeling the simulation is proposed. In Section 4, numerical tests are executed to discuss the performance of the models and to compare with proposed approaches. Finally, conclusions are offered in Section 5.

Literature Review

Transportation problems and their solution techniques have made big issues in logistics and supply chain management for reducing cost, improving service quality, etc (Cetin and Tiryaki, 2014). The general transportation problem is focused on any commodity distribution from any group of supply centres called sources to any group of receiving centres called destinations (Chaudhuri and De, 2009). Laporte (1992) advocated that the vehicle routing problem (VRP) plays a significant role in the fields of physical distribution and logistics. This problem could be solved by using not only exact algorithms but also heuristics algorithms. Wang and Lang (2008) combined a tabu search algorithm with a new solution indicating method to give a short computation time and stable results. Nevertheless, in last decade, simulation has also been a promising tool for solving the VRP. A mathematics simulation model was developed to minimize cost in the logistics processes of the radiopharmaceutical products (Kaewmam, 2011).

Tsuda (2003) investigated the inefficiency of the CMU mass transportation project. It was also found that the expectation was set at high level, but the satisfaction level was evaluated at the low level. Therefore, it is necessary to improve a CMU mass transport service project by applying the simulation technique for dealing with a complicated problem.

Research Methodology

CMU mass transport service problem was analyzed and evaluated via simulation study for reforming quality of services. The model was kept as simple as possible to keep away from any noise that affects the results. The simulated model was developed using the simulation commercial software ARENA 14.0. Numerical data were obtained by using time study sheets which comprised of an electric-powered vehicle duration form, a take on and off passenger data form. All statistical distributions were analyzed by goodness of fit tests (the Kolmogorov-Smirnov test or the chi-square test). Verification and validation techniques were tested to accredit the simulation model.

The Input Analyzer was used on observed historical data for estimating a probability distribution and parameters. An error-free computer program or debugging the model has been used which is called verification. This study employed a structured walkthrough technique to verify the model. The simulated results were compared with existing systems output data to determine event validity (Law, 2008). Internal validity was exploited to convince the model from the amount of stochastic variability (Sargent, 2008).

The ARENA was run at approximate replications to achieve a confidence interval with a pre-specific desired half width for forming outputs of lead time and delivery reliability as follows:

$$n \cong n_{\circ} \times \left(\frac{h_{\circ}^{2}}{h^{2}} \right) \tag{1}$$

where $n_{\circ}$ is the number of initial replications and $h_{\circ}$ is the half width from initial replications, h is a pre-specified desired half width.

Finally, the accredited model was analyzed and compared with proposed alternatives for observing results.

Results and Discussion

This section discussed the results of the simulation study for the CMU mass transport service problem. The study was performed on a computer with an Intel® Core™2 Duo CPU P8700 running at 2.53 GHz with 4 GB of RAM. Ten independent replications were set to observe the model. Each replication was terminated in one-hundred-twenty minutes. Common random numbers were adopted to diminish the variance across experiments.

An overview of the simulated design

A procedure of CMU mass transport service system was developed by mimicking current transportation operations as shown in Figure 1. On one hand, the stochastic passenger trip demand triggered the transport system. Each passenger goes to electric-powered vehicle stations and then waits for the restricted thirteen-seat vehicle. On the other hand, a planned schedule is typically set based upon experience. Scheduler drafts a timetable by utilizing the trial-and-error process for vehicle routing and scheduling practices. Sometimes, this timetable is adjusted with possible revisions. This process is iterated manually until a desirable timetable is obtained.

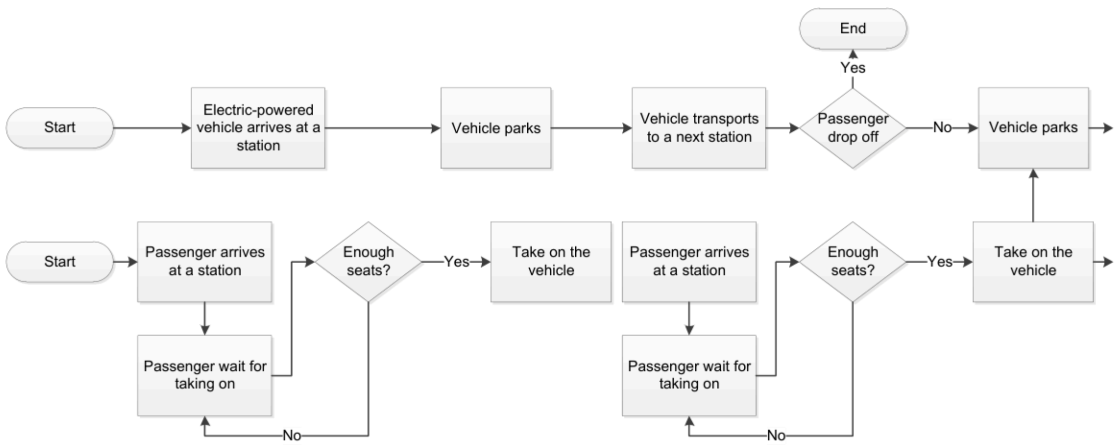


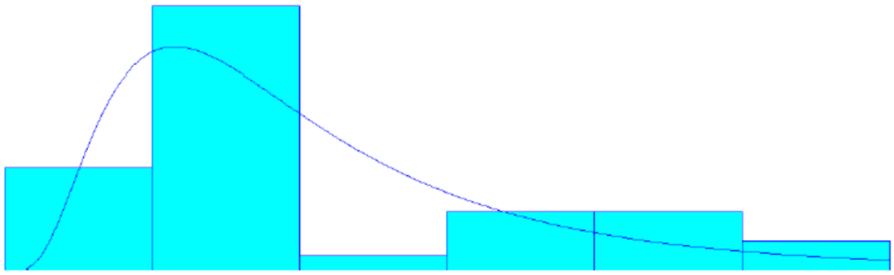
Figure 1: An overview of the mass transport service system in Chiang Mai University

Besides, the simulation model was built by using assumptions as follows:

- Route number one with service on specific time from 8:00 a.m. to 10:00 a.m. was selected as a case study. Hence, the simulation run length was started from 0.00 minute to finish at 120.00 minutes for each replication. Moreover, the first entity was generated at 0.00 minute and maximum number of arrivals was placed at infinity.

- All passengers were sequentially (on a first come, first served basis) assigned the same priority. Electric-powered vehicles could be continuously operated for serving passengers. Failure condition was unconsidered in this model.
- Simulated transportation average cost was set at 1 unit per minute.
- Level of service satisfaction was measured by considering passenger waiting time.

Verification and validation
Numerical experiments usd a historical data set of time study sheets. Statistical distributions from the Input Analyzer were tested by using goodness-of-fit tests. The Input Analyzer displayed a histogram of the electric-powered vehicle departure from the first station as shown in Figure 2. It formed a lognormal distribution (corresponding p-value > 0.15). The basic characteristics of the simulation model are listed in Table 1.



Shop	CMU Front Gate Station
Distribution	Lognormal
Expression	LOGN(0.603, 0.445)
Priority dispatching rule	FIFO
Time unit	Minute
P-Value	>0.15

Figure 2: Statistical distribution of the electric-powered vehicle

Number of stations:	Thirty-seven stations
The electric-powered vehicle departure:	Lognormal distribution (0.603, 0.445)
Passenger-arrival times:	Beta, Exponential or Weibull distribution
Priority queue:	First come, first served basis
Time unit:	Minute

Table 1: Summary of simulated model characteristics

It was found that Health Centre station, Agriculture passenger hall station, Faculty of Business Administration station, Cooperative Store passenger hall station and Faculty of Social Sciences station were high probability drop-off stations.

The model was verified by implementing a structured walkthrough technique. Event validity was made by equating simulation results to actual results. The simulation outputs report is stated in Figure 3. A comparative experiment was analyzed using confidence interval procedure for comparing results as exhibited in Table 2. Thus, it appeared that the model was reasonably valid.

Generally, the simulation report generates a column called “half width of 95% confidence intervals”, which determines the reliability of the simulated results. However, the half maximum width of this experiment was 2.05 minutes.

Replications: 10 Time Units: Minutes

User Specified

Tally

Interval	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Duration at Acc ba	61.5469	0.93	59.5815	63.5733	17.0000	120.00
Duration at Augkaew	64.7002	0.77	63.0047	66.0324	31.0000	119.99
Duration at Building4 of Education	62.1330	0.86	60.7017	63.8620	21.0000	119.99
Duration at Canteen of Education	62.4479	0.83	61.1284	64.0318	21.0000	119.99
Duration at CMU Food Court	56.0268	1.29	52.2674	58.2893	4.0000	119.92
Duration at CMU Front Gate Station	65.2203	0.66	63.7238	66.5620	34.0000	119.94
Duration at Department of Education	62.2513	0.88	60.5979	63.7930	20.0000	119.96
Duration at Dorm 40	62.0580	1.34	58.9416	65.0622	9.0000	119.94
Duration at Dorm G2	59.0864	1.07	56.5019	61.2346	5.0000	119.92
Duration at Dorm G4	61.0609	1.04	59.3252	63.7316	12.0000	119.91
Duration at Dorm G5	61.2815	1.06	59.3055	64.1389	12.0000	119.91
Duration at Dorm G6	61.3480	0.82	59.8871	63.5213	14.0000	119.84
Duration at Dorm G8	61.5601	1.55	58.6806	65.1536	11.0000	119.98
Duration at Dorm Pink	61.0648	1.23	57.4504	63.1962	7.0000	119.94

Figure 3: User specified simulated results

Station	Actual	Simulation
CMU food court	4.19-6.14	4.00
Women second dormitory	4.52-6.47	5.00
Pink dormitory	5.58-8.22	7.00
Forty-year anniversary dormitory	6.53-9.17	9.00
Women eighth dormitory	9.17-12.46	11.00
Women fifth dormitory	9.49-13.44	12.00
Women fourth dormitory	10.16-14.11	12.00
Women sixth dormitory	11.05-15.00	14.00
Faculty of Business Administration	16.45-20.42	17.00
Department of Home Economics, Faculty of Education	18.53-21.50	20.00
Canteen of Faculty of Education	19.06-22.03	21.00
Fourth building of Faculty of Education	20.42-24.44	21.00

Table 2: Partial results of a comparative experiment

However, the variance should be lower than one minute by referencing to corresponding officer's suggestions. From Equation one, a number of replications might be adjusted instead of ten replications to $n \cong 10 \times \left(\frac{2.05^2}{1.00^2} \right) \cong 42$ replications. Additionally, several replications of the simulation model were developed to obtain a satisfactory internal valid model.

Results comparison

Existing-simulated results were compared with proposed alternative systems to improve CMU mass transport service. Comparative experiments comprised of transportation average cost and passenger waiting time. These alternative approaches are:

- Increase five percent of electric-powered vehicle quantities.
- Operate an express route for stopping at high probability drop-off stations by using existing electric-powered vehicles.

As the results, transportation average cost and passenger waiting time are compared in Tables 3 and 4, respectively.

The first alternative increased cost 7.36% and reduced insignificant waiting times. The second alternative made an impact for decreasing waiting times in five specified stations. The other stations increased a little waiting time

Comparative issue	Existing	Alternative 1	Diff.	Alternative 2	Diff.
Transportation average cost	54.4524	62.0714	+7.36%	54.4524	-

Table 3: Comparative results of transportation average cost

Station	Existing	Alternative 1	Alternative 2
Division of General Affairs Office	0.4725	0.4522	0.8016
Faculty of Political Science and Public Administration	0.4785	0.4498	0.8012
CMU food court	0.5251	0.4943	0.8415
Women second dormitory	0.5624	0.5324	0.8780
Tennis court	0.6044	0.5719	0.9161
Pink dormitory	0.6619	0.6367	0.9646
Forty-year anniversary dormitory	0.7963	0.7633	1.1051
Pink dormitory (circulate route)	0.8691	0.8630	1.1829
Health Centre	0.9313	0.9151	0.6546
Women eighth dormitory	0.9486	0.9234	1.2517
Women fifth dormitory	1.0316	1.0328	1.3454
Women fourth dormitory	1.0345	1.0218	1.3390
Women sixth dormitory	1.2683	1.2184	1.5659
Swimming pool	1.2639	1.2361	1.5681
Main stadium	1.2587	1.2432	1.5698
Agriculture passenger hall	1.5275	1.4582	0.9706
Faculty of Business Administration	1.6317	1.6245	1.0355
Softball area passenger hall	1.9250	1.8884	2.2227
Department of Home Economics, Faculty of Education	2.0716	2.0698	2.3369
Canteen of Faculty of Education	2.2761	2.2732	2.5586
Fourth building of Faculty of Education	2.1977	2.2065	2.5400
Canteen parking lots of Faculty of Education	2.4363	2.3987	2.7065
Faculty of Engineering	2.7662	2.8176	3.1115
Faculty of Architecture	3.2531	3.2748	3.5683
Men first dormitory passenger hall	3.4556	3.4691	3.7079
College of Arts, Media and Technology passenger hall	3.7419	3.6479	3.9841
Cooperative store passenger hall	3.8737	3.8068	2.5903
Faculty of Social Sciences	3.9450	4.0000	2.5810
Social Science building passenger hall	4.1610	4.1925	4.3436
Ang-kaew	4.4398	4.3411	4.7935
Information Technology Service Centre passenger hall	4.6501	4.6768	4.9329
Sala dharm	4.7054	4.6669	4.8500
Rugby area	4.9100	4.9780	5.2752

Table 4: Comparative results of passenger waiting time

Conclusions

From the case study, experimental results indicated that this model nearly behaved the same as a real system. The simulated-prototype could be applied to design the case study. The assessment results showed that alternative two performed better than alternative one and the existing one.

The case study had some gaps to bridge such as an appropriate route, a number of available electric-powered vehicles, considering average operating speed and the turn-around time at the station, the related cost/revenue of electric-powered vehicle movements and the quality improvement of service to attract more people. The validated simulation model gives transportation planners to test various mass transport service scenario solutions involving the use of intelligent transportation systems prior to their implementation.

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