A Simulation Approach to Integration of Bus-Elevated Train System

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Abstract

This paper describes the way of integration between the existing bus system and the new constructing elevated train system by simulation approach. The paper firstly analyzed the existing transportation system of Bangkok and then introduced the conceptual simulation model for the new constructing elevated train system. The model was then formulated in ARENA simulation package. Base on the first conceptual model result, the model is extended to cover the main problem of integration between the bus system and the elevated train system. Finally, the paper discussed about the number of trains, the place of the train station and the schedule of the train system based on the simulation results.

1. Introduction

One major cause of traffic problems in large and heavily populated cities is *poor mass public transportation system*. The main mass public transportation that is solely relied on the city of **Bangkok** is the bus transportation system. With the rapid growing of over population of Bangkok together with the fetish of Bangkok people on cars, the bus transportation have not been able to effective accommodate all of its travelers. Like many other major cities in the world, when one mass public transportation system is insufficient to effectively accommodate all city travelers, these cities must have to implement another effective transportation system. Now, Bangkok is being implemented with an elevated train system. This train system is expect to accommodate a mass number of city travelers in *heavily populated and business oriented areas* that should significantly take weight off the public buses and ease traffic problems in those areas. However, like many other large cities that have implemented an additional mass system such as a train system, their bus system had modified to implement effectively on the new coming train system. Thus, the systematic approach to develop integration between the existing bus system and the new coming train system is very important issue.

2. Problem Statement

Improper integration between the existing bus system and the new coming train system, the expected outcome of reducing traffic problem, could not reach and can obtain the worse traffic problem with empty train and crowed buses or crowed trains with empty buses. Therefore, it is necessary to analyze the suitable approach for the effective integration that can give the best performance between the train system and the existing bus system. To find the best solution of this problem, the overall system must be analyzed closely. Then, it is necessary to develop the suitable train stops, number of lodges in a train and the train schedules for effective integration with the existing bus schedules.

There are several tools and techniques to analyze the interaction of mass transit system. Black (1989) stated that simulation is a powerful tool in the analysis of difficult real life phenomena with complex relationship among the numerous variables affecting bus transport operation. Dickey (1983) also presented many ways of analysis on traffic surveys. Seetraram(1986) developed a computer simulation model to study the performance of the public bus system during the peak periods and periods of congestion.

3. Model Development

Due to the probabilistic nature of problem and involving with many parameters in transportation models, many researchers finally suggested to use simulation as a good tool to handle that. (Seetraram, 1986). This research work also aimed to use the simulation as a tool for analysis the integration problem. The flow diagram of the research work was presented in Figure 1.

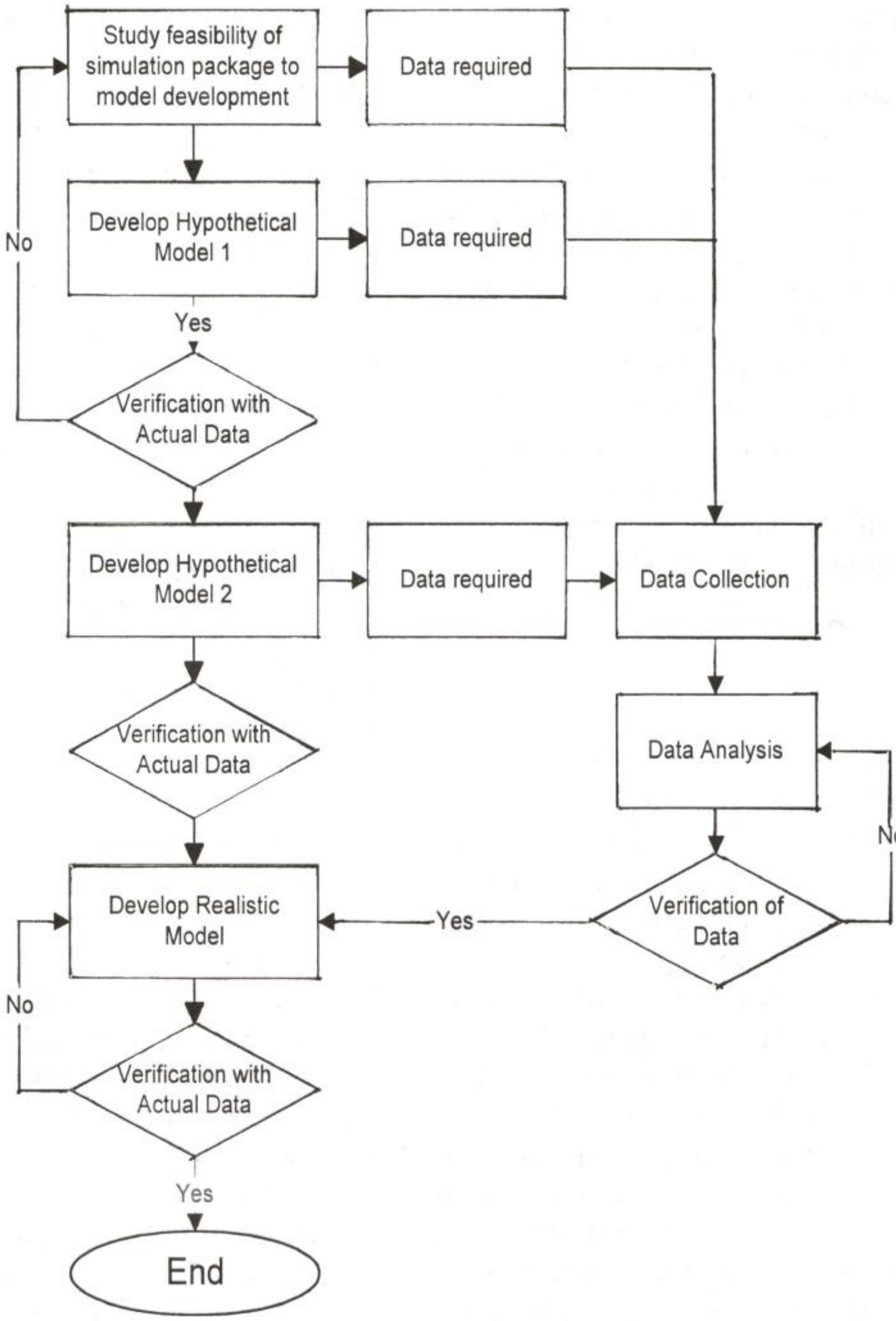

Figure 1 – Flow Diagram of Simulation Approach

It might be too late if the analyze is begun after the new transport is already used. Only one way to analyze the whole system before both of them are used is to simulate the system. When applying simulation approach, it is necessary to formulate the proper model that can be an image of the real situation as much as possible. In addition, there are many available simulation software and thus, it is necessary to select the proper one which can provide flexible tool and interface for development at model development. According to above mention situation, the approach firstly started with proper simulation package selection among available.

There are many programs that are suitable for the transportation system but the most suitable is ARENA. ARENA is not specific only for the transportation system but also for many types of simulation. This is a good point of ARENA because it can support as many cases as the user want and the simulated system would be more similar to the real system. The second benefit of ARENA is that the software contains the powerful tool about the statistical and many kinds of distribution. These support the user to simulate the system comfortably. Another advantage of ARENA is that it is a flowchart program so the system can be checked and understand easily. In addition, due to unavailable simulation packages at institute, the only ARENA simulation package was a dominant tool for formulating the problem stated.

After selection the simulation software tool, the scope of the system would be thought about. Like a saying of "Solve difficulties by think simple first", the simple hypothetical model 1 was developed by considering only two train stops with only one bus lane arrival. That can be described as shown in Figure 2. The simplest model was simulated in order to study for the feasibility of the direction of the model formulation. Then the more advanced system was simulated to make the system closer to the real world system.

After formulation of the model, the verification and validation are needed at the end of each model. For verification and validation after developing the completed final program, it is very difficult and too late to debug the model. To simulate the system, many parameters are also needed to be concerned and many data are needed collected.

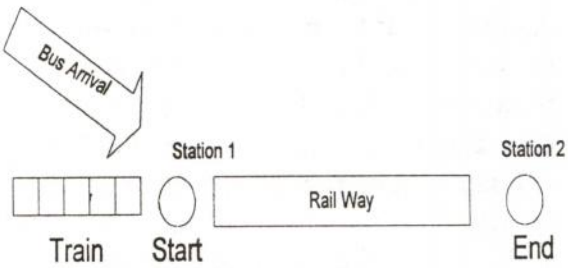

Figure 2 – Model Flow Diagram of Hypothetical Model 1

After developing the model 1 to cope with the general idea of integration, the model was tested with the theoretical weibull distributions with varying shape factor and scale factor. In that model 1, the train time between station 1 to station 2 was constant. The number of lodges at the train is 5. The output analysis was the queue length at the starting station based on the bus arrival. From analysis of output result, it is concluded that the number of queues at the station 1 was not much related with bus arrival on only one bus station with one bus system. The queue depends on the train schedule.

Then the model 1 was extended to analyze on multiple bus arrival condition. Thus, the hypothetical model 2 was developed. In that model, there are three ways of bus arrival and each way has three different bus numbers to be arrived. The model can be illustrated as shown in Figure 3. After developing hypothetical model 2, the model was tested with real data for validation.

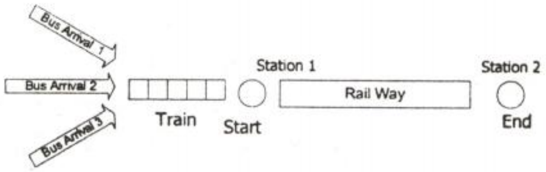

Figure 3 Model Flow Diagram of Hypothetical Model 2

3.1 Data Collection

After model construction, the estimated data were put to run on the final model in order to be used for verification and validation because the data that are close to the realistic data can reduce mistaken of verification and validation. The raw data of the coming traveler for rush hours (6.00-10.00 a.m.) were collected at the starting point of the elevated train system to estimate the number of the coming passengers who come to use the elevated electric train.

3.2 Input Data Assumption

However the real data were collected, there were many data that were not available such as train speed, train capacity, and etc. So these data were estimated by suggestion from the company. Although some of the assumption, the verification and validation of the program can show that the model is ready for the real data. After verification with the real data into the model 2, the model 2 was behaved as a block for each station of the train.

4. Implementation

After validation the model 2 with real data, the final realistic model was developed by combination of model 2 and analyzed based on the results appeared at the model 2. The final model was extended by many train stations with three bus arrivals to the first train stations as shown in Figure 4.

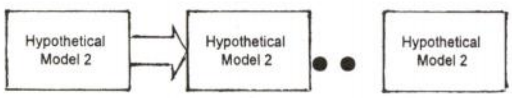

Figure 4 Model Development of Final Realistic Model by combination of Model 2

At first, the final model was extended by appending two model 2 as considering 4 train stations with 3 bus lane arrival on each two alternative station. Then, simulation was carried out based on actual data and find out the maximum queues by varying the train arrival time. The results of simulation can be shown from Figure 5 through 9.

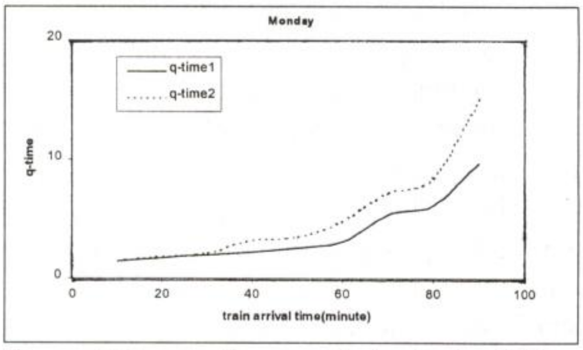

Figure 5 Queue time vs. Train Arrival Time for Monday

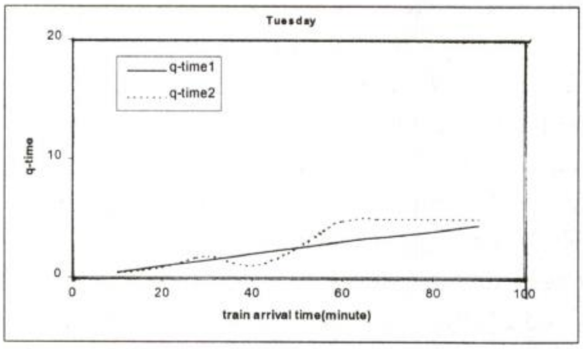

Figure 6 Queue time vs. Train Arrival Time for Tuesday

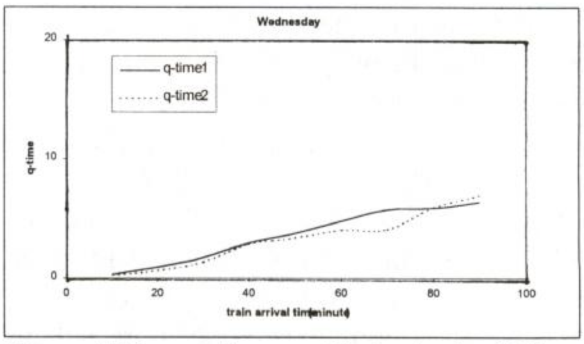

Figure 7 Queue time vs. Train Arrival Time for Wednesday

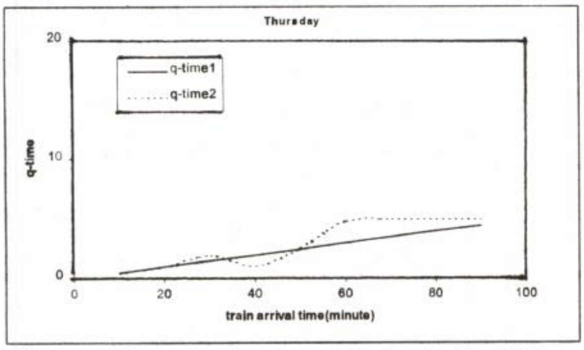

Figure 8 Queue time vs. Train Arrival Time for Thursday

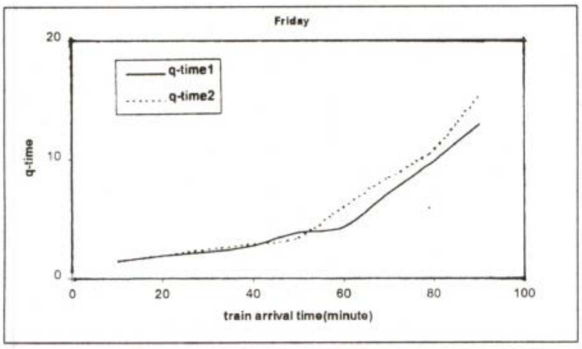

Figure 9 Queue time vs. Train Arrival Time for Friday

5. Results and Discussions

The important output data that are very necessary for the analyses are the queuing time at all stations (both bus station and train station). The passengers are directly effected by the queuing time. They might turn to use any other ways that may caused the traffic problem again if they had to wait for the train for a very long time.

Therefore, maximum waiting time was measured in analysis. At the first analysis, various data will be collected again and again for each different inter-arrival time of elevated train.

Then, the appropriate train arrival time distribution was derived. After that the model were run again with the fixed train inter-arrival time but variety in bus arrival time at the second stations. The same method was used to find the appropriate bus inter-arrival time.

There were five different data sets that were simulated in the final program for five days (Monday to Friday). The results of each are shown in table 1.

Table 1 The results of the final model

Day	train arrival time	q-time train station1	q-time train station2	q-time bus station
Monday	10 min.	5min.	5min.	3.5min.
Tuesday	15min.	5min.	5min.	2.0min.
Wednesday	15min	5min.	5min.	2.0min.
Thursday	15min.	5min.	5min.	1.5min.
Friday	10min.	5min.	5min.	3.0min.

From the results, it can be approximated that on Tuesday, Wednesday and Thursday, the waiting time for a passenger is small. On Monday, there are much more passengers than the first three day. This may be because it is the first day of the week. On Friday, the waiting time was increasing with the train arrival time. Based on the graph analysis, we can choose the best train arrival time by giving the suitable waiting at each station. If the waiting time for the train is too high, the passengers will not wait and change to select another available transportation and that might give worse condition to the system.

Therefore, the proper waiting time for train is very important. According to Figures (4) to (9), the common waiting time is defined as 5 min. Then, we can find the common train arrival or train schedule between each station can be selected. For example, on Monday, if train is scheduled to be appeared on the range between 20 min. to 30 min., the waiting time of a passenger does not affect much with the value of 5 min. to 6 min. only. Similarly, we can find out the suitable train arrival time that gives the acceptable waiting time for a passenger.

Based on the model 2, the final model was simulated as shown in Figure 4 and the results for the final model was tabulated in Table 1 for 5 number of stations for the train. The simulating had been done to show how to use the program and how to find the real optimum solution. Depended on the rough input data the results show that in each day the inter-arrival times are not similar to one another. To optimize the capacity of the system, the inter-arrival time must be changed to appropriate with the traveler need.

6. Conclusion

This paper presents the basic idea to avoid the problems that might be happened in the future. The elevated electric train introduced to the system will work with the bus system. It is not the real system, both the verification and validation are needed. In order to verify and validate the model to be ready to use for the real world, some raw data are collected from the real world. After analyzing and adjusting, these data are put in to the system as input parameters. These parameters consisted of arrival time and batch size of the passengers, capacity of train, capacity of bus, and travel time between each two train-stations. After running, the results are analyzed and variable parameters such as train arrival time and bus arrival time are changed in order to find the optimal solution. The final values of these variable parameters are the target of the analysis but the output data from the program are the queuing time at each station. These optimum values can be obtained from the output of the model. The accepted queuing time must be set in order to find the longest arrival time of both bus and train. Currently, the final simulation model is extended to accept more realistic condition by combining the constraints of possible places for the train stations together with the existing bus routing. Moreover, the research is planned to extend the model to be simulation optimization by using the concept of Genetic Algorithms (GAs).

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