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A Simulation Modelling For Bus Capacity Planning

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ABSTRACT
One of the main problems of the cities is the inefficiency of the service systems and, hence one of the primary goals of them is to improve the services for the citizens by increased utilization of the service resources. Therefore, a lot of techniques have been proposed in the literature. Among these techniques, simulation modelling is of great importance with its analysis power. The goal of this study is to provide the benefits of the simulation modelling in bus line planning and determine the efficiency of the bus capacities to meet the passenger demands and present solution for the problems.
KEYWORDS: bus planning, simulation modelling, service improvement, meeting the passenger needs, urban network, service efficiency, utilization of resources.

I. INTRODUCTION

Increasing the service quality is important for the cities. The citizen services can't be expressed not only the meeting the demands; but also it includes activities between administration and citizen.
Buses can be defined as the backbone of all urban public transport systems around the world (Babalık and Cengiz, 2015). The bus system management needs buses, driver and passenger resources in a manner that enables the service in desired quality, in desired period. In other words, bus system management seeks to optimize passenger demands, passenger numbers. For this reason, the necessity of using various solution methods. Bus planning problems generally are solved by mathematical programming approaches, agents systems and heuristic methods. Mathematical approaches are used to optimize bus capacities, time and cost minimization of using the system, scheduling the urban service systems; agent based systems are used for the dynamic bus systems; heuristic approaches are used for the larger case studies such as all country's network.
The main purpose of the bus system management is to examine the bus capacity considering resources (passenger demands, numbers). In this way, the bus system management

a. Aims to meet the demands of consumers in a best possible manner in terms of price, time, amount and quality,
b. Aims to keep the citizen numbers as low as possible or increase the bus turn,
c. Aims to increase the utilization rate of the resources

Some studies about the bus system are in the literature ([1]; [2], [23]; [4]; [5]; [6]; [7], [8]; [9]; [10]). There are studies about the bus services using simulation method in the literature. An agent-based simulation is developed to improve bus public transport systems by measuring the impact of passenger behaviours in the performance of new bus layout [11]. Bus lines are examined by a simulation model using transit network in the city determining level of service [12]. A simulation modeling is developed to maximize service performance by bus routes. Planned headways and a total fleet size are used [13]. A simulation and optimization tools are developed to improve the Bus Service Levels. Small changes in the headways of bus lines are provided to increase public transport service level [14]. A simulation model is developed for battery electric buses operation to investigate operational feasibility and grid impact analysis [15]. A problem is presented to minimize waiting times of passengers. They consider arrivals as stochastic. They develop a simulation model for this problem [16].
The remainder of the paper is presented as follows. We present the material-method in Section 2. We conduct results in Section 3. We conclude the paper with a summary of the study and future directions in Section 4.

II. MATERIAL- METHOD

A simulation model developed in the study is given in figure 1. Model is developed in the ARENA software and replication number is taken as 10. Dataset is formed by the authors.
In this model, processes are realized for the three bus lines and bus numbers at the same route. At the end of the model, the decision whether the bus numbers are enough is examined.

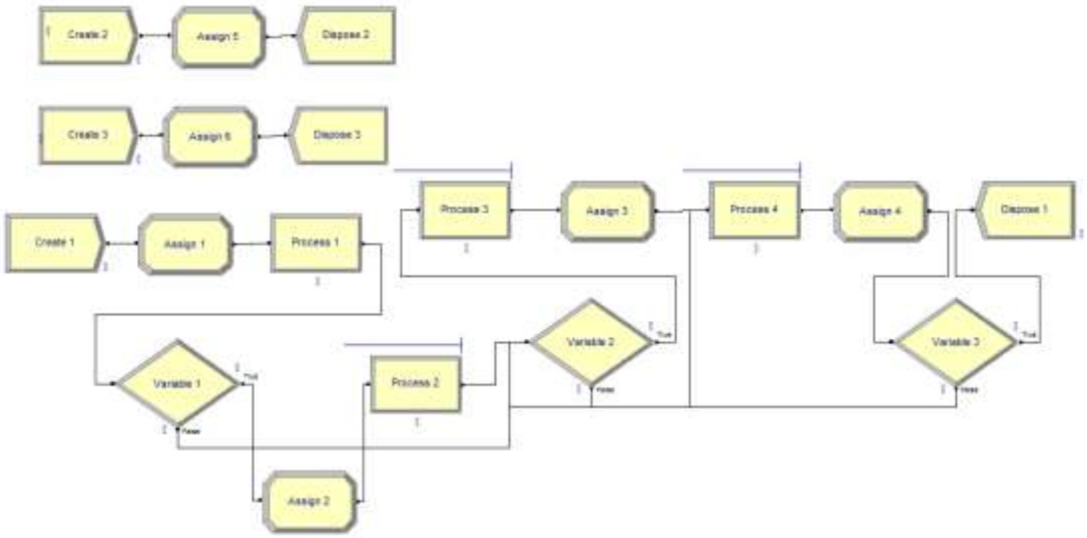

Figure 1. Developed simulation model by the authors

Module definitions of the developed model as bellows in Figure 1:

- Create 1 : Defines the times between arrivals of the passengers
- Process 1 : Show the waiting times of the passengers
- Variable 1 : Defines whether any passenger get off from the bus
- Assign 2 : Calculates the capacity of the bus when any passenger get off.
- Process 2 : Defines the time getting off from the bus.
- Variable 2 :Controls the empty seat after getting off the passengers.
- Process 3 : Defines the getting on of the passengers.
- Assign 3 :Calculates the capacity when getting on.
- Process 4 : Defines the next bus stop.
- Assign 4 : Defines the total bus stop numbers passed by the bus.
- Variable 3 : Provides that all bus stops are passed by the bus or reprocessing all the processes, finishing the system.
- Create 2, Assign 5, Dispose 2 defines increasing station numbers one by one; Create 3, Assign 6, Dispose 3 provides the processing of the passengers one by one.

III. RESULTS

The developed simulation model is simulated in the Arena software. The study is presented to examine the efficiency of the bus capacities with times between arrivals. The three numbers of bus and operating hours of the buses for 12 hours are assumed. The bus starts its tour at the terminal hourly. In addition, after defining of the routes of the buses, new route will start after half hour break.

Resource

Usage

Instantaneous Utilization	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Bus 1	0.8629	0,00	0.8604	0.8646	0.00	1.00
Bus 2	0.8000	0,00	0.8000	0.8000	0.00	1.00
Bus 3	0.7404	0,00	0.7382	0.7417	0.00	1.00

Number Busy	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Bus 1	0.8629	0,00	0.8604	0.8646	0.00	1.00
Bus 2	0.8000	0,00	0.8000	0.8000	0.00	1.00
Bus 3	0.7404	0,00	0.7382	0.7417	0.00	1.00

Figure 2. Utilizaiton of the resources

In figure 2, utilization of the buses and busy rates are shown. Bus 1 is the busiest vehicle and utilized mostly than the other vehicles.

Unnamed Project

Replications: 10 Time Units : Hours

Resource

Usage

Total Number Seized	Average	Half Width	Minimum Average	Maximum Average
Bus 1	2480.70	26,25	2397.00	2521.00
Bus 2	2324.10	28,57	2245.00	2394.00
Bus 3	2132.20	28,69	2053.00	2197.00

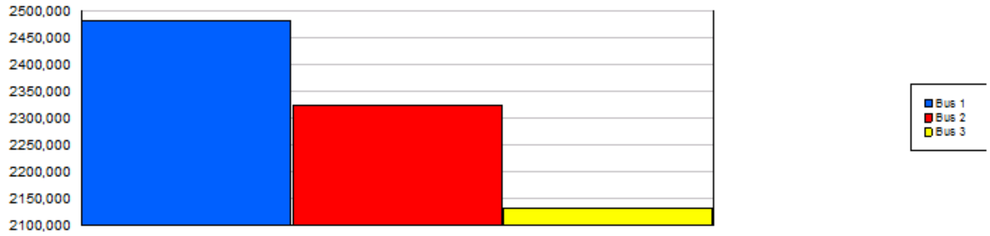

Figure 3. Passenger numbers of the buses

In Figure 3, replication number is determined as 10. Total passenger numbers in the buses are shown.

3.1. Scenario Analysis

Scenario analysis is used to change the parameters of the system and in this system; bus line numbers and bus numbers are increased and examined these results.

Resource

Usage

Instantaneous Utilization	Average	Half Width	Minimum Value	Maximum Value
Bus 1	0.6957	0,032133201	0.00	1.0000
Bus 2	0.6411	0,032321339	0.00	1.0000
Bus 3	0.5827	(Correlated)	0.00	1.0000
Bus 4	0.5609	(Correlated)	0.00	1.0000

Number Busy	Average	Half Width	Minimum Value	Maximum Value
Bus 1	0.6957	0,032133201	0.00	1.0000
Bus 2	0.6411	0,032321339	0.00	1.0000
Bus 3	0.5827	(Correlated)	0.00	1.0000
Bus 4	0.5609	(Correlated)	0.00	1.0000

Figure 4. Utilizaiton of the resources

In figure 4, utilization of the buses and busy rates are shown. Bus 1 is the busiest vehicle and utilized mostly than the other vehicles. According to the current system, utilization rates and busy rates are less.

Resource

Usage

Total Number Seized

	Value
Bus 1	1792.00
Bus 2	1690.00
Bus 3	1545.00
Bus 4	1467.00

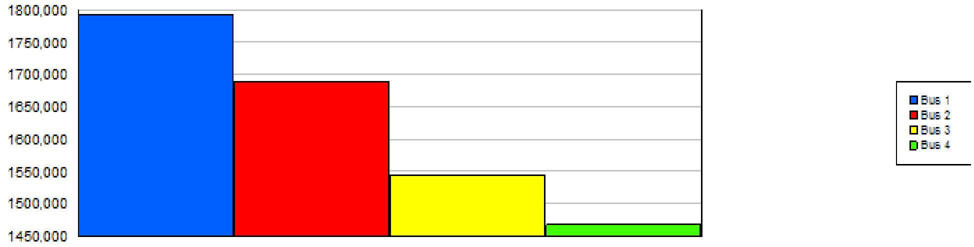

Figure 5. Passenger numbers of the buses

In Figure 5, total passenger numbers in the buses are shown. For increasing the bus lines, passenger numbers in the buses decrease.

IV. CONCLUSION

In this study, one of the major problems of the cities is examined and is performed through simulation modelling approach. In this case, current bus passenger in the city is not regular; therefore, the orders of the number of the passenger are randomly issued. As a result, the bus system faces high level complexity. Moreover, the bus planning is not well organized and planned with the ignorance of the citizen numbers etc.

This study presents a simulation modelling framework to plan the bus system along with the optimal usage of the resources. The power of the framework developed points out the potential opportunities such as allocation of bus system resources and work-force to enhance the efficiency.

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