Modeling and Simulation of Urban Traffic Network Using Enterprise Dynamics (Case study: the Sabzeh Meydan intersection in Qazvin city)

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Abstract— *The traffic problem is one of the greatest problems in today's life. Traffic imposes plenty of costs to people, and hence the need to provide solutions to improve it is necessary. In this paper, the traffic problem of one of the busiest passages in Qazvin city, namely Sabzeh Meydan intersection, has been investigated. After introducing the problem definition, the raw data collected from the environment will be explained. Using the data collected, a simulation model of the intersection is created in ED software. Lastly, two scenarios are designed to improve traffic conditions and reduce waiting time. To compare scenarios, both scenarios are modeled via ED. The results proved both scenarios are efficient. Given that the first scenario is costless and immediately applicable, it could be a better option in the short term; however, in the long term, the second scenario could be a positive alternative.*

Keywords— Traffic management, Simulation, Urban traffic, Timing lights, Enterprise Dynamics.

1. INTRODUCTION

People have created various systems of production and service to meet their demands. These systems have grown and developed over time, and in turn, have created a variety of problems [1]. The complexities of these systems have made the decision-making and control process very difficult for those who are responsible. Therefore, different systems, methods, and techniques have been developed to solve the problems and ultimately help the authorities to identify and improve the performance and decision making depending on the type of system and the problem involved. Simulation is one of the ways to understand the current state and improve the performance of systems. Simulation is the science of building a model of a process or system to evaluate and test strategies. In fact, simulation is a way of knowing the results of proposed ideas before they are implemented [2]. Researchers employed the simulation tool on a variety of topics. Mahdavi and Mousavi have provided a new solution to reduce the congestion of the convenience store chain queue with the ARENA software[3]. The purpose of this study is to analyze the queue system and provide a solution to the crowd congestion in the convenience store. Nuno et al. provide improved hospital workflow through the application of the principles of pure thinking and simulation by ARENA Software [4]. Rimo and Tin have proposed a simulation study of capacity utilization to predict future capacity for production system stability with ARNA software [5]. Sadjadi et al. designed a five-tier supply chain system to minimize costs and improve service levels [6]. Ebrahimzadeh and Arjmand provided ED software to simulate and optimize the Karaj oil storage system [7]. Lastly, scenarios to reduce the waiting time of tankers were presented and evaluated by a multi-criteria decision-making method called TOPSIS. One of the constant challenges of humans in all ages in today’s modern cities is the issue of transportation. Transportation has become an integral part of human life and has always been considered one of the most critical issues for governments in all countries. In today's modern world, the issue of transportation has become of great importance. Increasing the number of vehicles in addition to the constraints of urban spaces has created significant problems for urban mobility. In this regard, the researchers have fulfilled different studies. Hossinlo et al. analyzed the traffic in the city [8]. To do so, they investigated traffic on Tehran's Shahid Dastgheib Street using Corsim simulation software. The purpose of this study was to reduce waiting time at peak traffic. Salimifard and Ansari modeled and simulated urban traffic using the Petri Rainbow software [9]. Their goal was to reduce traffic by adjusting the traffic lights time. Moayadfar and Faizi designed and developed a simulation approach to improve the access network model in Sanandaj city [10]. Their goal was to reduce the traffic on Liberty Square in the city. Hejazi introduced various scenarios to simulate traffic flow in Kian Pars and Kian Abad neighborhoods of Ahvaz city using a simulation method [11]. He used AIMSUN software to simulate.

In this paper, the vehicles crossing the Qazvin freeway intersection is examined. Having Collected data on the vehicles entering each street, leading to this intersection and calculate their distribution, we provided the model via ED software. To improve traffic, metrics are defined and two alternative scenarios will be presented. Finally, the results of the scenario simulation model are presented, taking into account the criteria presented.

The general structure of the article is as follows: Section 2 and 3 introduce the problem definition and assumptions, respectively. In the next section, the model will be implemented in ED software. In section 5, the model validation is considered. Afterward, improvement scenarios are presented and compared. Lastly, the conclusion section is considered.

2. PROBLEM DEFINITION

THE CONSIDERED LOCATION IS THE INTERSECTION OF IMAM KHOMEINI WITH SABZEH MEYDAN STREETS IN QAZVIN CITY CALLED SABZEH MEYDAN INTERSECTION, WHICH HAS HEAVY TRAFFIC DUE TO BEING LOCATED IN THE CITY CENTER. THE TRAFFIC HAS CAUSED MANY PROBLEMS FOR CITIZENS AS THEY WASTE MUCH TIME IN TRAFFIC EVERY DAY. FOR THIS REASON, THE AUTHORITIES HAVE MADE MANY EFFORTS TO ENHANCE THIS PROBLEM, MOST NOTABLY BY ADDING BUS RAPID TRANSIT (BRT) LINES. DESPITE A LARGE AMOUNT OF MONEY SPENT ON THIS OPERATION, THE TRAFFIC PROBLEM HAS REMAINED. THE DIRECTIONS OF THIS INTERSECTION ARE AS SHOWN IN THE FIGURE. 1

3. PROBLEM ASSUMPTIONS

In this section, the assumptions of the problem are presented:

- According to the figure above, routes 3 and 4 are two-way, and routes 1 and 2 are one-way. Route 1 has six lines. According to the observations, the average percentage of movement from each line to each route is shown in Table 1.
- The width of 1 and 2 streets is 18 meters, while the widths of 3 and 4 streets are 20 meters.
- The average speed of vehicle departures (m/s) on lanes 1, 3, and 4 is 8, 7, and 7, respectively.
- In this system, the entity is cars.
- The feature of this system is speed and destination.
- The activity is a specified length of time in which the car moves.
- An event is an instantaneous event that can change the state of the system that enters or leaves the street in the desired system.
- System state refers to the set of variables required to describe the system at any given time for the study. In this system, the number of cars in queue and the number of lines of the street are the states of the system.

Based on the data collected, the vehicle entry rate and their stop rate at the intersection are shown in Table 2.

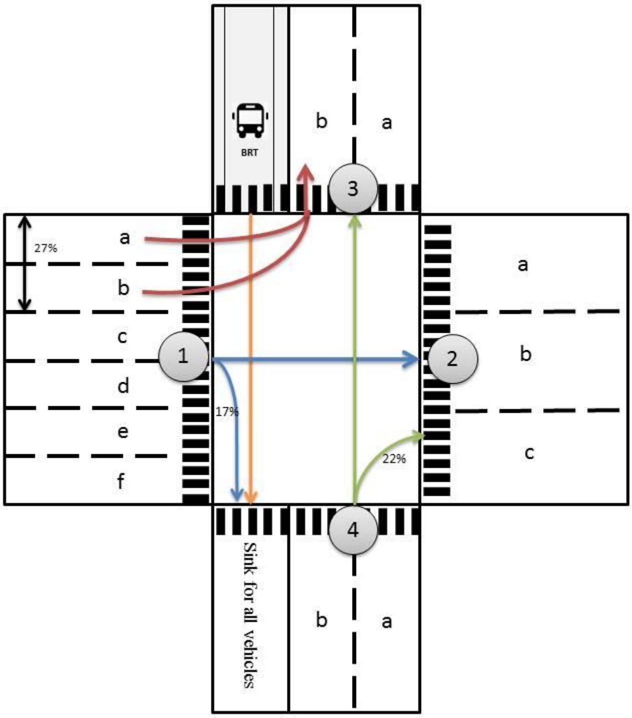

Figure 1. An overview of the system

Table 1. Entry rates for different routes

Line/Route	2	3	4
a(1)	-	100%	-
b(1)	-	100%	-
c(1)	97%	3%	-
d(1)	90%	5%	5%
e(1)	91%	-	9%
f(1)	86%	-	14%
a(4)	13%	87%	-
b(4)	9%	91%	-

Table 2. Schedule traffic lights

Route	Vehicles' Arrival Time Distribution Function		
	Lognormal (1.44,0.93)	21	24
	Weibul(80.77,0.8)	30	10
	Lognormal(6.41,6.04)	30	10

4. Modeling The Problem via ED

An overview of the system model status in ED software is shown in Figure 2. “Source” atoms are used to enter cars. Also, the distribution of the arrivals in each of the routes is based on the data collected at the inter-arrival time of each “source” atom. At the “Queue” atom, the cars enter and exit with the First Input First Output (FIFO) policy. “Time Schedule Availability” atoms are also employed to control the movement of cars as traffic lights. This atom is always connected to an “Availability Control” atom, and the “Availability Control” atom's output channels are connected to the central channel of the atoms we intend to schedule. In this output model, this atom is attached to the central channel of the Node atom.

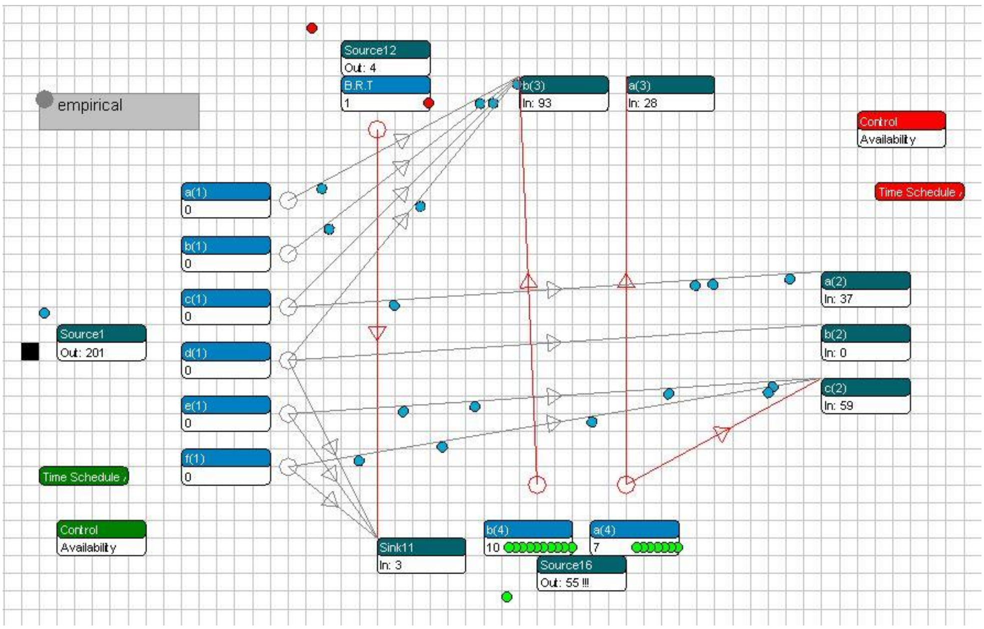

Figure 2. Schematic model in ED software environment

5. MODEL VALIDATION

To validate the simulated model with the real one and determine its validity for future decisions, we test the model. The validation process of a model has two purposes:

1. Create a model whose behavior is so close to the actual system's performance.
2. Promote the validity of the model to an acceptable level for managers and other decision-makers.

For the verification of the present simulation model and its compatibility with the mental model, the outputs have been examined and evaluated to fit our mental model. There are various ways to validate the mental model of each system, from consulting with experts and practitioners to performing a paired t-test. To complete the validation efforts, we compared the data throughout 3 hours at different K = 10 days and at congestion times, with the output from the model using paired t-test on the same days. Given the normality of the data, we now use the paired t-test to validate the model. The results are demonstrated in Table 3. Remark that the paired t-test is used due to the fact that the data follows a normal distribution. The hypothesis test is as follows:

$$H_0: \mu_d = 0 \quad \text{or} \quad H_0 = E(Z) = E(W) \tag{1}$$

Where Z represents the actual system output over 3 hours, and W is the forecasted output level in obtained by the simulation model. In this test, the level of significance is assumed to be equal to 0.05 (α=0.05).

The numerical value of the statistics is obtained according to Table 3

$$t_0 = \frac{\bar{d} - \mu_d}{S_d / \sqrt{K}} = \frac{-28.5}{\sqrt{1047714} / \sqrt{10}} = -0.088 \quad (2)$$

Table 3. Model Output

Input data (j)	System Output (Z_j)	System Output (W_j)	Difference (d_j)	$(d_j - \bar{d})^2$
1	9867	9323	544	2168256.25
2	8482	9362	-880	2352.25
3	8576	9222	-646	79806.25
4	10026	9175	851	773520.3
5	9638	9277	361	1662810.25
6	8435	9238	-803	15750.25
7	10215	9138	1032	3843560.25
8	8996	9245	-249	461720.25
9	9561	9288	273	1443602.25
10	8557	9325	-768	25760.25
			$\bar{d} = -28.5$	$S_d^2 = 1047714$

The critical value obtained $t_{\alpha/2;K-1} = t_{0.025;9}$ is equal to 2.26. Since $|t_0| = 0.088 < t_{0.025;9} = 2.26$, H_0 is not rejected. In other words, there is no different output between the system response and model predictions. This means that the simulated model is valid.

6. EVALUATION OF THE PROPOSED SCENARIOS

In this paper, two different scenarios are considered to reduce queue waiting time.

1. Optimization of traffic lights scheduling
2. Construction an overpass from Route 1 to Route 2.

Both scenarios have been modeled and their results are illustrated in Figure 3. In order to measure the results, five criteria are employed. Remark that the lower represent better performance in all criteria. According to Figure 3, both scenarios have improved traffic and reduce the waiting time regarding all metrics. Accordingly, the first alternative reveals that the timing of the traffic lights has improved and there is a significant improvement in all the criteria. Moreover, the second scenario also improves considering all criteria. Nevertheless, it should be mentioned that this scenario takes time and cost, while the first scenario can be done immediately and without any cost. However, the decision on this issue is up to the authorities.

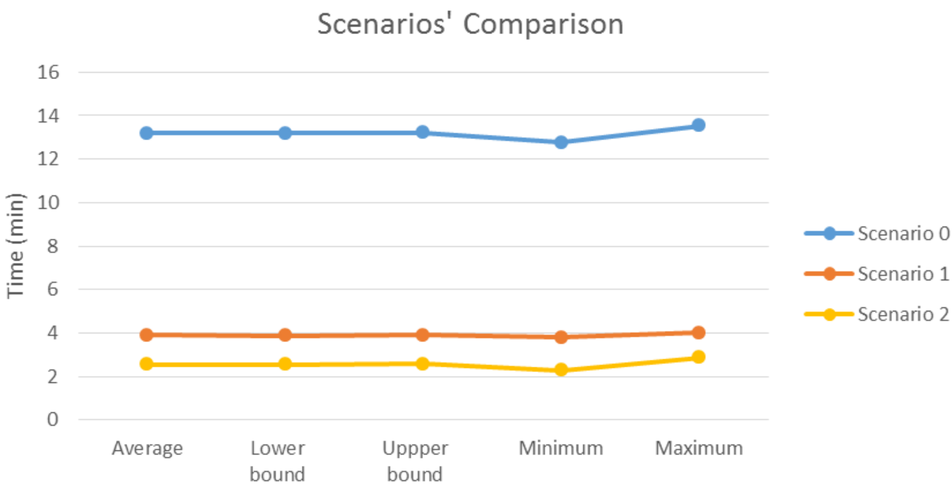

Figure 3. Compare the results of the scenarios

7. CONCLUSIONS

One of the biggest problems in today's modern cities is traffic. In this paper, the traffic problem of one of the passages of Qazvin city, called Sabzeh Meydan intersection, is investigated. To simulate the model, ED software is employed. In order to reduce the traffic time, two scenarios are recommended. In the first scenario, the schedule traffic lights are altered in a way to diminish the waiting time, and the second scenario is to construct an overpass from Route 1 to Route 2. The results revealed that both scenarios are useful; however, since the first scenario does not impose any cost, it looks more practical in the short term. However, the second scenario may have positive effects on urban traffic in the long run.

For future research, we propose to consider more realistic events like accident, Pedestrian crossing, blockage, and U-turn to make the model more practical. Furthermore, it is also recommended to consider a bigger model to have better insight and have a chance to suggest more scenarios to enhance the traffic situation.

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