ON-LINE SOLUTION TO THE BOTTLENECK CONGESTION: A CASE STUDY FOR ISTANBUL

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1 INTRODUCTION

Intercity transportation is shared mainly road transportation modes by 95%. Of course, these cause big problems in the city life such as traffic congestion, air pollution, noise pollution and traffic accidents. Traffic congestion mainly occurs a connection points between intercity traffic and D-100 Expressway and TEM Highway, the Bosphorus Crossings and the same sections that have same ramps along these roads. Some examples of last explanations are Kozyatagi and Kasacilar ramps.

These sections can cause the traffic congestion mainly peak hours. They result in economic and social loses. If advanced electronic devices and equipment can control these sections effectively, the traffic congestion would be diminishing as satisfied manner.

To reach this aim, the traffic control mechanisms are in use in different countries. The parameters that reflect the traffic characteristics can be measured using loop or other types of detectors in real time and then the evaluation can be made by using proper algorithms for warning the drivers along the road. To warn the driver, we can apply the Variable Message Sign (VMS) along the road. Finally, we can control the traffic flow along the road or along the Bottleneck section. The main traffic rules say that to decrease the traffic flow at certain section, the need is decreasing the vehicle speed or concentration before this section (FHWA, 1985; Takashi, 1975).

In this study, the bottleneck at the Kozyatagi is analysed using traffic control mechanisms. The main aim of analyses is to show that if the traffic control mechanism is applied properly, the Bottleneck congestion can be solved. To reach this aim, the each test is done by using VISSIM simulation program along the 2.5 hours of simulation.
2 VISSIM

Depending on the new developments on PC technologies, simulation programs have become very important tools for evaluating the alternative traffic assignment and traffic control applications at urban transportation systems. Simulation techniques allow us to handle much more detailed models than the theoretical analysis do, and so permit cheaper, safer and more rapid experiments than are possible by actual field experiments. They have become useful tool in a variety of transportation problem settings too. In this study such a simulation program VISSIM which is a microscopic, time step and behaviour based simulation model developed to model urban traffic and public transit operations has been used.

Essential for the accuracy of a traffic simulation model is the quality of the actual modelling of vehicles; e.g., the methodology of moving vehicles through the network. In contrast to less complex models using constant speeds and deterministic car following logic, VISSIM uses the psychophysical driver behaviour model developed by Wiedemann in 1974. The basic concept of this model is that the driver of a faster moving vehicle starts to decelerate as he reaches his individual perception threshold to a slower moving vehicle, his speed will fall below that vehicle's speed until he starts to slightly accelerate again after reaching another perception threshold. This results in an iterative process of acceleration and deceleration. VISSIM's traffic simulator not only allows drivers on multiple lane roadways to yield for two preceding vehicles, but also two neighbouring vehicles on the adjacent travel lanes.

Stochastic distributions of speed and spacing thresholds replicate individual driver behaviour characteristics. The model has been calibrated through multiple field measurements at the Technical University of Karlsruhe, Germany. Periodical field measurements and their resulting updates of model parameters ensure that changes in driver behaviour and vehicle improvements are accounted for.

The program can analyse traffic and transit operations under constraints such as lane configuration, traffic composition, traffic signals, transit stops, etc., thus making it a useful tool for the evaluation of various alternatives based on transportation engineering and planning measures of effectiveness. VISSIM can be applied as a useful tool in a variety of transportation problem settings too (VISSIM, 2000).

3 SIMULATION BASED TEST STUDIES

First, the geometric plan of the test region near the Kozyatagi bottleneck is created in VISSIM simulation environment (only for Harem-Gebze direction), by using the background map. There are two parts of links. Link-1 which has 3 lanes is the main part and lies from west to east which is Harem-Gebze direction. Link-2, which has 2 lanes, makes a ramp to the Link-1 at Kozyatagi region comes from north TEM highway. VISSIM's main
screen showing the 1.5 km length of test region in east-west direction has been shown in Figure 1.

![Figure 1(a)](image1a.png) ![Figure 1(b)](image1b.png)

Figure 1. (a)-VISSIM’s main screen showing the 1.5 km length of the test region, (b)- its Kozyatagi bottleneck close-up.

Due to the field observations, distribution of free transportation speeds of vehicles have been accepted as a linear function of vehicle speeds between 80-100 km/h; vehicle lengths have been accepted between 6 to 18 meters; traffic composition has been accepted as % 20 of heavy good vehicles for VISSIM simulations.

In the test area shown in Figure1(a), 2 vehicle input points have been chosen, each of them for Link-1 and Link-2. First of them is at the west end side of the Link-1 which has zero reference for length measurements at Link-1; also, the second of them is at the north end side of the Link-2 which has zero reference for length measurements at Link-2. To evaluate the tests results, 2 lane segments have been used in VISSIM for the link capacity usage and average travel time analysis. Also, 2 reference point each for two of links have been set near the bottleneck, for the analysis of maximum queue lengths and average number of stops in the queue. Selected way segments, their starting and terminating link and their lengths have been chosen as in Table 1(a). Also, the selected queue counter at the starting point positions have been chosen as in Table 1(b).

<table>
<thead>
<tr>
<th>Way Segment Nr.</th>
<th>Starting link and position</th>
<th>Terminating link and position</th>
<th>Segment length</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>1003.2 m.</td>
<td>993.2 m.</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>989.0 m.</td>
<td>887.7 m.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Link Nr.</th>
<th>Queue counter starting position</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>791.7 m.</td>
</tr>
<tr>
<td>2</td>
<td>700.8 m.</td>
</tr>
</tbody>
</table>

In the control process, the behaviour of the traffic flows on the certain section is interpreted by mathematical model and the knowledge based expert system approach is considered. Relation to this approach, mathematical model can be expressed as below formula (FHWA, 1985; May 1990).
\[ q = k \times v \]  
(1)

where, \( q \), \( v \) and \( k \) is the main characteristics of traffic flow respectively: flow, speed and concentration.

The traffic flow and speed can be measured by detectors (for microscopic measures) in the real-time traffic control applications. The traffic flow parameters used for traffic control process are time headway \( (h) \) and occupancy time \( (o) \). The traffic concentration can be calculated from the Equation 1. In the tests, it is assumed that the traffic flow characteristics are measured by microscopic way and the dimensions are accepted as vehicle/hour for the traffic flow, km/hour for the speed and vehicle/km for the concentration.

Not to cause traffic congestion, the traffic flows at any section on the bottleneck region does not pass the critical concentration depending on the mathematical model. The tests are applied using VISSIM simulation program to reach the critical concentration. For this reason, the traffic flows are chosen at the speed between 80-100 km/h on the entrance of the Link-1 only and increased step by step. After the one-hour simulation per each flow, the critical concentration is extracted. This value is equal to the maximum concentration of flow \( (q_{\text{max}} = 5400 \text{ vehicle/h}) \). Then the critical concentration is extracted from Equation 1 using 90 km/h average vehicle speed.

\[ k_c = \frac{q_{\text{max}}}{v} = \frac{5400}{90} = 60 \text{ vehicle/km} \]  
(2)

The sum of concentration of flows on Link-1 and Link-2 must be smaller than the critical concentration for solving congestion problem at Kozyatagi Bottleneck. Finally, if the concentration of flows on Link-1is \( k_1 \) and the concentration of flows on Link-2 is \( k_2 \), the equation becomes as below;

\[ k_1 + k_2 < k_c = 60 \]  
(3)

From these evaluation point of view, the results of the Test-1 is summarised at Table 2. The number of vehicles entering, related concentration and concentration at bottleneck are shown in this table. The performance data for (10 min.) obtained from Test-1 is shown in Figure 2, Figure 3, and Figure 4.

Table 2. Distribution of flow rates, average velocities and corresponding concentration values for Test-1.

<table>
<thead>
<tr>
<th>Simulation Time (sec.)</th>
<th>Vehicle Input from Link-1</th>
<th>Vehicle Input from Link-2</th>
<th>( k = k_1 + k_2 ) (veh/km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-3000</td>
<td>2500</td>
<td>28 (25-31)</td>
<td>60 (53-67)</td>
</tr>
<tr>
<td>3001-6000</td>
<td>3100</td>
<td>35 (31-39)</td>
<td>67 (59-75)</td>
</tr>
<tr>
<td>6001-9000</td>
<td>2800</td>
<td>32 (28-35)</td>
<td>64 (56-71)</td>
</tr>
</tbody>
</table>

The critical concentration of flow as seen in Equation 2, there is no congestion at first step. At the second and third step, it can be expected that there are queues. This result verifies the outcomes of Test-1. Test-1 is the simulation of the real situation of the bottleneck.
Test 2 is applied to simulate the control conditions for Test-1 using same flow condition at first step. However, it is assumed that the drivers are warned using VMS at the second and third step. As a result of that the flow concentration is decreased at the Link-2. The sum of the concentration is dropped then the densities are declined to 2000 vehicle/h and 2400 vehicle/h respectively. From these evaluation point of view, the results of the Test-2 is summarised at Table 3. The number of vehicles entering, related concentration and concentration at bottleneck are shown in this table. The performance data (for 10 min.) obtained from Test-2 is shown in Figure 5, Figure 6, and Figure 7.

Table 3. Distribution of flow rates, average velocities and corresponding concentration values for Test-2.

<table>
<thead>
<tr>
<th>simulation time (sec.)</th>
<th>vehicle input from link-1</th>
<th>vehicle input from link-2</th>
<th>k = k_1 + k_2 (veh/km)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>q_1 (veh./h)</td>
<td>v_1 (km/h)</td>
<td>k_1 (veh/km)</td>
</tr>
<tr>
<td>0-3000</td>
<td>2500</td>
<td>80-100</td>
<td>28 (25-31)</td>
</tr>
<tr>
<td>3001-6000</td>
<td>3100</td>
<td>80-100</td>
<td>35 (31-39)</td>
</tr>
<tr>
<td>6001-9000</td>
<td>2800</td>
<td>80-100</td>
<td>32 (28-35)</td>
</tr>
</tbody>
</table>

4 RESULTS

In this study link capacity usage, average travel times, and maximum queue parameters have been used to evaluate the transportation performance of Kozyatagı bottleneck. These parameters which are accepted from VISSIM in 10 minutes intervals have been arranged as different graphics for both Link-1 and Link-2. The variations of performance of Link-1 data obtained from Test-1and Test-2 have been placed the (a) positions of the above Figures and the same data obtained for Link-2 have been placed the (b) positions of the same figures through the 2.5 hours of simulations respectively. Due to these graphic representations of performance values, it can be exactly established that delays, and queue lengths can be decreased; capacity usage can be increased in satisfied manner by using the adequate on-line control mechanisms using VMS along the bottleneck as shown in Figures 5, 6and 7. This is a case study for Istanbul urban transportation system. So, many of similar traffic control problem can be solved in similar ways at bottlenecks.

Figure 2. Variation of the obtained average travel time for Test-1; (a) for Link-1, (b) for Link-2.
Figure 3. Variation of the obtained link capacity usage for Test-1; (a) for Link-1, (b) for Link-2.

Figure 4. Variation of the maximum queue length for Test-1; (a) for Link-1, (b) for Link-2.

Figure 5. Variation of the obtained average travel time for Test-2; (a) for Link-1, (b) for Link-2.

Figure 6. Variation of the obtained link capacity usage for Test-2; (a) for Link-1, (b) for Link-2.

Figure 7. Variation of the maximum queue length for Test-2; (a) for Link-1, (b) for Link-2.
5 CONCLUSION

Results obtained in this case study have shown that, transportation performance in bottleneck regions of the urban traffic networks can be increased by evaluating the simulation based tests and using VMS system like in this case study. Also, new case studies for urban transportation performance analysis can be planned.

Specially, for improving the transportation performance of critical expressways, freeways and arterial streets, adequate on-line control mechanisms can be offered. For these offers, evaluations can be made easily by using the simulation programs like VISSIM. Because, simulation techniques allow us to handle much more detailed models than the theoretical analysis do, and so permit cheaper, safer and more rapid experiments than are possible by actual field experiments. So, new case studies for urban transportation performance analysis like this study can be planned.

REFERENCES


