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Variable Speed Limit Analysis on the Highway in Istanbul

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Abstract: Application of variable speed limits (VSL) is gradually increasingly implemented especially on highways. As a result of conducted studies and implementations, it is observed that the variable speed limits have reduced the number of car accidents as well as proved positive results in terms of delays and environmental factors. Purpose of this study is to develop an algorithm for VSL application that is considered to be applied on Istanbul D100 highway and to assess the effects of application. Algorithm that is developed for VSL is a different VSL algorithm and compared with the constant speed system. According to obtained results, when the proposed system is compared to current system, it is observed that the number of delays and average stops are reduced %30 and %40 respectively and also emissions reduced at the rate of %12.

Key words: Variable speed limit, speed harmonization, VCL algorithm.

1. Introduction

Variable Speed Limit (VSL) performs the changing of speed limits dynamically according to traffic and weather condition in traffic management. This study presents the results of the VSL application on urban highways for Istanbul, Turkey.

Application of Variable Speed Limit is composed of dynamic message signs that communicate with center and positioned along the highway. VSL utilizes speed limit for regulation and notification. VSL, on the contrary of static speed signs, indicates proper speed limits dynamically according to instant traffic, weather and other conditions. While VSL increases the traffic safety, it also aims to reduce the driver stress. VSL systems were used in limited numbers in worldwide. This system harmonizes speeds and improves lane utilization and driver behavior by basically reducing speed variability and average speeds. It is difficult to observe the effects of speed limit changes and changes in traffic demand on before after analysis [1].

Variable Speed Limit (VSL) analysis is performed at parameters that are specified in micro simulation program. Purpose of this study is to assess the effects of VSL control strategies to safety and traffic flow in an urban region. By considering the differences that are specified in literature, detector data with 60-90-300-600 second intervals are used. By considering design standards, a practical application that will react dynamically was developed. For this purpose, variable speed limits (VSL) application was assessed in microscopic traffic flow simulation environment on the test corridor that is selected between Yenibosna - Kucukcekmece on D100 highway in Istanbul as study area [2].

Six different traffic scenarios were modeled in this study. Current condition and two different algorithms were designed and system delay, travel times analysis was evaluated by utilizing the VISSIM microscopic traffic flow simulation tool. In the study, the evaluations of simulation results are presented in this study.

2. Literature Research

There are limited studies conducted regarding to relation between traffic safety and speed compatibility [3]. Some studies analyzed about the applications of

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variable speed limit. Offline algorithms use historical data that historical traffic distribution repeats [4]. Garber and Gadirau have performed a study that researches the relation between speed change and accident rate [5]. Results indicate that the speed change is significantly affected in accordance with highway type, highway geometry and design speed. Also, it indicates that as speed change increases, accident rate increases as well [5].

A study was performed in Virginia State about the utilization of rational speed limits. In order to reduce speed deviation and help increasing the road safety, driving speed and driver perception and rational speed limit were selected. When the speed limit is increased from 55 miles to 65 miles, it is observed that there is significant increase in driver compatibility [6]. Giles has indicated that there are significant effects of congestion level, weather conditions and visibility range over speed in his study [7]. He also developed an analysis model that describes the variables relating to road components and vehicles.

In some studies, driver harmonization and safety were analyzed on VSL corridor. By performing VSL corridor simulation, effects of proper strategies VSL system on traffic safety were observed [8]. In a study conducted in Finland, it is indicated that the accident risks with injury was reduced as a result of reducing the speeds on VSL system on slippery surface especially very rough weather conditions. It is also observed that the VSL system helped giving the information of dangerous weather and road conditions [9]. Finland VSL system operates with constant speed limit instead of variable speed limit in case of slippery roads. According to another research based on simulation, VSL system is very sensitive to driver behavior and road safety [10].

3. Developing VSL Model for Istanbul

A VSL algorithm was developed for Istanbul that makes all calculations according to speed and occupancy data and utilizes relation between density and occupation by taking basic model as a reference. In the developed model, system outputs are indicated and recorded at desired time period for all road section or per lane.

Algorithm that is taken as example and VSL algorithm that is developed by us comply with Scenario Study Plan that is specified at Figure 1. Developed algorithm is given at Figure 2. An interface was programmed for the algorithms that are developed and takes as exampled on .NET platform.

Each VSL system operates as isolated and activates the proper scenario of the selected algorithm according to collected vehicle amount, occupation rate and speed information and it indicates the calculated speed value and adjusts flow speed of the road according to this value.

We have used the average speed, occupancy and vehicle number parameters for the developed model based on algorithms that are analyzed as a result of conducted literature researches. Starting out of the relation of density and occupation, we have logical approaches on the inquiry calculated values for %50 of occupancy value.

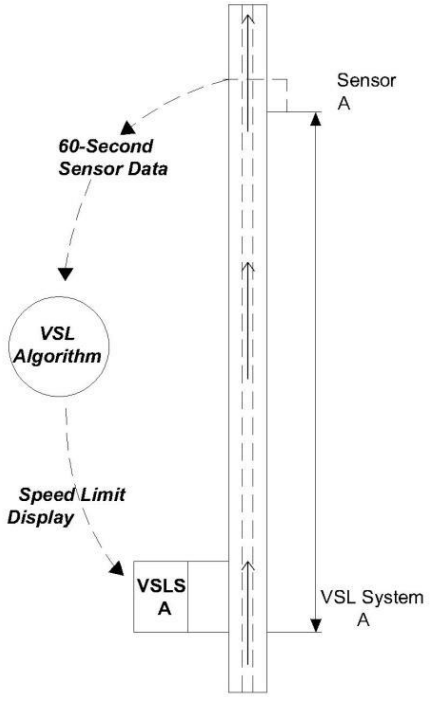

Fig. 1 Scenario Study Plan.

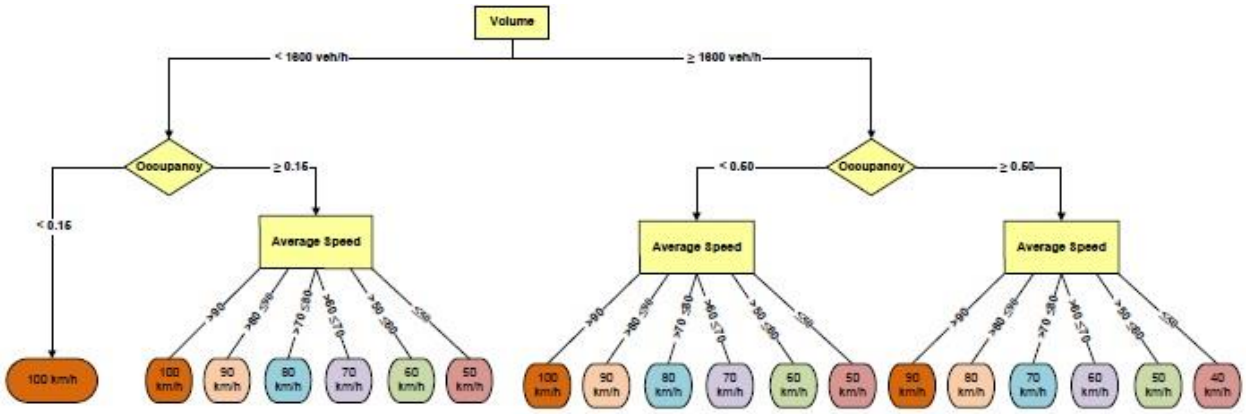

Fig. 2 Developed Algorithm.

4. VSL Model for Istanbul

Study field is the 7km section that remains between the Yenibosna-Kucukcekmece Lake of D100 Highway in Istanbul. D100 Highway serves high vehicle volume demands at morning peak and afternoon peak hours. Study field consists of 3 lanes with speed limit defined as 90 km/h. In this study, in which 5 hours of analysis are conducted, there is 4 interchange and 25.000 vehicles in one direction. There are total of 24 combination and separation junctions on study area and they are shown at Figure 3. Volume has taken from 4 different points on main road and all entr-exit points of study area and speed and density are received from all lanes at 7 VSL points with parametric intervals.

Current geometry and actual traffic counting data were used at the modelled study area. Study time was determined as a result of pre analysis on the are to be modelled. According to data received from RTMS sensors, most suitable study period is determined between 06:00 and 11:00 hours. Traffic counting data is from 10 October 2013 date. Traffic counting was performed on Thursday. While counting was performed, long term shock wave was observed. Traffic counting data was confirmed with detector data. Entry parameters were generated with 5 hours of counting data that are received with 15 minutes tables. Vehicle classification was performed in 2 vehicle classes as automobile and pickup truck. Density increase and distribution was modelled by computing observation data and simulation data.

Developed software allowed us to change parameters flexibly. Which algorithm to be used, calculation period (period time), vehicle number and occupation values are selected from parameters windowed that is specified at Figure 4. As study type, all lanes or single lane may be selected. In case of single lane is selected, calculations are made for each lane, found speed value is applied to all other lanes. Calculation that is performed for all lanes represent the majority of the road.

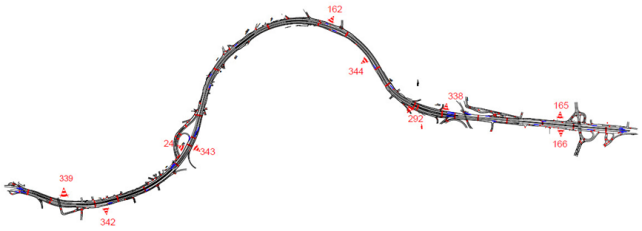

Fig. 3 Entr-Exit Points of Study Area.

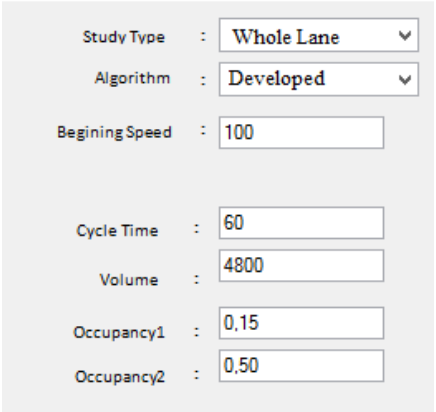

Fig. 4 Parameters Display.

In order to measure the performance of developed mode, VISSIM simulation program was used. VISSIM is a package program that allows its users to develop codes with COM interface [11]. With defined algorithm, VISSIM is able to change the speed information that is indicated at VSL system, by making an analysis during cycling that is pre determined dynamically.

Interface of the software that is developed on .NET platform as a COM application to VISSIM simulation program is given at Figure 5. With the developed software, VISSIM that is formed to study area is brought from folder, which have extensions from .inp and .ini files. Visual properties are stored in .ini file (of VISSIM), entry parameters in .inp file (of VISSIM), and background properties in .bgr file (of VISSIM) of the established VISSIM project. From the information to be reports, vehicle numbers are stored in .qmk file, arterial performance information in .npc file. On the report outputs vehicle counting are received from .mes file, artery performance information from .npe file, travel time information from .rsz file. As artery performance information, average delay per vehicle, average stop numbers per vehicle, fuel consumption of all vehicles, emission data of CO and NO and derivative gases and total travel time.

During the determined calculation period, It is seen speed information and change that is given on VSL systems. Vehicle number, occupancy and average speed data for determined calculation period are indicated.

Free flow speed of study area was assumed as 100 km/h, due to speeding on this highway on VSL systems first speed was given 100 km/h. Study area, which is composed by total of 7 VSL system and locations are selected in compliance to the original. Distances between systems are average 1000 meters as properly to reality.

By positioning detectors at same location with the study area, and they transmit data once per 60-90-300-600 seconds about average speed, occupancy and vehicle data. Basic mode was built according to conditions. Modelled timely speed and density distribution are compared with observed and simulated data. Until the speed and density distributions match the observed data, simulation parameters were arranged. By changing the driver aggression and following distance parameters are changed and combination distances at road surfaces are reduced.

In the study that is conducted at morning peak hours, repeatable congestion were experienced in this part of the D100 Highway. Generally, congestions are experienced from the bottleneck forming at the merging points. Average speed is changed between 40 km/h and 50 km/h, also it is observed that the traffic may come to condition of stop time to time. VSL control strategy allows vehicle to reduce speed and by minimizing, bottleneck tightening is accelerated.

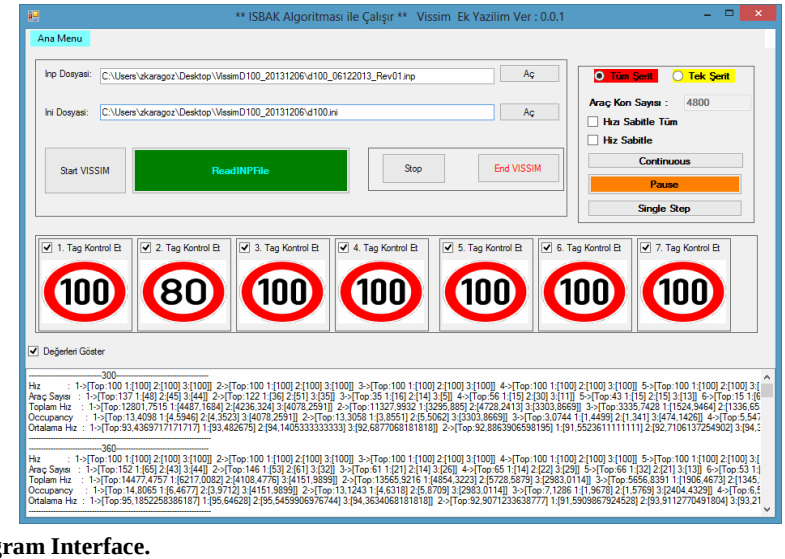

Fig. 5 Developed Program Interface.

5. Simulation Results

As a result of the works toward conducted study, analysis is performed for performance parameters from VISSIM .npe files. As performance criteria following are used for study area, average speed (km/h) average delay per vehicle (seconds), stop amount per period, fuel consumption (kg), CO and NO gas emission and journey time data of community travel period.

Analysis results of algorithm scenarios of developed and sampled algorithm give the following results. According to data that is obtained by various periods of detectors and given at Table.1

Current condition Sample Algorithms and performance outputs of new developed algorithm scenarios are given at Table 2.

Table 1 Scenario Table.

	Calculation Period (sec)	*Vehicle/hour*	*Occupancy*
Sample Scenario 1	60	4800	0.15
Sample Scenario 2	90	5700	0.20
Developed Scenario 1	60	4800	0.15
Developed Scenario 2	90	5700	0.20
Developed Scenario 3	300	4800	0.20
Developed Scenario 4	600	5100	0.25

Table 2 Results of Different Scenario.

Performance Parameters	***Current Condition***	***Sample Scenario 1***	***Sample Scenario 2***	***Developed Scenario 1***	***Developed Scenario 2***	***Developed Scenario 3***	***Developed Scenario 4***
Average speed (km/h)	46	45	45	47	48	49	47
Average delay per vehicle (sn)	97	89	89	70	68	65	74
Average stop per vehicle	3,345	3,049	3,046	1,979	1,841	1,783	2,177
Fuel consumption (kg)	21.231	20.563	20.503	20.213	20.215	20.339	20.516
CO emission (kg)	638	632	632	568	570	563	563
NOx emission (kg)	241	224	223	205	205	211	215
Total delay (sec)	2.329	2.133	2.130	1.683	1.644	1.569	1.777
Total drived distance (km)	326.140	326.937	326.605	327.564	328.449	328.554	326.514
Total travel time (sa)	7.152	7.229	7.230	6.928	6.900	6.771	6.934

5. Conclusions

According to obtained results, when the proposed system is compared to current system, it is observed that the number of delays and average stops are reduced 30% and 40% respectively and also emissions reduced at the rate of 12%. Fuel consumption is improved by 4%. Algorithms that are operated for predicted scenarios have given best values in 5-minute calculations. In studies of this time above and below the compatibility between the vehicle and speed balance is disrupted.

Additionally, to indicating speed information to VSL system model, also active traffic management applications such as ramp metering, dynamic route information and travel time shall be added to the model.

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