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Analysis of Congestion Phenomena on the One Lane Dropped Motorway Merge without Ramp-Metering in İstanbul

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Abstract

Motorway merges are typically congestion areas because of irregularities on lanes between upstream and downstream directions. At motorway merges, it is obvious that when the upstream and/or on-ramp flow is greater than the downstream (bottleneck) capacity, congestion arises. Therefore, queue will form and grow in relation with the demand and bottleneck capacity. The aim of this paper is to analyze the effect of mainstream and on-ramp flows on the congestion phenomena. As there is no ramp-metering application in Istanbul, on-ramp flow has an excessive effect on the congestion. In this study, macroscopic merge behavior is analyzed at one crucial motorway merge in Istanbul. Traffic data is obtained by Remote Traffic Microwave Sensors (RTMS) operated by the Municipality of Istanbul. RTMS data consists of volume, speed, occupancy and heavy vehicle counts per lane while minimum data collection interval is 2 minutes. Examined motorway merge section, main stream and on-ramp flows are observed by separate RTMS. Whole year weekday data of 2012 is used for analysis. It is seen that mainstream flow rate changes from 3360 pcph to 6210 pcph before congestion depends on the on-ramp flow rate that varies from 1755 pcph to 3060 pcph. In addition, on-ramp ratio is found between 0.23 and 0.43 which cause congestion on this motorway merge.

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Keywords: speed drop; motorway merge; traffic flow; congestion

1. Introduction

Motorway merges are the major locations of congestion because of weaving or merging behavior in relatively short distances. Besides, irregularities on lanes between the upstream and the downstream end up with congestion.

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Associated with bottleneck capacity, congestion inevitably arise at these locations. Either upstream or on-ramp flows reach a certain value, speeds are reduced on both flows which affects downstream capacity. Hence, queue will form and grows in relation with the demand.

This paper aims to analyze the relation between mainstream and on-ramp flows which causes the congestion phenomena considering macroscopic merging behavior. As there is no ramp-metering application in Istanbul, on-ramp flow has an excessive effect on congestion.

Several studies on motorway merge bottlenecks are performed in the literature. Analysis rely on the relation between upstream flows and the decrease on discharge flow which is observed in downstream. One of the simplest model proposed for merging behavior by Daganzo (1995) is Cell Transmission Model (CTM). CTM offers a macroscopic simulation based on traffic flow model to propagate the traffic along the cells and cells connectors. It is proved that CTM is computationally efficient and easy to analyze many crucial traffic phenomena, such as queue build-up and dissipation, and backward propagation of congestion waves. Further studies are conducted for ramp-metering control strategies (Papageorgiou and Blosseville, 1989) and analytically estimating of capacity drop with merging flows (Leclercq et. al. 2011). Analytical model for predicting capacity drop at merge bottleneck with respect to the on-ramp demand is offered by Leclercq et. al. (2011) and it is found the merge ratio does not affect the capacity drop when the main road has only one lane.

It is common that for the recovery of "dropped capacity" on a motorway merge bottleneck, ramp-metering has significant effect. Capacity drop is encountered just before occupancies increase to 27% and average occupancies of 27% and 22% can be thresholds for the initiating restrictive and relaxed metering respectively as mentioned by Cassidy and Rudjanakanoknad (2005). Kinematic wave models are used for motorway merge bottlenecks in order to identify congestion, traffic management strategies and route guidance for drivers (Newell, 1993; Ni and Leonard II, 2005). Bertini and Leal (2005) indicate that drop in flow observed at the same time with drop on speeds and increase in occupancies. It is found that higher flows prior to the queue formation were sustained for relatively short periods.

Certainly, downstream flow and queue formation are directly affected by upstream flow. If the demand exceeds the bottleneck capacity, congestion occurs, speeds decrease and queue will form. In the presence of ramp-metering, the effect of on ramp flow to the formation of congestion is minor. On the other hand, when there is no ramp-metering, the on-ramp ratio plays remarkable role on congestion phenomena. On-ramp ratio can be explained as the percentage of on-ramp flow rate to the total upstream, on-ramp and mainstream, flow rate. In order to clarify merging behavior, interaction between upstream flows require attention and have to be considered in analyses. This ratio is mostly depends on the merge design as mentioned by Bar-Gera and Ahn, (2010). In our study, relation between on-ramp ratio and downstream volume is investigated, then effects of on-ramp flow to the capacity of downstream is explained.

2. The Data

Traffic data is obtained by Remote Traffic Microwave Sensors (RTMS) operated by the Municipality of Istanbul. RTMS data consist of volume, speed, occupancy and heavy vehicle counts per lane and data collection interval is 2 minutes. A whole year data of 2012 obtained from 2 RTMS (#409 and #565) located on Trans-European Motorway (TEM) at one lane dropped motorway merge, given in Fig 1, are used in this study.

On the merge area, the mainstream has 3 lanes, on-ramp has 2 lanes, and downstream has 4 lanes. This type of merging section is defined as one lane dropped merge (HCM, 2010). Upstream flows, on-ramp and mainstream, have 5 lanes while downstream has 4 lanes that create bottleneck and cause congestion. TEM is one of the main arterial in İstanbul that connects Asia Europe sides with a quite high traffic demand. This road is used by intercity and urban traffic. However, in peak hours (06:30-10:30 and 16:00-22:00) trucks and trailers are not allowed on TEM in order to reduce traffic demand. Only busses are allowed as a heavy vehicle during these time intervals. Ratio of heavy vehicles is calculated as 5.8 % for peak hours. In the analyses, heavy vehicles are converted to passenger car unit (PCU) by using 1.5 coefficient as suggested by HCM (2010).

Data filtering is applied to traffic data in the case of accident, public holidays or heavy weather conditions which will affect the normal operating conditions. Capacity pattern are only encountered in weekdays since weekends have lower traffic flows and lack of congestion. Moreover, by deciding the congestion, speed drops which can occur by