QUANTIFYING PASSING LANE EFFECTS ON TWO-LANE EXPRESSWAYS

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1. Introduction

Two-lane expressway sections currently exist in Japan as provisional sections for future expansion to four-lane expressways. These are usually situated in rural to suburban areas where high vehicle speeds are deemed necessary but present demand does not justify the construction of four-lane, two-way sections. In the most recent update of the Road Structure Ordinance (2003), the Japanese guideline for geometric design, some specifications for the design of two-lane expressways have already been discussed.[1)] This could possibly mean that such type of roadways may be constructed sometime in the future for permanent use and that the analysis of its operational conditions and service level improvements are necessary.

The operational characteristics of two-lane expressways have not been thoroughly studied in existing literature and may fall somewhere between common (multilane) expressways and ordinary two-lane highways, with full access control and high speed limits but having only one lane per direction of travel. Traffic patterns could be significantly different from either category due mainly to passing restrictions caused by the presence of a median barrier. Passing lanes are thus installed in strategic locations within the whole stretch of the expressway to somehow improve the overall level-of-service (LOS). Such improvements in LOS however may or may not be directly attributed to the presence of passing lanes and are also quite unclear since service measures for two-lane expressway sections are still undefined. The direct effects of passing lanes on two-lane expressway operating conditions, if identified and estimated, will be very helpful in aiding highway planners in future decisions regarding passing lane construction.

The objective of this study is to identify how passing lanes directly affect flow patterns in two-lane expressway sections and to quantify these effects accordingly.

2. Literature Review

Since two-lane expressways and its operational characteristics are quite unique, the current Highway Capacity Manual (HCM) methodologies for freeways and two-lane highways are not applicable for such a highway type. For example, one of the main service measures for two-lane highways of the HCM is percent-time-spent-following (PTSF), which is primarily estimated based on the volume of the opposing flow (TRB-HCM, 2000).[2)] In two-lane expressways, the traffic in the opposite direction has virtually no effect in driving conditions since a median barrier is present in all sections.

A previous study found that an additional lane upstream of a bottleneck section in a two-lane expressway can reduce congestion at that bottleneck section (Yoshikawa, et. al., 2004).[3)] Although no significant changes in volume was noted after the extension of existing passing lanes, it was evident in the speed-flow relationships that congestion was somehow alleviated. This study also suggested the investigation of passing behavior of vehicles within passing lanes together with vehicle changes in platoons, for the determination of the optimum length of additional lanes.

A study conducted in South Africa considered follower percentage as one of the possible service measures for two-lane highways, although it stated later that this performance measure may not be a suitable gauge for capacity upgrading since it only takes into account individual users' experience and not those of all users (SANRAL, 2004).[4)]

3. Data Collection and Processing

Video data taken directly from the field were utilized

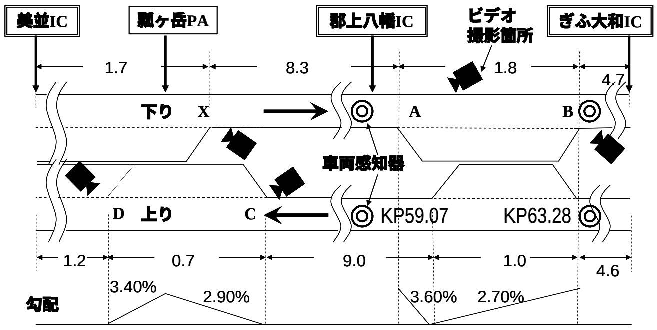

Figure 1 Study Area with Video Camera Locations

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together with detector data from Japan Highway Public Corporation (JH) of the Tokai-Hokuriku Expressway. These data were mainly used in observing follower flow behavior and determining average speed and flow rate.

The video survey was conducted for around three hours (9:00 ~ 12:00) in the morning of October 2, 2004, Saturday. Video cameras were strategically placed to observe traffic flow at both ends of the specified passing lanes (Refer to Figure 1). Each vehicle was identified for all camera observations to distinguish those which made passing maneuvers to those which did not and remained in their respective platoons.

Detector data during the video survey were obtained and processed to verify flow rates and average vehicle speed during the survey period. More recent detector data however have been obtained from JH, which include traffic flow characteristics during peak flow periods, specifically the Golden Week. Figure 2 shows the 24-hour traffic flow pattern comparison between a day during the peak period and an ordinary weekday in one of the detector locations (KP63.28, see Figure 1) on two-lane sections of the Tokai-Hokuriku Expressway. The flow pattern during the ordinary weekday is very similar to the flow pattern during the video survey with flow rates reaching only a maximum of around 550 – 600 vehicles per hour.

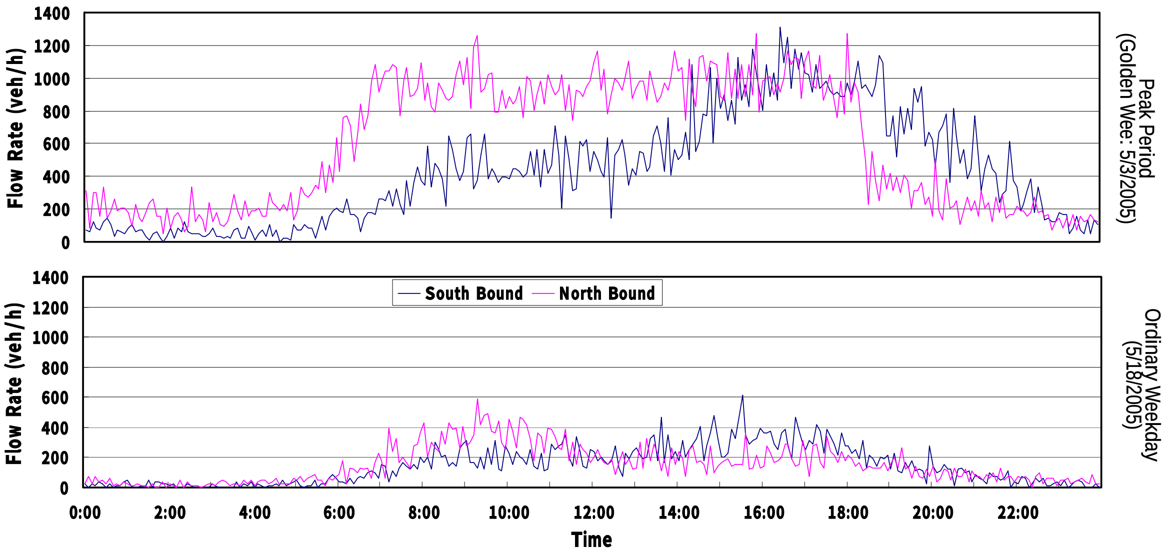

Figure 2 24-hour Traffic Flow Patterns – Peak vs. Ordinary Weekday Periods (KP63.28)

Based on the figure, traffic volume is around twice as much during peak periods compared to ordinary weekdays. Since the video data was taken during an ordinary weekday, further studies on peak periods (usually during long holidays such as the Golden Week and the Obon Week) should be conducted later to obtain follower flow behavior during near-capacity to capacity flow conditions.

4. Passing Lane Flow Analysis

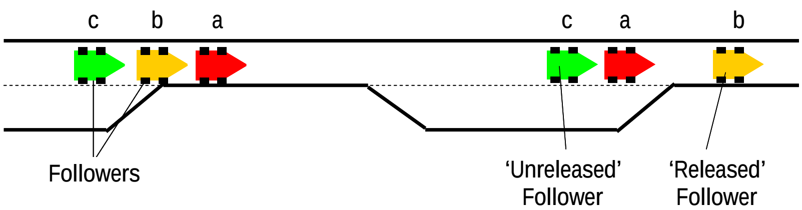

Figure 3 Observed Follower Behavior on Passing Lanes

Each vehicle on the passing lanes was observed and categorized as either follower or non-follower. Followers are assumed to be those vehicles with time headways less than or equal to 3 seconds relative to their respective lead vehicles. This definition is in accordance with the HCM, which also suggested using percentage followers as a surrogate measure at a representative location since PTSF is very difficult to measure. Platoons were also observed at each end of the passing lanes, so the vehicles which performed passing maneuvers ('released' follower) and those which did not ('unreleased' followers) were identified.

From Figure 1, observation sections were denoted as A, B, C, D, and X. Sections X, A and B are within the north bound portion of the study area, while the others are observations taken at the south bound side. The observed passing lanes shall henceforth be called passing lanes A – B (north bound) and C – D (south bound). Note that section X is at the end of a four-lane section prior to the passing lane A – B.

Analyzing follower behavior in the two passing lanes, percentage followers were estimated and showed slight improvement from the upstream side to the downstream side. Percentage follower reduction at passing lane A – B was about 6%, from 49% to 43%, while at passing lane C – D it was about 3%, from 49% to 46% (Refer to Table 1). These reductions however are not exactly indicative of the actual effect of the passing lanes on traffic flow rate.

Table 1 Percentage Followers and Percentage of 'Unreleased' Followers

Segment	Length (km)	Start of Segment	End of Segment	
		Percentage Followers	*Percentage Followers*	*Percentage 'Unreleased'*
X – B	10.1	51%	43%	37%
A – B	1.8	49%	43%	37%
C – D	0.7	49%	46%	27%

Note: Segment X – B includes the 8.3 km two-lane section in the immediate upstream of passing lane A – B.

Although it is somewhat apparent that the percent reductions in follower percentage represent vehicles that performed passing maneuvers and broke away from the platoons, it is hardly the case for most scenarios. Some of the vehicles 'released' within the passing lanes are sometimes replaced by other lagging vehicles catching up with the platoon, thus causing minimal or no change in percentage followers. Therefore, using percentage followers alone as a service measure is not very reliable.

The actual reduction in followers is the number of vehicles that left the platoon (by passing the lead vehicle) while traversing the passing lane. The percentage of 'released' vehicles can simply be calculated as the difference between percentage followers at the start of the passing lane and the percentage of 'unreleased' vehicles at the end of the passing lane. This idea was originally conceptualized by Expressway Technology Center (EXTEC) in their 2003 report.[5] From the table, 12% (49% to 37%) and 22% (49% to 27%) of vehicles in platoons passed their corresponding lead vehicles in segments A –B and C – D respectively. These figures are significantly higher than the percentage follower reductions, which further strengthens the claim that follower percentage is not a very good indicator of LOS.

This study was conducted during a period of low demand. Peak flows of only about 550 veh/h and 200 veh/h were observed at the north bound and south bound directions respectively. With these flow rates, the actual relationship between the length of passing lanes and the percentage of 'released' vehicles was not established. At the longer segment A – B (1.8 km), the percent reduction in followers was only 12% compared to the 22% reduction in the much shorter segment C – D (0.7 km). This can be attributed to several cases. One example is the formation of an equal number or more platoons in segment C – D even if it had lesser volume, making the percentage of passing vehicles higher than the other segment. For higher volumes at capacity or near-capacity flows, it is more or less expected to have an increase in the percentage of 'released' vehicles as the passing lane becomes longer. Thus, it is recommended to conduct further studies on follower behavior on passing lanes during peak periods.

5. Conclusions

The primary impact of passing lanes in two-lane expressway sections is that it provides an opportunity for followers to attain their desired speed by passing the lead vehicle of their respective platoons. Percentage followers may somehow describe the current operating condition of the expressway but its variation in different sections of the highway cannot be used as an indicator whether service level has been maintained, improved or deteriorated. Using the actual follower percentage reductions, or the percentage of 'released' vehicles is a much better gauge and shows the real effect, in quantified form, of passing lanes in two-lane expressway traffic flow operations. However, additional information of follower behavior during peak periods should be investigated to establish the relationship between the length of passing lanes and the reduction of followers. This will greatly help in determining the optimum length of passing lanes for certain levels of demand.

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