

MODELING PROFILE SPEEDS ON URBAN RESIDENTIAL STREETS WITH A 30 KM/H SPEED LIMIT

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1. INTRODUCTION

Excessive speeds have been found very common on urban residential streets with a 30 km/h speed limit in Japan that may cause traffic safety problem and threaten the livability of neighborhoods. To cope with speeding issues, it is important to discover the influence of street characteristics to drivers' speed choice on such kind of facilities in order to support for urban planning and street design process. To date, very few speed models have been developed for urban streets especially those with a 30 km/h speed limit. In addition, previous research often used spot-speed data for speed model development that may not capture the full vehicle speed characteristics. Furthermore, there is no existing model that can estimate vehicle speeds continuously on a given street section.

This study is to model profile vehicle speeds in term of mean speed at any location on urban residential streets with a 30 km/h speed limit by using a continuously-recorded speed data.

2. DATA COLLECTION

A speed survey was conducted on 85 varying-characteristic street sections located in an area of Saitama city, Kawaguchi city, and Warabi city, Saitama Prefecture, Japan. A section is defined as a segment between two intersections in which the exiting intersection (the location where a speed- recorded vehicle started to leave the section) must be un-signalized. In the survey, free-flow speeds were measured continuously by using STALKER ATS radar guns for each individual vehicle. For each street section, at least 70 speed profiles of passenger cars or light trucks were recorded during daytime, under nice weather. Along with speed data, various street characteristics including section length, cross-section features, roadside object density, driveway density, type of land use development, exiting intersection features were also measured.

3. DATA ANALYSIS

3.1. Speed data reduction

Speed data recorded by radar guns were used to construct speed profiles for all vehicles at each section. Fig.1 provides a typical profile-speed data at one street section.

Examining speed profiles for all street sections it was found that most drivers accelerated up to a maximum speed then decelerated afterward possibly due to the influence of the exiting intersections. For all street sections, statistic showed that more than 85% of drivers obtained their maximum speeds after passing the midpoint of street sections. Based on field observations, maximum speeds occurring in the first half of street sections were likely associated with drivers who passed the entering intersections at high speeds therefore their speeds were not totally affected by characteristics of the current driving street section. From that point, this study focused on examining vehicle speeds on the second half of study street sections.

In the next step, only speed profiles that cover the full second half of street sections with normal driving patterns were used. For each street section, individual speed profiles were excluded if their maximum speeds are lower or higher than two standard deviations from the mean of the section. After reduction, 5359 speed profiles of 85 street sections remained for further analysis.

3.2. Mean speed data

The second half of all street sections were divided into 10 equal-length segments then mean speed at the end points of each segment and their corresponding locations on the study section were identified (see Fig.2). Totally, 935 mean speeds by location were created that then were used for speed model development.

3.3. Modeling approach

Two methods were proposed to model mean speed at any location on a given street section. In the first one, namely "direct method", the dependent variable "mean speed by location" (V) is directly regressed by its corresponding location variables and street characteristics. In the second method, first, the maximum mean speed for each street section ($V_{\max}$) and its corresponding location ($L_{\max}$) were regressed by street characteristics. Then, two other separate regression equations were developed to calculate the speed deviation from $V_{\max}$ for the period before the maximum speed location (ΔV_a) and the period after the maximum speed location (ΔV_d). It should be noted that only mean speed data at the locations before the maximum speed locations of all street sections were used to model ΔV_a and similarly, only mean speed data after the maximum speed location were used to model ΔV_d . A profile mean speed then can be identified from $V_{\max}$, $L_{\max}$, ΔV_a , ΔV_d (see Fig.2). The second method, therefore, was named as "indirect method".

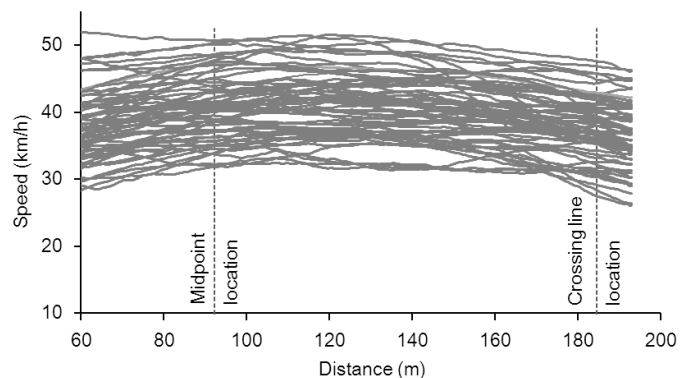


Fig. 1 Typical profile-speed data for one street section

Keyword: profile speed, regression model, residential streets, 30 km/h speed limit.

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The coefficient of determination (R^2) of the overall profile mean-speed model by the indirect method was calculated as follows:

$$R^2 = 1 - \text{SSE}/\text{SST} \quad (1);$$

$$\text{SST} = \sum_{i=1}^{85} \sum_{j=1}^{11} (V_{ij} - \bar{V})^2 \quad (2);$$

$$\text{SSE} = \sum_{i=1}^{85} \sum_{j=1}^{11} (\hat{V}_{ij} - V_{ij})^2 \quad (3)$$

Where: V_{ij} = observed mean speed at location j of the i th street; $\bar{V}$ = mean of V_{ij} ; and $\hat{V}_{ij}$ = estimated mean speed at location j of the i th street.

The present study employed a seemingly unrelated regression (SUR) to model both $V_{\max}$ and $L_{\max}$ simultaneously. The rationale for using this modeling approach is that the technique is able to account for contemporaneous correlation between the disturbance terms of the regression equations which are developed to determine $V_{\max}$ and $L_{\max}$ since these two dependent variables may be influenced by the same unobserved factors such as drivers' characteristics. Other dependent variables were modeled by ordinary least square regression (OLS). In the final models, all selected variables are significant at the 95% level.

3.4 Final models

By direct method:

- When mean speed at midpoint (V_{mid}) is unknown

$$V = 25.759 + 0.629\text{RSS} + 1.268\text{CAW} + 0.627\text{SWB} - 0.339\text{ROD} - 0.312\text{DWD} + 1.039\text{TLI} + 0.004\text{ACL} + 0.077\text{df} - 0.00063\text{df}^2 + 0.097\text{dt} - 0.00057\text{dt}^2 \quad R^2 = 0.57 \quad (4)$$

- When mean speed at midpoint is known

$$V = 5.791 + 0.702V_{\text{mid}} + 0.328\text{RSS} + 0.362\text{CAW} + 0.622\text{SWB} - 0.170\text{ROD} + 0.520\text{TLI} + 0.004\text{ACL} + 0.057\text{df} - 0.00063\text{df}^2 + 0.077\text{dt} - 0.00057\text{dt}^2 \quad R^2 = 0.78 \quad (5)$$

By indirect method:

Step 1: $V_{\max}$ and $L_{\max}$ are determined by the following equations:

- When mean speed at midpoint is unknown

$$V_{\max} = 30.091 + 0.420\text{RSS} + 1.300\text{CAW} + 0.012\text{LEN} - 0.384\text{ROD} \quad R^2 = 0.54 \quad (6)$$

$$L_{\max} = 22.328 - 1.905\text{SW} + 0.304\text{LEN} - 0.062\text{ACL} \quad R^2 = 0.43 \quad (7)$$

- When mean speed at midpoint is known

$$V_{\max} = 8.109 + 0.769V_{\text{mid}} + 0.122\text{RSS} + 0.185\text{SW} + 0.432\text{SWB} \quad R^2 = 0.90 \quad (8)$$

$$L_{\max} = -73.711 + 2.789V_{\text{mid}} + 0.297\text{LEN} - 0.027\text{ACL} - 3.407\text{SW} \quad R^2 = 0.57 \quad (9)$$

Step 2: ΔV_a and ΔV_d are estimated by the following equations:

$$\sqrt{\Delta V_a} = 0.482 + 0.149\text{SWL} - 0.0024\text{LEN} + 0.046x_1 - 0.00043x_1^2 - 0.016x_2 + 0.00018x_2^2 \quad R^2 = 0.80 \quad (10)$$

$$\sqrt{\Delta V_d} = 2.796 - 0.063V_{\max} - 0.0011\text{LEN} - 0.193\text{TLI} - 0.01\text{DCI} + 0.031\text{MSC} + 0.043y_1 - 0.00020y_1^2 - 0.015y_2 + 0.00016y_2^2 \quad R^2 = 0.82 \quad (11)$$

The overall R^2 in the indirect method determined by Eq. (1) were 0.56 and 0.78 for the case “when mean speed at midpoint is unknown” and the case “when mean speed at midpoint is known” respectively.

Notations: RSS = right safety strip width (m); CAW = carriageway width (m); SWB = sidewalk indicator (1 if there are sidewalks on both sides; 0 otherwise); SWL = sidewalk indicator (1 if there is a left sidewalk; 0 otherwise); SW = total street width (m); LEN = length of street section (m); ROD = roadside object density (number of objects per 100m); DWD = driveway density (number of driveways per 100m); TLI = type indicator of exiting intersection (1 if 3-leg intersection; 0 otherwise); ACL = distance from the crossing line location to the nearest control point (m); DCI = distance from the crossing line location to the center point of exiting intersection (m); MSC = maximum width of crossing street (m); df = distance to the midpoint location (m); dt = distance to stop line location (m); Other notations are defined in Fig.3.

Note: All kinds of speeds are measured by km/h.

3.5. Discussion

Although two proposed methods yield almost the same level of goodness of fit, the indirect method is recommended as a more favorable one since the resultant models can capture the different influence of street characteristics to drivers' speeds at different locations on a given street section. As can be seen in the Eq. (6), Eq. (8), Eq. (10) and Eq. (11), intersection features do not influence mean speeds before maximum speed locations while some of them are significant variables on the models to determine mean speed after the locations. In contrast, this theoretically-explained phenomenon cannot be seen in the model developed by the direct method.

4. CONCLUSIONS

This research is the first attempt to model profile speeds for urban residential streets with a 30 km/h speed limit. The developed models incorporated various roadway and roadside characteristics which provide helpful information for coping with speeding issues on urban neighborhood streets.

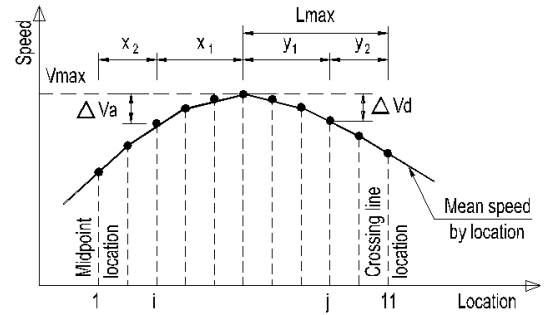


Fig. 2 Mean speed data by location