Empirical Observations and Analyses of Pedestrian Behaviors at Roadway Crossings with Pedestrian Countdown Signal

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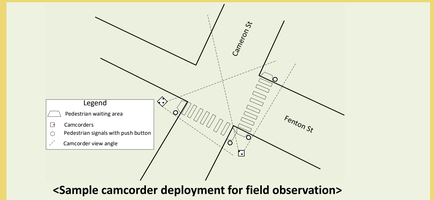
Abstract

- To address the increasing concerns of pedestrian-vehicle crashes at crosswalks with **pedestrian countdown signals** (**PCS**), this study presents the field observation results of **more than 3000 pedestrians' choices** at 11 urban crosswalks when they encounter the pedestrian signals.
- The dataset is divided into two groups based on the weighted **average of violation rate (25%)** to take the high variance of pedestrian violation rate across crosswalks into account.
- Logistic regression model is applied to identify factors that would significantly impact individual's compliance decision.
- The analysis results from logistic regression show that crosswalks from high- and low-violation group share five common significant factors but they weigh such factors, except required waiting time, differently in their crossing decisions, based on the results of **dominance analysis**.
- **T**ime **S**eries **C**ross **S**ection **Reg**ression **(TSCSReg)** model is calibrated to convert the understandings of individual's behaviors to safety assessment.

Field Observations

Data Collection



<Sample camcorder deployment for field observation>

$$\text{Violation Rate} = {}^{\#\ of\ temporal\ violators}/_{Total\ \#\ of\ pedestrians}$$

❖ **Key Features and violation rate at 11 selected crosswalks**

Intersection	No. of pedestrian-involved crashes	Crosswalk	Bus frequency (buses/hr)	Median island	Crosswalk length (m)	Traffic volume (veh/hr)	No. of observed pedestrians	Violation rate
US 29 @ Ellsworth Dr.	4	Ellsworth	20.00	Yes	27.3	1680	357	45.94%
Arlington Rd @ Bradley Blvd	3	Arlington	0.83	Yes	28.4	1053	210	25.71%
		Bradley	5.83	No	19.7	970	209	15.31%
Piney Branch Rd @ Flower Ave	3	Piney	11.67	No	13.9	894	230	11.30%
		Flower	11.67	No	14.9	595	157	17.20%
Fenton St @ Cameron St	3	Fenton	2.00	No	15.2	291	542	42.25%
		Cameron	2.00	No	14.9	226	243	26.75%
MD 500 @ MD501	3	MD 500	4.17	No	18.7	579	111	32.43%
		MD 501	4.17	No	22.5	1433	203	5.91%
US 1 @ Regents Dr.	3	US 1	0.00	No	11.0	256	463	9.72%
		Regents	0.00	Yes	21.3	1273	552	21.38%

Collected Factors

Pedestrian characteristics related factors

- Gender
- Senior or not
- Wearing a formal dress or not
- Walking free or carrying personal belongings
- Crossing with a group or not
- With or without children/pets
- Pressing the PCS button or not
- Using the cellphone in the waiting area or not
- Bike or not
- With or without witnessing noncomplying pedestrians

Traffic and signal-related factors

- Traffic volume by cycle; Average traffic flow speed
- Crosswalk length
- PCS's cycle length; Red-phase duration
- Required/Actual waiting time

Other factors

- Bus frequency
- Neighboring to office buildings/supermarkets
- Average income of residents in the crosswalk's zip code

Logistic Regression

❖ **Results of Logistic regression**

Variables	High-violation group		Low-violation group	
	Coefficient	Pr(>|z|)	Coefficient	Pr(>|z|)
(Intercept)	1.409	0.011	-0.863	0.008
Gender (male)	0.047	0.749	0.654	0.000*
Age Group (senior)	-0.394	0.040*	0.2	0.496
Dress-up (uniform)	0.291	0.182	0.499	0.205
Cross with a group	-1.106	0.000*	-0.554	0.002*
Press the PCS button	-1.275	0.000*	-0.719	0.004*
Cross with children	-1.438	0.001*	-14.832	0.967
Bicyclist	-0.654	0.119	0.045	0.899
Cross with pets	-0.273	0.558	-0.347	0.753
Witness noncomplying pedestrians	-0.853	0.000*	1.142	0.000*
Carry personal belongings	-0.194	0.188	-0.172	0.275
Use cellphone while waiting	-0.693	0.005*	-1.311	0.000*
Required waiting time	0.065	< 2e-16*	0.027	< 2e-16*
Traffic volume	-0.981	0.288	-3.781	0.000*
Bus frequency	0.006	0.858	-0.047	0.015*
Crosswalk length	-4.166	0.000*	-1.527	0.000*
Per capita income	-2.593	0.000*	0.883	0.004*

❖ **Factors with consistent statistical significance or signs between groups**

- The impact of **required waiting time** are consistent with the general belief and field observations that pedestrians are more likely to follow the PCS instructions if they need to wait for a relatively short time.
- Pedestrians are also found to be more likely to follow the signal if they are **using cell phones** in the waiting area.
- The noncomplying action to the PCS instruction is less likely to take place if pedestrians have **pushed the PCS button** or when the **crosswalk has a relatively longer length**.

❖ **Factors with statistical significance or signs varying between groups**

- The factor of gender shows a positive significant sign in the group of low violation, implying that **males** are more likely than females to violate the PCS instructions in the areas having less aggressive pedestrian populations.
- The factor of **senior pedestrians** or those **with children** both show significant negative signs only in the high-violation crosswalks, indicating that such pedestrians, even at the crosswalks plagued by a high PCS violation rate, are less willing to be jaywalkers.
- The likelihood of **following other jaywalkers** to illegally cross the street seems to play a role in the decision of pedestrians in both groups but with the opposite impacts, where those in the low-violation group are more likely to follow the observed noncomplying behaviors.
- **Traffic volume** around the high-violation group does not demonstrate a significant impact on pedestrians' decision-making. However, this factor shows a significant negative impact in the low-violation group.
- For those pedestrians in the low-violation group, the presence of **bus stops** and **high bus frequency** seem to have a negative impact on their decisions to ignore the "Don't Walk" signal.

Dominance Analysis

❖ **Results of Dominance Analysis**

High-violation group		Low-violation group	
Variable	R^2_M	**Variable**	R^2_M
Required waiting time	0.191	Required waiting time	0.064
Per capita income	0.023	Witness noncomplying pedestrians	0.048
Cross with a group	0.018	Crosswalk length	0.024
Press the PCS button	0.014	Gender (male)	0.014
Cross with children	0.011	Traffic volume	0.012
Witness noncomplying pedestrians	0.006	Use cellphone while waiting	0.006
Crosswalk length	0.005	Press the PCS button	0.005
Age group (senior)	0.002	Cross with a group	0.004
Use cellphone while waiting	0.002	Bus frequency	0.003
		Per capita income	0.002

- The impacts of key factors on a pedestrians' decision would vary between different population.

$$R^2_M = \frac{\ln(L_0) - \ln(L_M)}{\ln(L_0)} = 1 - \frac{\ln(L_M)}{\ln(L_0)}$$

L_0: The likelihood of the null model (i.e., $y = intercept$)

L_M: The likelihood of the fitted model with the intercept and independent variable M.

- R^2_M, each factor's contribution to the dependent variable under the logistic regression shows the relative weights of all significant factors in a pedestrian's decision-making process.
- **Required waiting time** stands out as the most critical factor for the pedestrians in both groups to decide whether to cross the street during the PCS message of "Don't Walk."
- Except for the same top concern of the "required waiting time", pedestrians in the low- and high-violation groups account for other significant factors in their decision-making process with quite different weights.

TSCSReg Analysis

- **T**ime **S**eries **C**ross-**S**ection **Reg**ression (TSCSReg) is presented to show the potential of transferring the understandings of individual pedestrian behaviors for **intersection safety assessment.**

$$y_{it} = \sum_{k=1}^{K} x_{itk}\beta_k + (\nu_i + \epsilon_{it}) \quad i = 1, \dots N; t = 1, \dots T$$

- y_{it} is the estimated pedestrian violation rate at crosswalk i and during the aggregated time interval t of 30 minutes from each crosswalk's 6-hour video data;
- x_k is the k^{th} independent variable in the regression;
- $(\nu_i + \epsilon_{it})$ comprises the random terms associated with the cross-sectional variation between 11 crosswalks and the time-series correlation within the set of data over the 12 aggregated time intervals (i.e., 30 minutes) from the same crosswalk

- A crosswalk's noncomplying pedestrian rate is expected to decrease with the percentage increase in the following factors over the total pedestrians during the observation period: **pedestrians accompanying others**, **seniors**, **pedestrians pressing the PCS button**, **and bicyclists**.
- An increase in the crosswalk's **traffic volume** will naturally discourage more pedestrians from ignoring the "Don't Walk" message.
- An increase in the **percentage of witnessing other violators** is likely to cause more pedestrians to follow the same illegal crossing.
- The signal plan that results in a **longer average waiting time** for the crosswalk's randomly arriving pedestrians is likely to encourage more jaywalkers.

❖ **Results of TSCSREG**

Variable	Coefficient	t Value	Pr > |t|
Intercept	-1.734	-1.210	0.230
% of pedestrians crossing with a group	-0.760	-2.220	0.029*
% of male pedestrians	-0.031	-0.380	0.702
% of senior pedestrians	-1.052	-2.110	0.037*
% of pedestrians dressing formally	1.256	1.680	0.096
% of pedestrians pressing the PCS button	-0.920	-2.760	0.007*
% of pedestrians witnessing noncomplying pedestrians	2.540	4.020	0.000*
% of pedestrians carrying personal belongings	-0.126	-0.380	0.703
% of pedestrians crossing with children	-0.948	-1.440	0.153
% of bicyclists	-1.414	-2.010	0.047*
% of pedestrians crossing with pets	-4.018	-1.760	0.082
% of pedestrians using cellphone while waiting	0.479	0.690	0.493
Bus frequency	0.039	1.050	0.297
Average cycle length	-0.207	-0.500	0.620
Average pedestrian arrival rate	-0.087	-0.840	0.401
Average vehicle speed	0.052	0.720	0.472
Average traffic volume	-1.988	-3.080	0.003*
Crosswalk length	-0.866	-1.290	0.200
Per capita income	0.423	0.550	0.580
Average required waiting time	0.013	2.210	0.029*

Conclusions

- This study has presented the observation results of more than 3,000 pedestrians' responses to the "Don't Walk" message at 11 crosswalks and identified a set of critical factors that may contribute to a pedestrian's non-compliance decision.
- From the result of logistic regression, five factors exhibit consistent impacts across all observed pedestrians on their decisions to the PCS: **required waiting time**, **pressing the PCS button or not**, **walking with others or not**, **using the cellphone or not**, and **crosswalk length.**
- **Pedestrians in different populations weigh those significant factors quite differently**, except for the factor of required waiting time that is ranked as the most important factor by those in both groups.
- To analyze the pedestrian's non-compliance rate **at the aggregate level**, this study has explored the use of a **panel dataset** of 11 crosswalks over 12 30-min intervals to identify critical factors.
  - ✓ Seven factors have significant impacts on a crosswalk's pedestrian non-compliance rate : **percentage of pedestrians crossing with a group**, **percentage of seniors in the total pedestrians**, **percentage of pedestrians pressing the PCS button**, **percentage of pedestrians witnessing other violators**, **percentage of bike riders in the pedestrian population**, **average traffic volume of a crosswalk, and average required waiting time**.
- **Further research:** conducting extensive observations at different crosswalks and collect additional socio-economic data that can reflect the collective characteristics of pedestrians and affect their decisions when encountering the PCS instructions.