ASSESSING THE SAFETY OF SIGNALIZED INTERSECTIONS:

The Influence of Geometric Attributes and Regionality on Traffic-accident Risks

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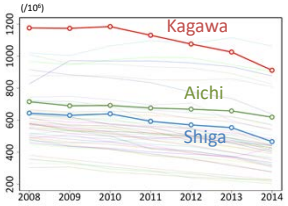
ABSTRACT

- This study identified and quantified the main factors influencing traffic accident risks at signalized intersections to propose effective countermeasures.
- Google Earth was used to collect numerical data related to the geometric attributes of intersections in three different regions in Japan.
- A lognormal hurdle model that considered regionality and geometric attributes was then used to quantify factors influencing the risk of traffic accidents involving various types of collisions.
- The important findings are:
  - (i) The results indicated the existence of significant regional differences in the geometric attributes of intersections in regions.
  - (ii) Intersection size, length of crosswalks, and setback distance of crosswalks generally and significantly influenced all collision risk types.
  - (iii) The regionality of risk factors was mainly caused by the differences in driving characteristics between regions.

1. INTRODUCTION

- Specific regions keep listed in the highest number of fatalities per capita, suggesting "regionality" effects on traffic accidents.
- More than half of traffic accidents occur in and around intersections.



Number of injuries per capita of 47 prefectures in Japan

OBJECTIVES

- To identify and quantify the main factors influencing traffic accident risks at signalized intersections with consideration of the geometric attributes of intersections.
- To examine the source of regionality in traffic accident risks.

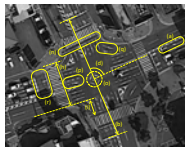
2. TARGET REGIONS

- Three regions in Japan: Kagawa, Aichi, and Shiga, where have a relatively higher number of traffic accidents per capita, and the land is flat and not mountainous.

3. DATA DESCRIPTION

- Quantification of geometric attributes of signalized intersections by using Google Earth.

General attributes:
(a) with or without exclusive right-turn lanes and signals
(b) distance between stop lines [m]
(c) number of legs
(d) intersecting angles [rad]
(e) distance to the closest neighboring intersection [km]
(f) land use at corners (with or without shops with parking lots or gas stations)
(g) number of lanes
Pedestrian facilities:
(h) length of the crosswalk [m]
(i) setback distance of crosswalks [m]
(j) with or without pedestrian bridges
(k) with or without two-stage crossings
(l) with or without curbstones or guardrails
(m) width of the sidewalks [m]
Bicycle facilities:
(n) with or without bicycle crossing zones
Motor vehicle facilities:
(o) with or without pavement markings for center indication
(p) with or without pavement markings for right turns,
(q) with or without pavement markings for left turns
(r) with or without exclusive stop lines for motorcycles
Road traffic census data:
(s) AADT-12 [veh/12 h]
(t) types of center dividers
(u) along-side situation
National census data:
(v) population in the zone where the intersection is located
(w) population of elderly individuals (65 years and older)



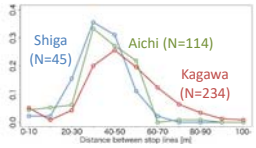
An example of geometric attributes of an intersection (https://www.google.com/maps).

- Category wise accident data collected from January 1, 2008 to December 31, 2013, associated with each intersection.

Integrated accident categories	Conditions
Rear-end	<All persons concerned use motor vehicles > and <Original accident category is "rear-end" >
Left and right turn	<All persons concerned use motor vehicles> and <Original accident category is "left turn") or (Original accident category is "right turn")>
Motor vehicles related	<All persons concerned use motor vehicles>
Motor vehicles with eldery drivers related	<All persons concerned use motor vehicles> and <Either persons concerned are 65 years old and older>
Motorcycles related	<Either of persons concerned use motorcycles>
Pedestrians related	<Either of persons concerned are pedestrians>
Elderly pedestrians related	<Either of persons concerned are pedestrians> and <The pedestrian is 65 years old and older>

4. REGIONAL DIFFERENCES IN ATTRIBUTES OF INTERSECTIONS

- Significant differences among regions are observed with respect to most variables except for two-stage crossings, pavement markings for left turns, and the number of legs.



Results of multiple comparisons

	With or without exclusive right-turn lane and signal[1]			Distance between stop lines [m]			Intersecting angle [sin]			Land use at corners[2]		
	Mean	p-value Shiga	p-value Kagawa	Mean	p-value Shiga	p-value Kagawa	Mean	p-value Shiga	p-value Kagawa	Mean	p-value Shiga	p-value Kagawa
Shiga	0.62	-	-	38.8	-	-	0.976	-	-	0.400	-	-
Kagawa	0.86	0.16	-	49.2	0.00	-	0.917	0.01	-	0.812	0.00	-
Aichi	1.31	0.00	0.00	40.9	1.00	0.00	0.941	0.33	0.28	0.710	0.00	0.28
	Length of crosswalk [m]			Setback distance of crosswalk [m]			With or without two-stage crossing[3]			With or without curbstones or guardrail[4]		
	Mean	p-value Shiga	p-value Kagawa	Mean	p-value Shiga	p-value Kagawa	Mean	p-value Shiga	p-value Kagawa	Mean	p-value Shiga	p-value Kagawa
Shiga	11.24	-	-	4.88	-	-	0.022	-	-	1.38	-	-
Kagawa	16.49	0.00	-	7.99	0.00	-	0.056	0.90	-	0.94	0.00	-
Aichi	14.01	0.05	0.00	6.91	0.01	0.03	0.018	1.00	0.28	1.35	1.00	0.00
	With or without pavement marking for center indication[5]			With or without pavement marking for right-turn[6]			With or without pavement marking for left-turn[7]			With or without exclusive stop line for motorcycles[8]		
	Mean	p-value Shiga	p-value Kagawa	Mean	p-value Shiga	p-value Kagawa	Mean	p-value Shiga	p-value Kagawa	Mean	p-value Shiga	p-value Kagawa
Shiga	0.333	-	-	0.356	-	-	0.222	-	-	0	-	-
Kagawa	0.594	0.00	-	0.620	0.00	-	0.235	1.00	-	0.44	0.00	-
Aichi	0.868	0.00	0.00	0.149	0.03	0.00	0.132	0.60	0.07	0.01	1.00	0.00
	Number of legs			Along-side situation			Width of side walk [m]			Number of lanes		
	Mean	p-value Shiga	p-value Kagawa	Mean	p-value Shiga	p-value Kagawa	Mean	p-value Shiga	p-value Kagawa	Mean	p-value Shiga	p-value Kagawa
Shiga	3.911	-	-	2.36	-	-	2.82	-	-	2.356	-	-
Kagawa	3.880	1.00	-	3.29	0.00	-	2.36	0.31	-	3.162	0.00	-
Aichi	3.877	1.00	1.00	4.06	0.00	0.00	3.51	0.08	0.00	2.982	0.17	0.65

5. A METHOD OF STATISTICAL ANALYSIS

- Numerical characteristics of traffic-accident risks:
  - (i) Non-uniform variance in the error term
  - (ii) Over-dispersion and under-dispersion
  - (iii) Continuous and positive values
  - (iv) A large number of zero observations
  - (v) Skewness characteristics

$$\text{Risk} = \frac{\text{Number of accidents}}{\text{AADT-12 at an intersection}} * 10^6$$

- A lognormal hurdle model was employed.

$$f_h(y|\pi,\boldsymbol{\theta}) = \begin{cases} 1-\pi & \text{if } y=0 \\ \pi f(y|\boldsymbol{\theta}) & \text{if } y>0 \end{cases}$$

6. ESTIMATION RESULTS

- Motor-vehicles-related collisions

Rear-end

1st layer			
Variables	Estimates	Std.err	t_value
Intercept	3.12	1.06	2.94 **
D. of Aichi (1:Aichi, 0: others)	-1.93	0.30	-6.38 ***
D. of exclusive right-turn lane and signal (1: either, 0: never)	1.04	0.31	3.34 **
Distance between stop lines (100 m)	4.75	2.09	2.27 *
Intersecting angle (sin)	-1.18	0.53	-2.23 *
Center dividers (7 categories)	-3.46	1.13	-3.05 **
Land use at corners (1: either shops or gas station, 0: never)	0.77	0.24	3.15 **
Initial log-likelihood			-273.79
Log-likelihood			-172.33
Adjusted-ρ^2			0.35
2nd layer			
Variables	Estimates	Std.err	t_value
Intercept	3.76	0.14	26.05 ***
D. of Kagawa (1:Kagawa, 0: others)	0.34	0.13	2.61 **
D. of Aichi (1:Aichi, 0: others)	-0.80	0.15	-5.33 ***
Distance between stop lines (100 m)	1.54	0.50	3.08 **
Intersecting angle (sin)	-0.37	0.20	-1.86 .
γ	-0.17	0.02	-8.79 ***
Initial log-likelihood			-4063.71
Log-likelihood			-1527.87
Adjusted-ρ^2			0.62
Total statistics			
N			395
DF			381
AIC			3426.39

During left and right turns

1st layer			
Variables	Estimates	Std.err	t_value
Intercept	2.07	1.01	2.05 *
D. of Aichi (1:Aichi, 0: others)	-0.88	0.27	-3.30 **
D. of exclusive right-turn lane and signal (1: either, 0: never)	7.73	3.85	2.01 *
Length of crosswalk (100 m)	11.92	6.74	1.77 **
D. of bicycle crossing zone (1:with, 0: without)	0.58	0.26	2.22 **
Center dividers (7 categories)	-3.21	1.01	-3.19 *
Land use at corners (1: either shops or gas station, 0: never)	0.90	0.23	3.92 *
Initial log-likelihood			-246.59
Log-likelihood			-198.21
Adjusted-ρ^2			0.17
2nd layer			
Variables	Estimates	Std.err	t_value
Intercept	3.43	0.23	14.78
D. of Kagawa (1:Kagawa, 0: others)	0.27	0.19	1.71 **
D. of Aichi (1:Aichi, 0: others)	-0.38	0.17	-2.21 *
D. of exclusive right-turn lane and signal (1: either, 0: never)	0.29	0.11	2.67 *
Setback distance of crosswalk (100 m)	2.35	1.22	1.92 **
Length of crosswalk (100 m)	5.16	1.99	2.59 *
D. of two-stage crossing (1: with, 0: without)	-0.46	0.21	-2.13 *
Proportion of eldery residents	-1.51	0.67	-2.25 *
γ	-0.15	0.02	-6.87 ***
Initial log-likelihood			-3514.35
Log-likelihood			-1403.89
Adjusted-ρ^2			0.60
Total statistics			
N			395
DF			378
AIC			3296.19

Motorcycle-related

1st layer			
Variables	Estimates	Std.err	t_value
Intercept	3.64	0.81	4.50 ***
D. of Aichi (1:Aichi, 0: others)	-1.37	0.26	-5.26 ***
Center dividers (7 categories)	-2.19	0.83	-2.65 **
Along-side situation (5 categories)	-0.28	0.11	-2.61 **
Land use at corners (1: either shops or gas station, 0: never)	0.49	0.21	2.35 *
Initial log-likelihood			-266.48
Log-likelihood			-221.73
Adjusted-ρ^2			0.15
2nd layer			
Variables	Estimates	Std.err	t_value
Intercept	2.27	0.27	8.46 ***
D. of Aichi (1:Aichi, 0: others)	-0.69	0.13	-5.33 ***
Distance between stop lines (100 m)	5.91	2.02	2.92 **
D. of exclusive stop line for motorcycles (1: with, 0: without)	-0.32	0.10	-3.12 **
Center dividers (7 categories)	1.21	0.27	4.49 ***
γ	-0.15	0.02	-6.87 ***
Initial log-likelihood			-2665.86
Log-likelihood			-1142.54
Adjusted-ρ^2			0.57
Total statistics			
N			395
DF			383
AIC			2750.54

* $p < 0.01$. ** $p < 0.05$. *** $p < 0.10$

- Pedestrian-related collisions

All pedestrian related

1st layer			
Variables	Estimates	Std.err	t_value
Intercept	0.41	0.36	1.14
D. of Aichi (1:Aichi, 0: others)	-0.71	0.26	-2.67 **
Along-side situation (5 categories)	-0.35	0.09	-3.71 ***
Land use at corners (1: either shops or gas station, 0: never)	0.66	0.20	3.31 ***
Initial log-likelihood			-317.98
Log-likelihood			-242.52
Adjusted-ρ^2			0.22
2nd layer			
Variables	Estimates	Std.err	t_value
Intercept	1.94	0.32	6.12 ***
Intersecting angle (sin)	-0.39	0.23	-1.73 **
Length of cross walk (100 m)	5.00	2.07	2.42 *
D. of exclusive stop line for motorcycles (1: with, 0: without)	-0.21	0.09	-2.26 *
D. of pedestrian bridge (1:with, 0: without)	-0.46	0.23	-2.04 *
Center dividers (7 categories)	1.16	0.31	3.75 ***
Width of sidewalk (10 m)	-0.82	0.26	-3.11 **
γ	-0.44	0.04	-11.17 ***
Initial log-likelihood			-1267.16
Log-likelihood			-567.66
Adjusted-ρ^2			0.55
Total statistics			
N			395
DF			382
AIC			1648.38

Involving 65 years and above

1st layer			
Variables	Estimates	Std.err	t_value
Intercept	-1.50	0.38	-4.00 ***
D. of Aichi (1:Aichi, 0: others)	-1.15	0.42	-2.72 **
Along-side situation (5 categories)	-8.21	4.32	-1.90 **
Land use at corners (1: either shops or gas station, 0: never)	0.58	0.28	2.11 **
Initial log-likelihood			-306.76
Log-likelihood			-147.71
Adjusted-ρ^2			0.51
2nd layer			
Variables	Estimates	Std.err	t_value
Intercept	2.50	0.31	8.02 ***
Distance to the most neighboring intersection (km)	1.54	0.44	3.46 *
Length of cross walk (100 m)	9.16	2.53	3.62 *
D. of pavement marking for right-turn (1:with, 0:without)	-0.30	0.16	-1.85 **
D. of pavement marking for left-turn (1:with, 0:without)	0.34	0.20	1.74 **
D. of pedestrian bridge (1: with, 0: without)	-0.73	0.26	-2.75 *
Width of sidewalk (10 m)	-1.20	0.42	-2.83 *
Proportion of eldery residents	1.52	0.80	1.91 **
Land use at corners (1: either shops or gas station, 0: never)	-0.39	0.12	-3.21 *
γ	-0.59	0.07	-8.36 ***
Initial log-likelihood			-409.73
Log-likelihood			-178.39
Adjusted-ρ^2			0.54
Total statistics			
N			395
DF			380
AIC			680.18

* $p < 0.01$. ** $p < 0.05$. *** $p < 0.10$

NOTES

- A logistic regression was applied in the first layer to model the binary variable (that is, zero or non-zero positive).
- The second layer modeled traffic-accident risks for intersections.
- A backward elimination method was independently applied for the first and second layer to select explanatory variables.

MAIN FINDINGS

- Differences in significant variables among the accident type suggest differences in the factors influencing the occurrence of traffic accidents according to the accident types.
- Variables relating to intersection size are significant in all cases. → Creating compact intersections may contribute to traffic safety.
- In the second layer, regional dummy is significant for motor-vehicle-related collisions, but not for pedestrian-related collisions. → Regionality of risk factors may be caused by the differences in driving characteristics.

7. DISCUSSIONS

- **Significant regional differences in the geometric attributes of intersections:** It could potentially arise from the differences in traffic situation, historical land use patterns, and road network configurations.
- **Intersection size significantly influenced the risks of all types of collisions:** This indicated that a compact intersection had lower risks, though the optimal intersection size should be also considered from various aspects including safety and efficiency.
- **The regional dummy variables were statistically significant:** This suggested that in addition to geometric attributes of intersections, there were regional differences in the factors influencing collision risks. The source of regionality should be investigated in detail by future studies.

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