Memoirs of the School of Engineering Okayama University Vol. 12, February 1978

A Statistical Analysis of Traffic Accidents in Minor Street Network

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(Received January 9, 1978)

Synopsis

A statistical analysis is applied to find what states of "block" are dangerous from view point of traffic accident. Here, the block is defined to be an area surrounded by some major streets and is feeded by a minor street network. The accidents under study are those which occur in the whole minor street network. They are grouped into three kinds; pedestrian, vehicle and the gross accidents. And each is classified to three types according to the place where the accident occurs.

At the beginning 22 variables are assumed to state a certain relationship of some states of the block with the occurrences of accidents and 12 variables are found significant finally through factor analysis. Further examination has reached several key variables that migth have something significant to cause traffic accidents in the block. The key ones are the number of lanes of street and the number of legs of intersection, especially nearly 2 lanes street and 3-leg intersection , respectively. The case study was carried out on 26 blocks sampled from Osaka City.

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1. Introduction

A statistical method is applied to the analysis of what states of the area, that is defined to be surrounded by some major streets and is called a block hereafter in the paper, are likely to cause traffic accidents in itself. The street network in the block may be considered to be composed mainly of minor streets with 2 or 3 lanes or less.

The reason why such a network of minor streets is put under traffic accident study is as follows.

(1) Traffic accidents on minor street may not always be of the same kind as those on major street. Therefore minor streets may require us another but proper approach to traffic accidents, on which some improvements of the states of block should be discussed for less accidents.

(2) Time interval and space for sampling; Traffic accident is of rare occurrence in itself, and it is likely to have such a large fluctuation in the number of occurrences (especially in a sense of the coefficient of variance) that the accident data sampled happens to be of less reliability, especially when sampled in a shorter interval of time and / or in a smaller space, for example in a single intersection or street section. On the other hand, some changes in the states affecting traffic accidents are unavoidable, though accident data may be rather reliably steady, when sampled in a longer interval of time and in a larger space. Those mentioned above may disturb us to find statistically the relation of traffic accidents to the state variables affecting them. From these points of view, data should be sampled in some cumulated form, that is, in a form cumulated in suitable time interval and space.

These are the reasons why traffic accidents "in the block" was put under study. As mentioned later, another attention is paid to sampling "well mixed" blocks, in each of which every variable under study has nearly uniform spacial distribution.

Though we have a very few accidents in each minor street, the number of them is very large when summed over the whole network within urban area. The study is meaningfully important. Through the statistical study, some characteristics are found significant in relation to the occurrence of traffic accidents in the block.

2. Factor Analysis of Traffic Accidents in Minor Streets

2.1 Sample Blocks and Variables

As described previously, the block under study is surrounded by some major streets. To sampling blocks was paid attention as follows; the block should not be so large or small, because, a very large block migth not be regarded uniform in the spatial distribution of any variable expressing the block characteristic (land use, for example) while a very small block migth give us an unreliable accident data because of its wide range of fluctuation, both of these extreme cases should disturb us to estimate statisticl relationship between occurrences of accidents and some characteristic variables. In the study, 26 blocks were chosen from among many blocks in Osaka City. These are shown in Fig.1.

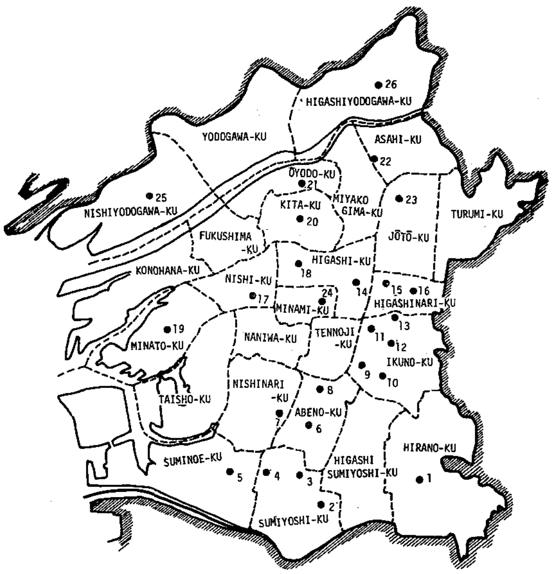

Fig.1 Osaka City and Blocks

Four kinds of characteristics adopted are as follows; physical pattern of street network, traffic regulation and ligth in street network, connectivity of street network inside with surrounding major streets and characteristics of land use, which are regarded apriori as direct or indirect causes of traffic accidents in the block. The first two characteristics may be direct to accidents. The third was introduced in relation to the accidents just inside the surrounding majors. And the last is considered to be indirect to accidents. As to the last it is noticed that land use is depended upon by volume and quality of traffic and pedestrians generated or terminated in the block and the number of curb-parked vehicles, which migth have a close relation to the occurrences of accidents. The reason why land use characteristics are adopted instead of traffic and pedestrian flow and so on is that we could not find observed data of them and that it costs too much to observe them in the field while land use could be picked up from land use map.

The name of each variable is shown in Table-1 with four characteristics. Note that these variables are not always independent each other.

Traffic accidents are grouped into three kinds; pedestrian accidents (including bicycle accidents) and the sum of them. For each kind rate of occurrences are shown in Table-2. Table-2 has three major columns. The first major column is calculated by dividing the number od each kind of accidents summed over the street network in the block by the total area of the streets. The second is concerned with those occured just on links of streets and the last just in intersections. Table-2 was calculated by use of the data of accidents occured from Jan. to Dec., 1975.

2.2 Procedures of the Analysis

Analysis is carried out through factor analysis according to the followings;

(1) Find communality, factor loading and factor score using normalized data. In this study, factor loading was obtained at first and the final one was found by varimax rotation. Factor score was estimated by use of least-square method.

(2) By checking both communality and factor loading, variables are removed or selected. The step is carried out for reducing the number of variables and for finding significant variables.

(3) Calculate correlation coefficient of each rate of accidents with each factor score. Find "accident factor" that should be strongly correlated with any accident rate.

(4) Try to find such variables that have closer relation to accidents by using factor loading and coefficient matrix of factor score.

(5) Some additional examination will be made. Accident factor score of block may be regarded as a certain measurement for grouping blocks into some kinds, risky, safe and so on, because the score expresses the level of accident factor in block.

Fig.2 shows an outline of the above procedures.

2.3 Numerical Results

According to the procedure described in the last section, twelve variables were determined together with five factors. Twelve variables are as follows;

Table-1 Block characteristics and variables

Characteristic	Variable No.	Variable
Physical pattern of street network	1	Percentage of the site for streets
	2	Ratio of the length of streets with 4 lanes or more to the total length
	3	Ratio of the length of streets with 2-4 lanes to the total
	4	Ratio of the length of streets with less than 2 lanes to the total
	5	Level of service of pedestrian walk
	6	Average number of intersections in unit area of block
	7	Average space between successive intersections in direction of longer side of block
	8	Average space between successive intersections in direction of shorter side of block
	9	Composition ratio of multi-leg intersections
	10	Composition ratio of 4-leg intersections
	11	Composition ratio of 3-leg intersections
Traffic regulation and ligth instreet network	12	Ratio of the length of one way streets to the total
	13	Ratio of the length of parking-regulated streets to the total
	14	Percentage of signal-controlled intersections
Connectivity of street network inside with surrounding major streets	15	Total length of surrounding streets
	16	Rate of the length of shorter side of block to the longer
	17	Average number of peripheral intersections in unit length of surrounding streets
	18	Percentage of signal-controled intersections on surrounding streets
	19	Average traffic on surrounding streets
land use	20	Percent..e of the residential site
	21	Percentage of the site for tertiary industries
	22	Percentage of the site for secondary industries

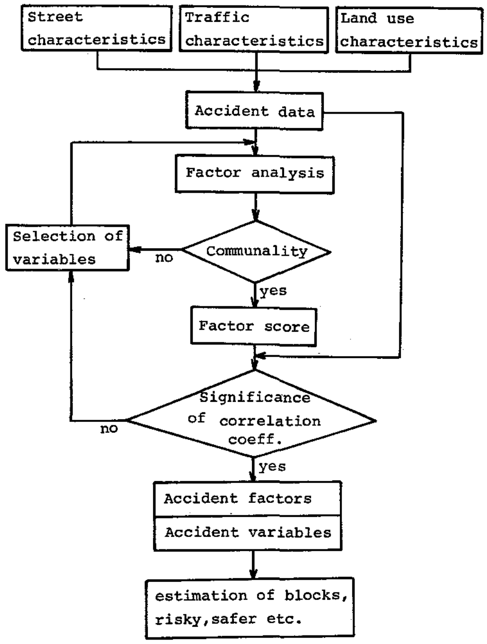

Fig.2 Flow of the study

Table-2 Accident rate

Kind of accident / Type No. / Block No.	Average number in site of street*			Average number in unit length of street**			Average number in an intersection***		
	Pedestrian	Vehicle	Total	Pedestrian	Vehicle	Total	Pedestrian	Vehicle	Total
	1	2	3	4	5	6	7	8	9
1	3.95	1.40	5.35	0.40	0.05	0.45	0.20	0.08	0.28
2	1.71	0.94	2.66	0.36	0.07	0.44	0.09	0.07	0.16
3	1.80	1.44	3.24	0.26	0.13	0.38	0.08	0.07	0.15
4	1.98	0.66	2.63	0.45	0.66	0.51	0.06	0.03	0.09
5	3.13	1.72	4.84	0.35	0.06	0.41	0.08	0.06	0.14
6	2.82	1.05	3.87	0.50	0.07	0.57	0.07	0.04	0.11
7	2.72	1.95	4.68	0.50	0.10	0.60	0.09	0.09	0.18
8	3.50	1.50	5.00	0.82	0.20	1.02	0.06	0.04	0.10
9	2.01	1.16	3.62	0.36	0 15	0.51	0.04	0.04	0.08
10	2.27	2.06	4.33	0.32	0.13	0.44	0.08	0.09	0.17
11	1.75	1.25	3.00	0.48	0.20	0.68	0.03	0.04	0.07
12	3.52	1.36	4.89	0.92	0.10	1.02	0.06	0.05	0.11
13	3.10	2.41	5.51	0.45	0.22	0.67	0.08	0.07	0.15
14	1.32	0.79	2.11	0.40	0.00	0.40	0.03	0.05	0.08
15	3.06	1.45	4.51	0.40	0.40	0.80	0.09	0.03	0.12
16	1.07	1.84	2.91	0.23	0.13	0.36	0.04	0.09	0.13
17	0.43	0.29	0.71	0.10	0.10	0.20	0.03	0.02	0.05
18	0.65	1.36	2.01	0.29	0.22	0.61	0.05	0.20	0.25
19	2.15	0.15	2.31	0.55	0.09	0.64	0.07	0.0	0.07
20	2.00	2.00	4.00	0.81	0.41	1.22	0.12	0.17	0.29
21	1.90	2.02	3.92	0.36	0.25	0.64	0.10	0.12	0.22
22	1.75	1.71	3.46	0.32	0.11	0.44	0.08	0.11	0.19
23	1.18	3.08	4.26	0.28	0.24	0.52	0.06	0.21	0.26
24	1.00	1.00	2.00	0.50	0.00	0.50	0.05	0.10	0.15
25	1.37	0.63	2.00	0.32	0.08	0.40	0.10	0.06	0.16
26	2.68	0.72	3.40	0.56	0.00	0.56	0.11	0.05	0.15

* The number of accidents, each summed over the whole network, devided by the gross street site.

** The number of accidents, each summed over just streetlinks alone, devided by the total length of streets.

*** The number of accidents, each summed' over just intersections alone, devided by the total number of intersections.

Variable number	Variable
1	Percentage of the site for streets
2	Ratio of the length of streets with 4 lanes or more to the total length
3	Ratio of the length of streets with 2-4 lanes to the total length
4	Ratio of the length of streets with less than 2 lanes to the total length
5	Level of service of pedestrian walk
9	Composition ratio of multi-leg intersections
10	Composition ratio of 4-leg intersections
11	Composition ratio of 3-leg intersections
13	Ratio of the length of parking-regulated streets to the total
14	Percentage of signal-controlled intersections
20	Percentage of the residential site
21	Percentage of the site for tertiary industries

The communality for 12 variables is shown in Table-3, the factor loading matrix in Table-4. Table-5 shows the correlation coefficients between factor scores and accident rate of each type, which are calculated by using each factor scores of 26 blocks and accident rate of every type (Table-2). Table-6 shows factor score coefficients used for calculation of factor score of blocks.

2.4 Examination

(1) All of the twelve variables finally reached seem to have some relation to accidents. Though the percentage of the residential site and the percentage of the site for tertiary industries may seem peculiar apparently, we have hypothesized at the beginning that these variables migth have some indirect relationship to accidents in a sense that these are depended upon by traffic and pedestrian flow and curb-parking and so on. On the other hand, those variables that are usually believed to have some direct and close relationship with accidents, that is, average number of intersections in unit area of block, ratio of the length of one way streets to the total etc., are not found in the twelve variables finally obtained. The reason why they are neglected may be that they have just small variances, which has been recognized in the original data.

(2) Table-5 showing correlation coefficients between five factors

Table-3 Communality

Variable No.	
1	0.71016
2	0.99907
3	0.99984
4	0.99972
5	0.72092
9	0.58055
10	0.99711
11	0.95694
13	0.75907
14	0.78577
20	0.63012
21	0.99342

Table-4 Factor loading matrix

Variable	Factor				
No.	F.1	F.2	F.3	F.4	F.5
1	-0.553	-0.229	-0.329	0.428	0.247
2	-0.332	-0.862	-0.141	0.256	-0.244
3	-0.414	-0.168	-0.250	0.856	-0.075
4	0.425	0.343	0.251	-0.790	0.116
5	0.028	-0.063	-0.371	0.569	-0.505
9	-0.034	0.124	0.100	-0.055	0.742
10	-0.307	-0.087	0.897	0.220	0.207
11	0.217	0.123	0.896	-0.280	0.118
13	-0.539	-0.323	-0.483	0.346	-0.108
14	-0.433	-0.153	-0.429	0.454	-0.429
20	0.451	0.141	0.293	-0.541	0.168
21	-0.861	-0.267	-0.274	0.319	0.057

Table-5
Correlation coefficients between accident rate of factor score

Type of accident	Factor				
rate No.	F.1	F.2	F.3	F.4	F.5
1	0.124	0.417	0.480	-0.308	0.084
2	-0.085	0.517	0.140	0.109	-0.095
3	0.044	0.599	0.452	-0.452	-0.033
4	-0.197	0.206	0.328	0.091	0.351
5	-0.199	0.096	0.073	0.026	0.338
6	-0.393	0.332	0.267	0.201	0.416
7	0.062	0.320	0.289	0.200	-0.302
8	-0.362	0.308	-0.205	0.529	-0.281
9	-0.260	0.405	-0.007	0.507	-0.368

Table-6
Coefficient matrix for factor score

Variable	Factor				
No.	F.1	F.2	F.3	F.4	F.5
1	0.0849	-0.1097	-0.0936	0.0222	0.3530
2	-0.0866	-0.7924	0.3267	-0.2904	-1.2273
3	-1.2615	2.1213	1.3907	0.7175	-4.1935
4	-2.0669	2.3394	1.5008	-0.9174	-5.3746
5	-0.0984	0.1312	00.1054	-0.0267	0.4230
9	0.1545	-0.1790	-0.1499	0.0436	0.5624
10	0.0504	0.2670	-0.9889	-0.2764	-0.7194
11	-0.3554	0.3398	0.3681	-0.0848	-1.0268
13	-0.0138	0.0024	-0.0022	-0.0066	0.0018
14	-0.1741	0.1898	0.1549	-0.0510	-0.5831
20	0.0414	-0.0413	-0.0337	0.0123	0.1230
21	-1.5053	0.3951	0.3678	-0.5887	-0.0736

and accidents rates of nine types give us the following constructions of these factors;

The second factor (F.2) ; Correlation coefficients with accident rates (in average number in unit site of street, No.1,2 and 3), are as large as 0.417, 0.517 and 0.599 respectively. The second factor can be supposed to be an accident factor.

The third factor (F.3) ; Correlation coefficients with accident rate of type No.1 and 3 are 0.480 and 0.452 respectively, while no correlation with the rate of No.2. F.3 may be interpreted to be concerned with pedestrian accident on streets.

The fourth factor (F.4) ; Correlation coefficients with vehicle accident rate (No.8) and total accident rate (No.9) are 0.529 and 0.507 respectively, while no correlation with type No.7. Accordingly, F.4 may be a factor concerned with vehicle accidents in intersection.

The other factors (F.1 and F.5) ; Correlation with every type of accident rate is very weak or nearly zero. No interpretation of them is possible.

(3) Some relationship of F.2, F.3 and F.4 with the twelve variables will be examined by Table-6.

F.2 ; The number of lanes (variable No.2,3 and 4) has larger contribution and percentage of the site for tertiary industries (variable No.21) and composition ratio of 3-leg intersections (variable No.11) have secondly larger contributions. Among those variables, the ratio of the length of streets with 4 lanes or more to the total (variable No.2) shows negative contribution while others positives.

F.3 ; This is similar to F.2 in contributions of the number of lanes, percentage of the site for tertiary industries and composition ratio of 3-leg intersections, while not similar in large negative contribution of composition ratio of 4-leg intersections (variable No.10) and in positive contribution of the ratio of length of streets with 4 lanes or more.

F.4 ; The factor is similar to F.1 and F.2 in comparatively large contributions of the variables, No.2,3,4 and 21, in disregard of their directions (+,-) : positive contribution of the ratio of the length of streets with 2-4 lanes but negative contributions of the other three variables, among which variable No.4 gives large negative contribution.

Table-4 shows a very remarkable fact that F.2 and F.3 are just alike, but are quite contrast with F.4, in signs (+,-) of loadings to every variable.

2.5 Accident Rate and Factor Score of the Block

Fig.3,4 and 5 show accident rates of three type vs. factor scores of the blocks which are obtained from Table-6 and values of variables observed in the blocks. Fig.3,4 and 5 show accident rates of No.3 type vs. F.2, No.1 type vs. F.3 and No.8 type vs. F.4, respectively, in which accident rates are plotted in normarized form on the ordinate. The selection of the three cases is because of the significantly larger correlation coefficients as shown in Table-5.

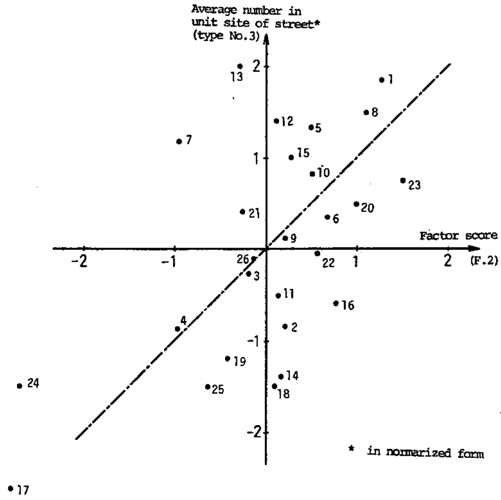

Fig.3 Accident rate of type No.3 vs. factor score (F.2)

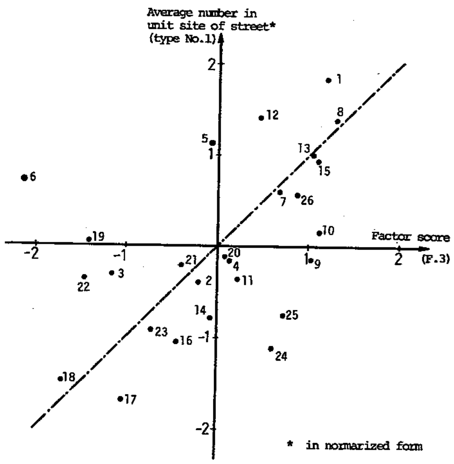

Fig.4 Accident rate of type No.1 vs. factor score (F.3)

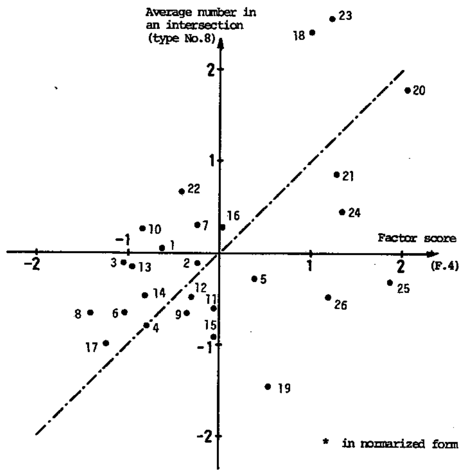

Fig.5 Accident rate of type No.8 vs. factor score (F.4)

3 Conclusion

(1) Correlation of each factor with nine types of accident rate suggests us about F.2, F.3 and F.4 that F.2 and F.3 are alike in that both should be named an accident factor (especially, pedestrian acci-

dent factor) in unit site of streets and that F.4 should be named intersection accident factor (especially, vehicle accident).

(2) Twelve variables selected will be grouped into two parts as follows: the first group containing the ratio of the length of streets with 2 lanes or less, composition ratio of 3-leg intersections and percentage of the residential site and the second containing the other variables. The first is a group that can be danger to pedestrians (with bicycle riders) from its close relationship to accident factor, especially to pedestrian accident one, in unit site of streets. The second can be regarded as something to cause accidents, especially vehicle ones, in intersection.

(3) It is suggested that the key variables are concerned with the number of the lanes of street (in other words, street width) and the number of legs of intersection. A higher ratio of the length of streets with less than 2 lane may be more likely to cause accidents, a higher composition ratio of 3-leg intersections to cause pedestrian (with bicycl rider) accidents and the one of 4-leg intersections to do vehicle accidents. Some considerations will be made about those above as follows; nearly two-lane streets are supposed to play a key parts among the streets with less than 2-lanes, because those streets are ill-conditioned in several facts that those are frequently assigned heavier traffic for the width for those are often feeders standing between surrounding streets and those with less lanes in a block, and at the same time, that mixed land use on both sides of those streets is generating very frequent curb-parkings, so many pedestrians and bicycle riders along or across them. Between 3-leg intersections and pedestrian (with bicycle rider) accidents there are probably those background that most pedestrian (with bicycle riders) are not seperated in space and / or time from vehicle traffic in a minor street network of higher ratio of the number of 3-leg intersections. In this connection, the original data showed that the block feeded by such a minor street network has a larger percentage of the sites for residence, secondary and tertiary industries (which migth generate a flow of higher density of pedestrians and bicycle riders throughout day and night) but has a lower level of service of pedestrian walk and bicycle lane.

(4)Though the three cases, shown by Fig.3,4 and 5 resulted in moderately enough estimation of accident rate, the estimation errors should not be overlooked. There are many possible sources of error in estimation. It is one of the most important matters among them what kinds of variables are adopted in the study. The followings are concerned mainly with the choice of variables;

(i) a limit to data collection : land use variables had to be adopted instead of those about vehicle traffic, pedestrian flow and bicycle traffic.

(ii) difficulties to collect data concerned with microscopic measures to counter traffic accidents; though microscopic countermeasures could be influential variables, they were not used for reasons of too much expensiveness for data collection. The followings are some of them; the kind and situation of curb-parking vehicles, level of service of street lighting, variables kinds of street markings,traffic signs, speed limit, turning regulation.

Factor analysis was applied to study traffic accidents in minor street network in a block surrounded by some major streets. The study, even though not so clearly, could find several factors and variables influencing traffic accidents in minor street network.

Acknowledgement

The authers would like to express their gratitude to the stuff members of the Department of Traffic Safety, Bureau of Public Works, Osaka Municipal Office, for their practical suggestions given in the meeting for discussion and for their provision of a great quantity of data.