Analysis on Characteristics of Traffic Accidents in Nagano (Second Report)

-Cluster Analysis-

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ABSTRACT: In previous report, the fatal accidents in hilly and mountainous area are paid attention to Nagano prefecture using statistical accident data analysis. Also, it was found that Wakayama and Yamanashi prefectures etc. belong to same cluster. This paper analyzed the comparison among these prefectures to clarify Nagano's and each cluster’s characteristics of accidents in detail. Principal component analysis was performed to clarify the characteristics of each cluster and remarkable accidents. Furthermore, the feature was verified by classifying and investigating fatal accidents in Nagano occurred in 2016. As a result, remarkable accidents of Nagano were vehicle to vehicle and vehicle alone accidents on the road with up-down slope and curve in hilly and mountainous areas. It was found that approximately 19% of fatal accidents in Nagano were these types of accidents. In addition, the principal component analysis indicates Wakayama and Yamanashi have the same characteristics of accidents as Nagano. This method for accident analysis is valuable to find out characteristics and their true causes toward zero accidents in local areas.

KEY WORDS: safety, statistical accident analysis, accident investigation and analysis / Hilly and mountainous area [C1]

1. Introduction

The number of fatalities of traffic accident in Nagano prefecture in 2017 was 79, which has been almost constant since 2012. Trend of reduction of the number of fatalities in Nagano prefecture is weak compared with the whole of Japan (Figure 1) (1). Nagano prefecture is located in the center of Honshu island and is a unique area surrounded by mountains. Traffic accidents occurring in such areas are considered to be hid in characteristic factors different from other prefectures and it is important to analyze the characteristics of each area and to grasp the true causes for local area.

In the previous report (2), the authors analyzed using traffic accident statistical data and extracted remarkable characteristics of traffic accident occurred in Nagano prefecture. As a result, Nagano prefecture has many accidents of vehicle alone in the fatal traffic accidents, and in particular, accidents on the road with up and down slope and curve in hilly and mountainous areas were extracted as remarkable accidents. Furthermore, cluster analysis was performed on the basis of prefecture’s traffic accident data, Nagano prefecture belongs to the same cluster as Wakayama, Yamanashi, Shiga, and Nara prefecture and was considered to share these regional characteristics and issues with these prefectures.

In this report, principal component analysis was performed together with the result of cluster analysis in the previous report, and characteristics of the traffic accident in Nagano prefecture was analyzed to clarify the meaning. In addition, detailed analysis for each accident (micro analysis) for 106 fatal accidents in Nagano Prefecture in 2016 was performed to verify the result of remarkable accidents. Furthermore, the purpose of this study is to clarify the usefulness of this method.

Fig.1  Trends in number of fatalities

2. Analysis method

2.1. Flow of this study

The flow of this study is shown in Figure 2. In order to extract remarkable accidents, their causes and countermeasures, three major steps are framed in this study. The first step is macro analysis using traffic accident statistical data. Remarkable accidents are grasped by macro analysis. In this step, statistical analysis methods such as cluster analysis and principal component analysis are applied. The second step is micro analysis. The micro analysis is analyzed accidents in detail for the obtained remarkable accidents and extracts true accident causes from the point of human, road and vehicle. Furthermore, common factors of similar accidents are identified. In the third step, countermeasures of preventing accidents are proposed, and common hazard factors are identified.
2.2. Trends in number of fatalities in prefectures classified into same cluster

According to cluster analysis of each prefecture on the basis of traffic accident statistical data performed in previous report, Nagano prefecture belonged to the same cluster as Wakayama, Yamanashi, Shiga and Nara prefecture as cluster 7 group. Yearly trends in the number of fatalities in these prefectures are shown in Figure 3. The number of fatalities in these prefectures have been around 50 to 100 people recently, and they have been flat. It is assumed that these prefectures are common issues.

2.3. Object of analysis

Principal component analysis and cluster analysis were analyzed using traffic accident statistics annual report of Institute for Traffic Accident Research and Data Analysis same as previous report. The accidents were compared using a total of three years in order to mitigate the effect of deviation due to a single year. References that are targeted are shown below.

Research literatures:
- Traffic Accident Statistics Annual Report (3)(4)(5)
- Accident content: Fatal accidents, Fatalities
- Accident occurrence year : 2014 - 2016

2.4. Content of analysis

Principal component analysis was performed for all prefectures using the analysis that were written in previous section. Principal component analysis is the method which utilizes the correlation between variables of quantitative data described by many variables and minimizes the loss of information. It transforms uncorrelated composite variables (6). In the study of Morimoto et al. (7), it is utilized to clarify characteristics of prefectures for analysis of police crackdown on traffic road. Factors used in principal component analysis were the same 14 items as the cluster analysis performed in previous report. Each factor which calculated as the composition ratio of each item for the total number of fatalities or fatal accidents is used. Factors analyzed are shown from these results.

In this report, as the second half of the first step, the principal component analysis was performed using the traffic accident statistical data. The remarkable accidents were specified together with the cluster analysis in previous report, and were validated by micro analysis.

3. Result of analysis

3.1. Result of principal component analysis

Results of principal component analysis for each prefecture using the analysis method in the previous chapter are shown as follow.

3.1.1. Consist of principal component

The consist of each factor obtained by the principal component analysis is shown in Table 2. The cumulative contribution ratio up to the fourth principal component was 68.2%.

The first principal component is consisted of four-wheeled vehicle, head-on collision, up-down road with curve, driving at unsafe speed violation and municipal road. In the case of negative values, it indicates head-on collision accident of four-wheeled vehicles in hilly and mountainous area with up and down and curve road. In the case of a positive value, it affects the pedestrian accident on municipal roads and bicycle accidents. Therefore, this component is considered as a road factor evaluating local type or city type accident.

The second principal component is consisted of male, vehicle alone, elderly and death rate. Since the signs of elderly and death rate indicates negative, it indicates the accident of high elderly rate and high death rate in the case of a negative value. Also pedestrian is composed of a negative contribution. Therefore, it is considered that this component indicates elderly pedestrian accident with high death rate. In the case of a positive value, it indicates vehicle alone accident of non-elderly male, and death rate is considered to be not relatively high. Therefore, it is considered that this component evaluates the elderly type accident such as pedestrian and vehicle alone.
the non-elderly type accident such as vehicle alone.

The third principal component is consisted of pedestrian, crossing, and bicycle accident. As the signs of crossing and bicycle are negative, and the sign of pedestrian is positive, in the case of a large negative value, it indicates bicycle accident is numerous. In the case of a large positive value, it indicates that pedestrian accident is numerous. Also, as pedestrian crossing violation is a positive, this component is considered to evaluate intersection accident such as bicycle or crossing accident and non-intersection accident such as pedestrian accident while crossing the outside pedestrian crossing.

The fourth principal component is consisted of careless driving and pedestrian crossing violation (second party) as law violations. It is considered that this component shows two opposites, that is, vehicle side violation such as careless driving and pedestrian one such as crossing violation because the sign of careless driving is negative and the sign of pedestrian crossing violation is positive. Therefore, it is considered that this component evaluates driver and pedestrian factor as a person's behavior factor.

### 3.1.2. Principal component scores of each prefecture

The results of the principal component scores of each prefecture are shown in Figure 4 and Figure 5. Figure 4 shows the distribution of the first principal component and the second one. Prefectures which have large negative value of the first principal component are Iwate and Shimane prefecture. It is estimated that head-on collision accidents of four-wheeled vehicle in hilly and mountainous areas are numerous in these prefectures. Prefectures which have large positive values are Tokyo, Osaka prefectures, and lots of metropolitan areas. These prefectures don’t have so large hilly and mountainous area, but large urban area, that is, pedestrian and bicycle accidents are more remarkable than four-wheeled vehicle accidents. The prefectures which the second principal components are large positive values, are Okinawa and Yamagata prefecture. In these prefectures, it is estimated that vehicle alone accidents by male are numerous. In addition, the prefectures which the second principal components are large negative values, are Tottori and Niigata prefecture. It is estimated that the accidents which have high death rate of elderly are numerous. Nagano has the first principal component is negative, and the second principal component is positive. Both values are high; therefore, it is estimated that four-wheeled vehicle accidents in hilly and mountainous areas and vehicle alone accidents by male are numerous.

### Table 2 Result of principal component analysis

| Factors                        | Principal components |       |       |       |       |       |
|--------------------------------|----------------------|-------|-------|-------|-------|-------|
|                                | 1st                  | 2nd   | 3rd   | 4th   |       |       |
| 4-wheeled vehicle              | -0.405               | -0.036| -0.245| -0.192|       |       |
| Head-on collision              | -0.397               | -0.089| -0.110| -0.190|       |       |
| Updown with curve              | -0.316               | 0.292 | 0.073 | 0.172 |       |       |
| Driving at unsafe speed        | -0.305               | 0.021 | -0.082| -0.275|       |       |
| Municipal roads                | 0.278                | 0.027 | -0.069| -0.236|       |       |
| Male                           | 0.152                | 0.528 | 0.032 | -0.117|       |       |
| Vehicle alone                  | -0.207               | 0.455 | -0.150| 0.285  |       |       |
| Elderly                        | -0.235               | -0.391| -0.102| 0.273  |       |       |
| Death rate                     | -0.250               | -0.256| -0.111| 0.157  |       |       |
| Pedestrian                     | 0.075                | -0.309| 0.685 | -0.071 |       |       |
| Crossing                       | 0.265                | -0.180| -0.480| -0.073 |       |       |
| Bicycle                        | 0.307                | -0.215| -0.376| 0.261  |       |       |
| Careless driving               | -0.153               | -0.138| -0.031| -0.549 |       |       |
| Pedestrian crossing violation  | -0.176               | -0.086| 0.153 | 0.437  |       |       |
| Proportion                     | 32.3%                | 49.4% | 60.1% | 68.2%  |       |       |

Figure 5 shows the distribution of the third principal component and the fourth principal component. The prefectures which the third principal components are large negative value, are Shiga and Nara prefecture. In these prefectures, it is estimated that crossing and bicycle accidents are numerous. Furthermore, the prefectures which the third principal components are large positive value are Okinawa and Oita prefecture. It is estimated that pedestrian is numerous in these prefectures. On the other hand, the prefectures which the fourth principal components are large negative values, are Miyagi and Yamagata prefecture, and it is estimated that the accidents of careless driving are numerous. On the contrary, the prefectures which have large positive values are Kochi and Wakayama prefecture, and it is estimated accidents caused by pedestrian crossing violation are numerous. In Nagano prefecture, there is no remarkable characteristic as for the third principal component and the fourth principal component.

### 3.2. Characteristic of each cluster

For each cluster, characteristics of the principal component scores were confirmed. The distribution of each cluster is shown by different markers in Figure 4 and Figure 5. Furthermore, from the results, we validated the accident characteristics estimated in the previous report.

Cluster 1: Hokkaido, Miyagi, Yamagata, Fukushima, Gifu

In this cluster, the first principal component has a negative distribution and head-on collision accidents of four-wheeled vehicle on local road are many. Also, the negative value of the fourth principal component is larger than that of the other clusters. Accidents caused by careless driving can be cited. The result shows that characteristics of "head-on collision accidents of four-wheeled...
vehicles caused by careless driving" estimated in the previous report.

Cluster 2: Aomori, Arita, Hiroshima, Yamaguchi, Nagasaki, Miyazaki, Kagoshima

In this cluster, the first principal component is a large negative value and it shows head-on collision accidents of four-wheeled vehicle on hilly and mountainous road are numerous as local road type. In the previous report, this cluster was inferred as "head-on collision accidents by elderly person in hilly and mountainous area", but the influence of elderly wasn’t appeared directly. However, the factor of the elderly is appeared as moderate negative (-0.235) in the composition of the first principal component, it is considered that the characteristic of accidents is same as estimated one.

Cluster 3: Iwate, Tottori

This cluster has large negative values in both the first principal component and the second principal component. Therefore, it is considered that there are many head-on collision accidents of four-wheeled vehicle and elderly pedestrian accidents in these prefectures. In the previous report since speed violation were also numerous, it is estimated that the characteristic of this cluster is "four-wheeled vehicle accidents and pedestrian accidents caused by speeding". As the speed violation factor is also constituted in the first principal component, it is considered that the characteristic of accidents is same as estimated one.

Cluster 4: Tokyo, Saitama, Chiba, Kanagawa, Aichi, Osaka

This cluster has a large positive value in the first principal component. It is considered that there many crossing accidents involving bicycle on city type of municipal road instead of four-wheeled vehicle accident on local road type. It is estimated that the characteristic of this cluster is "urban type accidents of collisions while crossing".

Cluster 5: Ibaraki, Tochigi, Shizuoka, Toyama, Mie, Kyoto, Hyogo, Ehime, Fukuoka, Saga

This cluster is scattered around 0 any of principal components, significant characteristic isn’t seen in other prefectures. It is considered that characteristic of accident is nationwide average type. "Nationwide average-type accidents of collisions while crossing" was estimated in the previous report. However, the third principal component isn’t shown a remarkable tendency, it is revised to proper description "nationwide average-type accidents".

Cluster 6: Gunma, Niigata, Ishikawa, Kagawa

In this cluster, the second principal component is negative value, and the third principal component is positive value, it is considered that elderly pedestrian accidents with a high death rate as accidents by elderly type and non-intersection type. It is estimated that the form of accident was "pedestrian accidents caused by elderly persons" in the previous report. However, the fourth principal component involving careless driving isn’t shown a remarkable tendency, it is revised to proper description "pedestrian accidents caused by elderly persons".

Cluster 7: Yamanashi, Nagano, Shiga, Nara, Wakayama

In this cluster, the first principal component has a negative value, the second principal component has a positive value. There are many head-on collision accidents of four-wheeled vehicle and vehicle alone accidents on local road type and non-elderly type on hilly and mountainous road. In addition to the vehicle to vehicle in the previous report, it is estimated that "vehicle to vehicle and vehicle alone accidents in hilly and mountainous road" as proper description. However, Nara and Shiga prefecture are different from distribution in Nagano, Wakayama, and Yamanashi prefecture slightly. The first principal component is close to 0, and the third principal component has a negative tendency in Nara and Shiga. It is considered that there are many urban type accidents of intersection slightly in Nara and Shiga.

Cluster 8: Fukui, Okayama, Tokushima, Kochi

In this cluster, the third principal component has a negative value, and the fourth principal component has a positive value. There are many accidents of intersection type and pedestrian factor type. It was estimated that "vehicle alone accidents and cyclist accidents by elderly persons" in previous report. However, it is revised to proper description to "accidents of crossing and cyclist accidents in intersection".

Cluster 9: Shimane, Kumamoto, Oita

In this cluster, the first principal component has a negative value, and the third principal component and the fourth principal component have positive values. It is considered that there are many accidents of four-wheeled vehicle on hilly and mountainous road as local road type, non-intersection and pedestrian factor type. It was estimated that "elderly pedestrian accidents with speeding and pedestrian’s crossing violation" in the previous report. However, it is revised to proper description to the characteristic of "local type accidents of four-wheeled vehicle and pedestrian accidents".

Cluster 10: Okinawa

In this cluster, it is classified peculiar as Okinawa prefecture. This cluster has positive values in both the second principal component and the third principal component. There are many accidents of non-elderly and non-intersection. In addition to non-elderly of the previous report, it is considered that the characteristic is "vehicle alone accidents by non-elderly male" as proper description.

4. Validation using micro analysis of Nagano prefecture

A micro analysis was carried out to validate the characteristics of traffic fatal accidents in Nagano prefecture obtained from the cluster analysis and the principal component analysis results using accident statistics data in the previous report and the previous chapter in this report.

4.1. Micro analysis method

The objects of the analysis were 103 cases of traffic fatal accidents occurred in Nagano prefecture in 2016 excluded three cases of train accidents. For these accidents, accident types were classified so that they can be compared with the results of the principal component analysis based on accident information. Accident types which related to the first principal component are vehicle to vehicle and vehicle alone accidents of four-wheeled on the road with up and down slope. The accident types related to the second principal component is the vehicle alone accident occurred on the road without up and down slope whose first party is four-wheeled or motorcycle male driver. In addition, male of 64 or younger and male of 65 or older were classified in these accidents to confirm the effect of elderly.

Accident types related to the third principal component are defined bicycle and pedestrian accidents. In addition, pedestrian accidents are classified by with or without law violation of pedestrian crossing. Accident types related to the fourth principal component are accidents including careless driving of law violation as vehicle side, but excepting accidents which are classified as accident type of the first, the second and the third principal component as mentioned above. The other accidents are classified as others.
Vehicle to vehicle
Vehicle alone
Train

| Country          | Person to vehicle | Vehicle to vehicle | Vehicle alone | Train |
|------------------|-------------------|--------------------|---------------|-------|
| Nagano (254)     | 32.7%, 83        | 31.5%, 80          | 33.9%, 86     | 2.0%, 5 |
| Wakayama (127)   | 26.0%, 33        | 37.0%, 47          | 37.0%, 47     | 0.0%, 0 |
| Yamanashi (115)  | 28.7%, 33        | 31.3%, 36          | 40.0%, 46     | 0.5%, 1 |
| Shiga (186)      | 21.5%, 46        | 49.5%, 92          | 28.5%, 33     | 0.8%, 1 |
| Nara (132)       | 23.5%, 31        | 40.2%, 53          | 35.6%, 47     | 1.1%, 12 |
| Japan (11,831)   | 35.7%, 4,221     | 38.7%, 4,577       | 24.6%, 2,985  | 1.1%, 12 |

Fig. 7 Percentage of fatal accidents

| Percentage |
|------------|
| 0%         |
| 5%         |
| 10%        |
| 15%        |
| 20%        |
| 25%        |
| 30%        |
| 35%        |
| 40%        |
| 45%        |
| 50%        |
| 55%        |
| 60%        |
| 65%        |
| 70%        |
| 75%        |
| 80%        |
| 85%        |
| 90%        |
| 95%        |
| 100%       |

Fig. 8 Type of fatal accidents

In accident type comparison shown in Figure 7, there are many vehicle alone accidents in Nagano prefecture, same as in Wakayama, Yamanashi, and Nara prefecture. On the other hand, Shiga prefecture has many vehicle to vehicle accidents, and the tendency is different from the others. Looking into accident type in detail (Figure 8), there are many head-on collision and collision with central reserve or guard fence in Nagano prefecture, and there is a similar tendency in Wakayama and Nara prefecture. In Yamanashi prefecture, there are few head-on collision and many collisions with central reserve or guard fence. Collision while crossing is numerous in Shiga prefecture. The breakdown of detail is a little bit different even in the same cluster.

In comparison of road user type (Figure 9), Nagano prefecture tends to be numerous in the number of fatalities of vehicle passenger. Wakayama, Yamanashi and Shiga prefecture also are similar to Nagano prefecture. Nara prefecture is close to the whole of Japan. There is a slightly different tendency in this comparison. As for road alignment type (Figure 10), accidents which have road alignment with up and down slope are numerous in Nagano prefecture. Wakayama, Yamanashi and Nara prefecture are similar. However, Shiga prefecture is close to the whole of Japan, and this item also has different tendency. The ratio of up and down slope

5. Discussion

In order to clarify the characteristics of the traffic accident in Nagano prefecture in detail, macro analysis, which compares in accident statistical data similar to the previous report, was carried out for each prefecture which belongs to the same group using cluster analysis.

5.1. Comparison using macro analysis

Nagano prefecture belongs to the cluster 7 group, in which belongs Wakayama, Yamanashi, Shiga, and Nara prefecture. For these prefectures, comparison of accident statistics was carried out as for accident type and so on using the total data of three years from 2014 to 2016 same as the previous report. The results of comparison are shown in Figure 7 to Figure 11.
road with curve are tended to be close to Wakayama and Yamanashi prefecture relatively. In addition, as for gender and age type (Figure 11), the ratio of elderly male in Nagano prefecture is tended to be many, and Wakayama and Yamanashi prefecture as well. On the other hand, Shiga and Nara prefecture are close to the whole of Japan, and no remarkable trends appeared.

From the results of macro analysis mention above, Nagano prefecture can be considered to be a prefecture that is closer to Wakayama and Yamanashi prefecture. This similar tendency was indicated in the result of the principal component analysis. It is considered that the common issues are hidden in these prefectures. On the other hand, Shiga and Nara prefecture belonged to the same cluster; however, the ratio of these items slightly different from the other prefectures. In the results of dendrogram of cluster analysis, hierarchical connection is branched among these prefectures. It is considered that there is room for investigating on the suitable number of clusters classified.

5.2. Usefulness of this analysis method

In this study, the authors extracted characteristics of traffic accidents of local area and specified remarkable accidents using macro analysis for traffic accident statistical data and micro analysis for individual accidents. Particularly in macro analysis, we were able to clarify these characteristics by carrying out comparison analysis for each prefecture using cluster analysis and the principal component analysis. Furthermore, the results obtained were agreed with micro analysis results. These results indicated that this accident analysis method is useful to identify remarkable accidents. From now on, regarding the remarkable accidents specified, micro accident analysis in detail can specify the true causes and lead to appropriate countermeasures. For example, in Nagano prefecture, expanding the recognition of the curve and suppressing excessive speed of the vehicle by information from the road side to the driver using signposts etc. are useful to prevent accidents on the hilly and mountainous roads.

6. Conclusion

In this study, Nagano prefecture was taken up and cluster analysis and principal component analysis were carried out using the traffic accident statistics tabulated by the National Police Agency as an attempt of a new approach for investigation of accident and countermeasure. From these results, remarkable characteristics of traffic accidents were extracted, and compared and validated with micro analysis results. The conclusions obtained are as follows.

(1) The remarkable traffic fatal accidents in Nagano prefecture are vehicle to vehicle and vehicle alone accidents on hilly and mountainous roads which have up and down slope with curve. Moreover, its validity was able to be confirmed from the micro analysis result.

(2) From the results of principal component analysis and macro statistics comparison analysis, it is considered that Nagano prefecture is similar to Wakayama and Yamanashi prefecture on characteristics of traffic accidents in particular, and they share regional issues.

(3) It is considered that this analysis method based on macro statistical comparison is useful for clarifying characteristics of traffic accidents in each prefecture.

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