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Study on the Application of Meteorological Data Based on K-Means Method to Highway Wind-Blown Sand Protection

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Abstract. Highway wind-blown sand reduces vehicle visibility and is likely to cause vehicle rollover and other accidents. In this paper, k-means algorithm is used to extract the annual maximum wind speed data of 10 stations in the central and western regions of Inner Mongolia and analyze the wind speed in different seasons. Through the results, it can be clearly seen that all stations in Inner Mongolia operate from April to June and from October to December. Wind speed shows strong characteristics. The strong performance of the wind speed is also affected by the topography of the central and western Inner Mongolia, which further increases the unsafe factors of road traffic. In addition, it can also be seen from the results that the highway environment around the meteorological station in Wengeng Town of Bayannur City is more susceptible to the influence of wind-blown sand, sandstorms, sand accumulation and other phenomena. Through the cluster analysis of this paper, it can provide scientific data support for the highway maintenance department to effectively resist the disaster caused by wind-blown sand.

Keywords. Cluster, Wind speed, Highway maintenance, wind-blown sand

1. Introduction

Inner Mongolia is relatively flat, due to the dry climate, lack of vegetation cover and frequent strong winds. These characteristics make Inner Mongolia prone to wind-blown sand phenomenon, which brings great challenges to road transportation. Wind-blown sand will not only cause road area sand, line of sight obstacles, but also have an adverse impact on traffic safety and driving conditions. Therefore, it is of great significance to study the application of wind-blown sand protection using meteorological data for the safety and smooth flow of highway transportation in Inner Mongolia.[1]

Meteorological data is an indispensable and important information source in the study of wind-blown sand protection. By collecting, analyzing and using meteorological data, the formation mechanism, occurrence rule and influencing factors of wind-blown sand can be better understood.[2] As an effective data analysis tool, K-means algorithm

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can be applied to cluster analysis of meteorological data in Inner Mongolia. Through the K-means algorithm, meteorological stations can be classified according to their observation data characteristics, and then the meteorological characteristics and change rules of different locations can be understood.[3]

In the study of the application of meteorological data based on K-means method to wind-blown sand protection, collect the data of the maximum wind speed of 10 stations in Inner Mongolia for one year in history. Then, by applying K-means algorithm, cluster analysis is carried out on these data to identify different meteorological models, which helps us to predict the occurrence probability and intensity of wind-blown sand and provide corresponding wind-blown sand warning information.[4]

The application of meteorological data based on K-means method to the protection of wind-blown sand on highways in Inner Mongolia also includes the identification and evaluation of the road sections formed by wind-blown sand. By analyzing the clustering results can identify the sections that are easily affected by wind-blown sand, and take corresponding protective measures to these sections, such as setting up shelterbelts and strengthening road maintenance. At the same time, the analysis of meteorological data by K-means algorithm can provide parameter initialization and adjustment of wind-blown sand protection measures, so as to improve the protection effect and reduce the protection cost.[5]

2. Cause and analysis of wind-blown sand

Wind-blown sand refers to the phenomenon that in dry areas, the wind blows up the sand and dust particles on the surface and moves and deposits with the wind. Dust particles are usually composed of fine mineral particles, such as sand, dust, etc. The formation of wind-blown sand is due to the special environmental and climatic conditions in dry areas. These areas typically lack vegetation cover, poor soil, and a dry climate, which makes surface dust particles vulnerable to wind. In addition, the strength of the wind is also an important factor to promote the formation of wind-blown sand. Wind-blown sand mainly occurs in dry and desert areas, such as deserts, sandy lands and desertification areas. Some typical areas include the Mongolian Desert, the Sahara Desert, and the sandy areas of Inner Mongolia.[6]

Wind-blown sand usually occurs during the dry season or on windy days in the spring. These seasons and weather conditions are key factors in the formation of wind-blown sand. In addition, due to meteorological conditions and seasonal variations, the severity of wind-blown sand may vary from year to year and from season to season.[7]

Wind-blown sand can cause soil erosion and vegetation destruction, which further leads to land impoverishment and the spread of desertification. Dust can also have a negative impact on air quality. In addition, wind-blown sand will cause dust particles to accumulate on the road, increase the friction on the road surface, and reduce the stability and safety of vehicle driving. Large amounts of dust can also reduce drivers' visibility and increase the risk of traffic accidents. A large number of dust particles brought by wind-blown sand pose a threat to human respiratory system and eye health. Dust can contain harmful substances and bacteria, and long-term exposure to these particles can trigger respiratory illness and allergic reactions.[8]

2.1. Importance of wind power

Wind power is the basic driving force of wind-blown sand phenomenon. Wind can lift dust particles from the surface and cause them to move and deposit. The strength and speed of the wind determine the movement capacity of the dust particles and the range affected by the wind.[9]

When the wind is strong enough, it can lift dust particles from the ground and suspend them in the air. These suspended particles move with the movement of the wind, forming the phenomenon of wind-blown sand. The size and direction of wind power determine the suspension height and movement path of sand particles. Strong winds can blow dust particles over great distances and deposit them in other areas. The strength and direction of the wind determine the range and strength of the sand blown by the wind. Strong winds tend to cause more extensive and violent wind-blown sand phenomena. When reduced or encountered an obstacle, dust particles are deposited and accumulate on the surface, forming dunes or sand mounds. The weakening of wind and the change of direction will affect the deposition position and accumulation form of dust particles.[10]

3. The right way of collecting data

Data is the new oil of today's world, and data collection is the tool to extract and refine this precious resource." The right way of collecting data can provide us with powerful information support to help us better understand and solve problems. However, the wrong way of collecting data can lead to misleading and erroneous conclusions. Therefore, when conducting data collection, we need to carefully choose the appropriate methods and technologies to ensure the accuracy, integrity and reliability of data. Only by collecting data in the right way can we truly discover the value of data and provide a reliable basis for our decisions.[11]

4. K-means algorithm technology introduction

K-means algorithm is a commonly used clustering analysis algorithm, which determines the cluster of samples by calculating the distance between samples.[12] The main process of K-means algorithm is as follows:

1) k samples were randomly selected as the initial clustering centers;

2) For each sample, calculate its distance from each cluster center and classify it to the nearest cluster;

3) For each cluster, its cluster center is recalculated, that is, the mean value of all samples in the cluster is taken as the new cluster center;

4) Repeat steps 2 and 3 until the clustering center no longer changes or reaches a predetermined number of iterations;

The start and end in the flowchart represent the start and end points of the algorithm. The random selection of k samples as the initial clustering center is to initialize the algorithm. Then, each sample is iteratively assigned to the nearest cluster center, and the new cluster center for each cluster is calculated. In the iterative process, the cluster to which each sample belongs is determined by calculating the distance from the cluster center. The iterative process will continue until the cluster center no longer changes or reaches a predetermined number of iterations, that is, the stop condition is satisfied. K-means algorithm flow chart is shown in Figure 1.

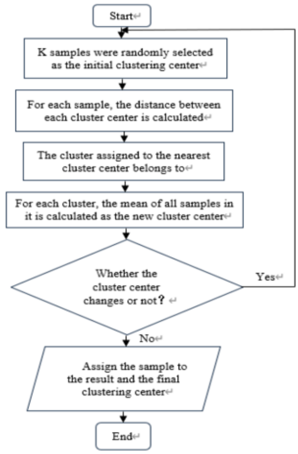


Figure 1. K-means algorithm flow chart

5. The application of K-means algorithm in traffic

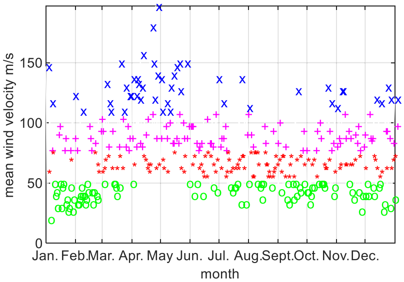
Using K-means algorithm to cluster the historical traffic flow data, the road network can be divided into different congestion modes. This helps to predict the probability and intensity of traffic congestion, and provides real-time traffic congestion warning information, so as to guide traffic participants to choose appropriate routes and travel strategies.[13]

In reference 5, Meng Jun proposed that K-means algorithm based on ant colony algorithm was applied to the layout planning of highway transportation hubs to effectively solve the clustering problem of highway main hub cities.

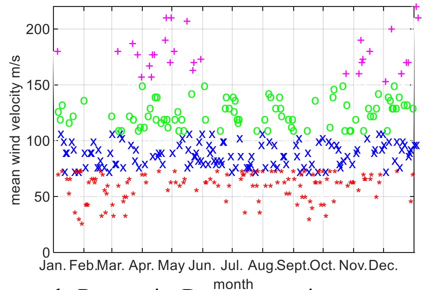
K-means algorithm has a wide range of applications in traffic meteorology, including traffic flow clustering, traffic congestion prediction, road condition monitoring, traffic accident hotspot analysis, and section division and optimization.[14] These applications help to improve the efficiency and safety of the traffic system and improve the level and capability of traffic management.

5.1. Wind-blown sand wind based on K-means clustering

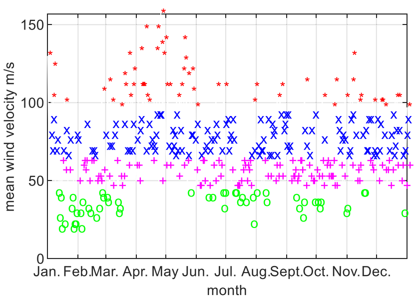
In order to ensure the applicability of the research results and reduce the interference of environmental factors, this study mainly focuses on the wind speed characteristics of the wind blown sand conditions that are prone to cause extreme climate in the central and western regions of Inner Mongolia. In order to make a better cluster analysis of wind speed, this paper refers to the industry standard of China Meteorological Administration on the classification of meteorological conditions of expressway traffic. The annual maximum wind speed data of 10 stations were extracted from the meteorological database and divided into four categories for K-means clustering analysis. The clustering results are shown in Figure 2. Table 1 shows the clustering centers of maximum wind speed at each station. This research method can help us better understand the characteristics of wind speed in the central and western regions of Inner Mongolia, and provide scientific preventive measures for highway traffic safety.



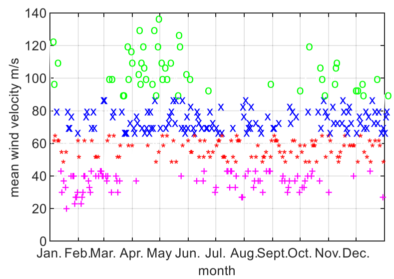
a. Bayannur City Wengeng town station



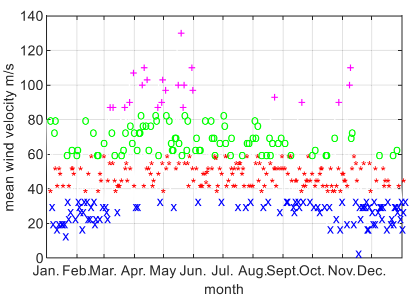
b. Baotou city Dura town station



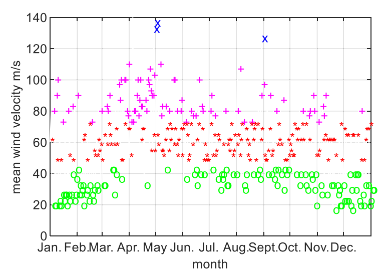
c. Baotou city Wukehudong town station



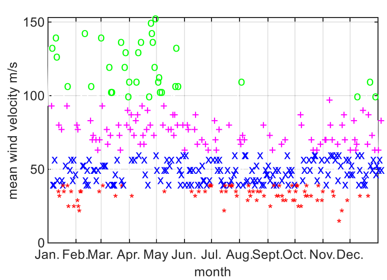
d. Baotou City Xiaowengong town station



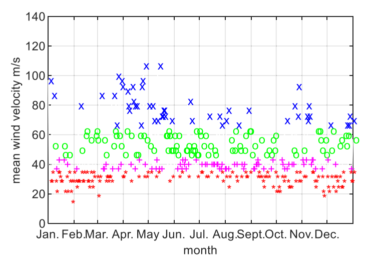
e. Wulanqab city Sanchakou town Jina line station



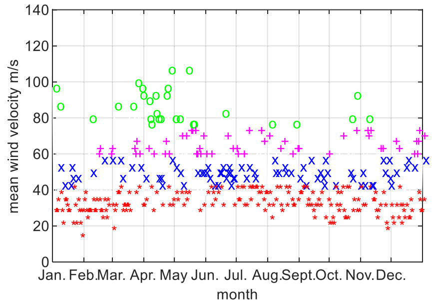
f. Hohhot city Toketuo County ancient town station



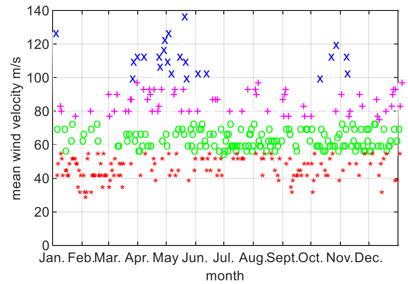
g. Ordos City Zhaojun town station



h. Ordos City Huhe Mu Duzhen grassland station



i. Erdos City Albas Sumu station



j. Ordos City Ejinholo town station

Figure 2. Clustering analysis results of maximum wind speed

Table 1. clustering center of maximum wind speed of each station

Cluster Center	Bayannur City Wengeng town station	Baotou city Dura town station	Baotou city Wukehudong town station	Baotou City Xiaowengong townstation	Wulanqab city Sanchakou town Jina line station
1	56.86	44.95	42.74	36.24	21.57
2	88.62	72.53	68.91	55.18	36.78
3	125.71	102.77	98.22	74.8	57.12
4	178.97	139	131.47	104.94	89.58
Cluster Center	**Hohhot city Toketuo County ancient town station**	**Ordos City Zhaojun town station**	**Ordos City Huhe Mu Duzhen grassland station**	**Erdos City Albas Sumu station**	**Ordos City Eiinholo town station**
1	27.17	36.64	28.12	32.07	42.52
2	45.51	59.32	40.84	47.33	62.53
3	64.87	89.25	56.99	70.98	85.31
4	91.87	133.67	81.22	108.58	112.09

Table 2. Classification of wind power

Rank	Wind speed range (m/s)	Name
1	0	Calm wind
2	0.3 – 10.7	Weak wind
3	10.8 - 17.1	Mild wind
4	≥ 17.2	gale

According to the national meteorological wind speed classification, it is divided into four levels, so in order to facilitate the analysis of k 4.

The clustering results in Figure 2, it can be clearly seen that the maximum wind speed of all stations in the central and western regions of Inner Mongolia showed relatively strong characteristics during April-June and October-December. According to Table 2, it can be seen that these wind speeds are in the strong wind category.

The collected data mainly cover the central and western regions of Inner Mongolia, including the terrain features of mountains, hills, plateaus, grasslands and river valleys.

The complex terrain of these areas, coupled with the effect of strong winds, is easy to form local wind channels and wind tunnels, which is easy to form sand and dust accumulation.

Bayannur City Wengeng Town station is located in the desert terrain, the west is Alashan desert. Under the blowing of strong winds, dust storms will form and accumulate sand and dust on the ground, further affecting the passage of roads.

Wulanqab City Sanchakou Township Jina Line station, Hohhot City Toketo County Gucheng station and Ordos City are mainly located in the plateau and grassland areas, the terrain is relatively flat. Stronger winds are able to blow through these areas more smoothly.

These research results have important reference value for the maintenance management department to allocate highway maintenance funds reasonably and formulate preventive maintenance management measures。

6. Scientific prevention of wind-blown sand

According to the clustering results of the last section, it can be seen that the wind-blown sand phenomenon is more serious at the four stations of Wengeng Town station, Dura Town station, Wukhudong Town station and Xiawengong Town station of Baotou City, and more funds can be allocated to this area. [15]

The following measures can also be taken to prevent the occurrence of wind-blown sand:

Implementation of sediment irrigation measures:

By spraying water mist and dust suppressant to the sand, the soil moisture and adhesion are increased, and the suspension and flight of dust particles are reduced.

Implementation of sandy land management and sand fixation measures:

For the sand already formed, such as sand fixation afforestation, sand closure, sand willow cultivation. These measures can promote soil consolidation, restrain the flying of sand particles and the further development of desertification.

Construction of sand protection facilities:

In areas susceptible to wind-blown sand, wind-blown sand protection facilities such as wind nets, wind walls and forest belts can be built. These facilities can slow wind speeds and reduce the speed and amount of sand carried by wind. [16]

Strengthening agriculture and animal husbandry management:

The use of reasonable agricultural farming methods and animal husbandry mode, such as reasonable crop rotation, windproof and sand-fixing farming, grassland management, etc., can reduce soil erosion and dust particles flying.

Establish monitoring and early warning systems:

Establish a monitoring and early warning system for wind-blown sand, collect and analyze wind-blown sand data in time, and predict the occurrence and development trend of wind-blown sand. Through early warning, corresponding measures can be taken to reduce the adverse impact of wind-blown sand on the environment and human activities.

7. Conclusion

Due to the influence of time, a group project study has just been started. The current project research mainly focuses on the maximum wind speed data, but this method has some limitations. First, the maximum wind speed can only provide a single wind speed value, can not reflect the long-term trend of wind speed and the overall level. Second, maximum wind speed data do not provide detailed information about the source and direction of wind, which is not comprehensive enough to study the behavior and impact of wind-blown sand. Therefore, future studies are planned to incorporate other data such as average wind speed and direction to compensate for these limitations. In future studies, statistical methods and models will be applied to analyze these multi-dimensional wind speed data to identify possible wind speed patterns and trends. Explore the complex relationship between wind-blown sand and other factors (such as temperature, humidity, etc.) and try to build more accurate and reliable wind-blown sand prediction models.

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