Model of the impact of traffic congestion based on Google Earth Engine: take Zhongguancun Street as an example

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Abstract: The traffic congestion in Beijing has become a significantly serious problem and is hindering the development of the city. It also causes inconvenience of traveling, especially commuting for people. Google earth and Google Earth Engine (GEE), can provide much information about the traffic and surrounding environment. However, there are few studies exist to utilize the GEE and traffic data to analyze the effect of the congestion on the city’s development and people’s life. Therefore, to explore and analyze the causes of traffic congestion and ultimately to put forward a viable solution, we propose to model the impact of traffic congestion based on Google Earth and Google Earth engine, taking Zhongguancun Street as an example. The results show that the congestion at the intersection of the main street has a radiation influence of about three kilometers on the main road. And according to the big data, we find that at 8:00 am and 6:00 pm every day, it is the peak time of traffic congestion. Finally, we can conclude that the GEE platform is a profound and potential tool for effectively analyzing traffic problems, and our subsequent research can be continued to be further developed based on this platform.

1. Introduction

Since the 21st century, with the highly integrated development of global industrialization and information age, cloud computing has emerged, and human beings have entered the era of big data. In the fields of geosciences and environmental sustainable development, massive geography, remote sensing, and social-economic data have caused that the traditional way of storing, managing, and analyzing data on a local platform is difficult to meet current requirement such as storage space and processing speed (Hao et al. 2018). With respect to environmental problems, traffic congestion remains a challenge for scholars because of its difficulties in handling huge data sets. Moreover, it has complex typical characteristics under the influence of different conditions and is a serious problem for city development and people’s life. Hence, it is significantly imperative to develop more appropriate management control programs for government managers, provide service and travel mode for people which requires information in a large scale (Mao et al., 2013). The Google Earth Engine (GEE) is a cloud computing platform which was designed to store and process a large number of data (https://earthengine.google.com/datasets/) for analysis and final decision making. Many researches have demonstrated that GEE platform is a very effective method of dealing with huge data sets at different scales and programing used at an operational level. The present archive of data includes most of the satellites data, as well as Geographic Information Systems (GIS) vector information and other demographic, digital elevation models (DEM), environment and climate data layers (Mutanga et al., 2019). Therefore, taking GEE as a tool, scholars can use huge data, map trends, quantify resources, and multitude of methods to undertake quantitative analysis of global problems. Based on current researches, the project topics using GEE can be divided into four major aspects: Vegetation Mapping and Monitoring, Landcover Mapping, Agricultural Applications, and Disaster Management and Earth
Sciences (Mutanga et al., 2019). For example, an ecosystem evaluation study in a Brazilian semi-arid landscape has demonstrated that GEE could produce a higher classification accuracy (Goldblatt et al., 2017). As for disasters, Liu et al. developed a flood prevention and response system using the cloud based GEE platform (Liu et al., 2018). With respect to these kinds of sustainable development and environment protection, however, its uptake and usage of the opportunity remains varied and unclear (Kumar et al., 2019), in particular, research on traffic flow or traffic congestion measurement based on GEE is a blank and brand-new area.

Previous studies of traffic flow or traffic congestion were mainly based on the analysis of video or network model such as Traffic Performance Index (TPI) (Wen et al. 2014) and Traffic State Index (TSI) (Ji et al., 2016) and so on. Relatively, single analysis of video is not comprehensive and perceptual intuition enough for the problem analysis and solution propose. Building a network for travel based on big data and intelligence is important (Li, 2007; Du, 2011). By contrast, GEE platform is attainable and can provide much more information. GEE’s front-end is easy to access and user-friendly, providing a convenient environment for interactive data and algorithm development. Users can also add and create their own data and collections, able to upload the data from video analysis to GEE and visualize it in the Google map. These cannot be achieved through other research applications, and are also characteristic of this research.

Hence, we propose to apply GEE computing platform into the study of traffic congestion and extend the GEE’s application scales. Meanwhile, though analyzing the information of the study area (i.e. Beijing) provided by the GEE archival, the distance and areas of the buffer and period of the traffic congestion can be obtained. And then we can give constructive suggestions to the people and make a comfortable living environment.

The paper is structured as follows: the second part is the method and the main procedures. The third part is the results and discussion, followed by the conclusions.

2. Method
In this study, basing on GEE, we use an online JavaScript (JS) language platform for our programming (https://developers.google.com/earth-engine/tutorials), and its built-in function to accomplish the measurement of the traffic congestion and its influence on the surroundings. And then we demonstrate that the GEE platform is a powerful tool for studying the traffic and potential for traffic measurement in a greater scale.

Firstly, we use the load functions of lots of satellite's data to analyze the terrain and different features of the objects in the study area, and visualization on the Google Map. After that, we used points and lines to clearly show the streets we study on the map. It also gives a picture of the traffic intersections. Then we use the function buffer and decorate illustrations to analyze the impact and period of the traffic congestion. To explore why the traffic congestion is so serious on the Zhongguancun Street, we utilize population density data provided by the GEE platform. Finally, combined with Google earth, quantitative analysis is conducted on the traffic performance index in the selected area when the congestion happened, and qualitative analysis is conducted on the causes.

3. Results and discussion
GEE is powerful and potential for the measurements of traffic flow and congestions, especially for urban. Taking Beijing as an example, Zhongguancun district is one of the most prosperous and commercial district. Therefore, we chose Zhongguancun Street as the study area. It is complicated and there are miscellaneous land use types on both sides of the road. Figure 1 shows that the main street visualized by the red plot and the three intersections shown red dots in the study street. At this GEE platform, we can clearly see the length of the street and important traffic intersections.
Traffic congestion has significant impact on the crossroads and can buffer the relevant regions around the crosses. Hence, combined with Google earth, we use the function of buffer of the traffic congestion, shown in Figure 2 in red, which represents the influence scale or radiation scope. It can be found that if the crossroads are too close, it will affect the traffic more adversely because the buffer areas overlap.

Ultimately, by recording videos and analyzing the daily Traffic Performance Index (TPI) on the July 8, 2019 in the street (shown in Figure 3), it can be seen that the traffic flow peaks in the whole street is from 7:30 to 8:30 am and from 5:00 to 7:00 pm, because of the commuting people and the complex use of the building. What’s more, due to different people have different working hours, there are other time existing a higher TPI, which leads to the dislocation of the peak traffic flow, which will aggravate the traffic congestion on the road.
Figure 3. The plot of the TPI changes with the time in the Zhongguancun North Street on July 8, 2019.

In Fig.3, the TPI ranges from 0 to 10 and is divided into five levels. Among them, 0–2, 2–4, 4–6, 6–8, 8–10 correspond to five levels of “unblocked”, “basic smooth”, “lightly congested”, “moderately congested” and “seriously congested”. The higher the value, the more serious the traffic congestion situation.

Moreover, to find the mutual effect between the traffic situations and the population density, programming the data of population density, we show that population density of the whole Beijing city (see Figure 4). From the Figure 4 we can see that the position of Zhongguancun Street is one of the highest population density in Beijing (see the red plot). This is why traffic congestion always happened in this main road. This can demonstrate that the population density exert a tremendous influence on the traffic flow.

Figure 4. The distribution of population density in Beijing

4. Conclusions
Considering Google Earth Engine (GEE) platform as a potential tool to provide data in a large scale, in this study, we propose to use the GEE platform to analyze the traffic performance index and evaluate the congestion in urban areas, taking Zhongguancun District in Beijing as an example. We utilize some functions including dots, points, buffer, and data visualization to show the influence and period of the traffic congestion in the Zhongguancun Street. The results illuminate that the congestion have a significant impact on the surrounding areas about three kilometers and the peak time is from 7:30 to 8:30 am and from 5:00 to 7:00 pm, affected by the commuting peak. What’s more, the population density is another reason which lead to the traffic congestion because of the mutual effect between it and the traffic flow. Hence, people can arrange their travel time and avoid the traffic congestion in advance. In conclusion, the GEE platform is open source and powerful tool for the traffic study. Therefore, we perceive that our subsequent research can be continued to be further developed based on this platform and make more streets and cities into this GEE archival and visualize these data to help people travel more conveniently and make more friendly and sustainable environment. And we also hope this research can provide new insights into the way of studying the traffic conditions.
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