Transportation Travel Accessibility Study Based on Traffic Big Data for Fenghuang Ancient Town

Zhenfei Liu¹*, Zhenning Dong², Yuelong Su³, Shuangchao Yin⁴

1. Zhenfei. Liu* is with President, AutoNavi Software Co, Beijing, China 100102 (e-mail: 380714854@qq.com).
2. Zhenning. Dong is with Vice President, AutoNavi Software Co, Beijing, China 100102 (e-mail: 1537446246@qq.com).
3. Yuelong. Su is with traffic management solution division, AutoNavi Software Co, Beijing, China 100102 (e-mail: yuelong.syl@alibaba-inc.com)
4. (Corresponding Author) Shuangchao Yin is with traffic management solution division, AutoNavi Software Co, Beijing, China 100102 (e-mail: shuangchaoy@163.com)

ABSTRACT

Travel of Fenghuang Ancient Town has been the most important pillar industry to the county-level cities of Xiangxi Autonomous Prefecture. Therefore, how well the transportation accessibility is has become one of main constrain factors for future tourism economy development of Xiangxi. Therefore, to study travel transportation accessibility, this study has referred former study on existing travel accessibility evaluation model, and picked some static indexes including central city distance and transportation facilities connection. But, more importantly, this paper has firstly introduced dynamic index and improved existing model, and such dynamic index is the congestion delay index for congestion level evaluation and is recorded and applied by AMAP Company. Through the combination of static and dynamic index together, the improved model can be more solid. Then, applied such model, we have calculated transportation accessibility of Fenghuang Ancient Town. Finally, by comparing with other related study, the result showed that the calculated value of Fenghuang Ancient Town is quite low, and there should be more construction on the road network improvement and more improvement on transportation mean connection.

KEYWORDS: Transportation Accessibility, Traffic Big Data, Tourism Economy, County-level Travel Management, Fenghuang

1 INTRODUCTION

1.1 Fenghuang Ancient Town History and Economic Background

Fenghuang Ancient Town is located in Fenghuang County, and this county is in the western edge of Hunan Province, southwest corner of Tujia and Miao Autonomous Prefecture in Western Hunan Province, and bordering on Tongren City and Songtao and Miao Autonomous County in Guizhou Province in the west. This ancient town has established near 3000 years with well conservation, and it has received the title of the “National AAAA Tourist Attraction” in China.

Nowadays, travel industry has been one of the fastest-growing sectors with a huge economic contribution in China. According to preliminary statistics from China Tourism Academy (CTA), the number of domestic trips was 5.01 billion, and the overall contribution of the national tourism industry to GDP was 9.13 trillion yuan, accounting for 11.04% of the total GDP in 2017 (Xinhua, 2018).

In the whole year of 2017, more than 15.10 million visitors has been arrived there, with nearly 141 billion travel tourism revenue received (Xiangxi Autonomous Prefecture Bureau of Statistics, 2018). Recently in 2019, this place has been predicted as the most popular travel spot in 2019 Spring Festival measured by Amap travel data (Xinhua, 2019). Beneficial from the Fenghuang Ancient Town, the Fenghuang County has been titled as the first batch of most powerful travel county in 2003. Besides,
according to the data from the People’s Government of Fenghuang County in 2017, the county has achieved a total County GDP of 810.458 million yuan, and the tertiary industry was at 5897.63 million yuan with industrial structure percentage increase from 72.5% to 72.8 in recent years (Fenghuang County Government, 2018). All figures have illustrated that the travel industry of Fenghuang Ancient Town, instead of regarding as a solely famous travel spot, has become the pillar driving force of the economic development for both Fenghuang County and Xiangxi Autonomous Prefecture.

1.2 Literature Review

Currently, travel spot study from the perspective of transportation has targeted on travel journey planning for the destination of theme parks (Zhang et al. 2018), tourism resort (Mei and Lyu, 2018) and tourist ancient towns (Wang and Xie et al. 2018), taking the factors of customer’s travel behaviour, surrounding transportation infrastructures’ location and their numbers into consideration. The study between travel and transportation also includes the travel spot accessibility evaluated by AHP model (Wang and Ge et.al, 2018; Song and Li et.al, 2017), which has added the consideration of the distance between city and travel spot and the distance between transportation facilities and travel spot. Some studies also use travel big data from social media, such as Wechat or Weibo, on comments and star rating to discover travellers’ satisfaction during their journey to travel spot, so as to evaluate the relationship between traffic development and travel spot development (Liu and Bao et al, 2017; Cao and Liu, 2018). However, nearly all related studies focuses more on static data including road network structure, travel’s behaviour, travel distance and so on, but lacks much on dynamic data component such as traffic flow data or traffic congestion level data, due to the lack of the mathematic ability and storage to calculate and record congestion information.

However, an important factor of the level of traffic congestion level has been often ignored. Integrated with traffic infrastructure establishment level and traffic road network connection level, the level of traffic congestion level has been closely linked with how well a travel spot could be developed. For example, a well establishment of road network connection can link more cities to attract more potential travellers and a suitable location and numbers of traffic facilities establishment can reduce travel time from airport, train station or passenger station, however, all these advantages will be disappeared due to a severe traffic congestion (Liu and Li, 2018; Le-Klähn et al., 2015; Zhang and Zhao, 2015). As a result, in order to improve existing travel accessibility model the factor of traffic congestion need to be considered.

1.3 Paper Innovation and Structure

Standing on the leading industry of traffic-related information record and travel route calculation and optimization, Amap always aims to create a better world to improve people’s travel satisfaction, and therefore, our huge amount of recorded dynamic traffic data will be quite valuable to improve the existing Travel Accessibility model.

Based on this fact, this paper has introduced AMAP’s traffic congestion delay index from AutoNavi traffic platform, and analyse successive traffic congestion level of Fenghuang Ancient Town within 2018, and use such result into existing model and improve the travel Accessibility model result more reliable to practice in real world.

For the structure of this paper, after the introduction, in the Part II, the congestion level analysis of Fenghuang Ancient Town will be presented, so as to introduce the dynamic index (getting from AMAP data) into existing model. Then, in the third Part, the introduced dynamic congestion level index will be integrated with the static factors of distance index to the nearest central city and the road network connection index to main transportation facilities near Fenghuang Ancient Town. After that, these three indexes will be mixed into an AHP model for transportation accessibility evaluation of Fenghuang Ancient Town. Finally, some suitable measures will be presented for decision-makers for future improvement, so as to meet the requirement of travel based on transportation travel defects.
2 CONGESTION LEVEL ANALYSIS OF FENGHUANG ANCIENT TOWN

2.1 Congestion Data Source and Data Process for Fenghuang Ancient Town

In this paper, to analyse the congestion pattern of Fenghuang Ancient Town, firstly, the daily average congestion delay index in the whole year of 2018 had to be examined. Then, based on congestion pattern in 2018, we selected those days with high daily average congestion delay index, and discover the average time distribution of congestion for the travel spot.

The average congestion delay index is shown in Eq.1:

\[
\text{Index}_{d} = \frac{1}{n} \sum_{i=1}^{n} \frac{T_{ci}}{T_f}
\]

where \( \text{Index}_{d} \) represents the daily average congestion delay index, \( T_{ci} \) represents the \( i_{th} \) travel time in every 2 minutes’ time slot and \( T_f \) represents the travel time under free flow state, and \( n \) presents the number of time slots from the time of 6:00 to 22:00 in every 2 minutes. For this parameter, four classes of traffic congestion has been classified to evaluate congestion level, namely smooth, slow speed, congestion and serious congestion. If the value of the index is higher than 2, it means traffic state is under congestion level; and if the index is higher than 4, it means traffic state is under serious congestion level. (AutoNavi, 2018).

2.2 Congestion Level Analyses for Fenghuang Ancient Town

As shown in figure 1, 5 out of 7 congestion peaks in figure 1 are related to public holidays, with all of their average daily congestion delay index value higher than 2. The remained 2 congestion peaks are due to adverse weather (heavy snow and heavy rain respectively). Among all peaks, the highest peak of average congestion delay index value was higher than 4.5 during Chinese Spring Festival from February 16 to February 23. It can be summarized that congestion level during public holidays was quite severe for Fenghuang Ancient own.

![Figure 1: 2018 Average Daily Congestion Delay Index for Fenghuang Ancient Town](image-url)
Then, we selected the most congested 18 days from all 29 public holidays in 2018 to discover the 24 hours congestion level distribution, and the result can be found in Fig 2. From this result, we can found that during the most congested periods of public holidays in 2018, the average daily congestion delay index of Fenghuang Ancient Town was congested since 9:00 with the congestion delay index at 1.93, and the congestion level increased to its peak until around 19:00 with the congestion delay index at 4.37; after that, the congestion level decreased, but the traffic statue was still under congested level (the congestion delay index was higher than 2).

Figure 2: 24 Hours Average Congestion Level Distribution during Congested Public Holidays

Therefore, from figure 1 and figure 2, we can summary that:
(1) Most days (18 out of 29 days) during public holidays were under congestion level; but far less congestion can be found during normal working days.
(2) Most public holidays with toll-free policy (Li and He et.al, 2016) were under congestion level, and the only two exceptions were dragon boat festival (June 16 ~June 18) and Mid-Autumn Festival (Sept 22 ~ Sept 24) in 2018.
(3) The congestion level during evening is usually higher than the congestion level before noon during the public holidays.
(4) The travellers’ outbound trip from Fenghuang Ancient Town seems far more intensive than travellers’ inbound trip to the place, by comparing the average daily congestion delay index at 9:00 and at 19:00.

3 TRANSPORTATION ACCESSIBILITY LEVEL ANALYSIS FOR FENGHUANG ANCIENT TOWN

3.1 Transportation Accessibility Evaluation Model Establishment

Based on former studies on transportation accessibility evaluation (Zhang and Wang et.al, 2010; Guo and Wang et.al, 2015; Song and Li et.al, 2017; Zhao, 2016), in this paper we built transportation accessibility model in Eq.2 as below:

\[
\text{Index}_{ac} = \sum_{i=1}^{3} a_i \times f_i 
\]

(2)

where Index_{ac} represents the transportation accessibility index; f_{i} presents the central city distance index that is categorised by the distance to the closest first-tier central city; f_{2} stands for the congestion level index that evaluated by the average daily congestion delay index; and f_{3} means the connection index that measured by major transportation facilities. As for a_{i} , it was the weight of each f_{i} , and it was marked by professional Chinese transportation experts using AHP method, with values of 0.25, 0.30 and 0.45 for each (Zhang, Wang and Eric, 2010).
3.2 Data Source and Data Process for Transportation Accessibility Model

The evaluation data source is calculated from Amap, and the measure calculation method is referred to Zhao in 2016.

(1) The central city distance index $f_1(x)$:

Central city usually hold large population or high economics development, and the central city distance index can reflect a potential attraction level that people in a central city choose to a near travel spot, and increase travel spot economics in return.

For the travel spot of Fenghuang Ancient Town, the closest central city is Changsha, which has been regarded as new first-tier cities since 2017 (China Daily, 2017). According to formula to calculate distance index to central city in Eq.3, the distance between Changsha and Fenghuang is about 480km by driving, so the value of $f_1(x)$ is equal to 0.5.

$$
f_1(x) = \begin{cases} 
0.5, & x \geq 160 \\
1, & 80 \leq x < 160 \\
2, & x < 80 
\end{cases} \quad (3)
$$

where x is the distance with unit of km from target city to closest central city.

(2) The congestion level index $f_2(x)$:

Congestion level index can reflect the congestion level to a travel spot, and it is clear that the higher congestion level index, the higher journey time on road will be consumed, and if a travel spot is with high congestion level index, both satisfaction of travellers and attractions of travel spot will reduce.

For the congestion level index of Fenghuang Ancient Town, the calculation method is shown in Eq.4. According to former analyse in Part 2, the congestion delay index in Fenghuang during public holidays was higher than 2.5, so the value of $f_2(x)$ is equal to 0.5

$$
f_2(x) = \begin{cases} 
3, & x < 1.5 \\
2.5, & 1.5 \leq x < 2 \\
1.5, & 2 \leq x < 2.5 \\
0.5, & x \geq 2.5 
\end{cases} \quad (4)
$$

where x stands for an accumulated average congestion delay index for a certain area.

(3) The transportation facilities connection index $f_3(x)$:

The connection index reflects the connection level from different types of transportation facilities to a travel spot, and it is clear that the farer distance from a transportation facility or the lower level of transportation facility it is, the lower satisfaction of travellers will have. As a result, travel spot will lose its attractions to customers.

According to Zhao in 2016, for transportation facilities near Fenghuang Ancient Town, the calculation method on the connection index is shown in Eq.5. Based on the index result of evaluation and calculation shown in Table 1, the value of each index for train station, airport, highway and road is 0.5, 0.5, 0.5, 1.5, and 1 respectively. So the value of $f_3(x)$ is equal to 4.0.

$$
f_3(x) = x_t + x_a + x_p + x_h + x_r \quad (5)
$$

where x stands for weighted value for different transportation infrastructure or transportation facilities, and $x_t$ is the weighted value for train station level, $x_a$ is the weighted value for airport level, $x_p$ is the weighted value for the level of passenger station, $x_h$ is the weighted value for the distance to highway, and $x_r$ is the weighted value for road level.
Table 1 Details of Connection Index Value of Fenghuang Ancient Town

<table>
<thead>
<tr>
<th>Transportation Facility Type</th>
<th>Transportation Facility Name</th>
<th>Facility Attribution</th>
<th>Index Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Train Station</td>
<td>Jishou Train Station</td>
<td>Fourth Level Train Station</td>
<td>0.5</td>
</tr>
<tr>
<td>Airport</td>
<td>Tongren Fenghuang Airport</td>
<td>Near 40km to Travel Spot</td>
<td>0.5</td>
</tr>
<tr>
<td>Passenger Station</td>
<td>Fenghuang Passenger Station</td>
<td>Second Level Passenger Station</td>
<td>0.5</td>
</tr>
<tr>
<td>Road infrastructure</td>
<td>G56 Hangrui Highway and G65 Baomao Highway</td>
<td>Both have Exit to Travel Spot</td>
<td>1.5</td>
</tr>
<tr>
<td>National Road</td>
<td>G209 national road</td>
<td>Close to Travel Spot</td>
<td>1</td>
</tr>
</tbody>
</table>

3.3 Transportation Accessibility Evaluation

Based on calculation above, the \( f_1(x) \), \( f_2(x) \) and \( f_3(x) \) is 0.5, 0.5 and 4.0 respectively, so according to Formula (2), the total transportation accessibility index represented by Index_{ac} is only 2.075. Looking at the result of Index_{ac}, by comparing with the study worked by Zhao in 2016, such value is quite lower than other city’s value in Zhao’s paper.

From each index, we can found the low value is due to reason shown as follow:
1. Far distance to the central city of Changsha (related to \( f_1(x) \));
2. The severe congestion level for Fenghuang Ancient Town (related to \( f_2(x) \));
3. As a travel industry dominate area, there is little high level of train station for Fenghuang area that high speed rail can stop. Besides, far distance (nearly 40km and more than one hour’s driving distance) need to take between travel spot and airport. (related to \( f_3(x) \));

4 FURTHER DEVELOPMENT SUGGESTION

From the transportation accessibility evaluation in Part 3, we can find that it is quite difficult to change the distance to central city, but it is possible to improve transportation facilities connection and congestion level. Therefore, some suggestions can be provided based on these two perspectives.

4.1 Transportation facilities connection improvement suggestion

Some latest transportation news about Fenghuang transportation improvement have been announced:
1. Airport: Tongren Fenghuang Airport has been successfully upgraded to become international level airport, with annual throughput exceeding 2 million;
2. High-speed Railway: the Fenghuang section of Zhang-Ji-Huai High-speed Railway has started construction, and the Tong-Ji High-speed Railway has been planned to stop at Fenghuang Train Station;
3. Link Road Construction: Pre-project road construction work of G352 Zunyi city to Jishou city, G354 Fenghuang High-speed Railway Station to Tongren Fenghuang Airport, and S320 Fenghuang Mujiangping to Luxi has progressed smoothly.
4. Ring Routes Construction: Great breakthroughs have been made in county ring routes, for example, the complete of Fengqi Road has been near to complete, the Fengming Road (G209 route) has been widened, and the demolition and newly construction of Nanhua Bridge and the newly construction of the tunnel of Folk Garden.

Based on such facts above, we can find that transportation facilities of Fenghuang will be improved dramatically. To meet such improvement, based on our analyses of transportation facilities connection index \( f_3(x) \), the improvement on road connection between transportation facilities and travel spot should be also improved at the same time (such as reducing driving time to airport and walking time to passenger station). In this way, the improvement of combined effects on transportation
facilities, their surrounding transportation infrastructure and travel spot connection will be effective enough.

4.2 Transportation congestion level improvement suggestion

From Figure 3, due to high congestion level (red stands for congested road, yellow stands for slow speed driving road and green means smooth driving road) near the travel spot, it is quite hard to connect between inner Fenghuang area and outer Fenghuang area, even though the connection of highway and road of Fenghuang has improved dramatically. In such situation, the advantage of transportation facilities have reduced or even vanished dramatically. Therefore, traffic congestion improvement should be set in the first priority for future travel development of Fenghuang Ancient Town.

![Figure 3: Severe Congestion Level around Fenghuang Ancient Town in 2018.10.03.10:15](image)

5 CONCLUSION

In this paper, through big data from AMAP and government statistics, we have made some contributions as follow:

(1) Firstly, we have improved traditional transportation travel accessibility evaluation model by newly adding dynamic factor of transportation delay index, which can be evaluate successive transportation congestion level within one year. In this way, our model have contained both static factors (including the distance to central city and connection level to different transportation facilities and highways) and dynamic factor, this makes our model can be more practical in real world.

(2) Then, based on our improved transportation travel accessibility model, we have calculated the level of travel accessibility of Fenghuang Ancient Town is quite low when comparing with calculated values in other related study using traditional transportation accessibility model.

(3) Next, we have analysed the reason of low value is due to the far distance to central city, low connection level to transportation facilities and highways and severe congestion.

(4) Finally, based on the reasons, this paper have suggested that traffic congestion issue should be in the first priority to deal with. Then, link roads should be improved between inner Fenghuang area and outer Fenghuang areas at the same time to meet the latest transportation infrastructure construction project in outer Fenghuang areas.

6 ACKNOWLEDGEMENT

This work was supported in part by Joint Laboratory for Future Transport and Urban Computing of AutoNavi.
REFERENCES

AutoNavi 2018,
‘2018 Traffic Analysis Reports 2018 Q3’,
https://report.amap.com/share.do?id=8a38bb866778466a01679d084f490d8f,
[Access in 2019/01/30].

Cao, X and Liu, D 2018,
‘Spatial Differentiation of Urban Tourism Satisfaction in China Based on Tourism Big Data’,

China Daily 2017,
‘Wuhan among China's top 15 'new first-tier' cities’,
[Access in 2019/01/30].

Fenghuang County Government 2018,
‘Statistical Communique of Fenghuang County on the 2017 National Economic and Social Development’,

Guo, J and Wang, D et.al 2015,

Le-Klähn et al. 2015,

Liu, X and Li, Y 2018,

Song, J and Li, M et.al 2017,

Lyu, W and Mei, W 2018,

Liu, Y and Bao,J et.al 2017,

Wang, Y and Ge D et.al 2018,

Wang and Xie et al. 2018,
‘Study of Transport Organization Pattern for Life-style Tourist Ancient Towns’, China Transportation Review, 40(04):16-20
Xiangxi Autonomous Prefecture Bureau of Statistics 2018,
‘Statistical Communique of Xiangxi Autonomous Prefecture Bureau on the 2018 National Economic and Social Development’,
[Access in 2019/01/30].

Xinhua 2018,
‘How tourism is becoming a new driving force in China's growth’
http://www.chinadaily.com.cn/a/201803/05/WS5a9d08eda3106e7dcc13faad.html
[Access in 2019/01/30].

Xinhua 2019,
‘The most popular travel spots perdition in the 2019 Spring Festival Published by AutoNavi’
[Access in 2019/01/30].

Zhang, G and Zhao, J 2015,

Zhang, X and Wang, R et.al 2010,
‘A study of the role played by renewable energies in China's sustainable energy supply’,
Energy, Volume 35, Issue 11, 2010, Pages 4392-4399, ISSN 0360-5442,
https://doi.org/10.1016/j.energy.2009.05.030.

Zhang Z et.al 2018,

Zhao, J 2016,
‘Study on Spatial Structure of Tourism Economy Based on Tourism Transportation Accessibility in Shandong Province.’ Resource Development & Market, 32(10):1263-1268