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Analysis on Characteristics of Traffic Demand about SuTong Bridge

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Abstract

Thanks to her special geographical location, SuTong Changjiang Highway Bridge, which lies in the most economically developed area-Yangtze River Delta, becomes the vital transportation passageway to prosper the economic development between South of Jiangsu province and Zhejiang & Shanghai. This paper analyzed the characteristics of traffic demand of SuTong Bridge from different angles, such as hourly/daily/monthly/space/vehicle-types features and drew some significant conclusions, based on the particular data of traffic volume of SuTong Bridge in 2010. The conclusions comprises: the traffic demand of Sutong Bridge increased by nearly 18 thousand vehicles per month; Average monthly growth rate was 1.95%; MADT in October was the highest (1/***k*** was up to 1.12); In addition, the spatial distribution and the motor-type proportion of river-crossing vehicles were analysed.

Keywords: Traffic demand; Characteristic analysis; Sutong Bridge;

1. Introduction

SuTong Changjiang Highway Bridge, which is called SuTong Bridge for short, lying between Nantong and Suzhou (Changshu) and going across the Yangtze River, is the national artery planned by the Ministry of Transport of the People's Republic of China and the important component that constitutes the main framework of the highway net in Jiangsu province. Within the 5 years after Sutong Bridge was opened to traffic, the economical development of the Yangtze River Delta was stably promoted. What's more, the transportation pressure between the sides of the Yangtze River was largely alleviated, and she enhanced the

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regionalized communication of politics and culture. However, with the rapid development of regional economy, especially adjoining the international center of finance, trade and shipping—Shanghai, the traffic demand of Sutong Bridge is sharply increasing. The aim of exploring the characteristics of traffic demand about SuTong Bridge, sequentially obtaining the time and space distribution of the volume, was as follows. On one hand, the aim was to help the drivers formulate their schedule reasonably and avoid the dispensable delay in the peak hours and ensure the driving safety. On the other hand, was to be beneficial to the realization of effective countermeasures which can be used to optimize the operating management, to improve the LOS of the bridge, and to ensure the traffic on the bridge works safely.

2. Overview on river-crossing segments in Jiangsu province

According to the regional partition of where to go across the river, the primary four segments that the part of Yangtze river that lies in Jiangsu were divided into are: Nanjing segment, Zhenyang segment, Changcheng segment and Sutong segment(which the Sutong Bridge belongs to). Because of the earlier construction and dominated quantity of river-crossing bridges, Nanjing segment plays a significant role in attracting river-crossing vehicles and prospering the regional economy, resulting in the burdensome responsibility on undertaking the transportation mission for the west of Jiangsu province. Whereas, the successional open of the Runyang Bridge, Sutong Bridge and Chongqi Bridge, made not only the spatial distribution of river-crossing bridges more and more balanced, but the proportion of undertaking the mission more and more reasonable. Based on the literature(Fan & Yang, 2009), the proportion of undertaking the river-crossing volume of Nanjing, Zhenyang, Changcheng and Sutong segment will stabilize in the ratio of 40:18:23:19, which can be shown in Figure 1.

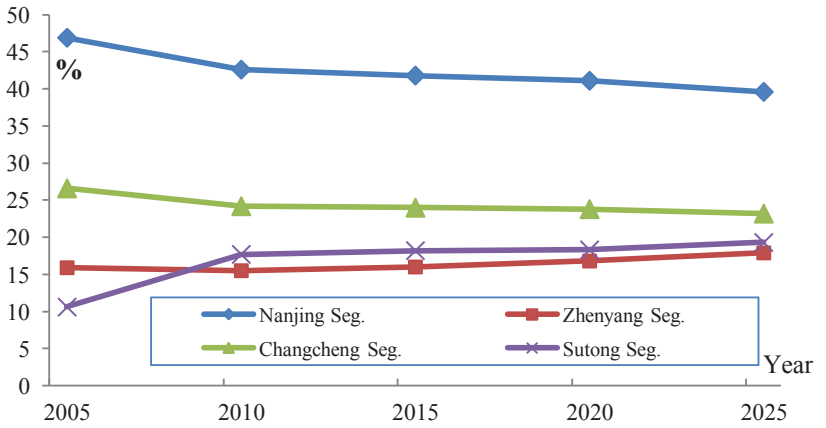

Fig .1 Predicted Sharing Ratio of River-crossing Volume Tendency of Each Segment in Jiangsu Province

Figure 1 shows that, as the time goes by, though the proportion of Nanjing segment undertakes decreases by a bit, it still remains nearly 40%. And the proportion of Changcheng segment also descends. Because of the open of Runyang, Sutong and Chongqi Bridges, the proportion of Zhenyang and Sutong segments increases by some different extent.

Among them, the amplification of Sutong segment is more evident. After June, 2008 when Sutong Bridge was opened to traffic, the traffic sharing ratio of Sutong segment increase from 10.6% in 2005 to 17.7% in 2010, which resulted in a 66.98% increase. To some extent, not only does the opening of Sutong

Bridge play a crucial effect on the enhancement of river-crossing sharing ratio of Sutong segment, but contribute a lot to the reasonable eastward-moving of the river-crossing traffic center in Jiangsu Province.

2.1. Modes of River-crossing

According to the vertical position relative to the surface of the river when the river-crossing transportation occurs, the main river-crossing modes may fall into three classes: Bridges (over the river), Car Ferry (on the river) and Tunnels (under the river).

• River-crossing Bridges

Among the four segments of Jiangsu Province, from the point of sharing traffic volume, bridges no doubt are playing a vital role in meeting the traffic demand. By now, the quantity of river-crossing bridges located in Jiangsu province or between the province and Shanghai is up to 8, whose details are tabulated in Table 1.

Tab.1 List of River-Crossing Bridges within or Border on Jiangsu Province

NO.	Names of bridges	SEG. Belongs to	Date for opening	Location	Overall lenghth（km）
1	Nanjing Yangtze River Bridge Highway bridge	Nan Jing SEG.	1968.12	Northwest of Nanjing	4.589
	Nanjing Yangtze River Bridge Railway bridge		1968.9		6.772
2	the 2nd Nanjing Yangtze River Bridge		2001.3.26	11km downstream of the Nanjing Yangtze river bridge	21.337
3	the 3rd Nanjing Yangtze River Bridge		2005.10	19 km upstream of the Yangtze river bridge	14.89
4	the 4th Nanjing Yangtze River Bridge		2012.12.24	10 km downstream of the 2nd Yangtze river bridge	28.996
5	The Runyang Yangtze River Bridge	Zhen Yang SEG.	2005.10.1	Between Zhenjiang and Yangzhou	35.66
6	Jiangyin Changjiang Highway Bridge	Chang Cheng SEG.	1999.10	Between Jingjiang and Jiangyin	5.176
7	Sutong Changjiang Highway Bridge	Su Tong SEG.	2008.6.30	Between Nantong and Suzhou	32.4
8	Chongqi Bridge		2011.11.24	Chongming Island,Shanghai,to Qidong,Jiangsu Province	52

• Car Ferry

The first construction of car ferry on Changjiang River dates back to the Huangtiangang car ferry built between Huangtiangang(belongs to Jiangyin city) and Bawei(belongs to Jingjiang city) in the seventies of last century. So far, there have been more than ten ship-lines of car ferry in the main channel of Jiangsu segment of the Changjiang River. Over 30 years, the quantity or number of times generated by car ferry of

Jiangsu Province has been added up to 500 million in total, binging about a huge convenience of transportation, materials circulation guarantee and stimulation of economic development for the people on both sides of the Changjiang River (Gui, 2009). In the Sutong segment, as tabulated in Table 2, there are mainly three car ferries which have a close relations with Sutong Bridge—Tongchang, Taihai, Tongsha.

Tab.2 List of Major Car Ferry Routes in SuTong Zone

NO.	Names of car ferry	Location of northern & southern harbor	The min distance away from Sutong Bridge（km）	The min Distance between both sids（km）	Time for one way（min）
1	Tongchang	north：downstream of former address of Shuishan Shipbuilding Corp.	5.0	6.1	20
2	Taihai	north：Haimen Harbor in Haimen city south：Huangjing town in Taicang city	9.6	7.2	25
3	Tongsha	north：East Harbor in western Nantong city south：Xijie harbor in Zhangjiajie city	36.0	7.5	30

• River-crossing Tunnels

At present, 3 river-crossing tunnels, Wuhan Changjiang Tunnel, Nanjing Changjiang Tunnel, Shanghai Changjiang Tunnel, have been lying along the Changjiang River. Among them, only the Nanjing Changjiang Tunnel which was opened to traffic on May 28, 2010, is located in the territory of Jiangsu province. The Hu-Chong-Su large channel which is composed of Shanghai Changjiang Tunnel, Shanghai Changjiang Bridge and Chongqi Bridge, make Pudong district, Chongming Island and Qidong city in Jiangsu an integrated north-south river-crossing huge channel.

2.2. Predicted Volume on Three Modes in Sutong Segment

As shown in Table 3, the predicted volume of average daily traffic (ADT) is up to 58924 vehicles in 2015, increasing by 18.4% when compared with the value of 2010. The average annual growth rate is 3.9%. From the year 2015 to 2025(2028), the average annual growth rate of traffic demand of Sutong Bridge is 2.7% (2.4%) (Fan & Yang, 2009).

Tab.3 Predicted Volume (veh/d) of the River-Crossing Modes in SuTong Zone(Fan & Yang, 2009)

Year	Sutong Bridge	Car Ferry			Hu-Chong-Su Channel(Jiangsu segment）
		Tongsha	Tongchang	Taihai	
2009	46850	7138	1619	2073	6063
2010	49774	7836	2504	2637	6853
2015	58942	9492	4209	3798	13260
2020	67478	11335	3002	5894	21854
2025	77149	13946	7697	9952	26538

3. Overall Characteristics of River-Crossing Traffic Demand

3.1. Monthly Characteristics

• Monthly Average Growth Rate

Compare the monthly traffic demand of 12 months in 2010 with each other in Table 4.

Tab.4 Traffic Demand over the SuTong Bridge in 2010

Month x	January.	February.	March	April	May	June
Total volume per month y （10 thousand veh.）	101.4827	104.245	104.9868	111.21	107.7414	103.4513
Month x	July	August	September	October	November	December
Total volume per month y （10 thousand veh.）	112.0908	115.0942	116.202	126.4731	116.3075	121.291

Regression function acquired by Least Square Method is $y = 1.8619x + 99.612$, while the square of sample correlation coefficient is $R^2 = 0.7599$, which means 75.99% data can fit well with the obtained model. Under the premise of $\alpha = 0.01$, the significant test on the linearly dependent is conducted, with a degree of freedom of 10.

$$T = \frac{R}{\sqrt{1-R^2}}\sqrt{n-2} = 5.626 > 3.169 = t_{0.005}(10),$$

So the significance of linearly dependent between x and y can be demonstrated, under the circumstance of a 99% reliability.

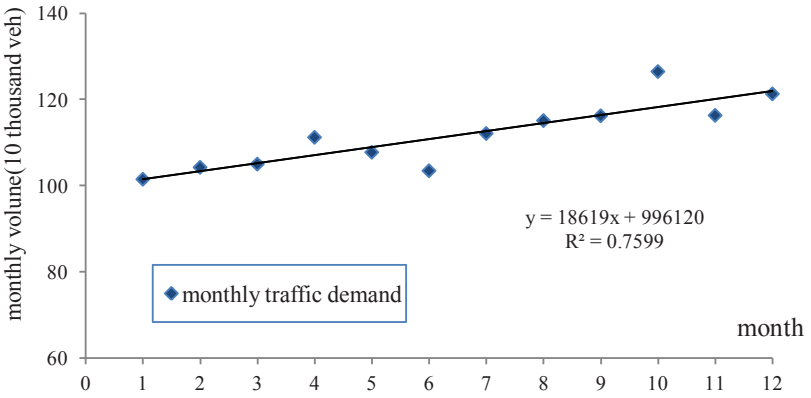

Fig .2 Fitting Curve of the Traffic Demand per Month in 2010

According to the outcome of linear fitting (shown in Figure 2), some conclusions that the traffic demand of Sutong Bridge increases by 18 thousand vehicles per month and monthly average growth rate is 1.95% can be drawn, which may provide a value of practical application and reference for a future prediction of monthly traffic demand.

• Monthly Variation of Volume

Due to the effect of social or economic activity and local climate on the traffic demand, the monthly volume of the same road can differ a lot in each month, presenting some definite change rule, which can be described as monthly variable coefficient *K*, i.e. the ratio of AADT and MADT (Wang & Guo, 2000). What's more, as shown in Figure 3, the monthly variable tendency of traffic demand can be illustrated by monthly variable figure (Li, 2002), which is drawn with month as the abscissa and the reciprocal of *K* as the ordinate.

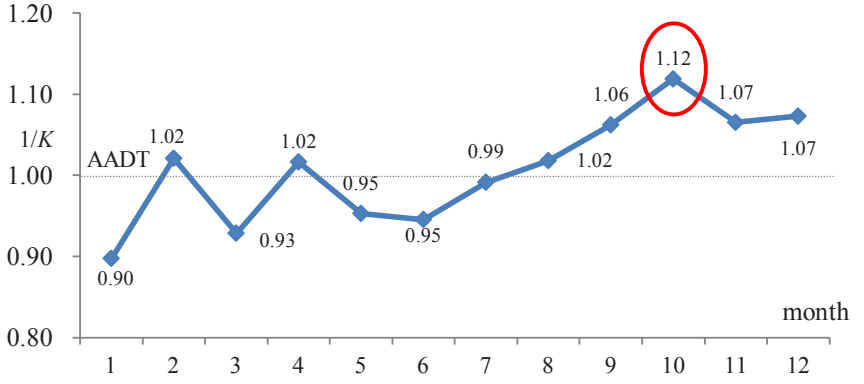

Fig .3 The Monthly Variation of Traffic Demand over the SuTong Bridge in 2010

Figure 3 shows us the peak value of MADT occurred in October with 1/ *K*= 1.12, which means a larger traffic demand in October. Combined with Figure 2, the total demand of Sutong Bridge in October is largely stimulated by the increase of people's travel desire on seven-day National Day holidays.

• Longitudinal Comparison of Representative Months

Known from the survey on relevant departments of Sutong Bridge Corporation and analysis on historical data, monthly traffic of October is larger than that of the other months. The MADT of October in 2010 is 40798 vehicles, which is about 11.9% more than the value of AADT. Daily traffic volume of October in 2009 and 2010 are compared longitudinally with each other in Figure 4.

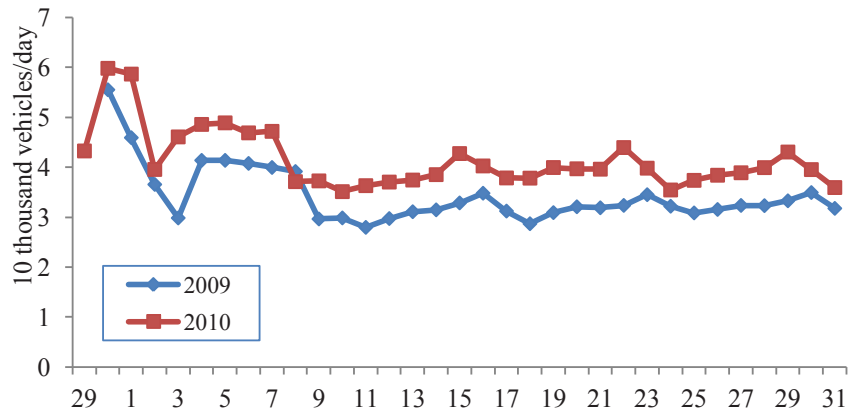

Fig .4 Daily Traffic Volume of Oct. in 2010, Contracted by that of Oct. in 2009

Informed from Figure 4, peak day volume in National Day holidays are both on 30th, September in 2009 and 2010, while reaching the bottom on 2nd or 3rd and keeping steady on 4th to 7th. This coincides with the traffic feature reported by the media on National Day holidays. After 8th, a periodism disturbed by National Day holidays returns to normal, and the law that the peak day volume occurs on Friday and the lowest occurs on Sunday turns out to be a truth.

3.2. Hourly Characteristics

To discuss the hourly volume of traffic demand, the 24-hour volume data which are from 15th to 21th, November, are selected as a sample for a further study. The 24-hour volume data of sample week are depicted in Figure 5.

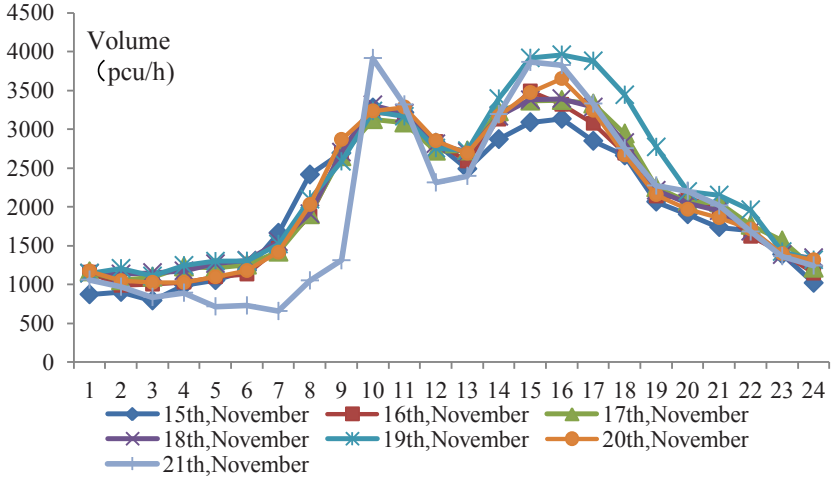

Fig.5 Hourly Feature Tendency of Traffic Demand (15th-21th, Nov) in 2010

As shown in Figure 5, Traffic flow across the bridge in 24 hours a day appeared two peak periods (according to the order in which they appeared, we call them morning peak and evening peak, respectively). Morning peak appeared from about 7:00 to 12:00, and traffic flow during 9:00-11:00 surged. Evening peak appeared from about 13:00 to 18:00, and traffic flow during 14:00-16: 00 surged. Since most drivers had lunch and rest during12:00-13:00, a flow valley existed between the two peaks.

3.3. Other Characteristics

• Spatial Distribution

Due to the differences (population, economic development and the nature of the land use, etc.) caused by regional characteristics of urban agglomeration between the north and south of the Sutong Bridge, it is bound to bring about effect on the spatial distribution of generation and attraction of traffic. There are 5 toll stations in the whole line of Sutong Bridge, which are the north and south of main line stations, Nantong / Changshu development-zone stations and Zhuxing station. Based on the empirical formula provided by the Sutong Bridge Corporation:

$$Q_E = Q_A * 99\% + Q_B * 95\% + Q_C * 95\% + Q_D * 81\% \quad (1)$$

in which: Q_E -- the bridge-crossing volume from one end of the bridge to another
Q_A --the entrance volume recorded by the North mainline toll station
Q_B --the entrance volume recorded by the Nantong development-zone station
Q_C --the entrance volume recorded by the South mainline toll station
Q_D --the entrance volume recorded by the Changshu development-zone station

i.e., the northbound volume: $Q_{NS} = Q_A * 99\% + Q_B * 95\%$

the southbound volume: $Q_{SN} = Q_C * 95\% + Q_D * 81\%$

We can know from the formula (1): the vehicles recorded by the mentioned four toll stations are overwhelmingly river-crossing vehicles. Furthermore, the proportion of river-crossing vehicles via the North mainline toll station (99%)is the highest, while the proportion via the Changshu development-zone station(81%) is the lowest.

• Proportion of Vehicle Types

As Table 5 shows, because different types of vehicles driving on the road occupy the road resource in different degree (described by vehicle conversion factor), one car can make different effect on the other driver's behavior in the traffic flow. As a result, the Sutong Bridge charges toll fees according to the types of vehicles. The higher extent a car occupies the road resource, the more power it possesses to accomplish a passenger or cargo transportation task.

Tab.5 Classification and Charging Criteria of Vehicles Going over the SuTong Bridge(Price Bureau, Department of Finance & Transport, Jiangsu Province, 2008)

Category	Models and specifications		Charging standard (yuan per veh per time)	Vehicle conversion factor *Ei* (initial)	Vehicle conversion factor *Ei* (adjusted)	Proportion *Pi* (flat hump)
	Passenger car	Freight car				
Type 1	≤7 seats	≤2 tons	30 40	1.0	1.0	76.57
Type 2	8-19 seats	(2，5] tons	40 70	1.0 1.5	1.3	13.78
Type 3	20-39 seats	(5，10] tons	60（privilege） 100	1.5 2.0	1.8	1.76
Type 4	≥40 seats	(10，15] tons 20 feet container car	60（privilege） 115	1.5 3.0	2.3	7.67
Type 5		＞15 tons 40 feet container car	120	3.0~4.0	3.4	0.22

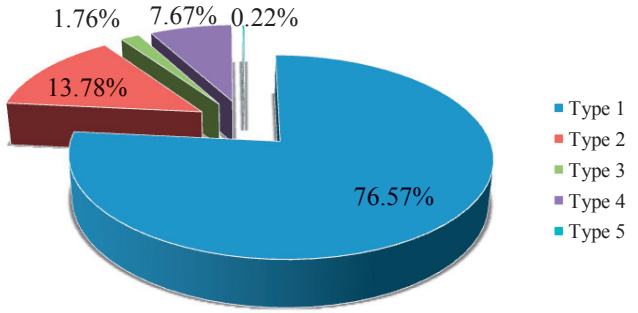

Fig.6 Constitution and Proportion of Motorcycle Going over the Bridge

It is not difficult to find that eighty percent of the vehicles across the bridge were type 1 cars in Figure 6, which means that passenger cars and pickup trucks formed the majority of the vehicles though the bridge, followed by the proportion of type 2 and type 4, nearly14% and 8% respectively. Trucks which carrying capacity is greater than 15 tons and size is above 40 feet are the minority, accounting for only 0.22%.

4. Conclusions

In this paper, the particular data, collected by the four toll stations- north and south of main line stations, Nantong and Changshu development-zone stations of Sutong Bridge in 2010, was analyzed in a qualitative and quantitative method, which is of great importance in ensuring most of the drivers developing a reasonable travel plan and regulating their own driving, in ensuring the Bridge Management Departments optimizing the operation and management means and improving the service level of bridge road, in ensuring the Sutong Bridge having a smooth and safe transportation condition. The main conclusions of this paper were followed:

First of all, the opening of Sutong Bridge made a positive effect on improving the volume sharing rate of Sutong segment, and contributed a lot to the reasonable eastward-moving of the river-crossing traffic center in Jiangsu Province.

What's more, the traffic demand of Sutong Bridge increases by 18 thousand vehicles per month and monthly average growth rate is 1.95%. The AADT of Sutong Bridge in 2010 is 36728 veh/d. The MADT in October was the highest (1/k was up to 1.12).The MADT of October in 2010 is 40798 vehicles, which is about 11.9% more than the value of AADT.

Finally, as for the spatial distribution of river-crossing vehicles, the proportion of vehicles that driven via the North mainline/Nantong development-zone/Changshu development-zone/South mainline toll station are 99%、95%、95% and 81%, respectively. Type 1 vehicle accounts for nearly eighty percent, while the proportion of type 5 is the least.

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