5-26-2012

The Congestion Evolution of Jingzang Expressway and the Analysis on Participants' Behavior

Xiaoxia Wang
School of Traffic and Transportation, Beijing Jiaotong University, China, xxwang@bjtu.edu.cn

Yue Shang
School of Traffic and Transportation, Beijing Jiaotong University, China

Wei Liu
School of Traffic and Transportation, Beijing Jiaotong University, China

Xing Chang
School of Civil Engineering and Mechanics, Huazhong University of Science and Technology,China

The Congestion Evolution of Jingzang Expressway and the Analysis on Participants' Behavior

Xiaoxia Wang[1], *Yue Shang*[1], *Wei Liu*[1], *Xing Chang*[2*]
[1] School of Traffic and Transportation, Beijing Jiaotong University, China
[2] School of Civil Engineering and Mechanics, Huazhong University of Science and Technology, China

Abstract: Road transportation networks are experiencing ever growing recurrent congestion and non-recurrent in developing China, which is a concurrent event. This paper takes Jingzang Expressway(G6) as an example, describes the saturation flow along the G6 compared with its designed capacity by the actual volume of each segment according to the density and structural characteristics of cars and trucks, and presents the congestion evolution in the past three years. Then provide inharmonious surveillance analysis among regions along this highway and game behavior between administers and carriers based on cost analysis. Finally, we point out that congestion is not only the road itself problems but also a social system problem, which should be transformed in the long term. Now we can apply some Intelligent Transport System to mitigate congestion.

Keywords ：traffic congestion, behavior analysis, Jingzang Expressway

1. INTRODUCTION

Supply chains that rely on Just-In-Time production and distribution require timely and reliable freight pick-ups and deliveries from the freight carriers in all stages of the supply chain. However, road transportation networks are experiencing ever growing congestion, which greatly hinders all travel and certainly the freight delivery performance.[1]

There are two kinds of congestion: (1)recurrent congestion that, for example, develops due to high volume of traffic during peak commuting hours; (2)incidents, such as accidents, vehicle breakdowns, bad weather, work zones, lane closures, special events, etc. are other important sources of traffic congestion. This type of congestion is labeled non-recurrent congestion in that its location and severity are unpredictable.

The early research related to modeling of traffic congestion appears to be limited for use either in the past-event off-line analysis or in the model-based estimation of freeway flow variables for non-incident cases. To our knowledge, developed countries research work had moved on from 'recurrent' congestion to 'non-recurrent' congestion, from freeway congestion in city areas, which may be more complicated and difficult to address. For instance, non-recurrent traffic congestion caused by incidents in urban areas[2].

As for China, we face totally different situation. Take Jingzang Expressway, namely No. G6, as an example, starting in Beijing and ending at Lhasa, travels through seven provinces, including Hebei, Inner Mongolia, Ningxia, Gansu, Qinghai(opened Ganjie to Xining), while Tibet segment is in planning, with a total length of 3710 kms. As an important transport corridor of northwest China, it has been congested constantly since 2010. Sept. 1, 2010, traffic congestion stretched hundreds of kilometers to Inner Mongolia and lasted for more than 20-days. As for May until Oct., 2011, frequent congestion happened along Hohhot to Baotou, influenced 5000 vehicles and brought losses to the nearby villages; hundreds accidents happened.[3] As a developing country, we should deal with severe transport developing problems, such as illegal overload, toll road, disaccord regulation,

* Corresponding author. Email: xxwang@bjtu.edu.cn(Xiaoxia Wang)

improper transport coal long distance by trucks via high road, along with the great increase of vehicle volume and accidents, and constant highway work zones.

Our contribution is two-fold: (1) methods for accurate and efficient representation of recurrent congestion, in particular, identification of multiple congestion states and their transition patterns; (2) the extra cost associated with inconsistent regulations by behavior analysis, including external cost like congestion.

The rest of the paper is organized as follows. The evolution assess of G6 traffic congestion within the last three years is given in Section 2. The behavior analysis between different participants, namely carriers and government sectors, is presented in Section 3. Finally, Section 4 offers some concluding remarks and proposes avenues for future research.

2. ANALYSIS OF THE EVOLUTION OF G6 TRAFFIC CONGESTION

This section describes the saturation flow along the G6 compared with its designed capacity by the actual volume of each segment according to the density and structural characteristics of cars and trucks, and analysis the congestion tendency in the past three years.

2.1 Assess the G6 congestion

2.1.1 Calculate the actual traffic of each segment

Take 2009 as an example, transfer passenger and cargo transport density of each segment (person/day and ton/day) into the actual equivalent traffic (pcu/d) distinguishing into and outbound Beijing.

1. Calculate passenger and cargo equivalent flow rate based on their structural characteristics

(1) passenger equivalent traffic for a segment

The volume of passenger traffic (passenger density as the original data) involves four types of passenger cars, respectively sharing ratio determined by the proportion of the sample data. Conversion factors varied with a different of the average number of seats and ride rate, Equation (1):

$$AET_{pj}=D_{pj}\sum((P_{ci}\times CC_{ci})/\ (ANS_i\times RR_i)) \quad (1)$$

Where AET_{pj} is the actual passenger equivalent traffic of segment j, D_{pj} passenger density on segment j (100,000 person km per km), P_{ci} the proportion of car i in total volume of passenger traffic, CC_{ci} conversion coefficient of car i, as Table 1.

ANS_i is the average number of seats of car i, RR_i the ride rate of car i, RR_i equals to ridership over seating capacity. ANS_i, RR_i show in Table 2:

Table 1. CC_{ci} set by the Ministry of Communications(JTG B01-2003)

car type	CC_{ci}	explanations
Car	1	≤ 19 seats / load mass ≤ 2 tons
Mid-sized	1.5	> 19 seats / 2tons < load mass ≤ 7tons
Large	2	7tons < load mass ≤ 14tons
Trailer	3	14tons < load mass

Table 2. Each type of passenger cars structural data in 2009[4]

type	seating capacity	average speed(km/h)	ANS_i	RR_i	sample size (10,000)
I	≤7	89.87	5.27	48.75%	73666
II	8～19	82.70	11.52	47.99%	3626
III	20～39	83.89	33.23	74.98%	4088
IV	≥40	85.70	45.98	76.43%	1902

(2) freight equivalent traffic for a segment

Here are two basic equations:

$$Z_j\sum(P_{ti}\times ALM_{ti})=\ D_{fj} \quad (2)$$

$$Z_j\sum(P_{ti}\times CC_{ti})=\ AET_{fj} \quad (3)$$

Where AET_{fj} is the actual freight equivalent traffic of segment j, D_{fj} freight density on segment j (10000 tons km per km); Z_j the total number of trucks in segment j(volume/d); P_{ti} proportion of truck *i*; ALM_{ti} the average load mass for truck *i* after overload revised; CC_{ti} conversion coefficient of truck *i*. Thus the AET_{fj} can be gotten by Equation (4).

$$AET_{fj}=D_{fj}(\sum(P_{ti}\times CC_{ti})/\ \sum(P_{ti}\times ALM_{ti})) \quad (4)$$

CC_{ti} is related to the load mass of trucks, changed due to the actually overload condition. Thus amend the load mass based on the overload statistics:

$$ALM_{ti}=\ ALM_i\sum(P_{is}\times\ (1+P_{os})) \quad (5)$$

Where ALM_i is the average load mass of truck *i*; P_{is} proportion of truck *i* with s-status; P_{os} overload percentage of s-status (according to the highest percentage of overload, overload by 100% count as 100% basis). The state 2009 statistical data shows as Table 3[4]:

Table 3. Proportion of freight trucks in 2009(%)

standards	empty	under load	overload				
			0～30%	30%～50%	50%～100%	>100%	Total
GB 1589	25.67	45.67	24.04	2.93	1.52	0.17	28.66
Road Administration Section	25.67	64.60	8.45	0.88	0.37	0.03	9.73

Four kinds of trucks share the volume of freight traffic[4]. ALM_{ti} is calculated in Table 4 by different truck-axis type considering overload statistical data.

Table 4. 2009 highway truck axis type and the revised load mass

type	P_{ti}(%)	proportion(%)		average speed(km/h)	sample size (100,000)	ALM_i(ton)	ALM_{ti}(ton)	CC_{ti}
		traffic	turnover					
2 axes & 4 tyres	13.40	7.82	1.12	67.24	5125	7	5.9	1.5
2 axes & 6 tyres	33.31	24.93	7.47	61.16	13399	10	8.4	2.0
3 axes & 4 tyres	15.97	17.22	15.27	57.44	6050	14	11.8	2.0
Semi-trailer Train	37.33	50.03	76.14	56.46	15421	20	16.8	3.0

In sum, AET_{pj} , AET_{fj} and the equivalent traffic of into and outbound Beijing is shown as Table 6.

2.1.2 Road saturation and Level-of-Service

Road saturation, the ratio of actual traffic to the biggest traffic capacity, is important to reflect the road Level-of-Service (LoS). China road LoS grades as Table 5.

The 2009's road saturation and LoS of G6 present as Table 6. The same apply to the 2008.

Table 5. Road saturation and LoS grades[5]

LoS	Road saturation	Road Description	LoS statement
1	0-0.6	Smooth	good
2	0.6-0.8	Little congestion	bad
3	0.8-1.0	Congestion	Worse
4	>1.0	Serious congestion	worst

Table 6. The road saturation and Los of G6 from Beijing to Inner Mongolia in 2009

segment	OD	direction	D_{pj}	D_{fj}	AET_{pj}	AET_{fj}	equivalent traffic	saturation	LoS
Beijing	1	outbound	164545	130484	58804.48	26367.8	85172.28	2.43	4
		into	399791	19433	142875.8	3926.96	146802.8	4.19	4
	2	outbound	49054	78931	17530.74	15950.13	33480.87	0.96	3
		into	36833	5480	13163.24	1107.381	14270.62	0.41	1
	3	outbound	39333	76339	14056.68	15426.35	29483.03	1.18	4
		into	35618	15233	12729.03	3078.237	15807.27	0.63	2
Heibei	4	outbound	24025	89598	8585.965	18105.68	26691.65	1.07	4
		into	25161	160294	8991.945	32391.71	41383.66	1.66	4
	5	outbound	8393	62363	2999.459	12602.12	15601.58	0.62	2
		into	9615	141949	3436.173	28684.61	32120.78	1.28	4
Inner Mongolia	6	outbound	8714	114705	3114.177	23179.23	26293.41	1.05	4
		into	2251	64138	804.454	12960.81	13765.26	0.55	1
	7	outbound	22124	131194	7906.593	26511.27	34417.87	1.38	4
		into	5794	71223	2070.638	14392.52	16463.16	0.66	2
	8	outbound	26282	91426	9392.564	18475.08	27867.64	1.24	4
		into	34020	171961	12157.94	34749.34	46907.28	2.08	4
	9	outbound	8261	32419	2952.286	6551.13	9503.416	0.42	1
		into	18868	77525	6742.976	15666.01	22408.99	1.00	3
	10	outbound	2947	19807	1053.188	4002.537	5055.725	0.20	1
		into	8666	53813	3097.023	10874.36	13971.39	0.56	1
	11	outbound	3585	38665	1281.194	7813.303	9094.497	0.36	1
		into	2767	31743	988.8602	6414.526	7403.387	0.30	1

Notes: (1)The segment LoS of Ningxia, Gansu and Qinghai are 1st level, so their data are omitted; (2)OD 1 to 11 in sequence denotes: Beijing six-ring to Juyong pass, Juyong pass to Kangzhuang, Kangzhuang to Beijing boundary, Donghuayuan to Xuanhua, Xuanhua to

Dongyang River, Mengji boundary to Ulanchap, Ulanchap to Hohhot, Hohhot to Dongxing, Dongxing to Baotou, Baotou to Linhe, Linhe to Mengji boundary; (3)Average Daily Traffic(pcu/d) designed: 70000 for OD 1 and 2, 45000 for OD 8 and 9,the others 50000.

2.2 Analysis of the evolution of road congestion

2.2.1 The 2010's congestion analysis based on growth rate method

We estimate the 2010's road passenger and freight traffic based on the statistics of 2008[6] and 2009 with the growth rate method. By this method, 2010's road traffic volume is partially greater than reality, for example outbound Beijing segment saturation from Mongolia and Hebei Border to Dongxing reached more than 2, the other way Juyong Pass to Beijing six-ring, Dongxing to Hohhot even up to 4 or more. Nevertheless, when road overloads, drivers will cut the inter car spacing and lower speed and result in the traffic volume reducing, consequently, the administrative sectors take measures to mitigate congestion. However we can still observe the G6 traffic congestion evolution trends.

2.2.2 Analysis of the evolution of road congestion

Draw by AutoCAD software with width of lines to represent road saturation, graphic contrast the congestion evolution from 2008 to 2010 as Figure 1, clearly the road saturation is increasing year by year.

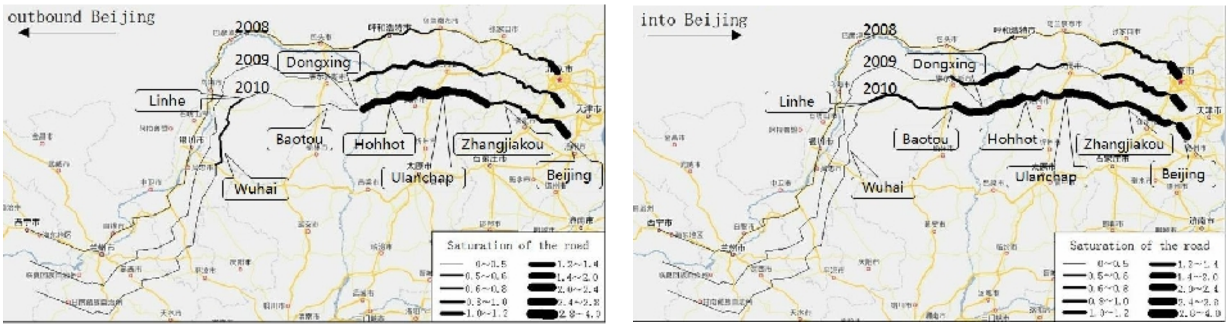

Figure 1. G6 road traffic congestion evolution from 2008 to 2010

The congestion outbound Beijing centralized from Beijing to Xuanhua and Dongxing to Ulanchap, which reached to the 4th LoS. Congestion is worsening, extending to Mengji boundary, while the west of Dongxing road is smooth. As for the traffic congestion into Beijing centralized the whole segment from Dongxing to Hohhot, Beijing and Hebei, at the 4th LoS, congestion gradually expanding to the boundary of Hebei and Inner Mongolia.

3. ANALYSIS ON BEHAVIOR OF THE TRANSPORT PARTICIPANTS

For the regulation of G6, Inner Mongolia, Hebei and Beijing differ from their standards and lack of effective communication, which causing information lag and an estimate shortage on the whole road congestion, then resulting in the big congestion events. [7]

3.1 Inharmonious surveillance among the administers

The big congestion events of G6 involve Beijing, Hebei and Inner Mongolia, who act for their regions, to achieve comprehensive benefits maximized.

3.1.1 Overload measures inconformity

The JingJiMeng segment of G6 has four main overload control points, in Xiaozhuo'er of Inner Mongolia, Xinghe County at the Mengji border, Huailai of Hebei and Kangzhuang Beijing. Vehicles at Huailai overload control point generally carry coal by G6 and Xuanda Highway to Beijing. While Hualai is the joint of G6 and G7(Jingxin Expressway), G7 turns north from here. Kangzhuang is the juncture of Jingji ,those trucks forbidden entering into G6 turn to north by 110 national highway.

Beijing, Hebei and Inner Mongolia take different measures for overload, like Inner Mongolia and Hebei fine instead of unloading, while Beijing offloads rather than punish. Meanwhile, they have different overload standards. Inner Mongolia compares with approval load mass, Hebei checks by standard of 10 tons per axis, while Beijing only allows trucks below eight tons to pass. This leads to all trucks into Beijing should be weighted at Kangzhuang, which takes about 600 seconds, greatly reducing the traffic capacity and contributing to congestion in Hebei segment.

As one of the economic pillar industries in Inner Mongolia, traffic regulation also serves for coal export. With regard to the grave competitive of the coal road transport market, shipping fare is relatively low. Transport enterprises choose to overload for higher profit, which severely prohibited by traffic control sectors. As for the choice of punishment, if only offload without serious penalty, not only consume labor resources, but also lost a large amount of fine revenue, and to some extent limit the coal industry development. Therefore, Inner Mongolia just fined without offload, as a result boost the coal transport cost and generate a vicious cycle. Hebei is the same.

As for Beijing, considering the capital smooth traffic, road safety and environmental impact caused by trucks, discharge the overload trucks exempt from fine at Kangzhuang.

3.1.2 Disaccord traffic limit measures

Overload leading to roads damaged, 110 national highway overhaul constructed on August 19, 2010 to September 13. This occupied a lane outbound Beijing and reduced the traffic capacity; Furthermore, due to the design flaws in Badaling highway Phase II, the traffic-control sector has been taking traffic limit measures. It only allows trucks under eight tons access, into Beijing under four tons, the rest shunt to 110 national highway, aggravating the congestion of 110 national highway.

June 2010, Hebei took traffic limit measures: large trucks in Zhangjiakou region not to Beijing, all detour the national and provincial road, prohibited passing through Jingzhang, Danla, Xuanda, Zhangshi highway. Although this greatly mitigated the traffic jam of Zhangjiakou territory, but large number of trucks from Shanxi, Inner Mongolia to Beijing has been extremely blocked in the Hebei and Shanxi junction, traffic jams extended to Shanxi and Inner Mongolia border.[8]

July 2010, Inner Mongolia began to take odd-even control to regulate G6 Inner Mongolia segment. For over 5-axis trucks, odd-day into odd-number and even-day into even-number, trucks not qualified shunted to 110 national highway. Thus large number of trucks stranded in the Hebei segment, resulting in congestion outbound Beijing.

3.1.3 Inharmonious surveillance

Local traffic control measures not only have an impact on their respective regional traffic, but also directly affect the neighboring areas. Taking G6 as example, Figure 2 illustrates hazard caused by inharmonious surveillance between regions.

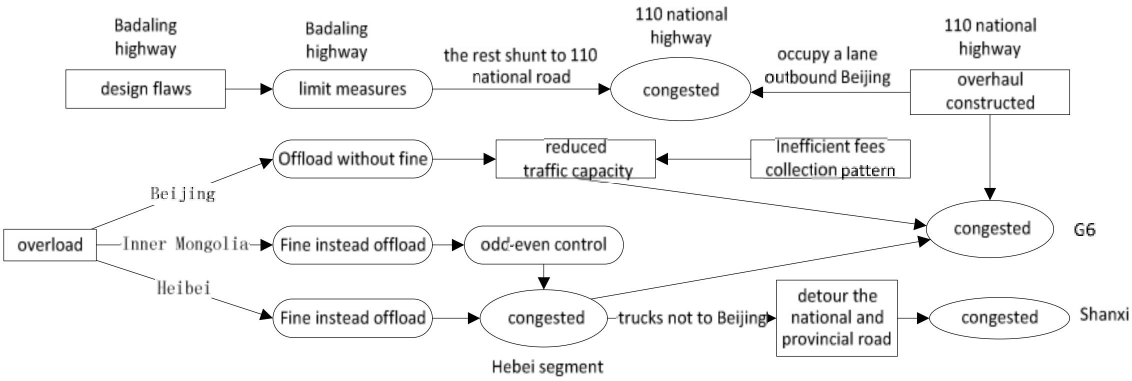

Figure 2. The causes of congestion in the JingJiMeng segments of G6

Although overload may be the origin, there are no unified coordination standards. Trucks needed to be weighed, fined or offloaded, seriously damaged transport capacity. Overload causes congestion, and congestion leads to control, not considering the adjacent regions, and finally results in severe congestion. So measures should consider their own as well as neighbor's interests and reactions, to achieve integrated balance.

3.2 Game between administers and carriers

The choices of the paths reflect carrier's behavior, considering the cost between the origin-destination transportation.

Transportation cost includes the basic cost, such as fuel consumption, toll expenses, repair and depreciation, and other additional costs, like overload fines, environment pollution fees. Ordos region as an example, an eastward coal truck with 40 tons capacity, highway transport basic cost is RMB 1.2 per ton per km. There are three paths: (1) 318 national road to north through Hohhot to G6; (2) via G65 highway north into Baotou to G6; (3) directly 109 national highway via Shanxi arrived at Beijing. The former two take about 780 km and cost about RMB 37,440. While the last one about 835 km and RMB 40,080, which RMB 2,500 higher. Apart from that, Shanxi province began to straighten out coal road environment in 2009 for all the coal trucks through Shanxi levy additional charges, which further increase the cost, objectively caused the freight drivers would rather congestion on the G6 rather than detour Shanxi.

Charge is one of the important leverage between the government and transport enterprises. Clearly, path's choices of carriers are levered by administers' control measures; In turn, different path's selections affect the traffic limit measures. If properly applied, the government will be able to regulate carriers voluntarily to divert and hence mitigate congestion. Shanxi is understandable to charge the additional fee on coal trucks for better environment. Nevertheless, the transportation cost, like oil consumption, depreciation, is inevitable, by contrast the toll fees can be controlled by government.

4. CONCLUSIONS AND REMARKS

Traffic congestion is a serious threat to efficient functioning of the road infrastructure. The G6 congestion is not only the road itself problems, such as defects of highway management model, but also a social system problem, like the uneconomical energy supply mode and the intensive development mode of Chinese cities, which should be transformed in the long term.

Considering the gross severity of the gridlock problem on freeways and in the perspective of higher traffic growth in near future, China has been taking a number of initiatives ranging from physical infrastructure expansion to administrative reform. For example, cancel the toll collection step by step, business tax change to value-added tax for transportation enterprises in Shanghai as a pilot.

In parallel with this supply-side approach, government has also been promoting Intelligent Transport System throughout the country and particularly at all major road networks to make traffic mobility more efficient and safer. For instance, like Korea, a tool named as Freeway Incident Analysis System[9] is developed that has the mission of assisting the traffic manager working in TMC with the sitting Freeway Traffic Management System.

However, confronted with such uncertain traffic conditions[10], carriers are known to develop some simple decision-making process to adjust their travel choices. We should also mention that one of our related studies in terms of carriers' behaviour accommodated with congestion and regulation information is underway.

ACKNOWLEDGEMENT

This research was supported by the “the Fundamental Research Funds for the Central Universities” under Grant 2009JBM054 and 2012JBM053.

REFERENCES

[1] Guner, A. R., A. Murat, et al. (2012). Dynamic routing under recurrent and non-recurrent congestion using real-time ITS information. Computers & Operations Research, 39(2): 358-373.

[2] Sheu, J. B., Y. H. Chou, et al. (2004). Stochastic modeling and real-time prediction of incident effects on surface street traffic congestion. Applied Mathematical Modelling, 28(5): 445-468.

[3] http://baike.baidu.com/view/3671070.htm#2(in Chinese)

[4] Comprehensive Planning Division of the Ministry of Transport. (2010). Transportation Research Institute of Chang'an University.Analysis of 2009 survey of China highway traffic. Beijing: China Communications Press,25-27(in Chinese)

[5] China Communications Press.(2005).Highway design standards. Beijing: China Communications Press,45-46(in Chinese)

[6] Comprehensive Planning Division of the Ministry of Transport. (2009).Transportation Research Institute of Chang'an University. Analysis of 2008 survey of China highway traffic. Beijing: China Communications Press,23-25(in Chinese)

[7] Yong Xue.(2010).The warning of Beijing-Tibet high-speed congestion. Zhejiang Economy,17:35-36(in Chinese)

[8] Ming Chen.(2010).The transmigration of Beijing-Tibet high-speed congestion and ease. Guangzhou: Southern Weekend. http://www.infzm.com/content/50121 .(in Chinese)

[9] Shah, S. A. A., H. Kim, et al. (2008). System architecture of a decision support system for freeway incident management in Republic of Korea. Transportation Research Part a-Policy and Practice 42(5): 799-810.

[10] Yin, Y. F., W. H. K. Lam, et al. (2004). New technology and the modeling of risk-taking behavior in congested road networks. Transportation Research Part C-Emerging Technologies 12(3-4): 171-192.