Research on Coordinate Systematic Analysis for Traffic and Regional Economy*

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Abstract Traffic infrastructure construction investment has obvious multiplier effect on regional economy and has always been viewed as an important and efficient method to maintain China's economic growth for dozens of years, especially after the financial crisis in 2008. Combining with the giant scale construction investment background in 2008, this paper selects a general and representative region to analyze the correlation and developing coordination between the traffic investment and regional economy growth from the point of systems engineering. Base on these, the paper puts forward suggestions and countermeasures that include cutting down the scale of traffic construction, shifting the construction emphasis to urban public transportation, etc.

Key words Regional economy; Traffic construction; GM(1,n); Coordination; System analysis

1 Introduction

1.1 Research condition at home and abroad

There exists intensive and strong relationship and interaction (investment and promotion, and etc) between transportation infrastructure construction and the development of social and economic system. This field has been approached differently by researches and traffic engineers at home and abroad on the basis of different subjects and technologies, such as macroeconomics, industrial economics, regional economics, system engineering, human geography, and traffic planning, etc.

Researchers have carried out a substantial amount of representative work from theoretica [1-6] and practical[7-21] viewpoints. Theoretical researches include the relationship and correlation among transportation, transport investment and economic development (Ma JL in 1998, Tang JX in 1999, David Banister, and Joseph Berechman in 2000, Jacob B-Polak, Arnold Heertje in 2000), traffic investment policies' influence on regional growth (John S. Miller et al in 2008), and transportation system coordination (Zhang SR and Yan BJ in 2002), etc. Practical researches include the relationship and correlation analysis between traffic construction and regional economic, investment and population[7-10] (David Banister and Yossi Berechman in 2001, Jin FJ, Dai TQ and Wang JE in 2005, Ellington DB, Hoel LA and Miller JS in 2005, Gong DY and Jiang AM in 2004), policy[11-14] (Zhou XZ and Zhang Q in 2000, Boarnett MG and Haughwout AF in 2000, Forkenbrock DJ in 2002, Ren H in 2008), industry [15] (Yang ML in 1989), and social system coordination analysis[16-19] (Wang CHX in 1999, Wang CHX in 2000, Zha WX, Xiong GL, and Liu HL, et al in 2007, Pei YL, Wang YG, and Yang G in 2008), etc. Still, there is a series of domestic research, including the practical research that aimed at specific region [20-21] (He GD in 2000, Lu J, Wang W, and Li XJ, et al in 2000).

1.2 Background analysis

In China, traffic infrastructure construction investment has always been playing the key role in triggering and impelling the domestic economy growth in recent years. However, to a certain degree, policy direction and the need of economy increasing have exceeded the rational thinking and also have caused various negative problems. For example, simply seeking an unduly high-grade mode of transportation resulted in investment imbalance, the low utilization rate or idle using of part of the traffic infrastructure also led to many other associated issues.

In 2008, the Chinese central government approved a giant scale stimulus package plan estimated at 4 trillion yuan in total (about 570 billion U.S. dollars). It will be spent over the next two years to finance programs in 10 major sectors, such as low-income housing, rural infrastructure, water, electricity, transportation, environment, technological innovation and rebuilding from the devastating earthquake in Sichuan. Transport infrastructure investment including railway, highway and airport construction, which accounted for a large proportion of the sharing (about 37.5%).

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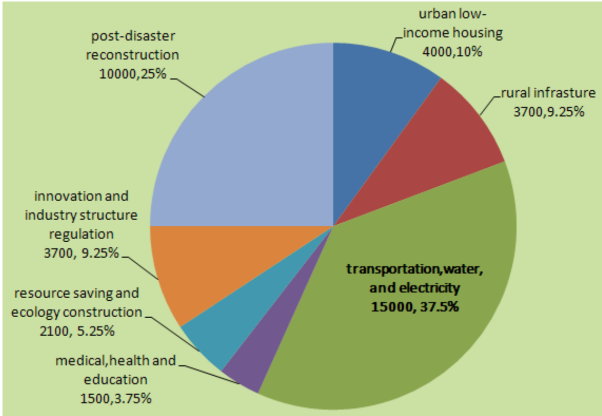
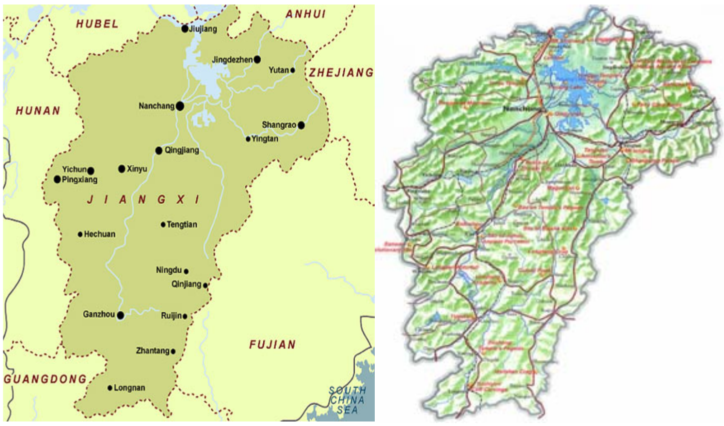


Note: data origin: National Development and Reform Commission of P.R.China, and the unit is one hundred million Yuan.

Figure 1 Distributed Amount and Proposition of 4 Trillion Yuan Investment

It is necessary for us to think about and discuss the problem of the necessity of giant scale investment, and capital rationing, etc., under this special background. Most of provinces in China are hedged about with economic and financial difficulties (especially the province in the west and central of China, which approximately account two-thirds of total), the effectiveness of this kind of investment are hence urgently needed as well as significant. With a view to the central government's strategic plan in 2006 to build an integrated transport hub in central China, this paper selects Jiangxi province as the object against the background of massive investment in 2008, and carries out venture research of driving effect, correlation and coordination between traffic construction and regional economic increasing, and study the rationality of the investment.

Jiangxi, located in the middle west of China, is a typical region where industry is less developed. However, various transportation modes are relatively complete and each mode plays an important role. The traffic construction investment scale, grade structure and the speed of construction are all relatively prominent in recent years in China. For these reasons, not only the analysis will be more valuable and representative, but the analysis on investment results and consequences will be of great practical significance. All these have great value for other similar regions of China.



Note: map picture origin: http://www.maps-of-china.com/jiangxi-s-ow.shtml

Figure 2 Jiangxi Province Position in China and Topographic, Transport Illustrate Map

2 Algorithms and Models

2.1 Correlation analysis algorithm and model: grey relation analysis

Grey analysis uses a specific concept of information. It defines situations with no information as black, and with perfect information as white. Though, neither of these idealized situations ever occurs in reality. In fact, situations between these extremes are described as being grey, hazy or fuzzy.

Therefore, a grey system means that a system in which part of information is known while part unknown.

With this definition, information quantity and quality form a continuum from a total lack of information to complete information – from black through grey to white. Since uncertainty always exists, one is always somewhere in the middle, somewhere between the extremes, somewhere in the grey area.

Grey analysis then comes to a clear set of statements about system solutions. At one extreme, no solution can be defined for a system without any information. At the other extreme, a system with perfect information has a unique solution. In the middle, grey systems will give a variety of available solutions. Grey analysis does not attempt to find the best solution, but does provide techniques for determining a good solution, an appropriate solution for real world problems.

Grey relation analysis describes the relation of various systems by using of the correlation coefficient of subsystems or factors. It is fit for the dynamic trend changing analysis of system[16-18], if the changing trend of various systems during the development process are consistent, then these systems can be viewed has strong correlation, and, similarly, weak relationship with smaller correlation coefficient. This provides a quantified measurement for system dynamic trend analysis. Combined with other methods, grey correlation analysis also can be amplified in related research fields [19-20].

2.2 Coordinate analysis algorithm and model: GM (1, n)

Coordinate degree is a quantified index that is used to elaborate the coordinate and cooperation condition among various systems. Set the system development synthesis evaluation function of traffic construction and regional economic system at time point t is $F_T(t)$ and $F_E(t)$ (equivalent to $X_T^{(0)(t)}$ and $X_E^{(0)(t)}$) respectively, and then the smaller the deviation coefficient is(Formula.1), the development of two systems coordinates more.

$$H(t)=\frac{\left|F_T(t)-F_E(t)\right|}{\frac{1}{2}\left|F_T(t)+F_E(t)\right|} \tag{1}$$

The coordinate degree can also be defined as:

$$H(t)=\left|\frac{F_T(t)\times F_E(t)}{\left|\frac{F_T(t)+F_E(t)}{2}\right|^2}\right|^K \tag{2}$$

In this paper, GM(1, n) is not only to be used to analyze the dynamic function between system function variable and system behavior variable, but to calculate the coordinate coefficient and degree as well [16-17]. Set $X_1^{(0)}$ as system behavior variable and $X_i^{(0)}$ as system function variable, and i = 1, 2, 3, …,n.

$$X_1^{(0)}=[X_1^{(0)}(1),X_1^{(0)}(2),\cdots X_1^{(0)}(n)],X_2^{(0)}=[X_2^{(0)}(1),X_2^{(0)}(2),\cdots X_2^{(0)}(n)] \tag{3}$$

$X_1^{(0)}$ and $X_i^{(0)}$ is set as onetime cumulative sequence.

$$X_1^{(0)}(k)+aM_1^{(1)}(k)=\sum_{i=2}^{n}b_i\cdot X_i^{(0)}(k) \tag{4}$$

$$M_1^{(1)}(k)=0.5X_1^{(1)}(k)+0.5X_1^{(1)}(k-1) \tag{5}$$

Formulated as differential form is:

$$(1+0.5a)X_1^{(0)}(k)+0.5aX_1^{(1)}(k-1)=\sum_{i=2}^{n}b_iX_i^{(0)}(k) \tag{6}$$

When a<0, X_i will exert a positive promotion effect on itself, and this indicates that the system X_i possesses self-development capacity in a certain degree, and on the contrary there is no such typical capacity.

In the formula, the correlation coefficient of b_2,…, b_n reflects the structure of the dynamic model GM(1,n).

When $b_2= b_3= \ldots =b_n = P$, GM(1,n) will be the GM(1,2):

$$(1+0.5a)X_1^{(0)}(k)+0.5aX_1^{(1)}(k-1)=\mathrm{P}\sum_{i=1}^{n}b_iX_i^{(0)}(k) \tag{7}$$

Where $b_2= b_3= \ldots =b_n = P$ indicates that each function of $X_2^{(1)}$, …, $X_n^{(1)}$ on X_1 is equal, but this condition can hardly be found in social reality and economy system.

If there is some i ($2 \le i \le n$) that makes $b_i < 0$ and $b_j \ge 0$ ($j \ne i$, $2 \le j \le n$), then the GM (1, n) is:

$$(1+0.5a)X_1^{(0)}(k)+0.5aX_1^{(1)}(k-1)=\sum_{j=2,j\neq i}^{n} b_j X_i^{(0)}(k)-\left|b_i\right| X_i^{(1)}(k) \quad (8)$$

Under this condition, $X_i^{(1)}(k)$ has inhibition on $X_1^{(0)}(k)$, and if:

$$\left|b_i\right| = \sum_{j\neq i}^{n} b_j X_j^{(1)}(k) / X_i^{(1)}(k) \quad (9)$$

$X_1^{(0)}(k)$ will not get any positive impulse from function variable. Generally, this condition can only occur in one or several typical points but not all of them.

When $X_j^{(1)}(k)$ ($j= 2, \cdots, n$, $j \ne i$,) vary monotonously, only one point appears this condition, and meanwhile with the gradual increase of $|b_i|$ the counter action of function variable on behavior variable will increase and relevant control measures is needed.

When there exist some i ($2 \le i \le n$), that makes $b_i >> |b_j| \ge 0$ ($j \ne i$, $2 \le j \le n$), then

$$(1+0.5a)X_1^{(0)}(k)+0.5aX_1^{(1)}(k-1)=\sum_{j\neq i} b_j X_i^{(1)}(k)+b_i X_i^{(1)}(k) \quad (10)$$

or:

$$(1+0.5a)X_1^{(0)}(k)+0.5aX_1^{(1)}(k-1)\approx b_i X_i^{(1)}(k) \quad (11)$$

According to the analysis above, two of definitions were introduced as followed.

First, when some $b_i \ge 0$ ($2 \le i \le n$), the function X_i has positive impulse on behavior variable X_1 , and when X_i has positive impulse on behavior variable X_1 with all of $i=2, \ldots, n$, then $X_2, \cdots, X_n$ are coordinate with X_1 in system structure.

Second, when $a<0$ and $X_1^{(0)}(k)>X_1^{(0)}(k-1)>0$, it dedicates that system behavior increases in quantity at point k and the system has self development capacity. On the contrary ($a<0$), there is no this kind of self development capacity.

3 Data Analysis

3.1 Indexes selection and correlation calculation

Table 3 Original Data of Traffic Construction Investment and Regional Economy of Jiangxi Province from 1985 to 2007

No.	1985	1990	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
A1	208	428	1169	1409	1605	1719	1853	2003	2175	2450	2830	3495	4026	4619	5469
A2	597	1134	2896	3452	3890	4124	4402	4851	5221	5829	6678	8189	9033	10769	12562
A3	48	119	391	488	581	661	740	817	881	962	1043	1188	1228	1501	1732
A4	207	254	503	517	569	570	589	597	622	682	689	707	719	765	805
A5	377	669	1537	1869	2107	2048	2129	2135	2231	2334	2457	2952	3269	3585	4098
A6	545	1094	3376	3780	4071	4251	4720	5103	5506	6335	6901	7559	8620	9400	11222
B1	12	25	78	101	115	145	167	194	216	243	261	300	378	432	501
B2	1481	1581	1640	2114	2114	2197	2245	2197	2201	2208	2208	2274	2280	2317	2409
B3	14171	18561	20942	21986	22557	24589	25328	34999	35093	36070	37791	40554	55171	63791	70346
B4	6630	4937	4937	4937	4937	4937	5537	5537	5537	5537	5560	5560	5560	5562	5612

Note: A1 is GDP, A2 is per GDP, A3 is Gross Product of the Third Industry, A4 is Employees Number of the Third Industry, A5 is per Capital Disposable Income of Village Residents, A6 is Income of Urban Residents, B1 is Product of Traffic, B2 is Railway Mileage, B3 is Highway Mileage, and B4 is Shipping Mileage. The unit of A1, A3, and B1 is hundred million Yuan, A2, A5, and A6 is Yuan, A4 is then thousand people, B2, B3, and B4 is kilometer.

Before using the above method, the original data should be standardized first. Then with the equation of $\Delta X_{i\text{-}0}(k)=|X_0(k)-X_i(k)|$, take GDP curve of A1 and each kind of traffic factors changing curve B as example, $\Delta X_{A1\text{-}i}(k)=|X_{A1}(k)-X_i(k)|$, $i=1,2,3,4$; $k=1,2,\ldots 15$.

$\Delta X_{A1\text{-}B1}$=(0.02,0.039,0.074,0.066,0.076,0.009,0.026,0.074,0.098,0.109,0.06,0.071, 0.103,0.092,0);

$\Delta X_{A1\text{-}B2}$=(0.592,0.573,0.387,0.526,0.47,0.474,0.457,0.393,0.346,0.27,0.161,0.154, 0.123,0.131,0);

$\Delta X_{A1\text{-}B3}$=(0.29,0.335,0.182,0.139,0.097,0.114,0.094,0.29,0.243,0.188,0.122,0.119,0.120, 0.107,0);

$\Delta X_{A1\text{-}B4}$=(1.133,0.765,0.563,0.485,0.429,0.396,0.466,0.423,0.374,0.295,0.19,0.176,0.163, 0.157,0).

The grey correlation degree between GDP and each item of traffic are: RA1-B1=0.926, RA1-B2=0.651, RA1-B3 = 0.802, RA1-B4= 0.624.

In the same way, the grey correlation coefficient between regional economy and each item of traffic construction are as follows.

The grey correlation coefficient between per GDP and each item of traffic are: *R*A2-B1=0.909, *R*A2-B2=0.623, *R*A2-B3 =0.788, *R*A2-B4=0.595.

The grey correlation coefficient between gross product of the third industry and each item of traffic are: *R*A3-B1=0.938, *R*A3-B2 =0.658, *R*A3-B3=0.836, *R*A3-B4=0.630.

The grey correlation coefficient between the number of employees of the third industry and each item of traffic are: *R*A4-B1=0.666, *R*A4-B2=0.792, *R*A4-B3=0.810, *R*A4-B4=0.736.

The grey correlation coefficient between per capital disposable income of village residents and each item of traffic are: *R*A5-B1=0.813, *R*A5-B2=0.698, *R*A5-B3=0.836, *R*A5-B4=0.669.

The grey correlation coefficient between per capital disposable income of urban residents and each item of traffic are: *R*A6-B1=0.895, *R*A6-B2=0.673, *R*A6-B3=0.872, *R*A6-B4=0.643.

According to the result of calculation, the correlation degree matrix between each item of traffic and regional economy is formatted.

3.2 Traffic and Regional Economy Coordinate Degree Calculation

Utilizing the algorithm and model above, selecting original statistical data of Jiangxi Province from 1999 to 2007, and calculating the coordinate relationship between transportation and regional economy, this paper tries to clear whether or not transportation coordinates with regional economy in structure and quantity in Jiangxi Province during various time periods.

Synthesis index of $X_T^{(0)}(t)$ (traffic and transportation system) and $X_E^{(0)}(t)$ (regional economy system) are:

$X_T^{(0)}(t)$ = (0.48695, 0.56704, 0.59078, 0.65412, 0.70838, 0.80349, 0.83649, 0.88266, 0.92029);

$X_E^{(0)}(t)$ = (0.40896, 0.47510, 0.5374, 0.56876, 0.61301, 0.65698, 0.70436, 0.78164, 0.85991).

(1) Applied with GM(1, 2), if set $X_E^{(0)}(t)$ as system behavior variable and $X_T^{(1)}(t)$ as function variable, where $X_T^{(1)}(t)$ is the per time cumulative value of $X_T^{(0)}(t)$, then:

$$(1+0.5a)X_E^{(0)}(t)+0.5aX_E^{(1)}(t-1)=b_T X_T^{(1)}(t) \tag{12}$$

Where a = -0.2163, and b_T= -0.1965.

(2) Set $X_T^{(1)}(t)$ as system behavior variable and $X_E^{(0)}(t)$as function variable, then:

$$(1+0.5a)X_T^{(0)}(t)+0.5aX_T^{(1)}(t-1)=b_E X_E^{(1)}(t) \tag{13}$$

Where a = 0.3171, and b_T= 0.2946.

4 Traffic Construction and Regional Economy Correlation Analysis

Based on the correlation coefficient calculation, we set each item of traffic construction as the independent variable and regional economy as the dependent variable, and then we can get the comparison of traffic investment correlation priority degree.

a: $R_{A1\text{-}B1} > R_{A1\text{-}B3} > R_{A1\text{-}B2} > R_{A1\text{-}B4}$;

b: $R_{A2\text{-}B1} > R_{A2\text{-}B3} > R_{A2\text{-}B2} > R_{A2\text{-}B4}$;

c: $R_{A3\text{-}B1} > R_{A3\text{-}B3} > R_{A3\text{-}B2} > R_{A3\text{-}B4}$;

d: $R_{A4\text{-}B3} > R_{A4\text{-}B2} > R_{A4\text{-}B4} > R_{A4\text{-}B1}$;

e: $R_{A5\text{-}B3} > R_{A5\text{-}B1} > R_{A5\text{-}B2} > R_{A5\text{-}B4}$;

f: $R_{A6\text{-}B1} > R_{A6\text{-}B3} > R_{A6\text{-}B2} > R_{A6\text{-}B4}$.

(1) The correlation degree between traffic construction total investment and GDP, per GDP, gross product of the third industry, the number of employees of the third industry, per capital disposable income of village residents, and per capital disposable income of urban residents separately is all high. The correlation degree between traffic construction total investment and per capital disposable income of urban residents is higher than the correlation degree between traffic construction total investment and the per capital disposable income of village residents. This is also fit to the actual condition.

(2) The correlation degree between traffic construction total investment and highway is higher than the others.

(3) The correlation degree between traffic construction total product and the number of employees of the third industry is low, combing with the fact that the traffic and transportation accounted for nearly 1/4 to 1/3 proportion of the third industry, we can draw a conclusion that the per product of the third industry is low. The connotation promotion is an urgent task for upgrading the level of traffic and transportation comprehensive services.

5 Traffic and Regional Economy Coordinate Development Analysis

(1) Traffic and transportation system effect on regional economy system

According to the definitions of 2.2, a<0 and indicates that regional system has self development capacity in 2007; b_T<0 and it indicates that traffic and transportation has little positive impulse effect on regional economy.

(2) Regional economy system effect on traffic and transportation system

Similarly, a>0 it indicates that traffic and transportation system has no self development capacity in 2007, b_E>0 and indicate that regional economy system still has obvious positive impulse effect on traffic and transportation system.

In general, despite the sum quantity of regional economy and traffic and transportation are both increasing over time, the coordinate condition is not satisfied.

6 Conclusions

Focusing on the series problems of traffic construction investment structure and proportion, traffic investment benefit, and coordinate of related systems, combing with the actual condition of financial strength, industrial development stage, and the need of regional economic growth of Jiangxi Province, the following conclusions can be drawn from the analysis above.

(1) For promoting the regional economic growth of Jiangxi Province in the future, it is necessary to invest in the traffic construction, but the scale of investment must be downsized, especially the expressway investment.

(2) While downsizing the investment scale, the proportion of traffic construction investment needs to be regulated.

(3) Not only the scale but the quality of traffic and transportation construction also needs to be improved.

(4) The focus of construction must be shifted from inter cities to inner cities and to upgrade the quality and capacity of urban public transportation, especially the periphery traffic hinge exchange with urban public transportation.

Traffic and transportation investment is complex system engineering and it involves various factors, such as environmental protection, financial condition, industrial development, and resource exploitation, etc. It is essential to summarize experience and deficiency. Only in this way, can the imbalance in the ratio of investment be avoid while the synthesis transportation system construction is considered, and waste of resource and reduction of social efficiency be prevented while the life of facilities and financial condition is taken in consideration.

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