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A study of the symbiotic relation between urban traffic and urbanization

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Abstract. In big cities of China, the urbanization process is always accompanied with deterioration of traffic situation. In this paper, we emphasize on the interaction between urban traffic and urbanization, together with the mechanism of this interaction. The study is based on not only the traffic theory, but also a creative analysis of the active function of urban traffic on urbanization, and the influence of urbanization on urban traffic layout. The goal of this study is to improve the healthy sustainable development between one and the other. Furthermore, we can offer the mode choice for the urban traffic development for Beijing.

Keywords: Urbanization, Urban Traffic, Symbiotic relation, Development strategy

1. Introduction

Nowadays, big cities of most countries are still suffering from the traffic jams. Traffic problems are always big troubles for them. The strategy of urbanization is not only an important way to enhance regional competitiveness, but also the key procedure to improve the development of modernization. In China, urbanization is now in an era of rapid development. Meanwhile, urbanization process can't avoid being accompanied by a lot of problems, such as energy shortage, environmental deterioration and traffic jams. A sustainable development strategy is necessary for urban traffic system. Therefore, we study the traffic development problem in the strategic level, namely integrating urban development and traffic development.

2. Basic properties of urbanization in China

Urbanization started from the mid-eighteenth century when the Industrial Revolution occurred. From then on, human society started the transformation from agricultural society to industrial society, as well as from rural lifestyle to urban lifestyle. Urbanization is defined as the procedure that rural population keeps transferring into urban population, which is always accompanied with the change of the ways that rural population live, think and work. This procedure, including the change of both society and economics, has a very deep and wide influence, which is the result of the law, that productivity determining production relations and conformity of the latter to the state of the former.

Since the Founding of the People's Republic of China, there happened a significant development of urbanization in China. There are some common properties between the urbanization in China and in the rest of the world. The economics keeps a high growth speed; industrial structure keeps optimizing; city space keeps compressing; big cities grow rapidly with small cities grow slowly relatively. Meanwhile, the urbanization also brings us some negative influences like energy shortage, environmental deterioration and traffic jams.

3. The interaction between urban traffic and urbanization

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The urbanization and urban traffic depend on and help each other. Urban traffic situation is an important condition for urban life and production, as well as a part of the city and its dynamics process. The development of urbanization includes the development of urban traffic, also drives and stimulates the relative improvement of urban traffic which will in turn satisfy the demand of urbanization[1]. The study of the relation between urbanization and urban traffic is for improving the healthy sustainable development between them.

3.1. The active function of urban traffic on urbanization.

Urban traffic keeps a powerful impact on the process of urbanization and people's living and working styles. It is urban traffic that undertakes, connects and realizes the enormous and complicated economical activities. Traffic facilities, means and organizations need to vary to satisfy the different demands of cities as their various properties, sizes and topographic structures. An effective urban traffic system will help maximizing the benefit of urban economics and the speed of urbanization, yet a noneffective one will do the negative relative influences. Urban traffic can raise the value of real estate, and affect the regional competitiveness and industrial development. Therefore, the development of urban traffic has an important active function on urbanization.

3.2. The influence of urbanization on urban traffic layout

With urbanization, there were changes of urban spatial structure, land using methods, urban population size and distribution. These changes essentially determined the intensity, density and spatio-temporal distribution of urban traffic and travel. Our urban patterns transferred from one-center to multi-center, from industrial cities to integrated cities, and from single city to professional and complementary multi-level cities community. This transformation broke the old regional concepts and the economical, social and cultural relation among urban residents; furthermore influenced the production mechanism of traffic demand in the whole cities and travel distribution properties. The increase of the number of urban motor vehicles and variety of urban traffic methods satisfied the increase of regional passenger and freight volume. Meanwhile, it helped regional transportation corridors become the axis of megalopolis together with commutative traffic circle conformation.[2] In addition, urbanization caused some problems for urban traffic, such as the increase of confliction between traffic supply and demand, serious traffic jam and difficult parking.

3.3. Symbiotic integration Model.

Based on the Population Ecology Theory, Logistic Growth is a fundamental population growth manner under limited circumstances. We employ LV model to describe the symbiotic relation between urban traffic and urbanization.

3.3.1 Assumptions and Symbols

In this model, we simply denote the variance of urban traffic and urbanization by the level of sustainable development, the characterization of which is used to describe the variance process of symbiosis. We state the associated assumptions and symbols as follows:

y(t) denotes the level of sustainable development at time t, where y is the dependent variable which changes as independent variable t changes. y_1(t) and y_2(t) denotes the level of sustainable development for urbanization and urban traffic at time t, respectively. y_1(t) is decided by urban economy, population and average income, living standard, and consumption level, while y_2(t) is decided by traffic facilities, transportation capacity, and management ability.

N provides how rich resources are, which is called Carrying Capacity. If given a fixed time period and a fixed region, then we assume factors, such as technologies, materials, labor force, capital, and market size, are fixed. Therefore, we assume N is a finite constant. N_1 and N_2 denote the maximal levels of sustainable development of urbanization and urban traffic independently decided by circumstances, respectively.

r>0, which is called Intrinsic increase rate, provides the average increase rate for research subject. We assume r is a constant. r_1 and r_2 denote the average increase rates of levels of sustainable development for urbanization and urban traffic, respectively.

y1/N1 and y2/N2 denote the proportions of ideal maximum taken by the achievement of levels of sustainable development for urbanization and urban traffic, respectively, which are also called Natural Growth Saturation. $(1-y_1/N_1)$ and $(1-y_2/N_2)$ denote the proportions of ideal maximum taken by the parts that are not achieved by levels of sustainable development for urbanization and urban traffic, respectively. They indicate the deceleration effect from the natural growth saturation upon the benefit growth of levels of sustainable development for both urbanization and urban traffic.

σ_1 denotes the distribution of natural growth saturation of urban traffic to the growth of level of sustainable development of urbanization, and vice versa for σ_1 $\sigma_2>0$, $\sigma_2>0$. If $\sigma_1>0$, then we can conclude that the distribution it stands for is greater than the deceleration effect that urbanization has to itself (its deceleration effect parameter is 1). The same to σ_2.

3.3.2 Modeling

Logistic growth model can describe the independent growth term of level of sustainable development for urbanization as follows:

$$y_1'(t)=r_1y_1(1-y_1/N_1) \quad (1)$$

The independent growth term of level of sustainable development for urban traffic is:

$$y_2'(t)=r_2y_2(1-y_2/N_2) \quad (2)$$

Also, since urbanization and urban traffic can exist independently, and affect each other when coexisting, their growth terms then become:

$$y_1'(t)=r_1y_1(1-y_1/N_1+\sigma_1y_2/N_2) \quad (3)$$

$$y_2'(t)=r_2y_2(1-y_2/N_2+\sigma_1y_1/N_1) \quad (4)$$

(3) and (4) describe the growth disciplines of urbanization and urban traffic of the considered region, which is the symbiotic integration model.

3.3.3 Equilibria and stability conditions

From (3) and (4), we know this is an ordinary differential equations (ODE) model, therefore we can solve by following steps:

Let: $f(x_1,x_2)=r_1x_1(1-x_1/N_1+\sigma_1x_2/N_2)$ (5)

$g(x_1,x_2)=r_2x_2(1-x_2/N_2+\sigma_1x_1/N_1)$ (6)

Let: $\varphi(x_1,x_2)=1-x_1/N_1+\sigma_1x_2/N_2$ (7)

$\phi(x_1,x_2)=1-x_2/N_2+\sigma_1x_1/N_1$ (8)

From (5) and (6), since (3) and (4) are ODE

Let: $\begin{cases} f(x_1,x_2)=0 \\ g(x_1,x_2)=0 \end{cases}$ Solutions are: $P_1(N_1,0)$, $P_2(0,N_2)$

$P_3[\frac{(\sigma_1+1)N_1}{1-\sigma_1\sigma_2},\frac{(\sigma_2+1)N_2}{1-\sigma_1\sigma_2}]$, $P_4(0,0)$, which are four equilibria of (3) and (4).

To analyze the stability of the symbiotic integration for the levels of sustainable development of urbanization and urban traffic in this region, we carry on the following steps:

Let $A=\begin{pmatrix} f_{x_1} & f_{x_2} \\ g_{x_1} & g_{x_2} \end{pmatrix} \overset{(2)(3)}{=} \begin{pmatrix} r_1-2r_1\frac{x_1}{N_1}+\sigma_1r_1\frac{x_2}{N_2} & \sigma_1r_1\frac{x_1}{N_2} \\ \sigma_2r_2\frac{x_2}{N_1} & r_2-2r_2\frac{x_2}{N_2}+\sigma_2r_2\frac{x_1}{N_1} \end{pmatrix}$

And let $p=-(f_{x_1}+g_{x_2})|_{P_i}$, $q=\det(A)|_{P_i}$, $(i=1,2,3,4)$

$\Rightarrow \lambda=\frac{1}{2}(-P\pm\sqrt{p^2-4q})$. The values at P_i are shown in the following table:

Table 1 The equilibria and stability of the symbiotic integration model

P_i	p	q	Stability condition
P_1	$r_1 - r_2(1+\sigma_2)$	$-r_2 r_1(1+\sigma_2)$	Unstable
P_2	$r_2 - r_1(1+\sigma_1)$	$-r_2 r_1(1+\sigma_1)$	Unstable
P_3	$\frac{r_1(1+\sigma_1)+r_2(1+\sigma_2)}{1-\sigma_1\sigma_2}$	$\frac{r_1 r_2(1+\sigma_1)(1+\sigma_2)}{1-\sigma_1\sigma_2}$	$\sigma_1\sigma_2 < 1$
P_4	$-r_1 - r_2$	$r_1 r_2$	Unstable

Local stability analysis,We can see that only when $\sigma_1\sigma_2 < 1$, P_3 is stable, levels of sustainable development of urbanization and urban traffic will go to nonzero final values, respectively. Otherwise, since these two can both exist independently and affect each other, it will make them both go to infinity.

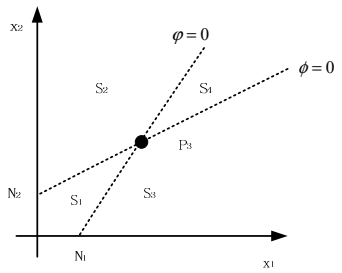
Global stability analysis

We can sketch a graph based on (4) and (5), and we discuss under the assumption that $r_{1,2} > 0$ and $x_{1,2} \geq 0$.

It is clear from the expression of P_3 that, in order to make P_3 meaningful, i.e., located in the first quadrant of the plane（$x_{1,2} \geq 0$）, one of the following two conditions must be satisfied:

$$A_1 : \sigma_1 < 1, \sigma_2 > 1, \ \sigma_1\sigma_2 < 1; \quad A_2 : \sigma_1 > 1, \sigma_2 < 1, \sigma_1\sigma_2 < 1$$

From table 1: P_3 is stable only under the condition A_1. Straight lines $\varphi = 0$ and $\phi = 0$ separate the plane（$x_{1,2} \geq 0$）into 4 regions: S_1: $x_1 > 0$, $x_2 < 0$; S_2: $x_1 > 0$, $x_2 > 0$; S_3: $x_1 < 0$, $x_2 > 0$; S_4: $x_1 < 0$, $x_2 < 0$。Picture 1sketchs the graph of phase trajectory under the condition A_1.



Picture 1 Graph of phase trajectory when P_3 is stable

When $\sigma_1\sigma_2 < 1$, the equilibrium $P_3[\frac{(\sigma_1+1)N_1}{\sigma_1\sigma_2-1}, \frac{(\sigma_2+1)N_2}{\sigma_1\sigma_2-1}]$ is stable, therefore levels of sustainable development of urbanization and urban traffic will go to nonzero final values, respectively. Otherwise, since these two can both exist independently and affect each other, it will make them both go to infinity.

To sum up, under the reasonable macro-economic control by the government and the market economy system, we need to integrate the transportation system with economy and ecology systems. By the promotion effect from the demand from economic and social development upon integrated transportation system, together with the effect from mechanism of division in the integrated transportation system, it will become a kind of positive dynamical development with coordination, cooperation, mutual adaptation and promotion.

4. References

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