Hindawi Publishing Corporation
Discrete Dynamics in Nature and Society
Volume 2012, Article ID 710854, 23 pages
doi:10.1155/2012/710854

Research Article

Transportation Structure Analysis Using SD-MOP in World Modern Garden City: A Case Study in China

Jiuping Xu,[1,2] Jing Yang,[1,2] and Liming Yao[1,2]

[1] *Low-Carbon Technology and Economy Research Center, Sichuan University, Chengdu 610064, China*
[2] *Uncertainty Decision-Making Laboratory, Sichuan University, Chengdu 610064, China*

Correspondence should be addressed to Jiuping Xu, xujiuping@scu.edu.cn

Received 6 July 2012; Revised 7 September 2012; Accepted 26 September 2012

Academic Editor: Wuhong Wang

The idea of the "garden city" was developed theoretically to offer solutions to serious city development problems such as traffic congestion, population, and environmental pollution, among which the transportation is considered the most important. The question is how to develop balanced transportation in a garden city. Transportation is a complex system, particularly in a garden city. Therefore, we establish a new approach named the transportation multiobjective optimization system dynamics (SD-MOP) model, which firstly calculates the optimal proportion of different transport means with an MOP approach and then applies them to the dynamic transportation system to analyze the results and analyze the influence on the whole system using different transportation means variation. In this paper, we take Chengdu as an example, one of the few cities in the world declared as building a garden city, and then develop some recommendations about world modern garden city transportation system development.

1. Introduction

It is generally recognized that cities are experiencing huge change in terms of their development and mobility patterns, while transportation, and will continue to plays, a critical role in city development [1–3]. Energy consumption is one of the most severe transportation problems. IEA [4] argues that transport plays an important role in addressing the challenges of climate change mitigation as it consumes nearly half of global oil and contributes 25% of total fossil fuel combustion-related CO_2 emissions of the world, and road transport is responsible for about 75% of the emissions from the transport sector. Petri et al. [5] compare the development of transport and energy use with a focus on CO_2 emissions and suggest a more sustainable passenger transport system. Dominic [6] examines recent temporal and spatial trends and forecasts in energy consumption, energy efficiency, and energy costs in the transport sector across Europe. Meanwhile, land use, health effects, employment, population growth, and transport alternatives are all considered as related to the transportation problems. Frank [7] focused on land use, noting that, with different land uses, traffic designs need to be different. Messenger and Ewing [8] think that employment, the balance of living space, ownership, and the public transport service level affect people's transport choice. Martin [9] investigates the association between means of transportation to work and overweight and obesity. In this paper, transportation structure is our main concern to the research. Transportation structure is the proportion of traffic amount carried by different transport means in extent of time and space. As the transportation structure directly influences resource allocation, a reasonable urban transportation structure can contribute to the rational use of resources and ensure a well-functioning system [10]. Although these studies have contributed a lot to transportation, we feel that all of the studies had not analyzed the transportation in a systematic and dynamic way. Thus, this paper seeks to further research in solving transportation problem and differs from its predecessors and we hope to introduce completely and accurately new viewpoints and models and research.

China is the largest developing country in the world. With rapid process of industrialization and urbanization, China has maintained an extensive growth in economic development while the deficiency of transportation began to emerge and became an urgent problem for us to deal with. Traffic congestion exists widely in metropolitan [11] capacity excess or overload caused by road passenger volume [12], which has already led to problems such as environmental pollution, lack of rational planning [13], economic intervention, and greenhouse gas emission excess [14]. Steps need to be taken to prevent the situation from deteriorating, otherwise, in return, this may hinder the development of the world modern garden city.

The "garden city" was first proposed by Howard [15] in the late 19th century, which came into being with the overcrowded, pollution, and epidemic spreading problems. It focuses on the coalition of city and countryside in essence and, later, makes some city planning about city scale, layout and structure, population density, and green belt [16]. A garden city is designed for health, life, and industry; it contains both rural and urban areas and has a strictly controlled city scale. It is the farmlands and towns around the central cities that control the expanding of urban land without limit. The garden city can ensure every resident to be close to nature and surrounded by self-sufficient farmland; especially in an ideal garden city, the land belongs to the public and under the responsibility of a professional committee. Therefore, the world modern garden city has its own features that differ from the ordinary city. Firstly, the form and pattern of garden city are multicenter, networking, and clustered in development along with being humanized in urban spatial structure. Secondly, harmonious nature and society: there are two kinds of harmony which refer to the strengthening of ecology and environment, social welfare, and wellbeing. Thirdly, the development path: the city aims to modern service industry and headquarters economy as the core, for the direction of high-tech industry, based on the powerful modern manufacturing industry and agriculture, all of which projects to be an internationally regional hub and central city on the basis of to be western and national central city. Fourthly, land use layout and transportation: it is the decentralized layout that is put into use in garden city, while in ordinary city, the public buildings are always arranged in concentrated form.

To realize the construction of world modern garden city, transportation should play its due role in it and act as a stimulus to promote it. As for the transportation in garden city, we think it is the traffic arteries that connect the central city with peripheral group city, with the agricultural land scattered around it, which finally realize the garden city. And the key way to build a world modern garden city is to promote the modernized and intellectualized transportation, that is, to make the linking of the urban and rural areas come true. In garden city, environmental and faster high-speed railway is the best choice to create the traffic circle in connecting between cities. In order to construct garden city, the transportation should match the development of garden city, and, in turn, the garden city will surely promote the transportation construction. Therefore, a strategy is needed to balance transportation system development and garden city construction, as transportation is an essential element of its success. Since regional transportation system is constantly changing, it is necessary to find a dynamic simulation method. System dynamics (SD) approaches as a modeling tool to provide a flexible way of building simulation models from causal loop or stock and flow diagrams. Therefore, to reflect the dynamic characteristics of garden city transportation system, the SD approach is the main methodology used in this paper, combined with multiobjective optimization (MOP) for its effectiveness.

The aim of this paper is to propose a system dynamics and multiobjective programming integrated support model to predict and adjust transport structure for the modern garden city in the world. The remainder of this paper is structured as follows. Section 2 describes the general system and solution approach problem. Section 3 develops a detailed garden city transportation system based on the SD-MOP model. In Section 4, Chengdu in China is discussed as a case study. Finally, we present some conclusions and proposals for the development of the transportation system in Chengdu and other garden cities in the world.

2. Problem Description

In this Section, a description of the problem is discussed, then a general framework to address the given problem is proposed. We give a basic background for our study.

2.1. System Description

It is of great significance to analyze logical urban transportation system in Chengdu, because it can assist in the development and management of the transportation plan and has a practical significance in helping relieving city traffic congestion [17]. Transport structure is an important factor in the whole system; a reasonable logic transport structure is a part of city planning and the adjustment of industrial structure, meanwhile, it guarantees minimum time waste, costs, and environment pollution.

As has been mentioned, an urban transportation system is a complex system and is especially important in the development of the garden city. With population, transport means, transport congestion, transport demand, and vehicle travel time are emerging as concerns in transportation system analysis. These elements are highly interrelated, but they are not the only factors that affect the system, there is also social, economic, political, environmental, and technical factors [17]. From previous research [18, 19], we assume that the garden city transportation system consists of five subsystems: the economic subsystem, the environmental subsystem, the traffic congestion subsystem, the policy management subsystem, and the traffic mode subsystem. The whole system is constantly changing and has an interrelationship with each other. Figure 1 shows the relationships between them. With economic development, there are more travel demand and transport choices or modes, and if

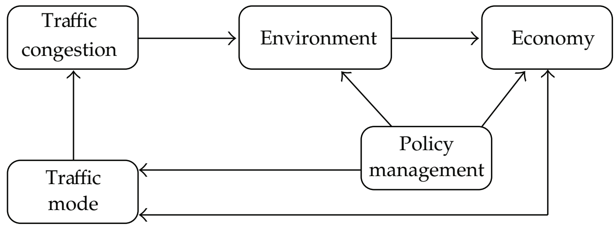

Figure 1: The subsystems of garden city transportation system.

not managed properly, they will lead to traffic congestion, which can result in environmental pollution, and, in turn, impacts the economy. However, through manual intervention, policy management can be used to control these effects when necessary.

2.2. Method Design

System dynamics (SD) is a simulation technology that studies complex systems based on feedback control theory. It establishes synthetical models using system structures, the relation of consequent to antecedent and feedback loops, and, further, to find the solution to system performance using simulations. SD has been applied to a number of studies, not only the social sciences field, but also the agricultural practices [20], environmental issues [21], and economic controls [22] and has proven to be especially appropriate for modeling problems. Meanwhile, a number of system dynamics (SD) approaches have been used to do transportation modeling [23, 24], which give us successful examples for our research. SD can be used to forecast the trends in the next ten years by using certain parameters, but cannot be used to estimate exact levels reliably [25–27]. Therefore, while a system dynamics method is used as the main approach, we introduce multiobjective programming in the system dynamics model to develop an integrated model, which we call a system dynamics multiobjective programming model (SD-MOP), for the solution. The SD-MOP model not only provide better understanding of complex problems but also have considered the multiple objectives and also involve expert opinions in the decision. A general framework of the modeling process is shown in Figure 2. In a garden city transportation system decision process, a thorough analysis of the decision problem is conducted. Then, using the system dynamics (SD) approach, a causal loop diagram and detailed flow diagram are established. We run a series of MOPs to get the optimum value of those sensitive variables, and place these values into the SD model for simulation. Based on results of the SD-MOP integrated approach, different policy experiments are compared to choose the best route. If we are not satisfied with the result of the simulation, we can adjust the MOP models to yield better results; otherwise, the decision process is ended.

2.3. Basic Assumption

The basic assumptions of a garden city transportation system are as follows.

(1) The main environmental pollution emissions we consider are CO_2, excluding the exhausted gas from motorcycles.

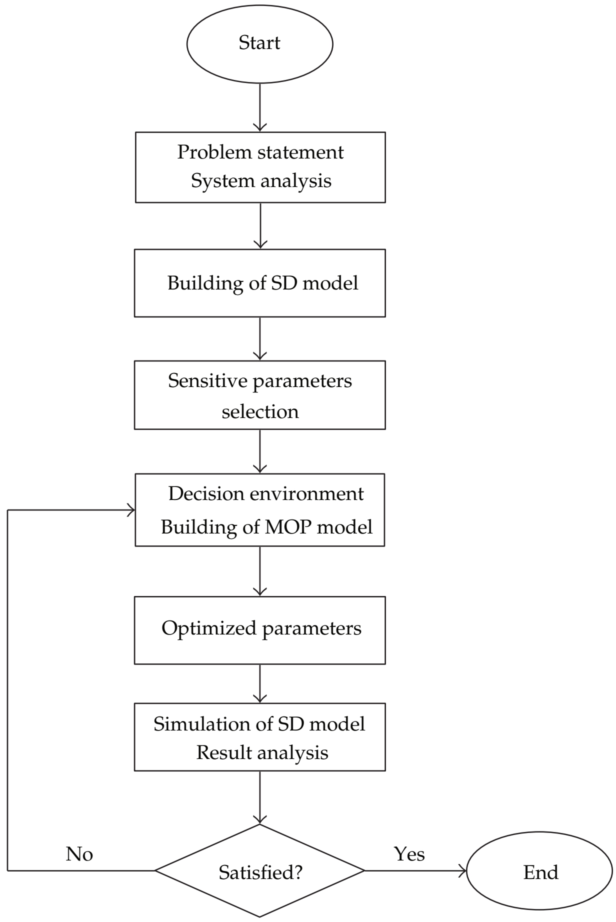

Figure 2: The general framework of the modeling process.

(2) We consider private cars, buses, taxis, and rail as the four main transportation means that directly influence transportation congestion and ignore others such as bicycles, pedestrians, and others.

(3) The influence of employment is ignored in the whole system so the employment is ignored.

(4) We use gross domestic product (GDP) to measure the economic development.

(5) The purpose of this study is to promote coordinated economic development, environmental protection, policy management, and population through the optimization of transportation construction and structure.

2.4. Index System

The transportation system is one of the most complex systems in modern city. Similarly, the analysis of transportation has been a vital element in world modern garden city. Factors analysis is an effective way to understand the structure and function of a system well. According to the subsystems of garden city transportation system (Figure 1) and the characteristic of world modern garden city, we analyze the subdivision of each subsystem by selecting variables and influential factors synthetically based on the relative theoretical basis and the existing and our own research foundation, in principle of integrality, objectivity, scientificity, nonlinearity, practicality, and availability. Here, we list the main variables and influential factors of this model in Table 1 (variables and symbols in garden city transportation system). In order to facilitate our research and establish a mathematical model, we sort them according to the symbol of the name.

3. Modelling

Referring to the system description for garden city transportation structures, we construct a corresponding model. Firstly, the system dynamics general model is constructed. Secondly, a model is established, and the system dynamics model based on multiobjective optimization (SD-MOP) is developed. Finally, the model simulation method is analyzed.

3.1. System Dynamics Model

This Section is divided into two parts for a particular description of the modeling; firstly, the cause-effect relationship diagram, and, secondly, the stock and flow diagram, both of which are the two main steps when using system dynamics.

3.1.1. Cause-Effect Relationship Diagram

The SD model for the present study is developed for a transportation system. There are many variables in the subsystems occupying important positions in the system; thus, we build the cause-effect relationship diagram (see Figure 3) by incorporating the various features associated with the system. In this Figure, the arrows denote the cause-and-effect relationships and the plus and minus signs denote the positive and negative effects, respectively. The main feedback loops are given below:

(1) economic development $\xrightarrow{+}$ total number of vehicles $\xrightarrow{+}$ transportation congestion $\xrightarrow{+}$ environmental pollution $\xrightarrow{-}$ economic development;

(2) population $\xrightarrow{+}$ trip demand $\xrightarrow{+}$ total trips $\xrightarrow{+}$ transportation congestion $\xrightarrow{-}$ economic development $\xrightarrow{-}$ urban population;

(3) economic development $\xrightarrow{+}$ infrastructure investment $\xrightarrow{+}$ road investment $\xrightarrow{+}$ road capacity $\xrightarrow{-}$ transportation congestion $\xrightarrow{-}$ economic development;

(4) policy management $\xrightarrow{+}$ economic development $\xrightarrow{+}$ environmental pollution $\xrightarrow{-}$ policy intervention.

3.1.2. Stock and Flow Diagram

The causal relationship diagram emphasizes the feedback structure of the system, which, however, can never be comprehensive. We need to convert the causal relationship diagram

Table 1: Variables and symbols in garden city transportation system.

Sort	The meaning of variables	Variable units	Symbol
1	Road passenger capacity	Yuan	LEV_{CR}
2	Railway passenger capacity	Yuan	LEV_{CRW}
3	Exhaust emission	g	LEV_{EE}
4	Emission intensity	g	LEV_{EI}
5	Environmental pollution	L	LEV_{EP}
6	Fuel consumption volume	L/100 km	LEV_{FC}
7	Gross domestic product	Ten thousand	LEV_{GDP}
8	Investment of bus	Yuan	LEV_{I_1}
9	Investment of taxi	Yuan	LEV_{I_2}
10	Investment of railway	Yuan	LEV_{I_3}
11	Investment of infrastructure	Yuan	LEV_{II}
12	Investment of public transportation	Km	LEV_{IPT}
13	Investment of road	Yuan	LEV_{IR}
14	Length of road	Km	LEV_{LR}
15	Length of railway	Km	LEV_{LRW}
16	Number of buses	Ten thousand	LEV_{N_1}
17	Number of taxies	Ten thousand	LEV_{N_2}
18	Number of railbus	Ten thousand	LEV_{N_3}
19	Number of private cars	Ten thousand	LEV_{N_4}
20	Private car increment	Ten thousand	LEV_{PC}
21	Turnover of bus	Person/km	LEV_{T_1}
22	Turnover of taxi	Person/km	LEV_{T_2}
23	Turnover of railway	Person/km	LEV_{T_3}
24	Turnover of private car	Person/km	LEV_{T_4}
25	Traffic intensity	Person	LEV_{TI}
26	Traffic load	Person/yuan	LEV_{TL}
27	Total population	Ten thousand	LEV_{TP}
28	Travel volume of bus	Person/day	LEV_{V_1}
29	Travel volume of taxi	Person/day	LEV_{V_2}
30	Travel volume of railway	Person/day	LEV_{V_3}
31	Travel volume of private car	Person/day	LEV_{V_4}
32	Travel volume of public transport	Person/day	LEV_{VPT}
33	Travel volume of total trip	Person/day	LEV_{VT}
34	Rate of average trip	%	RAT_A
35	Transformation coefficient of bus	km/yuan	RAT_{C_1}
36	Transformation coefficient of taxi	km/yuan	RAT_{C_2}
37	Transformation coefficient of railway	km/yuan	RAT_{C_3}
38	Transformation coefficient of private car	km/yuan	RAT_{C_4}
39	Coefficient of discharge	g/L	RAT_D
40	Coefficient of economic decrease	Yuan/g	RAT_{ED}
41	Coefficient of emission factor	g/person	RAT_{EF}
42	Coefficient of environmental influence	No dimension	RAT_{EI}
43	GDP growth rate	%	RAT_{GDP}
44	Investment proportion of infrastructure	%	RAT_{II}
45	Investment proportion of public transportation	%	RAT_{IPT}
46	Investment proportion of road	%	RAT_{IR}

Table 1: Continued.

Sort	The meaning of variables	Variable units	Symbol
47	Public transportation share rate	%	RAT_{SR_1}
48	Private car share rate	%	RAT_{SR_2}
49	Trip frequency of total average	Times	RAT_{TF}
50	Net growth rate of population	%	RAT_{TP}
51	Peak hour flow of bus	Person/times	PHF_1
52	Peak hour flow of taxi	Person/times	PHF_2
53	Peak hour flow of railway	Person/times	PHF_3
54	Peak hour flow of private car	Person/times	PHF_4
55	Travel distance of bus	km	TD_1
56	Travel distance of taxi	km	TD_2
57	Travel distance of railway	km	TD_3
58	Travel distance of private car	km	TD_4
59	Trip frequency of bus	Times	TF_1
60	Trip frequency of taxi	Times	TF_2
61	Trip frequency of railway	Times	TF_3
62	Trip frequency of private car	Times	TF_4
63	Investment proportion of bus	%	x_1
64	Investment proportion of taxi	%	x_2
65	Investment proportion of railway	%	x_3
66	Investment proportion of private car	%	x_4

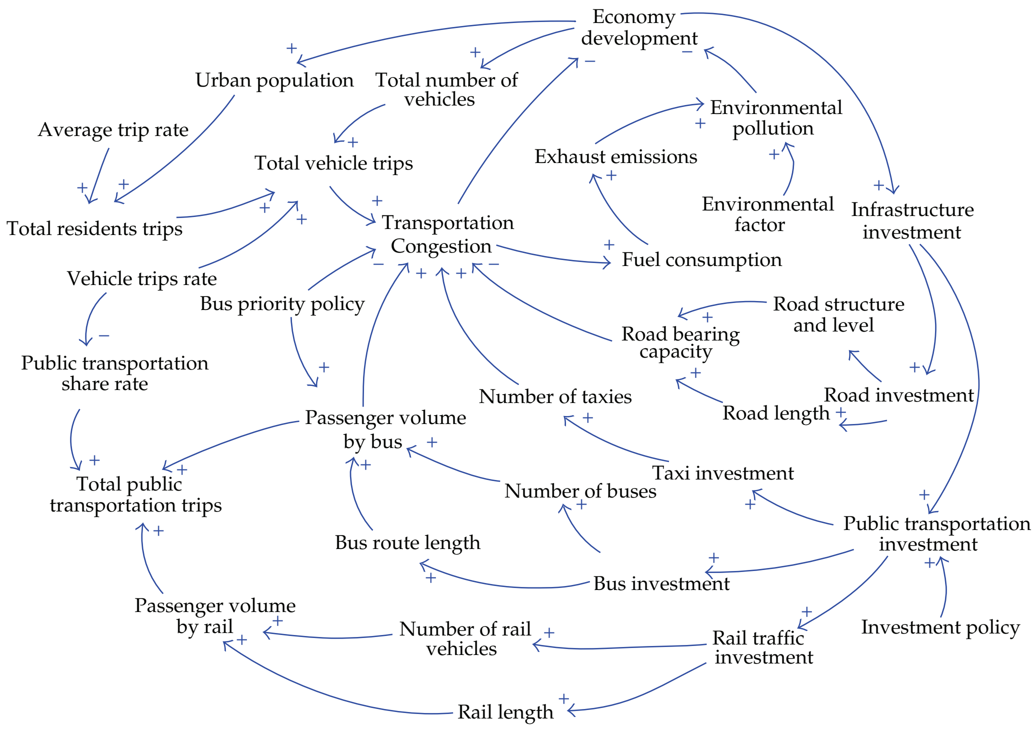

Figure 3: The cause-effect relationship diagram of garden city transportation system.

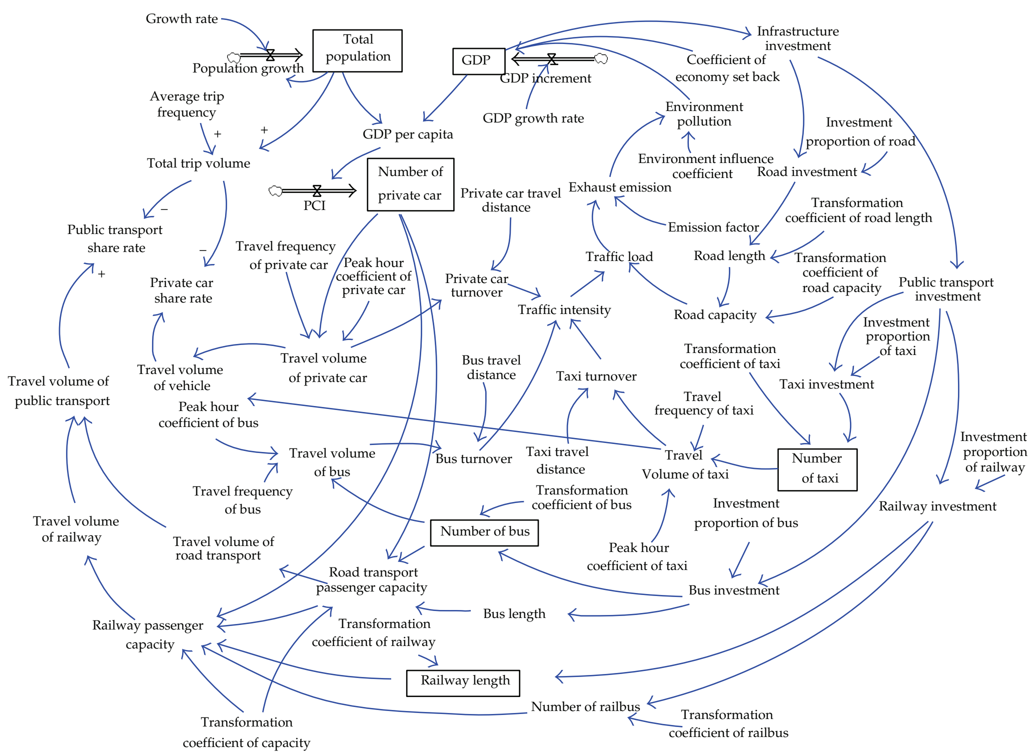

Figure 4: The stock and flow diagram of garden city transportation system.

into the stock and flow diagram that emphasizes the physical structure of the model, which tends to be more detailed than the causal loop diagram [28], to force us to think more specifically about the system structure. Figure 4 gives a detailed description, with the main formula as follows.

Through system dynamics modeling, we can get the first-order differential equations. The change rate of the turnover of bus, the $d(\mathrm{LEV}_{T_1}(t))/dt$, is dependent on the stock of the turnover of bus $\mathrm{LEV}_{T_1}(t)$, and there exists the basic stock O_{T_1}, which is subject to factors of transport planning, demand volume, and so on; besides, it would be effected by functioning time OT, which regularly means one year:

$$\frac{d(\mathrm{LEV}_{T_1}(t))}{dt} = \frac{\mathrm{LEV}_{T_1}(t) - O_{T_1}}{OT}. \tag{3.1}$$

Similarly, the differential equations of the turnover of the taxi, railway, and private car are

$$\begin{aligned} \frac{d(\mathrm{LEV}_{T_2}(t))}{dt} &= \frac{\mathrm{LEV}_{T_2}(t) - O_{T_2}}{OT}, \\ \frac{d(\mathrm{LEV}_{T_3}(t))}{dt} &= \frac{\mathrm{LEV}_{T_3}(t) - O_{T_3}}{OT}, \\ \frac{d(\mathrm{LEV}_{T_4}(t))}{dt} &= \frac{\mathrm{LEV}_{T_4}(t) - O_{T_4}}{OT}. \end{aligned} \tag{3.2}$$

Through the previous analysis, we get the main part of the links in the garden city transport system:

$$\begin{aligned}
\mathrm{LEV}_{\mathrm{GDP}}(t) &= \mathrm{LEV}_{\mathrm{GDP}}(t-1) \times \mathrm{RAT}_{\mathrm{GDP}}(t), \\
\mathrm{LEV}_{\mathrm{II}}(t) &= \mathrm{LEV}_{\mathrm{GDP}}(t) \times \mathrm{RAT}_{\mathrm{II}}(t), \\
\mathrm{LEV}_{\mathrm{IPT}}(t) &= \mathrm{LEV}_{\mathrm{II}}(t) \times \mathrm{RAT}_{\mathrm{IPT}}(t), \\
\mathrm{LEV}_{I_1}(t) &= x_1 \cdot \mathrm{LEV}_{\mathrm{IPT}}(t), \\
\mathrm{LEV}_{N_1}(t) &= \mathrm{LEV}_{I_1}(t) \times \mathrm{RAT}_{C_1}(t), \\
\mathrm{LEV}_{V_1}(t) &= \mathrm{PHF}_1 \times \mathrm{TF}_1 \times \mathrm{LEV}_{N_1}(t), \\
\mathrm{LEV}_{T_1}(t) &= \mathrm{TD}_1 \times \mathrm{LEV}_{V_1}(t).
\end{aligned} \tag{3.3}$$

Till now, we obtained the turnover of bus LEV_{T_1}, similarly, the turnover of taxi, railway, and private car can be also described as LEV_{T_2}, LEV_{T_3}, and LEV_{T_4}, and the traffic intensity can be formulated as the following:

$$\mathrm{LEV}_{\mathrm{TI}}(t) = \mathrm{LEV}_{T_1}(t) + \mathrm{LEV}_{T_2}(t) + \mathrm{LEV}_{T_3}(t) + \mathrm{LEV}_{T_4}(t). \tag{3.4}$$

Further,

$$\begin{aligned}
\mathrm{LEV}_{\mathrm{TL}}(t) &= \frac{\mathrm{LEV}_{\mathrm{TI}}(t)}{\mathrm{LEV}_{\mathrm{CR}}(t)}, \\
\mathrm{LEV}_{\mathrm{EE}}(t) &= \mathrm{LEV}_{\mathrm{TL}}(t) \times \mathrm{RAT}_{\mathrm{EF}}, \\
\mathrm{LEV}_{\mathrm{EP}}(t) &= \mathrm{LEV}_{\mathrm{EE}}(t) \times \mathrm{RAT}_{\mathrm{EI}}, \\
-\mathrm{LEV}_{\mathrm{GDP}}(t) &= -\mathrm{LEV}_{\mathrm{EP}}(t) \times \mathrm{RAT}_{\mathrm{ED}},
\end{aligned} \tag{3.5}$$

where it can indicated that the irrational structure of transportation can increase the environmental pollution and ultimately decrease the development of economy to a certain extent. Meanwhile,

$$\begin{aligned}
\mathrm{LEV}_{\mathrm{TP}}(t) &= \mathrm{LEV}_{\mathrm{TP}}(t-1) + \mathrm{LEV}_{\mathrm{TP}}(t-1) \times \mathrm{RAT}_{\mathrm{TP}}(t), \\
\mathrm{LEV}_{\mathrm{VT}}(t) &= \mathrm{LEV}_{\mathrm{TP}}(t) \times \mathrm{RAT}_{\mathrm{TF}}, \\
\mathrm{RAT}_{\mathrm{SR}_1} &= \frac{\mathrm{LEV}_{\mathrm{VPT}}(t)}{\mathrm{LEV}_{\mathrm{VT}}(t)}, \\
\mathrm{RAT}_{\mathrm{SR}_2} &= \frac{\mathrm{LEV}_{V_4}(t)}{\mathrm{LEV}_{\mathrm{VT}}(t)}.
\end{aligned} \tag{3.6}$$

Through this circulate series of formulation, each variable (the standard variable and rate variable) is defined, thus, building the foundation of our model.

3.2. Multiobjective Programming Model

The purpose of multiobjective programming (MOP) is to maximize (or minimize) different multiobjective functions under a set of constraints, which is suitable for decision making in systems which have two or more goals [29]. According to the analysis of the system above, the optimization of a garden city transportation structure needs to consider the economic, social, and environmental subsystems and the transportation structure together to maximize the final benefits. Therefore, a multiobjective method can be used to solve this problem. In this Section, we will apply a multiobjective optimization model into the stock and flow diagram to measure the most optimal transportation structure to invest.

3.2.1. Objective Function

As usual, the objective is to pursue the maximal economic and, social benefit with minimal environmental pollution. Here we list our three main objective functions.

(1) Maximal Gross Domestic Product (GDP)

Economy is an important part involved in garden city transportation system, and, often, we use GDP to measure the level of it, the higher the GDP we produce, the better we operate our country and more investment on transportation be conducted and the system develops better:

$$\max f_1 = \mathrm{LEV}_{\mathrm{GDP}} - M_1 \sum_{i=1}^{4} \mathrm{LEV}_{\mathrm{EP}_i} \cdot \mathrm{RAT}_{\mathrm{ED}_i}, \tag{3.7}$$

here, the $\mathrm{LEV}_{\mathrm{GDP}}$ represents the quantity of GDP, and $\mathrm{LEV}_{\mathrm{EP}_i} \cdot \mathrm{RAT}_{\mathrm{ED}_i}$ is the economy decrease caused by environment pollution of each transportation means. Since $\mathrm{LEV}_{\mathrm{EP}_i}$ represents the environment pollution, while GDP is dimensional, we add an M_1 to the balance to make them under the same unit.

(2) Less Environment Pollution

As the economy develops, the public consciousness of environmental protection is aroused. The automobile exhaust emission occupies most parts in air pollution, so the optimal the transportation structure combination, the minimal air pollution and environmental damage. To achieve this, we must guarantee the least exhaust emissions:

$$\min f_2 = \sum_{i=1}^{4} \mathrm{LEV}_{\mathrm{EE}_i} - \delta_1 f_1, \tag{3.8}$$

where $\mathrm{LEV}_{\mathrm{EE}_i}$ represents the level of exhaust emission, and $\delta_1 f_1$ represents the environment pollution reduction resulting from economy growth investment.

(3) More Social Benefits

Social benefit is also an important aspect. Because transportation system can make people's life more convenient; if the system is not operating well, there will not be sufficient supply for people to travel. Therefore, it needs more turnover of each transport means to bear people's travel demand, which is a criterion to measure the transport capacity:

$$\max f_3 = \sum_{i=1}^{4} \mathrm{LEV}_{T_i} - M_2\delta_2 f_1 - M_3\delta_3 f_2. \tag{3.9}$$

LEV_{T_i} is the turnover of each means of transportation and $\delta_2 f_1$ and $\delta_3 f_2$ represents the negative influence on turnover of transport means from the economy growth investment and environment pollution respectively. M_2 and M_3 are an equivalent used to balance different units.

3.2.2. Constraints

(1) Total Transportation Structure Proportion Constraint

We assumed that there are only four means of transportation in the system, thus making the sum total 1:

$$\sum_{i=1}^{4} x_i = 1. \tag{3.10}$$

(2) Investment Constraint

Because plans have been made in the government 5-year plans the transportation structures and therefore expenditures have already been determined. Thus, for each means of transport considered here there is a maximum and minimum ranges:

$$\begin{gathered} a_{11} \leq x_1 \leq a_{12}, \\ a_{21} \leq x_2 \leq a_{22}, \\ a_{31} \leq x_3 \leq a_{32}, \\ a_{41} \leq x_4 \leq a_{42}, \\ b_1 \leq x_1 + x_2 + x_3 \leq b_2, \end{gathered} \tag{3.11}$$

x_1, x_2, x_3, x_4 represent each means of transportation, here, $a_{11}, a_{21}, a_{31}, a_{41}$ represent the lower limit of proportion, while the $a_{12}, a_{22}, a_{32}, a_{42}$, the upper limit. b_1 is the lowest proportion of public transport, while b_2 is the upper limit.

(3) Ratio Constraint

There are two kinds of share rate in this system, the public transportation share rate and private car share rate, both of them are between 0 ∼ 1, and the sum of them is equal to 1:

$$0 < \frac{\mathrm{LEV_{VPT}}}{\mathrm{LEV_{VT}}} < 1, \quad 0 < \frac{\mathrm{LEV_{V_4}}}{\mathrm{LEV_{VT}}} < 1. \tag{3.12}$$

(4) Intensity Constraint

Usually, the emission intensity index decreases along with technological progress and economic growth. The emission intensity of this year is expected to be smaller than that of the last year. Therefore, the emission intensity has an upper limit and decreases every year:

$$\frac{\sum_{i=1}^{4} \mathrm{LEV_{EE_i}}}{f_1} \leq \sum_{i=1}^{4} \mathrm{LEV_{EI_i}}(1 - c_1), \tag{3.13}$$

where $\mathrm{LEV_{EE_i}}(t-1)$ represent the exhaust emission and $\mathrm{LEV_{EI_i}}(t-1)$ represents emission intensity of last year, and c_1 is the the average rate of decrease required.

Similarly, the intensity of road occupation to economy also decreases:

$$\frac{f_3}{f_1} \leq \sum_{i=1}^{4} \mathrm{LEV_{TI_i}}(1 - c_2), \tag{3.14}$$

where $\mathrm{LEV_{TI_i}}(t-1)$ represents road occupation intensity and c_2 is the the average rate of decrease required.

From this, we get (3.16) as follows:

$$\max f_1 = \mathrm{LEV_{GDP}} - M_1 \sum_{i=1}^{4} \mathrm{LEV_{EP_i}} \cdot \mathrm{RAT_{ED_i}}$$
$$\min f_2 = \sum_{i=1}^{4} \mathrm{LEV_{EE_i}} - \delta_1 f_1$$
$$\max f_3 = \sum_{i=1}^{4} \mathrm{LEV_{T_i}} - M_2 \delta_2 f_1 - M_3 \delta_3 f_2 \tag{3.15}$$

$$\text{s.t.}\begin{cases}\displaystyle\sum_{i=1}^{4}x_i = 1\\ a_{11}\le x_1\le a_{12}\\ a_{21}\le x_2\le a_{22}\\ a_{31}\le x_3\le a_{32}\\ a_{41}\le x_4\le a_{42}\\ b_1\le x_1+x_2+x_3\le b_2\\ 0<\dfrac{\mathrm{LEV}_{\mathrm{VPT}}}{\mathrm{LEV}_{\mathrm{VT}}}<1\\ 0<\dfrac{\mathrm{LEV}_{\mathrm{V}_4}}{\mathrm{LEV}_{\mathrm{VT}}}<1\\ \dfrac{\sum_{i=1}^{4}\mathrm{LEV}_{\mathrm{EE}_i}}{f_1}\le\displaystyle\sum_{i=1}^{4}\mathrm{LEV}_{\mathrm{EI}_i}(1-c_1)\\ \dfrac{f_3}{f_1}\le\displaystyle\sum_{i=1}^{4}\mathrm{LEV}_{\mathrm{TI}_i}(1-c_2)\\ e_1\le\delta_i\le e_2\\ 0\le a,b,c,e\le 1,\quad i=1,\ldots,4.\end{cases}\tag{3.16}$$

3.3. Solution Method

In this Section, we make use of the ideal point method proposed by Yingming et al. [30]; Rakowska et al. [31]; and William [32] to resolve the multiobjective problem (3.16) with crisp parameters [33]. If the policy maker can firstly propose an estimated value $\overline{F}_i$ for each objective function $f_i(x)$ such that

$$\overline{F}_i \ge \max_{x\in X} f_i(x),\quad i=1,2,3,\tag{3.17}$$

where $X=\{x \mid x\in X\}$, X is the collection range of constraints, and then $\overline{\mathbf{F}}_i=(\overline{F}_1,\overline{F}_2,\overline{F}_3)^T$ is called the ideal point, especially if $\overline{F}_i\ge\max_{x\in X}f_i(x)$ for all i, we call $\overline{\mathbf{F}}$ the most ideal point.

The basic theory of the ideal point method is to take an especial norm in the objective space $\mathbf{R}^m$ and obtain feasible solution x so that the objective value approaches the ideal point $\overline{\mathbf{F}}=(\overline{F}_1,\overline{F}_2,\overline{F}_3)^T$ under the norm distance, that is, to seek the feasible solution x satisfying

$$\min_{x\in X'} u\big(f_i(x)\big)=\min_{x\in X'}\left\| f_i(x)-\overline{F}\right\|.\tag{3.18}$$

Next, we take the p-mode function to describe the procedure for solving the problem (3.16).

Step 1. Find the ideal point. If the decision maker can give an ideal objective value satisfying condition (3.17), the value will be considered the ideal point. However, decision makers do not know how to estimate the objective value, so we can get the ideal point by solving the following programming problem:

$$\max\ f_i(x) \quad \text{s.t. } x \in X. \tag{3.19}$$

Then the ideal point $\overline{\mathbf{F}} = (\overline{F}_1, \overline{F}_2, \overline{F}_3)^T$ can be fixed by $\overline{F}_i = f_i(x^*)$, where x^* is the optimal solution of problem (3.19).

Step 2. Fix the weight. The method of selecting the weight is referred to in much research that interested readers can consult these. We usually use the following function to fix the weight:

$$\omega_i = \frac{\overline{F}_i}{\sum_{i=1}^{3} \overline{F}_i}. \tag{3.20}$$

Step 3. Construct the minimal distance problem. Solve the following single-objective programming problem to obtain an efficient solution to problem (3.16):

$$\min \left[\sum_{i=1}^{m} \omega_i \left| f_i(x) - \overline{F}_i \right|^t \right]^{1/t} \quad \text{s.t. } x \in X, \tag{3.21}$$

usually, we take $t = 2$ to compute it.

4. A Case Study

In this section, we choose Chengdu, first city that advocates to “being a world modern garden city,” in China as our application to verify the approach in the previous section. we apply the data and parameter values of Chengdu into the system dynamics model. A system simulation was performed using the simulation software VENSIM and the data from 2010 as initial conditions, time = 0. Our simulation spans 11 years, from 1 to 11, and results in data analysis for the years 2010 to 2020 and we depict the main pattern in figures.

4.1. Regional Situation

As a general transportation hub for western China, Chengdu is an important nexus city linking up China to mid-Asia, south Asia, west Asia, and Europe. Located in the middle of Sichuan province in southwest China, Chengdu covers a total land area of 12121 square kilometers, with its central downtown area extending for approximately 350 square kilometers. With its name and location kept unchanged for more than 2300 years, the city’s history traces back far and the culture reaches wide. As the main hub for western transportation and the most developed city in the southwest China, with the nature advantages, the proposition of the objective of a “world modern garden city” is necessary and surely no accident. Chengdu is blessed with unsurpassed resources, and the nature, humanity, and history of Chengdu make it well qualified for garden city construction. In late 2009, the city committee and government made the development of a “world modern garden city” its historic positioning and long-term target based on in-depth research, sufficient analysis, and extensive public participation in the notion. It presents an attempt to capitalize on the historic opportunities generated by the prosperity of China to further the urban-rural integration and push along the strategic transformation of growth models so that the city can better contribute to the new round of opening-up and development activities in western China and to the province’s strategic move to become the top driving force in the development of western China. However, in the way of garden city construction, the transport problems have become increasingly severe. We have to deal with the traffic problems as an ordinary city and as a particular problem emerged in the construction of world modern garden city, which is brand new for us.

4.2. Simulation Results and Analysis

We collect the parameter statistics by studying the garden city transportation system and analyzing the flows of processing technique and show the results in Table 2. The settled values for the substance transforming rates, and some settled parameters in the system dynamic model, are mainly based on the administration annual report for the region: and National Statistical Bureau [34, 35], Ministry of Transport and Communication [36], Chengdu Bureau of Statistics and the planning reports: Chengdu Twelfth Five Years of planning [37], and National Twelfth Five Years of planning [38] on correlative industries and the present market situation. The settled values were obtained via equilibration, linearity regression, index smoothness, and other related mathematical models based on the principles like relativity, comparability, scientificity, and comprehensiveness. We define the parameters used to describe and analyze the system, and the parameters of the transportation system are presented in Table 2.

In order to achieve the government’s goal, a multiobjective optimization problem incorporating the decision makers’ preferences is formulated. The multiobjective model is based on Model (3.16). There are some parameters which are determined by the decision maker of local government. In the current case, parameters such as a, b, c, d have to be given according to the preferences of decision maker. The decision maker can provide different values and decide which solutions are adopted by comparing the solutions. The decision maker is encouraged to give probable numbers to express their preference. With this method, we obtained three different solutions as shown in Table 3 (control variables) for different weights considered for the objective functions, among which the current program presents the current situation of transport proportion. In this table, the different proportions of transport means show that from the current program to optimization program 3, the proportion of public transport is increasing, especially the bus and railway, while the private car decreases dramatically, and the number of taxi decreases slightly. Finally, these numbers and cases will be used as control variables in transportation system dynamics modeling to operate along with the initial data. We use the four groups of figures (Table 3) to predict the coming 10 years, and, in turn, suggest actions to improve the present situation.

The results after the system dynamics modeling are shown from Figure 5 to Figure 10. As the system is simulated, six variables are selected for observation which are classified in three groups: the transport structure represented by the public transport share rate and railway passenger capacity (Figures 5 and 6), the road use situation represented by

Table 2: The value of parameters.

Symbol	Value	Units
RAT_A	82	%
RAT_{C_1}	96.94	%
RAT_{C_2}	94.40	%
RAT_{C_3}	92.30	%
RAT_{C_4}	90.50	%
RAT_D	3.9175	g/L
RAT_{ED}	−0.29	Yuan/g
RAT_{EF}	1.5	g/person
RAT_{EI}	0.6	No dimension
RAT_{GDP}	14.70	%
RAT_{II}	12	%
RAT_{IPT}	40	%
RAT_{IR}	60	%
PHF_1	0.3242	Person/times
PHF_2	0.2260	Person/times
PHF_3	0.3065	Person/times
PHF_4	0.4006	Person/times
TD_1	10.545	km/time
TD_2	9.413	km/time
TD_3	12.413	km/time
TD_4	10.517	km/time
TF_1	11.37	Times
TF_2	10.5	Times
TF_3	12.28	Times
TF_4	4.16	Times

Table 3: Control variables.

	Current program	Optimization program 1	Optimization program 2	Optimization program 3
x_1	0.3830	0.3000	0.3600	0.1750
x_2	0.1036	0.2000	0.1375	0.2096
x_3	0.4080	0.2750	0.3400	0.2658
x_4	0.1054	0.2250	0.1625	0.3496

the traffic intensity and public transport volume (Figures 7 and 8), and the environmental circumstances represented by the exhaust emissions and environment pollution (Figures 9 and 10). From Figure 5, the public transport share rate is increasing, if no changes had taken place, the public transport share rate will remain the same as the current situation. And we can see that optimization 3 is the highest in the coming 10 years, and optimization 2 is higher than optimization 1 in the first several years, and all the three optimizations show significant improvement than continuing with the current situation. Figure 6 describes that the railway passenger capacity will be greatly strengthened if optimization cases are adopted. In terms of the road use situation, Figure 7, traffic intensity means the higher the intensity, the more utilization of the road, and Figure 8 presents travel volume of public transport is always increasing, and indicates the demand of transport. Both of them show that optimization 3 is the best choice. Lastly, in terms of the environmental circumstance, both Figures 9 and 10

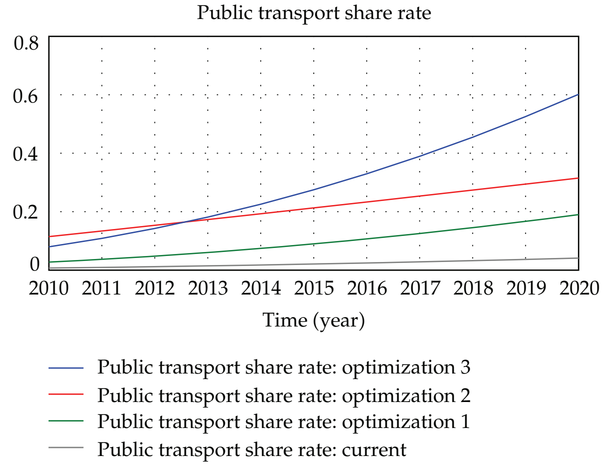

Figure 5: Public transport share rate.

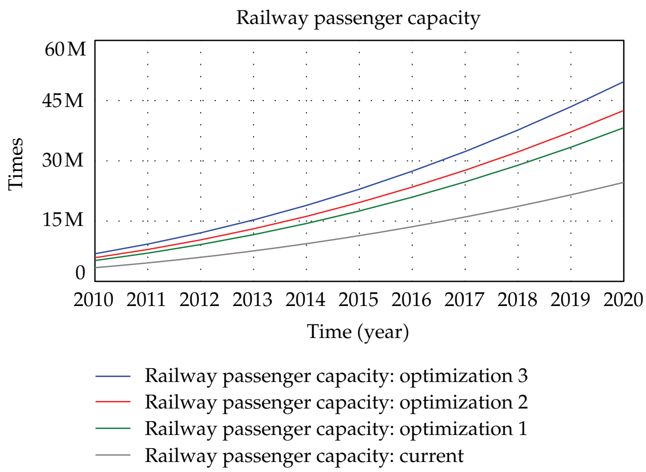

Figure 6: Railway passenger capacity.

are critical factor in assessing environment contamination. Most of the exhaust emission contributes to the environment pollution, and there is a linear relationship between them. Generally speaking, from analysis of these 6 graphs we observe that the most suitable case is optimization 3, which in all cases offers better progress towards the goal of a garden city than the current situation.

5. Proposals

From an analysis of the results and in consideration of local conditions, suggestions are made to find a feasible solution to the transportation development in garden city. To achieve a continual optimization of the transportation structure, low-carbon transportation development needs to be promoted through the formulation of relevant policy by the local government.

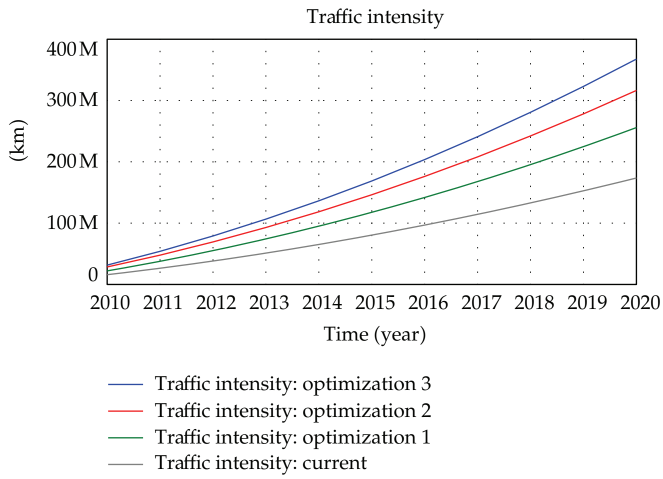

Figure 7: Traffic intensity.

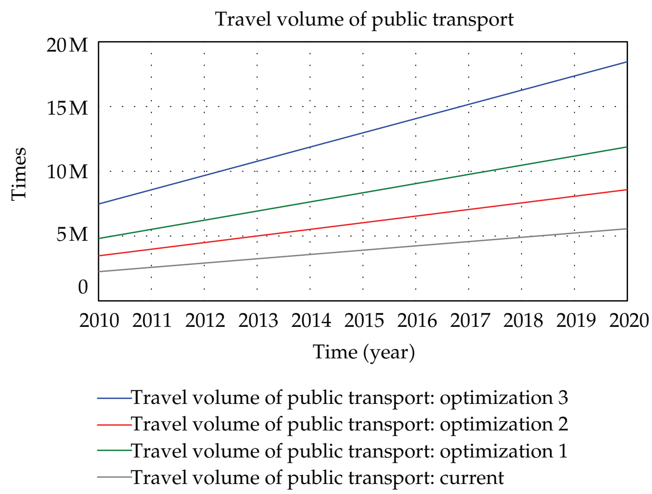

Figure 8: Travel volume of public transport.

(1) Transportation Structure Optimization

The adjustment of the transportation structure is a long complicated process which cannot be achieved through a single policy. A previous simulation confirms that if the government ensures the preferential development of the public transport, the situation can get better. Firstly, develop the loop line. The loop line and radiation transport route can associate the central city with the countryside areas, which takes a great advantage of the plain landscape, as well as, the standard model of garden city transportation. Secondly, the subway construction. It is convinced that the railway transport is the context to open garden city construction. With the 1st line of Chengdu Metro operating well and its notable benefit, new subways should be constructed to spread further and ultimately to the whole city. Thirdly, construct the bus rapid transit (BRT), which is an important part in mass rapid public transit. Here, the mass rapid public transit is an resources saving and socially beneficial which

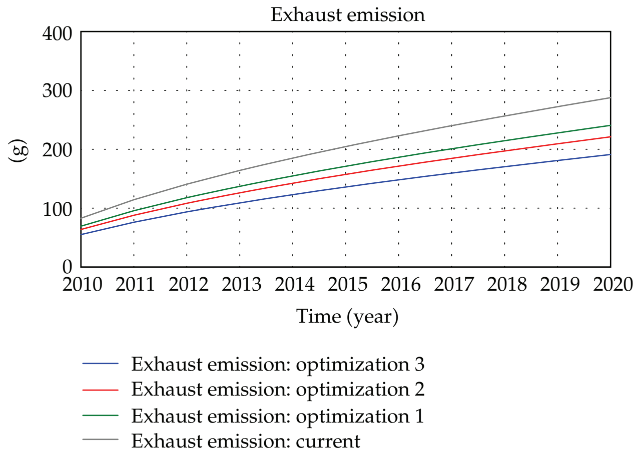

Figure 9: Exhaust emission.

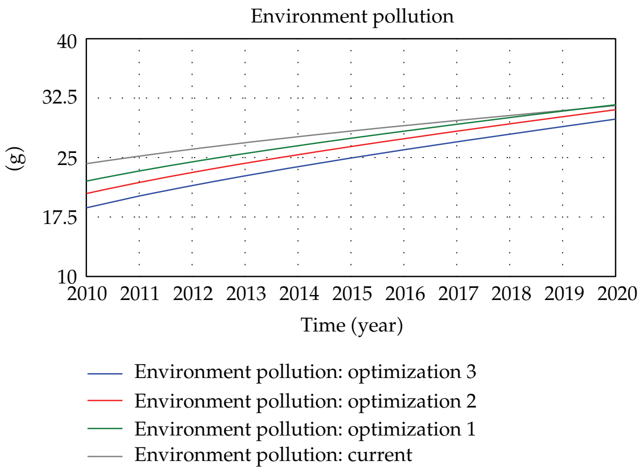

Figure 10: Environment pollution.

includes BRT, subway, light railway, and others. The bus rapid transit (BRT) integrates the bus technology, intelligent traffic system with rail transit operations management mode into a relatively low-cost mass transit mode, which is regarded as a revolutionized solution of public transport by International Energy Agency. Fourthly, restrict development of private cars. As the private cars are at an absolute disadvantage in transport area possession, energy consuming, and exhaust emissions, measures should be taken to restrict it such as purchase limiting, levying a tax based on the emissions to the environment, and reducing the supply of oil.

(2) Promoting the Land Use Mode

There is a close relationship between land use planning and transport construction. Land use planning is crucial to the whole transportation system. As our simulation model shows, land use influences the transport infrastructure such as road length, road capacity, and the investment proportion of road. According to the actual land situation of Chengdu, firstly, emphasis on the mixed use of land and the various functional complement with each other is applied in order to improve the overall efficiency of central district. Secondly, newly developed areas should conduct preliminary transport planning before the land use plan. Thirdly, the public transport guide land use mode needs to be developed to shorten the travel distance between bus stops and increase the operating speed. Fourthly, controlling the diversity of land use intensity along the road lines to maintain traveling speed and raise land use intensity and efficiency. Fifthly, attention should be paid to the ecological construction of land. The government should transfer the distant and relatively large land parcels to farmland to develop urban agriculture which can improve the environmental quality, and suppress the unlimited extension of city construction land use scale, for example, the Shahe, Sansheng, and Shiling park. Lastly, free up the original lane space to provide for the new bus station and parking place, at the same time, set up new bicycle squares in the city center.

(3) Strengthening the Low-Carbon Consciousness

Because there is a high value put on environmental protection in our model, it is necessary to examine and weigh the optimization using environmental indexes. A green travel consciousness needs to be developed which would focus on the sustainable development of the urban inhabitable environment. Thus, both the walking and alternative means need to be promoted along with the low-carbon, safe, comfortable, and low-pollution public transport. It is an effective way to introduce the low-carbon consciousness into primary school classroom education, which cannot only guide the students to establish the right consumption concept, but also to foster their socially responsible manner and has a profound effect on low-carbon transportation construction. This promotion of green transportation will lower the dependence on motor vehicles and encourage people to use hybrid or clean fueled vehicles which would also satisfy one of the measures proposed by the State Council for reducing greenhouse gas emissions and conserving energy.

6. Conclusion

Great many cities are experiencing traffic problems in the process of city development, including the garden city. Many researchers did not conclude all the factors in the transport system when estimating it. Therefore, to address the problems, a methodology for the analysis of the whole transportation system by adjustment of transport structure was outlined. Particularly, we develop a system dynamics and multiobjective programming integrated model (SD-MOP) to simulate different results with different proportions of transport means. The system dynamics model describes the relationships between the economy, environment, traffic mode traffic congestion, and the policy management. A multiobjective programming model helps policy makers to make choices according to their preferences. In the case study, a representative city, Chengdu, a world modern garden city was chosen. Various scenarios and different optimization cases were simulated to show the future trends of the transportation system. According to the simulation results, we propose the reasonable pieces of advice on transportation structure and transportation development mode in world modern garden city.

It is of great significance to study transportation system by system dynamics integrated with multiobjective optimization model. There is much scope to expand this field of research into the future. There may exist some omissions in this system, future research will focus on establishing a more complex transportation system which considers more factors and deals with other optimizations.

Acknowledgments

This research is supported by the Key Program of NSFC (Grant no. 70833005), Chinese Universities Scientific Fund (Grant no. 2010SCU22009), and the Key Project of Philosophy and Social Sciences Research, Ministry of Education of China (Grant no. 08JHQ0002). The authors would like to thank the anonymous referees for their insightful comments and suggestions to improve this paper, as well as Uncertainty Decision-Making Laboratory and Low-Carbon Technology and Economy Research Center of Sichuan University for helpful comments and discussion.

References

[1] C. Cooley, "The theory of transportation," *Economics Association*, vol. 9, no. 3, pp. 1–148, 1894.

[2] F. Moavenzadeh and D. Geltner, *Transportation, Energy and Economic Development: A Dilemma in the Developing World*, Elsevier, New York, NY, USA, 1984.

[3] W. Owen, *Transportution and World Development*, Johns Hopkins University Press, Baltimore, Md, USA, 1987.

[4] International Energy Agency (IEA), *Key World Energy Statistics*, International EnergyAgency (IEA), 2010b.

[5] T. Petri, B. David, L. Jyrki, V. Jarmo, and W. Risto, "Energy and transport in comparison: Immaterialisation, dematerialisation and decarbonisation in the EU15 between 1970 and 2000," *Energy Policy*, vol. 35, no. 1, pp. 433–451, 2007.

[6] S. Dominic, "Transport energy efficiency in Europe: temporal and geographical trends and prospects," *Journal of Transport Geography*, vol. 15, no. 5, pp. 343–353, 2007.

[7] S. Frank, A Technical Review of Urban Land use. Transportation Models as Tools for Evaluation Vehicle Travel Reduction Strategies. The Office of Environmental Analysis and Sustainable Development U.S Department of Energy, 1994, http://www.thepep.org/ClearingHouse/docfiles/A%20Technical%20Review%20of%20Urban%20Land%20Use–Transportation%20Models%20as%20-Tools%20for%20Eva.pdf.

[8] T. Messenger and R. Ewing, "Transit-oriented development in the sun belt," *Transportation Research Record*, no. 1552, pp. 145–153, 1996.

[9] L. Martin, "Means of transportation to work and overweight and obesity: a population-based study in southern Sweden," *Preventive Medicine*, vol. 46, no. 1, pp. 22–28, 2008.

[10] S. Komei, "Transportation system change and urban structure in two-transport mode setting," *Journal of Urban Economics*, vol. 25, no. 3, pp. 346–367, 1989.

[11] S. Jian, L. Qiong, and P. Zhongren, "Research and analysis on causality and spatial-temporal evolution of urban traffic congestions-a case study on Shenzhen of China," *Journal of Transportation Systems Engineering and Information Technology*, vol. 11, no. 5, pp. 86–93, 2011.

[12] H. Wang, P. Zhou, and D. Q. Zhou, "An empirical study of direct rebound effect for passenger transport in urban China," *Energy Economics*, vol. 34, no. 2, pp. 452–460, 2012.

[13] W. Xiao, "Discussions on some issues of the eleventh five-year plan for transport of China," *Journal of Transportation Systems Engineering and Information Technology*, vol. 6, no. 6, pp. 1–5, 2006.

[14] C. Bofeng, Y. Weishan, C. Dong, L. Lancui, Z. Ying, and Z. Zhansheng, "Estimates of China's national and regional transport sector CO_2 emissions in 2007," *Energy Policy*, vol. 41, pp. 474–483, 2012.

[15] E. Howard, G. H. Peter, D. Hardy, and W. Colin, *To-Morrow: A Peaceful Path to Real Reform*, Routledge, London, UK, 1898.

[16] E. Howard, *Cities of to-Morrow*, MIT Press, Cambridge, Mass, USA, 1965.

[17] P.D. Kieran and A. S. Laurie, "Managing congestion, pollution, and pavement conditions in a dynamic transportation network model," *Transportation Research Part D*, vol. 3, no. 2, pp. 59–80, 1998.

[18] W. Jifeng, L. Huapu, and P. Hu, "System dynamics model of urban transportation system and its application," *Journal of Transportation Systems Engineering and Information Technology*, vol. 8, no. 3, pp. 83–89, 2008.

[19] Ü. Füsun, Ö. Şule, Y. Ilker Topçu, A. Emel, and K. Özgür, "An integrated transportation decision support system for transportation policy decisions: the case of Turkey," *Transportation Research Part A*, vol. 41, no. 1, pp. 80–97, 2007.

[20] S. Anand, P. Vrat, and R. P. Dahiya, "Application of a system dynamics approach for assessment and mitigation of CO_2 emissions from the cement industry," *Journal of Environmental Management*, vol. 79, no. 4, pp. 383–398, 2006.

[21] K. S. Ali, B. Yaman, and Y. Orhan, "Environmental sustainability in an agricultural development project: a system dynamics approach," *Journal of Environmental Management*, vol. 64, no. 3, pp. 247–260, 2002.

[22] F. Andrew, "System dynamics and the energy industry," *Encyclopedia of Energy*, vol. 40, no. 1, pp. 809–818, 2004.

[23] L. C. Wadhwa and Y. M. Demoulin, "A system approach to regional economic and transport planning in Australia," in *Proceedings of the 2nd International Symposium on Large Engineering Systems*, pp. 95–100, Ontario, Canada, 1978.

[24] Y. Tanaboriboon, *A transportation planning strategy for the Bangkok metropolitan area [Ph.D. thesis]*, Virginia Polytechnic Institute and State University, Virginia, Va, USA, 1979.

[25] J. D. Sterman, "Learning in and about complex systems," *System Dynamics Review*, vol. 10, no. 2-3, pp. 291–330, 1994.

[26] X. Jiuping, D. Rentao, and D. W. Desheng, "On simulation and optimization of one natural gas industry system under the rough environment," *Expert Systems with Applications*, vol. 37, no. 3, pp. 1854–1862, 2010.

[27] Y. N. Yu, *Electric Power System Dynamics*, Academic Press, New York, NY, USA, 1983.

[28] B. Tung and L. Claudia, "Supporting cognitive feedback using system dynamics: a demand model of the Global System of Mobile telecommunication," *Decision Support Systems*, vol. 17, no. 2, pp. 83–98, 1996.

[29] D. Kalyanmoy and T. Santosh, "Omni-optimizer: a generic evolutionary algorithm for single and multi-objective optimization," *European Journal of Operational Research*, vol. 185, no. 3, pp. 1062–1087, 2008.

[30] W. Yingming, Y. Jianbo, X. Dongling, and C. Kwaisang, "The evidential reasoning approach for multiple attribute decision analysis using interval belief degrees," *European Journal of Operational Research*, vol. 175, no. 1, pp. 35–66, 2006.

[31] J. Rakowska, R. T. Haftka, and L. T. Watson, "Tracing the efficient curve for multi-objective control-structure optimization," *Computing Systems in Engineering*, vol. 2, no. 5-6, pp. 461–471, 1991.

[32] K. S. William, "Multiobjective decision analysis with engineering and business applications," *Engineering Geology*, vol. 19, no. 4, pp. 289–291, 1983.

[33] J. Xu and L. Yao, *Random-Like Multiple Objective Decision Making*, vol. 647 of *Lecture Notes in Economics and Mathematical Systems*, Springer, Heidelberg, Germany, 2011.

[34] National Statistical Bureau, *Statistical Yearbook [M]*, Press of China, Beijing, China, 2010.

[35] National Statistical Bureau, *China Energy Statistical Yearbook [M]*, Statistical Press of China, Beijing, China, 2010.

[36] Ministry of Transport and Communication, *China Transport Statistical Yearbook [M]*, People's Commumication Press, Beijing, China, 2010.

[37] Chengdu, Economic and Social Development of the Twelfth Five Years of planning [M], 2011.

[38] National Economic and Social Development of the Twelfth Five Years of planning [M], 2011.

Advances in
Operations Research
Advances in
Decision Sciences
Mathematical Problems
in Engineering
Algebra
Journal of
Probability and Statistics
The Scientific
World Journal
International Journal of
Differential Equations
Hindawi
Submit your manuscripts at
http://www.hindawi.com
International Journal of
Combinatorics
Advances in
Mathematical Physics
Journal of
Complex Analysis
Journal of
Mathematics
International Journal of
Stochastic Analysis
Abstract and
Applied Analysis
Discrete Dynamics in
Nature and Society
International
Journal of
Mathematics and
Mathematical
Sciences
Journal of
Discrete Mathematics
Journal of
Function Spaces
Journal of
Applied Mathematics
Journal of
Optimization