Chapter 1

Background and Theoretical Interpretation of Urban Green Development

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Cities are humanity's greatest invention. Urbanization is a process through which humanity not only uses and changes the natural environment but also identifies with and adapts to its self-development support system. Whether in the past, at the present or in the future, the quality of urban development depends largely on the way we understand and build cities. The UN 2030 Agenda for Sustainable Development began amidst the conflicts between prosperity and poverty, progress and decline, and opportunity and challenge; and amidst the impacts of environmental destruction, economic recession, escalating poverty and social imbalances. The Agenda rethinks the relationships between man and nature, man and economy, and man and society; in turn, it redefines the goals, implications and patterns of urban development. Green development is the inevitable direction of urban development.

I. Green Development: Direction of Sustainable Development for 2030

Humanity never stops thinking about its self-development, especially since the mid-20th century after the arrival of industrial civilization. Industrial civilization is the state of civilization following the industrial revolution that is characterized by widespread use of powered machines and the commonly seen chimneys, wastewater and sprawling slums. Since the industrial revolution, various conflicts had been escalating and the issues facing the economy, resources, environment and society had become increasingly salient. This has provoked humanity into thinking seriously about its development pattern. The book *Silent Spring* written by Rachel Carson (an American biologist) and published in 1962 revealed the detrimental impacts of industrial development to the environment, calling for effective actions to reduce environmental pollution and disruption caused by industrialization. The report *The Limits to Growth* published by the Club of Rome in 1972 warned that population and industrial growth will become limited, since the earth's resources are depleted and the ecological environment is disrupted. The report holds that the earth's resources are finite and growth could not continue indefinitely. It also proposed the well-known "zero growth" strategy. In the same year, the first United Nations Conference on the Human Environment was held in Stockholm. At the conference, the slogan "Only One Earth" was proposed and the *Declaration of the United Nations Conference on the Human Environment* (the first international environmental declaration) was adopted. This has not only impacted the conventional perception on relations between society and nature but also helped humanity identify with the sustainable development idea. In 1987, the World Commission on Environment and Development, headed by Mrs. Brundtland, published the report *Our Common Future*. The report formally used the concept of sustainable development and defined sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs". In 1992, the *United Nations Conference on Environment and Development* adopted "Agenda 21", which formed an action

plan for sustainable development worldwide and received the highest level of political commitment. Since the conference, the concept of sustainable development has been put into practice. In 2000, the United Nations Millennium Summit adopted the *Millennium Declaration* and set the Millennium Development Goals (MDGs), which established indexes and schedules for achieving the development goals at global level for the first time ever. It marks a groundbreaking moment in the history of human development.

On 25 September 2015, the United Nations Sustainable Development Summit was held at UN Headquarters in New York. *Transforming Our World: The 2030 Agenda for Sustainable Development* adopted by the summit maps out the blueprint for global development in the next 15 years (Table 1.1). The 2030 Agenda is a set of 17 “Global Goals” with 169 targets between them, which are clustered into five categories: people, planet, prosperity, peace and partnerships. Ending poverty remains the primary goal of the agenda. The 2030 Agenda remains committed to improving health and education, promoting gender equality and combating climate change. In addition, it sets higher standards for protecting water resources, ensuring energy security, reducing inequality within and among countries and protecting marine resources, in an attempt to build consensus between the developed and developing countries. The agenda serves as a road map for ending poverty and allowing everyone to benefit from sustainable development.

The 2030 Agenda for Sustainable Development is a set of global goals and programs designed to end poverty, protect the earth and ensure prosperity for all, amidst the increasing global problems and challenges. Compared with the MDGs set in 2000, the 2030 Agenda reflects a new global understanding of sustainable development. The SDGs cover a wider scope of targets and fields than the MDGs. The SDGs not only involve the concept of intergenerational equity explored in sustainable development but also cover the ecological, economic, social and governance fields. They are designed for the following purposes: protecting the ecosystems and climate on which all lives rely; developing innovation-based, environmentally friendly economic systems; building peaceful, inclusive and well-governed

Table 1.1. The Sustainable Development Goals (SDGs) of the UN 2030 Agenda for Sustainable Development.

No.	Goals
1	End poverty in all its forms everywhere
2	End hunger, achieve food security and improved nutrition, and promote sustainable agriculture
3	Ensure healthy lives and promote well-being for all at all ages
4	Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all
5	Achieve gender equality and empower all women and girls
6	Ensure availability and sustainable management of water and sanitation for all
7	Ensure access to affordable, reliable, sustainable and modern energy for all
8	Promote sustained, inclusive and sustainable economic growth; full and productive employment; decent work for all
9	Build resilient infrastructure; promote inclusive and sustainable industrialization; foster innovation
10	Reduce inequality within and among countries
11	Make cities and human settlements inclusive, safe, resilient and sustainable
12	Ensure sustainable consumption and production patterns
13	Take urgent action to combat climate change and its impacts
14	Conserve and sustainably use the oceans, seas and marine resources for sustainable development
15	Protect, restore and promote sustainable use of terrestrial ecosystems; sustainably manage forests; combat desertification; halt and reverse land degradation; halt biodiversity loss
16	Promote peaceful and inclusive societies for sustainable development; provide access to justice for all; build effective, accountable and inclusive institutions at all levels
17	Strengthen the means of implementation and revitalize the global partnership for sustainable development

Source: United Nations Environment Programme.

societies; fundamentally changing the development outlook from traditional excessive pursuit of economic growth to a balanced development of the economy, society and the environment by strengthening multilateral cooperation through the revitalization of global partnerships. The SDGs also offer a clear action plan.

The concept of green development is consistent with that of sustainable development, especially the concept of the *2030 Agenda*

for *Sustainable Development*. In 1989, David Pearce, a British environmental economist, first used the term “green economy” in his book *Blueprint for a Green Economy*. He treats the term “green economy” as a synonym of sustainable development and has explored the ways to achieve sustainable development from the perspective of environmental economics. Amidst the increasingly severe international financial crisis, the United Nations Environment Programme (UNEP) launched a “Global Green New Deal” in 2008. The new deal was designed to allow global leaders and policy makers of relevant departments to realize that a green economy is not a burden on economic growth but an engine of growth. The UNEP called on countries to develop green economies by transforming the pattern of economic growth, which has received positive responses from the international community. In 2009, the Organisation for Economic Cooperation and Development (OECD) issued the *Declaration on Green Growth*. In 2010, the EU introduced the *Europe 2020 Strategy*. These documents present green development as a core strategy for promoting regional and national competitiveness. The US, Japan and other developed countries have launched green development strategy plans in an attempt to get out of the financial crisis by transforming their previous development pattern to a green one driven by technology and innovation. Green development has become the trendy pattern of global development. It is widely believed that in the short term, promoting green development not only can boost employment and the economy but also can effectively adjust the economic structure and strike a balance between resources and economic growth; in the long term, it can serve to achieve coordinated, sustainable development in a large number of fields and prevent another round of international financial crisis.¹ Generally, green development is a development pattern that is gradually emerging under the backdrop of sustainable development. Green development starts with the sustainable development of the economy, society, nature and the environment. It is highly consistent with the core value and philosophy upheld by the *2030 Agenda for Sustainable Development*. Both green and sustainable development patterns pursue a balance between economic, ecological and social benefits.

Moreover, emphasizing fairness, sustainability and development, both patterns aim to transform development patterns and enhance human well-being. Like sustainable development, green development is also the result of humanity's self-examination of traditional civilization, especially industrial civilization. It represents a great progress in the development philosophy and the form of human civilization. Moreover, it serves not only as a way to reduce and prevent environmental pollution and ecological disruption so as to achieve sustainable development of the economy and society but also as a new option that humanity has chosen to improve its ways of living, production and development.

Although the concepts of both sustainable and green development are interlinked, their implications are different primarily in the following three aspects:

1. Green development focuses more on development than resource conservation and environmental protection. Based on the philosophy of achieving economic and social development not at the expense of natural resources and environment, green development seeks a balance between environmental protection and development and highlights "sustainable development".
2. Green development emphasizes actions rather than concepts. Green development focuses more on the ways of solving "unsustainability" and the approaches to achieving fair development. It serves as a feasible support and guarantees for achieving the balance between economic and social development and environmental protection.
3. Green development focuses more on overall coordination than local improvement. Green development is a process in which governments, enterprises and the public participate to achieve economic and social development yet not at the expense of the environment. In this process, the ecological environment should be improved. Moreover, natural resources and environment should not be treated as external factors but as an integrated part of the social and economic value. Factoring in the interests of all stakeholders, green development is an overall coordinated development pattern.

The key to green development lies in development. Green development is an effective pattern of sustainable development. In green development, natural resources and environment are treated as internal factors of growth. As a transformed development pattern, green development is efficient and environmentally friendly with regard to the use of intelligence, capital, technology and system. Such efficient development pattern will, in turn, enhance humanity's capability of protecting the environment and balance economic growth, social progress and ecological conservation. Green development serves to improve the quality of human lives and promote the sustainable development pattern that is fair, balanced and shared by all.

II. Why Green Development for Cities?

Cities are the carriers of human civilization. Aristotle, the ancient Greek philosopher, once said, the city "comes into existence, originating in the bare needs of life, and continuing in existence for the sake of a good life". Oswald Spengler, the German historian, once said, "it is a conclusive fact — yet one hitherto never appreciated — that all great Cultures are town-Cultures."² Humanity has undergone a long process of evolution from traveling from place to place to settling in walled communities and to living in today's cities. From the perspective of history, people and the economic and social activities concentrate in cities is a phenomenon that commonly seen in global development. In the 21st century, the vast majority of people worldwide will live in cities rather than rural areas, which is unprecedented in human history. For countries worldwide, including low-income countries, the ever faster urbanization may bring numerous benefits.³ Green development requires close attention to efforts and practices at the city level. Urban green development has irreplaceable influences on the concepts and practices of green development. Cities are the spatial carriers of green development. The industries, geography, population and development pattern of cities have a bearing on the level and quality of green development. The changes of social attitudes and customs in urban development affect the spread of green development concept. Cities have obvious economic advantages in the pursuit of green development strategy.

As the innovation center, cities serve to promote the agglomeration of economies, the knowledge spillover, the overall planning for labor market and the sharing of investments, by gathering skills and businesses. This plays a key role in implementing the strategies designed to cope with climate change and resource scarcity.⁴ The cause, process and result of green development are shown through cities. In the past, cities created wealth while also causing brown development issues. At present, more than half of the world's population lives in cities. Accordingly, most of the greenhouse gas emissions and energy consumption occur in cities. Economic wealth is mainly concentrated in urban areas; green development and innovations are mostly seen in cities. Therefore, cities have become key nodes for the economic, social and cultural contact regionally and internationally. With the urban renewal of developed countries and the accelerating urbanization of emerging economies, urban green development will have a far-reaching effect on the green development capabilities and patterns of different countries and the entire world alike. Moreover, it will have a bearing on the future of all countries and humanity.

(I) Solve the historical issue of urban development

Urban development has created a great deal of material and spiritual wealth. However, since the industrial revolution, driven by the development concept that focuses only on the pursuit of material wealth and economic growth, a large quantity of natural resources, energy and primary products have been consumed to boost the economy and increase material wealth. As a result, natural resources have largely decreased, ecological environment has deteriorated with frequent contamination and pollution incidents, and imbalances between economic growth, ecological conservation and environmental protection have become increasingly salient. In reality, urban brown development issues exist in both developed and developing world but in different forms. Cities in developing countries where industrial development is generally at low level tend to rely on industrial development to boost their economy. Accordingly, these cities have

densely distributed heavy industries, which have caused air, noise, and solid waste pollutions. As a result, the health of urban residents is harmed, which in turn negatively affects their work and life. Pollutions caused by heavy industries are particularly severe in smaller cities, where in most cases waste is dumped from one or two factories into a river nearby or a large volume of exhaust gas is emitted from factories to the air. As a result, the water and air environments of these cities are polluted. Moreover, with the urban–rural dual structure, numerous slums in cities have also posed daunting challenges to urban development. Dense population, poor housing, substandard education, worrisome sanitation and public security environment result in various “urban diseases” and their spread. Cities in developed countries where industrial development is generally at high level face the same problems, though not as salient as environment deteriorate, young people and well-educated people tend to migrate, leading to a lack of labor required to drive economic growth. Historical issues cannot be avoided. If we followed the traditional urban development pattern that prioritizes economic growth as its primary goal, how long would natural resources and environment sustain? This is a question worth asking. As a balanced, coordinated and sustainable development concept and pattern, green development is expected to solve the brown development issues in conventional urban development process.

(II) Respond to the existing crises of urban development

With the spread of global sustainable development concept, the international community has reached a consensus on the view that the environment should be protected in the human development process. As a result, the *2030 Agenda for Sustainable Development* has been developed. In the practices of urban development worldwide, an increasing number of leaders and general public realize that what matters most in urban development is not the availability of lucrative investment but its sustainability. Nature is not only generous but also very vulnerable. Natural resources are limited. If they are overused,

the integrity of the natural system will suffer and urban life will suffer accordingly. Moreover, the drive for changes also comes from the global financial and economic crises we are facing. The crises make it salient that if the global economy and technological innovation lag behind real economy, and if real economy lags behind virtual economy, the balance of the overall economic development will be disrupted, and the urban development will face huge pressure. Facing the downward pressure on the economy and its lack of vitality, some developing countries suffer from deteriorating economy and mounting debts, which in turn cause these countries to overlook environmental planning and natural resources protection when developing urban and industrial development plans. As a result, many cities cut their budgets on environmental protection programs, hindering the remediation of brown development. Moreover, many of the approaches to brown development remediation have to be redesigned and relevant assistance and cooperation are affected. In this context, urban green development becomes particularly important. It is not only an inevitable choice for the change of urban development pattern but also an important approach to coping with the existing crises in urban development. According to relevant studies, cities that implement green development policies tend to be wealthier, with the incidence of poverty being 11.7% on average, whereas cities that implement non-green development have the poverty incidence of 17% on average.⁵ Promoting economic growth in an environmentally friendly way through green development will serve to greatly ease the pressure on cities caused by limited natural resources and energy, and effectively improve the supply and demand structure. In addition, it can create new market demand, stimulate the supply and demand of green products and services, foster new growth poles, increase market capacity and significantly enhance the dynamic growth of cities. It is also worth noting that in response to the crises, we need to turn crises into opportunities. The world is in a period where the fifth technological revolution and the third industrial revolution occur at the same time. Unlike the first and second industrial revolutions, the emerging third industrial revolution is based on renewable energy distributed worldwide. The concentrated business pattern formed in

the first and second industrial revolutions will be replaced by the dispersed business pattern formed by the third one.⁶ Cities have a large number of talented people and advantages in technological research, development and application, making them the primary carriers of distributed intelligent energy network and cooperative organizations. Promoting urban green development will help cities grasp the opportunities of the third industrial revolution so that they can make technological innovations for using and developing energy and resources. Moreover, it can help create new demand and markets, develop new ways to boost the economy and provide new impetus for the economic recovery of cities.

(III) Achieve urban development goals

Cities are not only the engine of economic growth but also serve human development and carry humanity's hope for a better life. From remote ancient times when people lived on fishing and hunting and traveled from place to place, to despotic society when "the castle was built to protect the monarch and the outer wall was built to protect the people", to feudal society when the concept of citizens emerged and finally to industrial society when population largely expanded and productivity increased rapidly, the evolution of cities mirrors the development of human civilization. From 2000 B.C. to this day, as cities at the center of human civilization in different times, namely Ur, Thebes, Babylon, Xi'an, Luoyang, Athens, Rome, Constantinople, Kaifeng, Hangzhou, Beijing, London, Paris, New York and Tokyo have achieved the dreams of humanity and created numerous development miracles. In the future, cities will still be the juncture of human ideal and reality. The United Nations Center for Human Settlements (UNCHS) held that cities would provide us with the following: numerous job opportunities; adequate access to good education; access to basic transport services; affordable access to safe water and complete health facilities; affordable access to medical care services; access to housing; clean air and a safe, inclusive and healthy environment; available parks, community gardens and public spaces; recreation and entertainment; opportunities for people

to participate in local democratic governance; access to enjoying nature.⁷ The *2030 Agenda for Sustainable Development* shifts the focus of development from the pursuit of economic growth to the pursuit of inclusive and green development that “leaves no one behind”. The agenda proposes to build inclusive, safe, resilient and sustainable cities, and human settlements. Cities have gone through primitive civilization, agricultural civilization and industrial civilization. Urban green development not only heralds the arrival of ecological civilization for cities but also serves to achieve urban development goals in an environmentally friendly manner. Following the green development pattern, cities will focus on people’s all-round development and treat the capacity of ecological environment and the carrying capacity of resources as the internal factors of social and economic development. Moreover, cities will promote sustainable use of natural resources, constant improvement of ecological environment, continuous improvement of the quality of life and sustainable economic growth. In doing so, cities not only will meet people’s rising demand for natural resources as population increases but also can integrate the development of economy, society and people with environmental protection, so as to create a better environment for city dwellers, achieve urban development goals and truly realize the urban dream of the humanity.

III. Theoretical Model and Realization Mechanism of Urban Green Development

City is a comprehensive system that includes economic, ecological and social factors.⁸ The traditional urban development outlook should be re-examined for urban green development, and the sustainable growth of urban economy, sustainable use of resources and harmonious coexistence of society should be integrated into the system framework of urban green development. On the basis of the classical model of traditional urban economic growth, this report constructs a theoretical model of urban green development, explores the realization mechanism of urban green development and analyzes the urban green development system.

(I) Model construction: Urban growth system under constraints

Urban green development is an improvement process of both quantity and quality. The natural environment factors are assumed as exogenous variables in the traditional urban development model, so they are not discussed in the model. We believe that urban green development is a complex and profound system, and the degree of development is determined by all the state variables within the system. The problems of urban environmental economy stability, social development, environmental protection and resource conservation should be discussed in the form of endogenous variables. Specifically, urban green development pursues overall optimization under certain constraints, i.e. the concept of “1 + 1 > 2”. It requires the overall system utility to be optimal, rather than requiring the subsystems to be optimal at the same time. The key for achieving optimal overall utility of urban green development is creating balance and coordination among various factors, including the coordination among the various factors within the system, as well as among various systems. Therefore, urban green development is an urban growth system under constraints. According to the theory of maximum effect and relevant models of urban economic development, the report selects variables from the perspective of input, and then constructs urban green development model.

First of all, it is assumed that the urban green development system covers five input factors, i.e. labor, capital, resource, environment and technology. The utility equations of the five factors are as follows: Labor utility function: $U_p(t, s) = f_1(x_{pts}, M_{ts})$; capital utility function: $U_c(t, s) = f_2(x_{cts}, M_{ts})$; resource utility function: $U_r(t, s) = f_3(x_{rts}, M_{ts})$; environment utility function: $U_e(t, s) = f_4(x_{ets}, M_{ts})$; technology utility function: $U_f(t, s) = f_5(x_{fts}, M_{ts})$.

Each of the aforementioned variables has its constraints, which include, labor capacity constraint: $X_{pt} \leq X_p^{\max}$, indicating that the labor capacity does not exceed the maximum urban labor capacity; resource carrying capacity constraint: $X_{rt} \leq X_r^{\max}$, indicating that the resource usage does not exceed the maximum carrying capacity

of urban resources; environmental supporting capacity constraint: $X_{et} \leq X_e^{\max}$, indicating that the environmental usage does not exceed the maximum urban environmental supporting capacity.

There are two additional constraints: the first is the intergenerational development constraint, indicating that the total utility of future generations should be at least no less than the total utility of contemporary people, i.e. $U(t, s) \leq U(t + 1, s) \leq U(t + 2, s) \leq \dots \leq U(t + n, s)$; the second is the intercity development constraint: $\partial U^2 / \partial t \partial s \geq 0$, indicating that the urban development cannot weaken the total utility of other cities.

Thus, we can construct the conceptual model of urban green development, i.e.

$$\begin{aligned} \max U = & \pi_{pt}U_{pt}(t, s) + \pi_{ct}U_{ct}(t, s) + \pi_{rt}U_{rt}(t, s) \\ & + \pi_{et}U_{et}(t, s) + \pi_{ft}U_{ft}(t, s). \end{aligned}$$

The variables in the model are described as follows: t is a time variable, representing the stage of urban green development; s is a space variable, representing the cities in different spaces; $U(t, s)$ is the total utility of the t generation of s city; $U_i(t, s)$ is the utility value for the development of the i system factor (p, c, r, e and f represent labor, capital, resources, environment and technical factors, respectively) of the t generation of s city; X_{it} is the horizontal vector of the development of the i factor of the t generation; π_{it} is the weight of development utility of the i system factor of the t generation; $X_p^{\max}$, $X_r^{\max}$ and $X_e^{\max}$, respectively, indicate the threshold of labor, resource carrying capacity and environmental carrying capacity.

According to the principle of system dynamics, the aforementioned formula also satisfies the Bertalanffy equation, i.e.

$$\begin{aligned} \frac{dX_{pt}}{dt} &= g_1(X_{pt}, X_{ct}, X_{rt}, X_{et}, X_{ft}, X \propto_1), \\ \frac{dX_{ct}}{dt} &= g_2(X_{pt}, X_{ct}, X_{rt}, X_{et}, X_{ft}, X \propto_2), \\ \frac{dX_{rt}}{dt} &= g_3(X_{pt}, X_{ct}, X_{rt}, X_{et}, X_{ft}, X \propto_3), \end{aligned}$$

$$\frac{dX_{et}}{dt} = g_4(X_{pt}, X_{ct}, X_{rt}, X_{et}, X_{ft}, X \propto_4),$$

$$\frac{dX_{ft}}{dt} = g_5(X_{pt}, X_{ct}, X_{rt}, X_{et}, X_{ft}, X \propto_5).$$

The Bertalanffy equation shows that there are pairwise correlations among all factors in the urban green development system, and any factor may cause changes in the overall system on the basis of affecting other factors.

It can be seen that the objective function ($\max U$) representing the goal of urban green development is the maximum overall utility of urban system, which is obtained by weighted average of utility values of each subsystem. The weights of each generation vary according to the preferences of a particular generation. For example, in cities with relatively developed economy and society, people may attach more importance to resources and environment, so the weight of utility may be higher; while cities in developing countries are in urgent need of economic growth, so the weight of utility value for economic growth may be higher. Therefore, weights can also be expressed as functions of the development level of each system, i.e.

$$\vec{\pi}_t = \theta(X_t).$$

Among them, $\vec{\pi}_t$ is the weight vector, that is $\vec{\pi}_t = (\pi_{1t}, \pi_{2t}, \pi_{3t}, \pi_{4t}, \pi_{5t})$; X_t is the vector of the development level of each system; $X_t = (X_{pt}, X_{ct}, X_{rt}, X_{et}, X_{ft})$.

Generally speaking, the weights π_i of labor, resources, environment and technology are the increasing functions of time (t), i.e. $d\pi_{pt}/dt > 0$, $d\pi_{rt}/dt > 0$, $d\pi_{et}/dt > 0$ and $d\pi_{ft}/dt > 0$; while the weight π_i of economic system is a decreasing function of time (t), i.e. $d\pi_{ct}/dt < 0$.

The aforementioned conceptual model of urban green development indicates that urban green development is a developing pattern with stage characteristics, comprehensiveness and multi-dimension. It requires the overall promotion and improvement of various parts in urban development, including improvement of the development level of each system, development potential and coordination. At the same time, the model emphasizes the integrity of urban development

which considers that the optimization of the urban system is based on the optimization of each subsystem, and requires attention to the factors, structure and balance among subsystems.

(II) Realization mechanism: From general development to green development

According to the urban economic theory, the development of urban composite system is affected by two categories of factors: The first category refers to positive factors that support development activities, known as the “guiding factors”; under the guidance of such factors, cities move forward quickly by actively utilizing resources and embracing competition; the development speed of this stage is generally fast. The second category refers to factors that restrict development activities, known as the “limiting factors”. With the consumption and continuous usage of guiding factors, some restricting and limiting factors are gradually emerging; at this time, the urban development process is to seek development in the case of overcoming limiting factors, so the development speed is generally limited. The essence of urban development is the continuous improvement of development condition of urban composite system, i.e. the process of constantly promoting guiding factors and overcoming limiting factors.

1. General mechanism of urban development

In order to analyze the urban development mechanism, X is used to indicate the urban development level, $X(t)$ is used to indicate the urban development process, the urban development speed is expressed as dX/dt , and the relative development speed is expressed as $dX/dt/X$. With the development of the city, the function of the limiting factor will be gradually prominent and the speed of urban development will be slowed down. In this case, the relative development speed is taken as the linear decreasing function of X , i.e.

$$\frac{1}{X} \cdot \frac{dX}{dt} = r - \frac{r}{K} \cdot X.$$

Among them, K represents the highest development level of the city under development and environment conditions, i.e. $X_{\max} = K$; r represents the maximum relative development speed promoted by the limiting factors of the city under development and environment conditions.

The aforementioned equation is a first-order ordinary differential equation with separable variables. After the separation of variables, the differential equation of the Logistic curve is as follows:

$$\frac{dX}{dt} = r \cdot X \left(1 - \frac{X}{K} \right).$$

The changes in urban development level (X) and development speed (dX/dt) are further investigated. According to the three points where the second and the third derivative are zero in the Logistic equation, we can divide the urban development curve into four stages, including the initial stage, the development stage, the mature stage and the peak stage. In the initial stage, the urban development speed is slow, gradually rising from 0 to $rK/6$. In the development stage, the city is in a stage of rapid development, and the development speed is continuously increasing, gradually rising from $rK/6$ to $rK/4$. In the mature stage, the urban development level is high, and the development speed declines gradually but is still greater than $rK/6$. In the peak stage, the urban development speed is declining gradually to zero, and the development level is no longer increasing. It can be seen that the urban development level (X) increases rapidly and maintains a high level in the development stage and mature stage, and these two stages can be regarded as the rapid development zone of urban development. Therefore, the urban development should be kept in the two stages as long as possible.

Table 1.2 shows the specific changes in the four stages of urban development. For cities in the initial stage, due to lack of available resources, backward technology, and low production and consumption levels, the whole urban system is growing slowly. For cities in the development stage, due to continuous improvement of scientific and technological means, and continuous increase of available resources and unapparent environmental restriction, cities

Table 1.2. Four Stages of Urban Development.

t	X	dX/dt	d^2X/dt^2	Development Stage
$(0, t_1)$	Rise slowly	Rise	Rise	Initial stage
t_1	$K/2 - K/2^{\sqrt{3}}$	$rK/6$	$r^2K/6^{\sqrt{3}}$	
(t_1, t_0)	Rise rapidly	Rise	Decline	Development stage
t_0	Inflection point	$rK/4$	0	
(t_0, t_2)	Continue to rise	Decline	Decline	Mature stage
t_2	$K/2 + K/2^{\sqrt{3}}$	$rK/6$	$-r^2K/6^{\sqrt{3}}$	
$(t_2, +\infty)$	Tend to be smooth	Decline	Rise	Peak stage

show a trend of rapid development. In the mature stage, cities are restricted by population, environment capacity and resources. The function of limiting factors is gradually prominent, and urban development begins to be restricted. When urban development reaches its peak, the development speed slowly decreases to 0. If the city cannot overcome the limiting factors of the system, there may be a recession.

2. Mechanism of urban green development

The purpose of green development is to maintain normal operation and sustainable growth of urban composite system, i.e. the urban development level X is increasing constantly, and will not decline from the peak stage. To achieve this goal, we must overcome the limiting factors of urban development and look for opportunities for development starting from the guiding factors, so that the city can transit to a higher development level from a lower level and step into the next round of development. Therefore, the urban green development curve can be expressed as a combined Logistic curve, that is, although there are fluctuations in a short time, it is a smooth and sustainable process in the long run (Figure 1.1).

In order to realize urban green development, it can be considered from two perspectives. The first is to extend the period of

Figure 1.1. Realization Mechanism of Urban Green Development.

development and maturity, i.e. to extend (t_1 and t_2) intervals; the second is to delay the time for entering the recession and to remain in the mature period as much as possible, and to promote urban development from the current equilibrium into a better equilibrium through structure optimization and system configuration. From either perspective, urban green development is a constant process from equilibrium to better equilibrium. It is of vital importance to promote the upgrading and coordination of various subsystems of urban green development, and to drive forward the optimization of economic structure, innovation of science and technology and constant progress of life quality and social welfare. Therefore, in order to promote urban green development, efforts should be made to guide the harmonious development of urban systems, so that they will evolve into a more balanced and complementary state.

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