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Important influencing factors analysis of airport sustainable development capacity: The case of China

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Abstract

Purpose: This paper seeks to define and build the formation mechanism for airport sustainable development capacity.

Design/methodology: Structure Equation and System Dynamic Model are used to research the formation mechanism of airport sustainable development capacity.

Findings: The most influencing factors are: airport own investment, Gross Domestic Product and power consumption of unit income.

Originality/value: Firstly, a new concept to evaluate the dynamic work on sustainable development is proposed, which is defined as airport sustainable development capacity. Secondly, the formation mechanism of airport sustainable development capacity is studied through Structure Equation Model and System Dynamics model. It fills in the gap of existing research whose main focus is static evaluation of airport sustainable development capacity and influencing factors identification rather than dynamic formation mechanism.

Keywords: Airport sustainable development capacity; important influencing factors; Structure Equation Model; Dynamic equations

1. Introduction

In recent years, with the rapid development of China and the improvement of household consumption level, aviation demand has increased enormously, so many cities are planning to invest on new airports or on airport extension, which can offer convenience to people's travel and promote the development of Chinese economy. However, airport extension has brought some environmental disruptions, especially aviation noise and aviation gas emission. Those problems would become more prominent with the rapid development of China, so airport sustainable development problem becomes a hot public concern.

For the past few years, airport sustainable development problem has been a popular research topic and the existing research has focused on airport sustainable development capacity evaluation and influencing factors identification.

- The evaluation of airport sustainable development capacity. In some literatures, evaluation index system was built from many aspects of operational ability, social benefit, resource utilization and environment influence, and all kinds of models were used to study the airports in a certain region (Cui, Wu & Kuang, 2012; Barrett, 2000; Graham & Guyer, 1999; Lee & Yang, 2003; Zhang, 2003; Upham, Thomas, Gillingwater & Raper, 2003; Phang, 2003). Typically, Cui et al. (2012) defined airport sustainable development capacity and constructed evaluation system of airport sustainable development capacity from four aspects: operational ability, social benefit, resource utilization and environment influence, and then analyzed the main factors affecting airport sustainable development capacity before decision-making guidance for Chinese airports' healthy and steady development was provided. Upham (2003) analyzed the ways in which environmental factors and public perceptions influenced airport development and thought that more attention were needed to be given to defining and finding commercially viable ways of working within environmental limits. Phang (2003) thought that the most difficult assessment might be the game consideration of how much capacity and how far ahead excess capacity were needed to ensure the sustainable development for hub airports.
- Influencing factors identification of airport sustainable development capacity. Longhurst, Gibbs, Raper and Conlan (1996) considered the application of sustainable development principles to an airport situation and stated that research was necessary on application and localization procedures for sustainable development. Veldhuis and Essers (1999) constructed a comprehensive airport competition model, which could supply analysis tool on airport sustainable development in a competitive environment. Graham (2004) discussed airport competition strategies and evaluated the airport adaptation level under all kinds of strategies so that every airport could choose the best strategy to

assure its sustainable development. Three aspects of Ningbo Airport were discussed on the base of its present state and some advice about the development strategy of the airport was given (Huang, 1999). Zhang (2008) analyzed the dominant performance and influencing factors of airport competitiveness and constructed a model on airport sustainable development. Cai (2010) qualitatively analyzed the current situation and development direction of Chinese airline industry and proposed some advice for Chinese airports on sustainable development.

The limitations of existing research are:

- Existing research mainly focuses on static evaluation of airport sustainable development capacity instead of formation mechanism, so the dynamic work on improving airport sustainable development capacity has not been evaluated, which is vital to the sustainable development of airports.
- The objects of most existing studies are confined to some specific influencing factors and little research focuses on the influencing mechanism of combined factors, which leads to insufficient pertinent suggestions on how to enhance airport sustainable development capacity.

This paper is structured as follows: Firstly, airport sustainable development capacity is defined; Secondly, static measurement index and formation mechanism index system for airport sustainable development capacity are built; Thirdly, an empirical study on the formation mechanism of airport sustainable development capacity is done by Structure Equation Model and System Dynamics; Finally, important influencing factors of airport sustainable development capacity are simulated by Vensim software before some conclusions are gotten according to the results.

2. Definition and index system

Definition

There are many literatures focusing on many kinds of capacities. In O'Reilly (1986), tourism carrying capacity is defined as the ability of the destination area to absorb tourism before negative impacts of tourism are felt by the host community. In Pearce (1989), carrying capacity is commonly considered as the threshold of tourist activity beyond which facilities are saturated (physical carrying capacity), the environment is degraded (environmental carrying capacity) or visitor enjoyment is diminished (perceptual or psychological carrying capacity). Improving capacity is widely introduced in communication and networks (Cai & Li, 2004; Bose, 2004). It is defined as the capacity to improve communication efficiency under different conditions and different mediums. These definitions lay good theoretical foundation for energy efficiency improving capacity.

Based on the literature (Cui et al., 2012) and the real situation of airports, airport sustainable development capacity in this paper is defined as: **Under the condition of realizing its operational goal to assure its market position in leading field as well in future competition, the capacity to balance environment carrying capacity and resource usage. It is the capacity to pursue the harmonization of economic demand, social demand and environmental impact.** Airport sustainable development capacity is not only an integration of capacities supporting and promoting sustainable development, but also a capacity supporting system consisted of regional development driving force, own operational capacity, social benefit creative capacity, resource usage capacity, market driving force, support industry driving force and environment driving force. It supports the process from quantitative change to qualitative change in promoting airport sustainable development.

Index system

According to existing research (Cui et al., 2012; Upham, 2003) and the definition of airport sustainable development capacity, it is believed that the influencing factors of airport sustainable development capacity contain seven aspects: regional development driving force, own operational capacity, social benefit creative capacity, resource usage capacity, market driving force, support industry driving force and environment driving force.

Regional development driving force is defined to describe the airport's regional situation, which contains four small indices: Gross Domestic Product of located city, Proportion of third industry output, City R&D input and Graduated students number.

Own operational capacity is defined to reflect the airport's operational situation, which contains five indices: Flight zone level, Per capita flight times in service radius, Total assets, Profit rate and Airport' own investment.

Social benefit creative capacity is defined to describe the airport's impact on social development, which contains three indices: Directly provided job number, Paid tax and Passenger number on average flight.

Resource usage capacity is defined to reflect the airport's resource usage situation, which contains two indices: Income of average flight and Productivity of unit staff.

Market driving force is defined to describe the market situation of the airport, which contains three indices: City residents traffic spending, Service radius and City fixed investments.

Support industry driving force is defined to reflect the situation of related industry, which contains three indices: Passenger volume of road, railway and waterway, Freight volume of road, railway and waterway and Total tourism revenue.

Environment driving force is defined to reflect the airport's environment influence, which contains two indices: Noise grade and Power consumption of unit income.

In this paper, "Annual increase rate of main business income" and "Annual increase rate of return on asset" are defined as the static evaluation indices of airport sustainable development capacity.

The detailed indices are shown in Table 1.

Index classification	Latent variables	Measurable variables
Static evaluation index	Airport sustainable development capacity (CAPA)	Annual increase rate of main business income Annual increase rate of return on asset
Influencing factors	Regional Development Driving Force (REG)	Gross Domestic Product of located city Proportion of third industry output City R&D input Graduated students number
	Own Operational Capacity (OPE)	Flight zone level[1] Per capita flight times in service radius[2] Total asset Profit rate Airport's own investment
	Social Benefit Creative Capacity (SOC)	Directly provided job number Paid tax Passenger number on average flight
	Resource Usage Capacity (RES)	Income of average flight Productivity of unit staff
	Market Driving Force (MARK)	City residents traffic spending Service radius[3] City fixed investments
	Support Industry Driving Force (SUP)	Passenger volume of road, railway and waterway Freight volume of road, railway and waterway Total tourism revenue
	Environment Driving Force (ENV)	Noise grade[4] Power consumption of unit income

1. Flight Zone Level is defined as the biggest aircraft that the facilities of airport flight zone can support, it has two measurement indicators: the length of runway and the distance between the wingspan of the biggest supported airplane and the felly of main landing gear. In China, flight zone level is divided into several grades: 4F, 4E·60, 4E·45, 4D and 4C, and their measurable value are 5, 4.5, 4, 3, and 2 respectively (Cui et al., 2012).

2. Per capita flight times in Service Radius is defined as the passenger throughput of the airport divided by the population size in service radius.

3. Service radius is officially defined by Civil Aviation Administration of China as people amount within 100km from airport or within 1.5 hours driving range. Service Radius is defined as people amount of the Directly Controlled Municipalities and Prefecture Level Cities in China (Cui et al., 2012).

4. The airport noise can be classified into four grades: Grave, Serious, Common and Slight, and their measurable value is 4, 3, 2, and 1 respectively (Cui et al., 2012).

Table 1. Evaluation index system of airport sustainable development capacity

3. Static formation mechanism model

Structure Equation Model (SEM) will be used in this section. It is consisted of latent variable layer and measurable variable layer, which is a linear statistical modeling tool in analyzing the relationship of variables. Its principle is: some hypotheses on latent variable layer must be given before structure equation model is built to verify the hypotheses and the related equations can be obtained (Liu, Wang & Cao, 2010).

Following hypotheses on latent variable layer are proposed according to the research on formation mechanism:

H1: Regional Development Driving Force (REG) has positive influence on Airport Sustainable Development Capacity (CAPA).

H2: Environment Driving Force (ENV) has negative influence on Airport Sustainable Development Capacity (CAPA).

H3: Social Benefit Creative Capacity (SOC) has positive influence on Airport Sustainable Development Capacity (CAPA).

H4: Own Operational Capacity (OPE) has positive influence on Airport Sustainable Development Capacity (CAPA).

H5: Own Operational Capacity (OPE) has positive influence on Social Benefit Creative Capacity (SOC).

H6: Resource Usage Capacity (RES) has positive influence on Own Operational Capacity (OPE).

H7: Market Driving Force (MARK) has positive influence on Own Operational Capacity (OPE).

H8: Support Industry Driving Force (SUP) has positive influence on Own Operational Capacity (OPE).

The data is obtained from the airports of Guangzhou, Shanghai, Shenzhen, Xiamen, Beijing, Haikou, Jinan, Chongqing, Urumqi, Xi'an, Dalian, Wuhan, Shenyang, Harbin, Sanya, Changsha, Hangzhou, Taiyuan, Zhengzhou, Qingdao, Kunming, Chengdu, Tianjin, Nanjing and Ningbo from 2001 to 2010. Since the new century, Chinese government and many sectors are promoting the sustainable development capacity strategy. Many airports have made plans to enhance their sustainable development capacity. It is meaningful to study the sustainable development capacities of airports during this period. These twenty five cities are the most developed cities in China, it has enough representativeness to study airport sustainable development capacity of the twenty five airports, and it could also enrich the formation mechanism theory of airport sustainable development capacity in China. The data of Guangzhou, Shanghai, Shenzhen, Xiamen, Beijing and Haikou is obtained from list airports (these six airports are listed airports). The data of other airports comes from research report, network data and city statistical yearbook.

Visual-Pls software is used in empirical test and the value of is used to test explanation power, as shown in Figure 1.

In Figure 1, all the are very big, this reflects that the model has good interpretive power.

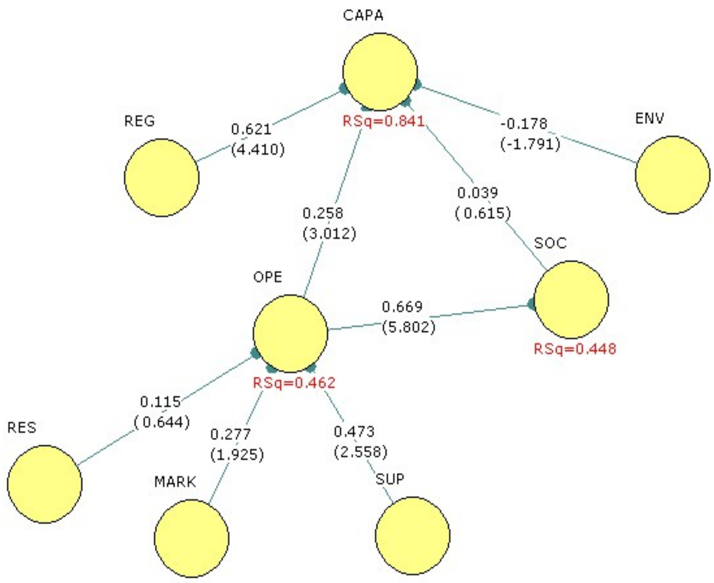

Figure 1. Static formation mechanism

There are two test methods in structure equation: reliability test and validity analysis. In reliability test, the value of *Cronbach's alpha* and *Composite Reliability* is bigger than 0.6, which can meet requirement; in validity test, all the square roots of *AVE* are bigger than the absolute value of latent variable related coefficients, and all *AVE* are bigger than 0.5, which shows the model can totally pass test.

4. Dynamic formation mechanism model

Dynamic flow graph design

The analysis of structure equation is static and isolated, which can not reflect formation mechanism of influencing factors on airport sustainable development capacity, so System Dynamic model will be used in this section. Its principle is: total related variables of airport sustainable development capacity are considered as a system, and influence paths among variables are built according to the equations from Structure Equation Model. After that, their influence on airport sustainable development capacity is verified through changing the value of some variables, then the variables with important impacts will be obtained (Zhao & Dang, 2008).

All the related variables of airport sustainable development capacity are considered as an economic system. According to the principle of system theory (Von Bertalanffy, 1968), the inputs of economic system can be classified into 3 types: labor resources, material resources and financial resources, so Population (POP), City Investment (INV), Airport Investment (Airport Inv) and Energy Consumption (ENE) are defined as system starting points and Vensim software is used to construct the flow graph of dynamic formation mechanism, as shown in Figure 2.

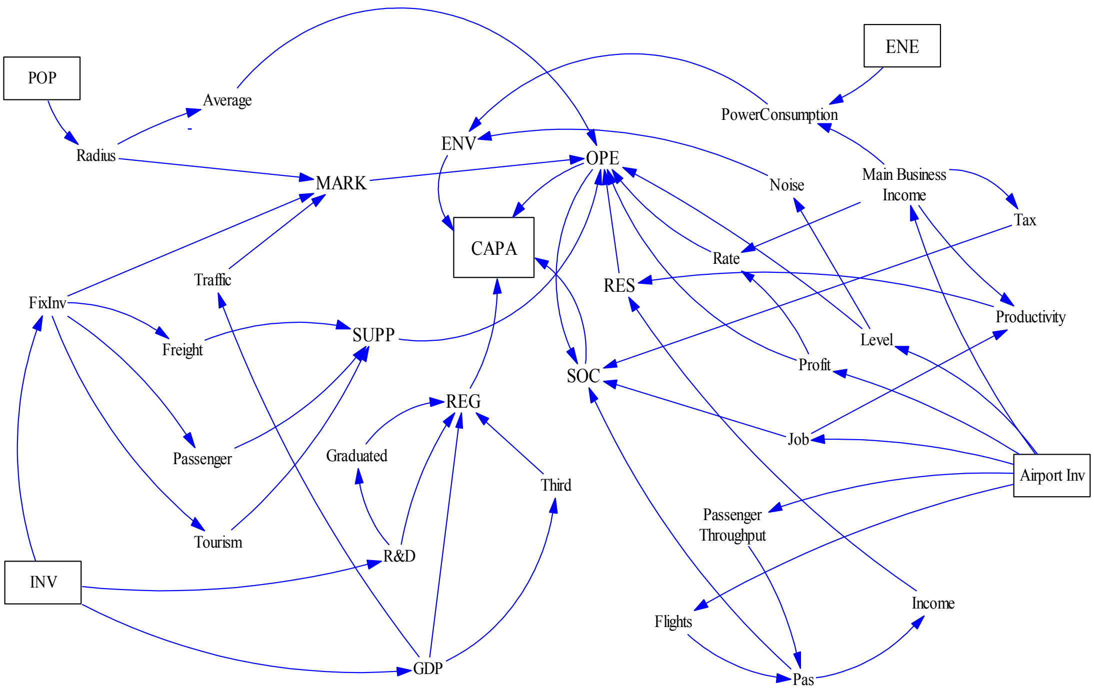

Figure 2. Flow graph

Dynamic equations

Dynamic equations are constructed on basis of the parameters from Structure Equation Model:

1. Dynamic equations between latent variable layer and measurable variable layer.

1 Regional development driving force (REG)

There are four measurable variables for regional development driving force: Gross Domestic Product (GDP), Third industry output (Third), City R&D input (R&D) and Graduated students number (Graduated).

Dynamic equations:

$$GDP(t) = C_1 * INV(t)$$

$$R\&D(t) = C_2 * INV(t)$$

$$Third(t) = C_3 * GDP(t) = C_3 * C_1 * INV(t)$$

$$Graduated(t) = C_4 * R\&D(t) = C_4 * C_2 * INV(t)$$

$$REG(t) = 0.312 * GDP(t) + 0.326 * Third(t) + 0.296 * R\&D(t) + 0.188 * Graduated(t)$$

C_1, C_2, C_3, C_4 proportionality factors, $INV(t)$ is City Investment. The coefficients of *REG* are from the results of Structure Equation Model.

2 Own operational capacity(OPE)

There are four measurable variables for own operational capacity: Flight Zone Level (Level), Average flight time in Service Radius (Average), Total profit (Profit) and Profit rate (Rate).

Dynamic equations:

$$Level(t) = C_5 * Airport\ Inv(t)$$

$$Radius(t) = C_7 * POP(t)$$

$$Average(t) = C_6 * Radius(t) = C_6 * C_7 * POP(t)$$

$$Profit(t) = C_8 * Airport\ Inv(t)$$

$$Main\ Business\ Income(t) = C_9 * Airport\ Inv(t)$$

$$Rate(t) = Profit(t)/Main\ Business\ Income(t) = C_8/C_9$$

$$OPE(t) = 0.516 * Level(t) + 0.213 * Average(t) + 0.564 * Profit(t) + 0.293 * Rate(t)$$

C_5, C_6, C_7, C_8 are proportionality factors, *POP(t)* is regional population of year *t*, *Airport Inv(t)* is airport investment in year *t*. The coefficients of OPE are from the results of Structure Equation Model.

3 Social benefit creative capacity (SOC)

There are three measurable variables for social benefit creative capacity: Directly provided job number (Job), Paid tax (Tax) and Passenger number on average flight (Pas).

Dynamic equations:

$$Job(t) = C_{10} * Airport\ Inv(t)$$

$$Tax(t) = C_{11} * Main\ Business\ Income(t) = C_{11} * C_9 * Airport\ Inv(t)$$

$$Flights = C_{12} * Airport\ Inv(t)$$

$$Passenger\ Throughput(t) = C_{13} * Airport\ Inv(t)$$

$$Pas(t) = Passenger\ Throughput(t) / Flight(t) = C_{13} / C_{12}$$

$$SOC(t) = 0.595 * Job(t) + 0.531 * Tax(t) + 0.256 * Pas(t)$$

C_{10}, C_{11}, C_{12}, C_{13} are proportionality factors, *Airport Inv(t)* is airport investment in year *t*. *Passenger Throughput(t)* is passenger throughput in year *t*. The coefficients of *SOC* are from the results of Structure Equation Model.

4 Resource usage capacity (RES)

There are two measurable variables for resource usage capacity: Income of average flight (Income) and Productivity of unit staff (Productivity).

Dynamic equations:

$$Income(t) = C_{14} * Pas(t) = C_{14} * (C_{13} / C_{12})$$

$$Productivity(t) = Main\ Business\ Income(t) / Job(t) = C_9 / C_{10}$$

$$RES(t) – 0.698 * Income(t) + 0.762 - Productivity(t)$$

The coefficients of *RES* are from the results of Structure Equation Model. C_{14} is proportionality factor.

5 Market driving force (MARK)

There are three measurable variables for market driving force: City residents traffic spending (Traffic) and Service Radius (Radius) and City fixed investments (FixInv).

Dynamic equations:

$$Traffic(t) = C_{15} * GDP(t) = C_{15} * C_1 * INV(t)$$

$$Radius(t) = C_7 * POP(t)$$

$$FixInv(t) = C_{16} * INV(t)$$

$$MARK(t) – 0.382 * Traffic(t) + 0.533 * Radius(t) + 0.326 * FixInv(t)$$

C_{15}, C_{16} are proportionality factors, *INV(t)* is city investment in year *t*. The coefficients of *MARK* are from the results of Structure Equation Model.

6 Support industry driving force (SUP)

There are three measurable variables for support industry driving force: Passenger volume of road, railway and waterway (Passenger), Freight volume of road, railway and waterway (Freight) and Total tourism revenue (Tourism).

Dynamic equations:

$$Passenger(t) = C_{17} * FixInv(t) = C_{17} * C_{16} * INV(t)$$

$$Freight(t) = C_{18} * FixInv(t) = C_{18} * C_{16} * INV(t)$$

$$Tourism(t) = C_{19} * FixInv(t) = C_{19} * C_{16} * INV(t)$$

$$SUP(t) – 0.097 * Passenger(t) + 0.447 * Freight(t) + 0.624 * Tourism(t)$$

C_{17}, C_{18},C_{19} are proportionality factors, *INV(t)* is city investment in year *t*. The coefficients of *SUP* are from the results of Structure Equation Model.

7 Environment driving force (ENV)

There are two measurable variables for environment driving force: Noise grade (Noise) and Power consumption of unit income (Power Consumption).

Dynamic equations:

$$Noise(t) = C_{20} * Level(t) = C_{20} * C_5 * Airport\ Inv(t)$$

$$Power\ Consumption(t) = C_{21} * ENE(t)$$

$$ENV(t) – 0.344 * Noise(t) – 0.928 * Power\ Consumption(t)$$

C_{20}* C_{21} are proportionality factors, *Airport Inv(t)* is airport investment in year *t*, *ENE(t)* is energy consumption in year *t*. The coefficients of *ENV* are from the results of Structure Equation Model.

8 Airport sustainable development capacity (CAPA)

There are two measurable variables for airport sustainable development capacity: Main Business Income and Return on Asset (ROA).

Dynamic equations:

$$CAPA(t) – 0.623 * Main\ Business\ Income(t) + 0.564 * ROA(t)$$

The coefficients of *CAPA* are from the results of Structure Equation Model.

2. Dynamic equations on latent variable layer.

$$OPE(t) – 0.115 * RES(t) + 0.277 * MARK(t) + 0.473 * SUP(t)$$

$$SOC(t) – 0.669 * OPE(t)$$

$$CAPA(t) = CAPA\ (t-1) + 0.621 * REG(t) + 0.258 * OPE(t) + 0.039 * SOC(t) – 0.178 * ENV(t)$$

The coefficients are from the results of Structure Equation Model.

5 Simulation

Change trend

It is assumed that the initial value of population(POP), city investment (INV) and Energy Consumption (ENE) is 1 and the initial value of airport own investment(Airport Inv) is 0.1, the annual growth rate is 5%, the proportion of the population in service radius divided by total population is 5%, the driving coefficient of city investment to GDP is 10, the proportion of city fixed investment divided by city investment is 10%, the value of all other coefficients is 0.01, the operation cycle is 10 years. The change diagram of airport sustainable development capacity is shown in Figure 3.

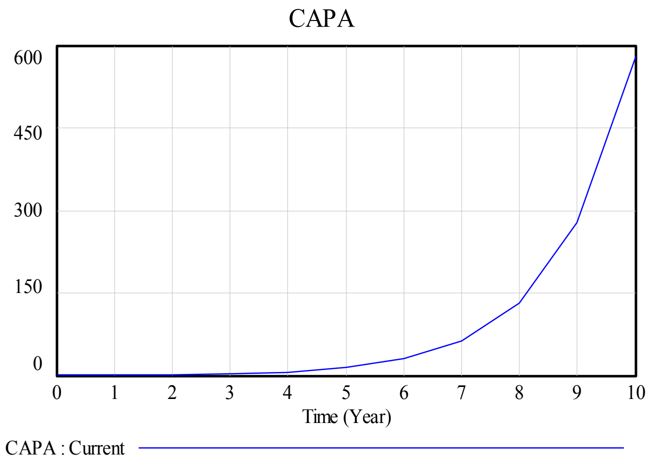

Figure 3. Change diagram

Important influencing factors analysis

Through the dynamic equations, it can be concluded that Airport Own Investment (Airport Inv), Gross Domestic Product (GDP) and Power consumption of unit income (Power) are the most important influencing factors of airport sustainable development capacity, and then the influencing degree of these three factors will be analyzed.

Airport Own Investment (Airport Inv) has important implications for airport sustainable development capacity. All aspects have very close relationship with airport own investment such as upgrade of flight zone level, talent introduction and main business income. It can be concluded that the bigger Airport Own Investment (Airport Inv) is, the bigger airport sustainable development capacity is. The simulation process is shown in Table 2.

Own Investment (Initial value is 0.1)	**Airport sustainable development capacity**									
	1	2	3	4	5	6	7	8	9	10
Annual increase rate is 10%	0.5513	1.3862	3.0978	6.6962	14.2982	30.3630	64.2915	135.8970	286.9200	605.2480
Annual increase rate is 30%	0.5513	1.4057	3.1873	6.9937	15.1823	32.8600	71.1408	154.2950	335.4950	731.6090
Annual increase rate is 50%	0.5513	1.4230	3.2690	7.2815	16.1055	35.6986	79.6287	179.1110	406.6580	932.2530

Table 2. Simulation process of airport own investment (Airport Inv)

Gross Domestic Product (GDP) has important influence on airport sustainable development capacity and the sustainable development of airport cannot stand away from the development of urban economy. It can be concluded that the more developed urban economy is, the bigger sustainable development space of the airport is. The simulation process is shown in Table 3.

Driving coefficient of INV to GDP	Airport sustainable development capacity									
	1	2	3	4	5	6	7	8	9	10
10	0.5513	1.3809	3.0738	6.6187	14.0775	29.7706	62.7530	131.9890	277.1590	581.2170
15	0.5513	1.3809	3.0738	6.6189	14.0780	29.7718	62.7559	131.9950	277.1740	581.2510
20	0.5513	1.3809	3.0739	6.6191	14.0785	29.7731	62.7587	132.0020	277.1890	581.2850

Table 3. Simulation process of Gross Domestic Product (GDP)

Power consumption of unit income (Power) has important influence on airport sustainable development capacity and the sustainable development of airports must take low-carbon and energy saving road. It can be concluded that the more Power consumption of unit income is, the smaller sustainable development space of the airport is. The simulation process is shown in Table 4.

Power	Airport sustainable development capacity									
	1	2	3	4	5	6	7	8	9	10
0.1	0.5513	1.3809	3.0738	6.6187	14.0775	29.7706	62.7530	131.9890	277.1590	581.2170
0.2	0.5513	1.2999	2.7137	5.5302	11.2840	23.2041	48.1093	100.4130	210.5770	442.9480
0.3	0.5513	1.2594	2.5039	4.8026	9.1727	17.6695	34.5156	68.4940	138.0370	282.0840

Table 4. Simulation process of Power consumption of unit income (Power)

6. Conclusions

The definition and formation mechanism of airport sustainable development capacity are studied in this paper. Airport sustainable development capacity is defined to reflect the dynamic work on sustainable development. It contains seven aspects: regional development driving force, own operational capacity, social benefit creative capacity, resource usage capacity market driving force, support industry driving force and environment driving force. Structure Equation Model and System Dynamics model are applied to explore its formation mechanism. The empirical study is based on the real data of twenty five airpots from 2001 to 2010.

The main conclusions are:

1. According to the results of Structure Equation Model, the main direct influencing factors come from regional development driving force, own operational capacity, social benefit creative capacity and environment driving force.
2. From the results in Section 5, airport own investment, Gross Domestic Product and power consumption of unit income are the most important influencing factors of airport sustainable development capacity.

On the whole, the contribution of this paper to the literatures is embodied in two aspects. Firstly, a new concept to evaluate the dynamic work on sustainable development is proposed, which is defined as airport sustainable development capacity. Its definition and evaluation indices are offered in Section 2. Secondly, the formation mechanism of airport sustainable development capacity is studied through Structure Equation Model and System Dynamics model. It fills in the gap of existing research whose main focus is static evaluation of airport sustainable development capacity and influencing factors identification rather than dynamic formation mechanism. Further research could focus on the evolution trend analysis of airport sustainable development capacity.

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