Growth of Enterprise Information Technology Application:

System Dynamics Model and Empirical Evidence

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Abstract: *The present research on the growth of enterprise information technology applications is to build an effective system dynamics model which can reveal the internal laws of the general process experienced by an enterprise integrating the application of modern information technology and management. Based on the literature review and surveys on more than two hundred companies, we sum up the mechanism among the information technology application and key impact factors. In accordance with the conventional modeling methods of system dynamics, a model has been built and tested. The model is also supported by the empirical evidence.*

Keywords: System dynamics model, Information Technology application maturity, Industrial Experience

1. INTRODUCTION

In the business operation and developmental process of a modern enterprise, Information Technology (hereinafter called as IT) has become an important management tool. The relationship between an enterprise's IT applications (hereinafter called as ITA) and other regulatory elements is a kind of mutual influence, mutual reinforcing and a cycle of causes and effects. The system dynamics is quite suitable for describing this relationship. At present, the system dynamics (hereinafter called as SD) is becoming a research method to understand and recognize the complex systems of human dynamics. Using system dynamics to research on the field of information system is still rare. Major researches focus on the dynamic development of technological and business activities of an IT enterprises, the interactions between planning & controlling system and business growth, the security of an enterprise's e-mails and information and other fields (Pardue 1999, Bianchi 2002, Dutta and Roy 2008, Kanungo and Jain 2008)[2-4]. Among the mentioned researches above, Clark and Jones (2008) put forward the system dynamics model of a management support system, providing with an explanation of the relationship between the use of a management support system and the cost and quality of decision-making [5].

Considering the core issues in the IT industry, the topic of ITA research mainly includes the following subjects: (1) ITA benefit evaluation, as the famous argument of "Productivity Paradox", resolves to the Investment issues of "necessary or not" of the IT Information System. (2) ITA conversion process ,as the methods Weill has used to introduce the concept of "Conversion Efficiency" which explain the inherent mechanism of the impact that IT investment make on the Enterprise Performance, resolves to the issues of "how to implement the IT Performance from the Investment "[1]. (3) The research on ITA growth stage, as the Nolan Stage Theory, resolves to the need of IT industrial understanding to the feature and the tendency of ITA Development. (4) The research of ITA evaluation model in enterprise, as the famous "D&M IS Success Model", resolves to the rationality of ITA in Enterprise. (5) The research of ITA critical impact factors is blooming these years, all kinds of factors having been summed in different contexts.

Inspired by the latter three research topics, which belong to management-type research in contrast to the former two economic researches, we try to construct a model integrating these three with the properties of SD method. The critical impact factors research will help select suitable system variables (endogenous and exogenous). ITA evaluation model manifest the connotation of ITA, and help make the interactions of variables (ITA and critical impact factors) clear to seek endogenous explanations. The research on ITA growth stage focuses on the general phenomena of ITA growth. Most elements are ready for conceptual model, which is beckoning us to jump in.

In order to know more about how ITA growth, we began to take field researches (survey and interview) at the initial of 2005. Up to the end of 2008, we have dropped in more than 300 enterprises in 24 provinces throughout China, obtaining a great deal of one hand materials. During the process, Xiao (2007) built a model for the evaluation and measurement for ITA, called "ITA maturity" (hereinafter called as ITAM), through an empirical way and putting forward the key impact factors involved in the growth of enterprise ITA [5,6]. The present paper introduce the process of building the SD model, which manifests the inner system mechanism, some of which relative research have implied, and the simulation result that is checked by existed theories and empirical evidence.

the enterprise ITA

has researches based on the available studies, by which an enterprise's ITAM and its key impact factors' forcing mechanism have been analyzed, a system dynamics model has been built, a upgrading path of an enterprise's ITAM is displayed through simulation which reflects the typical development trajectory for ITAM in Chinese enterprises. The model can explain more comprehensively the hackneyed phenomena from industries.

Jing-hua Xiao (2007) had field researches on 132 enterprises' related information systems in 22 provinces throughout China, building a model[6] for the evaluation of ITAM through an empirical way and putting forward the key impact factors[7] involved in an enterprise's ITAM. The present paper has researches based on the available studies, by which an enterprise's ITAM and its key impact factors' forcing mechanism have been analyzed, a system dynamics model has been built, a upgrading path of an enterprise's ITAM is displayed through simulation which reflects the typical development trajectory for ITAM in domestic enterprises.

2. BUILDING THE MODEL

In this paper, the system dynamics modeling method[8] raised by Randers (1980) is based to discuss four aspects, i.e., the modeling ideas, the concept model, mathematical model and the test of model, and put forward the dynamic hypothesis corresponding to the clear issues and boundary posed by Randers, to provide four steps for constructing equations and testing evaluation results.

2.1 Modeling Ideas

Enterprises, enterprise management, enterprise information systems are all systems of a certain type and certain level. The ITA of an enterprise is in fact a systemic issue in relation to business management. The ITA, top leader, employees, management capability, regulations, corporate culture, IT investment, business and technology alignment in a certain enterprise are all parts of such systemic issues. Here we'll discuss the focus of what is the typical growth process of enterprise ITA which is the main concern taken by the model and the other parts are called as its key impact factors. The boundary for determining issues is to select firstly those appropriate key impact factors. Jing-hua Xiao (2007) summarized and discussed the key internal impact factors influencing ITAM, including the top leader,

employees, management capability, corporate culture, business and technology alignment. Related field investigations, interviews and questionnaire issues have proved that the above-mentioned five factors have a significant impact on the enterprise ITAM [7]. In the present paper, the management capability and corporate culture are merged into one discussed as the management maturity (hereinafter called as MM) acceded with IT investment. The key impact factors discussed are top leader, employees, IT investment, management maturity, business and technology alignment (hereinafter called as BTA) and so on.

Speaking of the top leader's role involved in the IT application, Raghunathan (1992) pointed out that top leader participating in the Steering Committee of IT Implementation will result in a maximized relevance useful to the planning of information system and corporate strategy, enable employees aware of the importance and effectiveness of the information system planning and, at the same time, provide adequate resources to the applications of IT system[9]. Somers and Nelson (2004) used evidences to describe that top leader would play an important role throughout the life cycle of ERP[10]. Huigang Liang et al (2007) pointed out that top leader working as an agent should have the responsibility to change the organization's standards, values and culture so that ITA could be implemented more smoothly, and to promote other members of the organization(s) initiating active adoption of information technology [11].

Referring to MM, Zmud (1989) believed that the standardization of the corporate management foundation and a clearly stipulated business process would contribute effectively to the IT application [12]. Somers and Nelson (2001,2004) also highlighted a number of factors related to management capability when they studied the critical successful factors for IT application, including clear objectives, IT adopting a Steering Committee, process management, changing management, effective data analysis, trainings for strengthening IT application and process management, etc.[10,13] Weill (2004) studied 250 companies of 23 countries and found that the difference between those high-performance and low-performance ITA-based enterprises is that the former could apply more effectively those management tools for the IT governance [14].

Regarding BTA, Zmud (1991) studied the relationship between the provider of information technology (IT sector) and users (business units) and indicated that regular communications and mutual understanding could play a positive role in the IT application [15] . Luftman (1993, 2006) made his model for evaluating the matching maturity in respect to IT and business, in which mutual communications and coordination between IT sector and business units are deemed as the parts of its dimensions for evaluation. Furthermore, mutual communications and coordination are increasingly becoming the most concerned matters for the application of information system in an enterprise [16, 17]. Tan and Gallupe (2006) also considered that a common recognition of the information system from every aspect shared by IT and business personnel is quite necessary for ITA [18].

Concerning employees, Kown and Zmud (1987) believed that employees' educational level, job tenure as well as their attitudes to changes could create an important impact on the application effect of an information system [19]. Demeester (1999) believed that attitudes and values could decide the people's perceptions and emotional reactions, as well as their approaches for job-treating and problem-solving. Therefore, the attitude of employees would play an important role in the different effects of information system application [20]. Somers and Nelson (2001, 2004) pointed out that employees' supporting extent for a project, trainings on application of information technology and new business process are essential for the use of information system [10,13].

Summing up those discussed above, the present paper can summarize the modeling ideas as follows: Firstly, top leader can control resources (such as IT investment), enhance MM (including systems, culture, values, process, etc.), coordinate BTA, have employees educated, affected and trained to promote the growth of enterprise ITAM. Secondly, MM-related systems, culture and values will affect the working enthusiasm and attitude of employees, including their attitude towards ITA. Thirdly, the alignment among business, technology and staff can help business staff use information system more effectively and accurately. At the same time, technological staff will be assisted to understand the business function and value provided by information system so that the use of information system can be disseminated and promoted in a better way. Such a process is a flow which can enhance the ITA capacity of staff. Fourthly, staff members are the principle part using the information technology. Therefore, how can an enterprise's ITAM be is based on how the staff use their information system.

2.2 Conceptual Model

The concept model refers to dynamic hypothesis, including two important tasks, i.e., seeking the endogenous explanation on issues and related phenomenon and mapping system structure [21].

Through the above analysis, we can summarize the endogenous explanation on force mechanism of an enterprise's ITAM and the related key impact factors as follows: The desire of top leader for obtaining better use of IT would make IT investment increased, MM enhanced while BTA strengthened. Increasing IT investment can increase, firstly, an information system's hardware performance and software functions and, secondly, the ITAM itself; Enhancing MM can urge, firstly, employees improved more and, secondly, the better application of IT for various systems and regulations and process; Strengthening BTA can strengthen employee operation capacity of IT; and training can also play such a similar role. Employees' strong ITA capacity and positive attitude will contribute to the formation of a high level ITA in an enterprise and thus achieved satisfactory ITA effect will see the perception of top leader whose desire for the IT application will be enhanced then. However, the top leader's concern and desire for ITA will be regulated by their expectation of the ITA level reached. When ITAM perception and expectation are far away greatly, the related concern and desire will then be strengthened and the related concern would be shifted to other aspects if the perception is closer to expectation. In addition, there is a depreciation process for ITAM. As time goes by, the original used hardware and software will be depreciated along with technical aging while business requirements and IT are not matched along with the environmental changes. All these and some other factors may degrade the ITAM. The present study has presented simple levels of the system and, therefore, the system structure will be indicated in the related steps of causal loop diagrams all together.

2.2.1 Model Boundary Table

The main task here is to identify key variables. The model boundary sums up the model range based on various variables, including endogenous variables and exogenous variables, as well as those variables outside the model, which are explained upon requests. The endogenous variables here include ITAM, top leader perception, top leader desire, IT investment, MM, BTA, employee trainings, employee capacity (hereinafter called as EC), employee attitude of staff and depreciation while the exogenous variables include top leader ideal expectation (for ITAM) and perceived influence factor (top leader).

2.2.2 Causal Loop Diagrams

The endogenous explanation describes the causal relationship among variables, from which the causal loop diagrams are shown in Figure 1, which has totally 11 loops. Apart from the depreciation loop at the top, which is the simplest balanced one, below it there are five pairs of 10 loops. ITAM depreciation has many factors and has a gradually changing process over a period of time. Since it is not the main target studied by us, we have had a simplified treatment to integrate it into a variable depreciation.

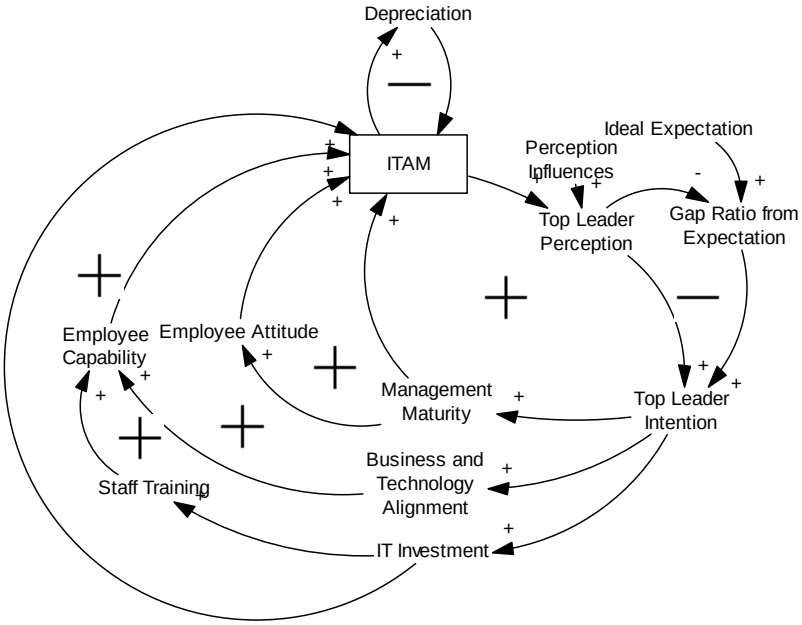

Figure 1. Causal Loop Diagrams of ITAM growth

Following from ITAM to top leader perception below the top leader desire, there are five paths and the causal chain of each variable is the cathode, meaning the enhanced loop with changes in the same direction. And there are two paths from top leader perception to top leader desire, the cathode causal chain meaning that top leader would form a desire to further strengthen the relevant work upon the relate perception of the effects achieved from the upgrading of ITAM, and the other negative electrode one meaning that top leader, along with the deeply continuing and a deeper understanding of ITA, would form an ideal expectation of ITAM. The smaller gap between the actual ITAM and expected application, the lower of power and desire for continuing to pay attention and strengthen the related work is. Therefore, the aforementioned five positive paths become 10 loops formed after following two different polarities of paths, of which 5 are enhanced loops and 5 are balanced ones. At the initial stage, the enhanced loops play a leading role in promoting the development of ITAM. With the continuous improvement of ITAM, the balanced loops' role begins and the ITAM growth rate will become slow down. This is the typical S-shaped Logistic Growth, which is on one hand enlightened by the Nolan Stage Model, the similar characterized S-shaped curve, and on the other hand compliant to the fact.

2.2.3 Stocks and Flows

The focus of the model variables, ITAM, is stocks. For flows, variables affecting the effect of

ITAM inflows include IT investment, EC, employee attitude and MM. The role of outflow is the depreciation. The flows here are not clearly marked in diagrams, but are equivalently implied in relations set by the corresponding variables (stocks and auxiliary variables).

The model stock variables include ITAM, EC, MM, BTA. Those other than these are auxiliary variables.

2.3 Math Model

The Mathematical relationship here is the math expression and refinement of the above endogenous explanation. We select the import expression to be explained here.

ITAM: It is a cumulative quantity (stocks) whose dynamic changes (flows) are influenced by IT investment (ITI), EC, employee attitudes (EA) and depreciation (D). IT investment is mainly reflected in the impact on IT hardware and software systems. IT application of an enterprise is mainly subject to the actual use of employees and directly affected by their application capacity and their working attitude which will play a double role in the application effect. Such a relationship can be expressed as below:

$$\frac{d(\mathrm{ITAM})}{dt} = \left(\mathrm{ITI} \times k_1 + \mathrm{EC} \times \mathrm{EA} \times k_2\right) \times \frac{\mathrm{MM}}{\overline{M}} - \mathrm{D}$$

Where, $\overline{M}$ is the middle value of management, which will have its amplification effect affecting other factors when MM is higher than $\overline{M}$, or vice versa. k_1 is the adjustment coefficient of conversion to some extent, by which IT investment is converted into ITAM-type value. The k_i appearing in the latter relationship has such a similar role.

IT Investment (ITI): It is directly affected by the top leader's desire for the development of IT application.

$$\mathrm{ITI} = \mathrm{TLD} \times k_3 + m_2$$

m_2 is the basic value of IT investment here.

EC: It is also a type of stocks whose flows are mainly influenced by the relevant employee trainings (ET) as well as BTA. Besides, EC has its limit of E_1 about ideal expectation.

$$\frac{d(\mathrm{EC})}{dt} = \left(\mathrm{BTA} \times k_4 + \mathrm{ET} \times k_5\right) \times \frac{E_1 - \mathrm{EC}}{E_1}$$

Employee Attitude (EA): It is mainly affected by MM whose higher value will form a high positive attitude of employees and lower a negative attitude. The positive or negative impact accumulation to ITAM will lead ITAM to success or failure.

$$\mathrm{EA} = \ln \frac{\mathrm{MM}}{\overline{M}}$$

$\overline{M}$ is the middle value of management here. When MM is higher than $\overline{M}$, the employee attitude becomes a positive value and, lower, a negative one.

Depreciation (D): It has positive correlation with ITAM.

$$\mathrm{D} = \mathrm{ITAM} \times k_6 + m_4$$

m_4 is the basic value of depreciation here.

MM: It is a type of stocks whose corresponding flows are mainly affected by the top leader desire and expectation of MM. the MM expected value is E_2.

$$\frac{d(\mathrm{MM})}{dt} = \mathrm{TLD} \times \frac{E_2 - \mathrm{MM}}{E_2} \times k_7$$

Top Leader Desire (TLD): It is decided by the general result of ITAM effect perceived by the top leader (TLP) and the gap ratio from the expectation.

$$\mathrm{TLD} = \mathrm{TLP} \times \mathrm{GRE}$$

The Gap Ratio from the Expectation (GRE): It is ratio between the distance of top leader perception to ideal expectation (IE), and ideal expectation.

$$\mathrm{GRE} = \frac{\mathrm{IE} - \mathrm{TLP}}{\mathrm{IE}}$$

BTA: It is a type of stocks and similar to MM, whose corresponding flows are mainly affected by the top leader desire and the expectation of themselves.

$$\frac{d(\mathrm{BTA})}{dt} = \mathrm{TLI} \times \frac{E_3 - \mathrm{BTA}}{E_3} \times k_8$$

The BTA expected value is E_3 and its initial value is m_6 .

Employee Trainings (ET): A certain ratio of IT investment is used for employee trainings.

$$\mathrm{ET}=\mathrm{ITI} \times k_9$$

Top Leader Perception (TLP): It is the top leader perceived ITAM, which is adjusted by the impact factors of perception (IFP, equals 1 for simple here).

$$\mathrm{TLP} = \mathrm{ITAM} \times \mathrm{IFP}$$

The present paper has studied the enterprise ITAM and the measurement of its key impact factors using mainly the Likert Scale whose 5-scale method was selected for measuring and converted into a percentile system. Therefore, the changing range of the above said major stock-variables was 0~100. In addition, such a study has focused on the developmental applications of information systems that are implemented. Most parameters have been set based on such conditions.

2.4 Test of the Model

Sterman (2000) pointed out that it is impossible to have a completely valid model which could be thoroughly tested. Based on the testing of models done by Forrester, Senge and Barlas, he summarized the evaluation and testing methods for a model of system dynamics[21]. In this paper, all the exogenous variables and endogenous variables represent the concept of social sciences, whose measured values describe a relative difference, the interval scale used to reflect changes and trends rather than the accurate concept corresponding to strict numerical values. It is unnecessary and meaningless to demand rigorous and authenticated figures. Nevertheless, we have still, within the reasonable limits in accordance with the testing ideas of the literature [21], more fully tested the model as follows.

2.4.1 Test of the Boundary

The studied measurements have been designed to embed that the range of boundary values for these key corresponding variables is basically 0~100, including ITAM, top leader desire, MM, IT investment, EC, BTA and other key factor. The model has been tested for 96 iterations, of which the initial values of three key stock-type impact factors in respect to MM, employees and BTA are in the changing range of 10~80. Test results have shown that all variables are within reasonable limits.

2.4.2 Structure Evaluation

The literature-foundation and logical exploration for the modeling ideas listed in the present paper have shown the related structural thinking and rationality. In addition, during the interview process,

more than 90% of the respondents[1] agreed (or agreed to a certain extent) the key factors of ITAM. When interviewing the recent years' Chinese outstanding candidates of CIO of Dalian Wanda, Tasly, XCMG, China United Cement, Nanfang Lee Kum Kee, etc., the causal chain of the model was recognized. At the forum on the 13th Annual Session (2008) of China Information Economics Society, the model received the affirmed recognition from participants, Professor Sheng-hua XU and Professor Zhang-qi TAO.

2.4.3 Evaluation of Parameters

Forrester (1980) specified that numerical data, writing material and subjective material would be requested for building a model structure[22]. Each value of the constant-type E_i, $\overline{M}$, top leader expectation, impact factors of perception are all calculated based on ideal circumstances while most of the m_i series are set into changeable initial values. The k_i series of conversion factors, their basic principle are fundamental in line with reality, i.e., the principle for testing model boundary which should pass the qualified standards stipulated. Of course, it is difficult to avoid the existing discretionary space. For instance, k_1 and k_2 corresponding to the role of IT investment and employee impact on the regulating role of the cumulative value of ITAM would be roughly 5% monthly of its own the ITAM of the regulating role of the cumulative value of roughly 5 percent of its own per month. k_4 and k_5 reacting EC to improve this needs a necessary process of gradual accumulation, therefore, the smaller rate similar to k_1 and k_2 is set. k_6 is assumed based on the yearly depreciation rate of approximately 60% and monthly depreciation rate of 8%. k_7 and k_8 express that top leader desire has a greater impact on MM and BTA, including the more greater impact on the changes of the former. According to our field research findings, about 20% of the enterprise IT investment is required for trainings and k_9 is set to 0.2.

Table 1 parameter setting

Parameter	Value	Narration
E_1	100	The ideal expectation of EC is 100
E_2	100	The ideal expectation of MM is 100
E_3	100	The ideal expectation of BTA is 100
m_1	20*	Initial value of ITAM, 1 in 5 point scale equals 20 in 100
m_2	20	Basic input on Information system, same as above
m_3	20*	Initial value of EC, same as above
m_4	1	Fixed Depreciation on ITAM
m_5	20*	Initial value of MM, 1 in 5 point scale equals 20 in 100
m_6	20*	Initial value of BTA, 1 in 5 point scale equals 20 in 100
$\overline{M}$	50	Middle value of MM
k_1	0.05	Transformation coefficient from ITI to increment of ITAM
k_2	0.05	Transformation coefficient from employee effect to ITAM
k_3	1	Transformation coefficient from TLD to ITI
k_4	0.05	Transformation coefficient from BTA to EC
k_5	0.05	Transformation coefficient from IT training to EC

1 The main respondents interviewed, totally more than 460, included top leader, CIO and middle-level IT and business personnel.

k_6	0.08	Depreciation ratio of ITAM per month
k_7	0.3	Transformation coefficient from TLD to MM
k_8	0.2	Transformation coefficient from TLD to BTA
k_9	0.2	Transformation coefficient from ITI to ET, about 20 percent

* These initial values are set low, and can be set higher according to fact.

2.4.4 Other Tests

Some other tests are not strictly necessary and some might not be applicable for this study. For example, dimensional uniformity is necessary for model bearing clear units of measurements. However, since this study did not have score-related measurements, in order to avoid any confusion among the types of different variables, the conversion factors of k_i series were used for converting purpose. In addition, the model was inspected strictly in respect to the existence of error accumulative. The simulation results have obtained affirmed recognition from CIO Xiang-yun ZENG of Tasly, Xue HAN, the consultant for SAP and Oracle, CEO Jun-qing KANG of Taiwan-funded Hongli and so on, which can better reflect the typical growth process of the enterprise ITAM enhanced from lower stage to a higher level. The model simulation results (including the numerical changes and the corresponding relations of ITAM, MM, EC and BTA) have been supported by samples of evidence from hundreds of Chinese enterprises, which, due to the space limitation here, will be discussed in other articles. In addition, the model can well explain the Nolan Stage Theory and further enhance the persuasiveness and theoretical value of the model.

3. SIMULATING THE MODEL

In this paper, the Vensim PLE 5.7 modeling tool is used to simulate separately an enterprise ITAM status and the key impact factors.

3.1 Simulating the Growth of Enterprise ITAM

Figure 2 is provided with the ordinates as the percentile units for the evaluation of enterprise ITAM and abscissa as the monthly timelines, simulating the 96-month development for the enterprise ITA for 8 years. Primarily, the time here is for reference and for a better reflection of its developmental trend. Assuming the circumstances of an enterprise begin with (1) the initial value of ITAM is 20, then, (2) the initial value of MM, EC and BTA is 30.

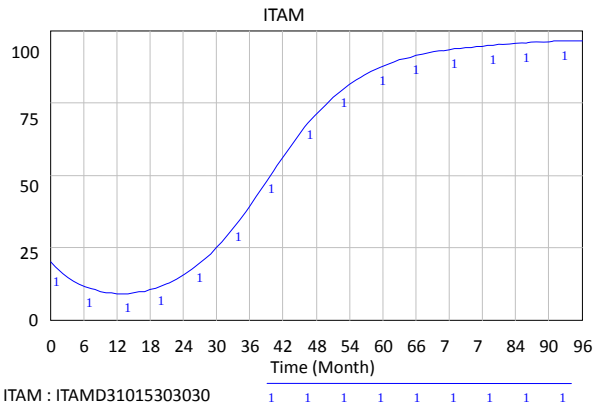

Figure 2: The Enhancing Process of ITAM

The simulation results reflect the developmental process of enterprise ITAM from lower level to a higher level shown as an S-shaped curve which is similar to Nolan four stages model (figure 3), but more concrete. The growth of enterprise ITAM goes through the adjustment period, the rising period and the stable period. At the period of adjustment upon the implementation of on-line or information system remolded, it would initially goes through a period to adapt adjustment, during which the initial integration of ITA may be not good enough and ITA effect is not satisfactory, but gradually it would adapts to rebound. During the rising period, along with the gradual breaking into adaptation, ITA effects, beginning its embodiment of all aspects of favorable factors actively mobilized, are obvious and ITAM has a virtuous circle of faster upgrading. In the stable period, based on the step-by-step sophisticated ITA, an enterprise should not have a moment leaving the support from IT that has become essentially important. As a large scale of the IT system obtained, the overall growth of it becomes difficult already and ITA now is in a status of basic supporting and maintenance working and some improving.

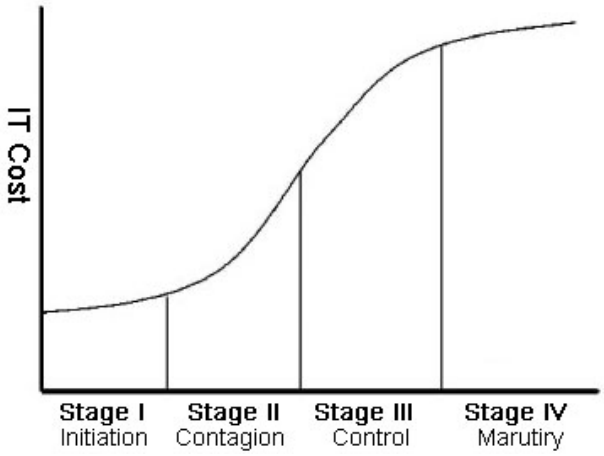

Figure 3: Nolan four stages model

3.2 Environment change on ITAM

Nolan Stage Theory was originated from the survey data of enterprises in United States, of which enterprise ITA is divided into four stages: initiation, contagion, control and integration[23]. During these four stages, an enterprise has its investment in the application of information technology with a certain variation, showing an S-shaped curve (Figure 5).

With the passage of time and further development of information technology, the four-stage model was gradually difficult to fully describe the process of growth of information. In order to explain the new phenomenon, Nolan, in 1975, began his consideration of adding the fifth stage to the model[24] and subsequently, in 1979, the stage-model was extended to become a six-stage one [25]. Nolan Stage Theory, in the 80's of the 20th century, was introduced to China to meet China's needs from enterprises which had tried information and required theoretical guidance. The six-stage model has become the most well-known Nolan model in China and is still frequently cited[26]. The six-stage model has two versions of which the second one is more consistent with its context (Figure 4) with its emphasis placed on different eras and technological discontinuity and two S-shaped curves constituted of which each S-shaped curve across the three stages.

As mentioned earlier, the four-stage model presents the formation of S-shaped curve believing that enterprises studying and absorbing new information technology would be developed gradually along every stage bearing specific characteristics of stages. And each S-shaped curve's developing process is only a circle of ITA in an enterprise, not all of its process. Every major technological change in the field of information technology would enable enterprises starting a new cycle of study. At each cycle of study, the enterprise IT-related spending, or the growth changes in the organizational learning process will draw a regular S-shaped curve. Such a cycle is called an "Era". According to that of the United States, major technological changes taken place include large-scale computer, micro-computer and the Internet. Accordingly, the enterprise ITA has experienced data processing, micro-computer and network. Nolan believes that every organization is bound to be followed by the experience of stages of growth and learning.

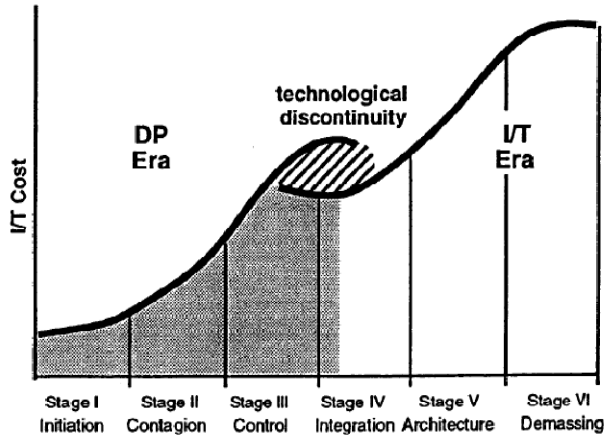

Figure 4: The Nolan Stage Model (six stages) of IT Cost

Although Figure 4 and 5 are to study IT Cost changes of different stages, Nolan said that they can also be used to explain the need for organizational learning, the "Growth Process". The meaning of such concept lies in the fact that enterprises' learning process in relation to ITA can be reflected dimensionally by application portfolio, resources, users, management tools, etc.[25-27] This is also a process by which enterprise information system application and management integrated. Therefore, its meaning is basically the same as the enterprise ITAM. We've proved in other paper that the model can explain more comprehensively the Nolan Stage Theories, from Four Stage, Six Stage to Era theories, all being refined upon empirical observation.

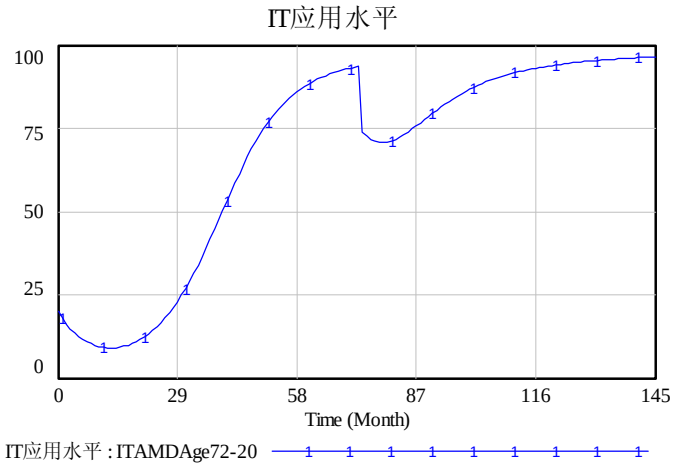

Figure5: the curve path of IT Application Maturity in rapid adjustment

Figure 5 simulate the path that Enterprise IT Application Maturity follow in the circumstances of stronger external elements influence in a longer period. It suppose that in the 73rd mouth (after six years) ,each of IT Application Maturity ,Management Maturity ,the staff business ability and the interaction between business and technology decrease by 20 at the same time suddenly.

The figure illustrate that after the sudden decrease of IT Application Maturity ,it is in the process of increasing following “S” curve .This process go through the adjustment stage**,** the increasing stage and the stable stage. From the overall terms ,we can see that, as Management Maturity ,the influential elements comparatively become much stronger than ever before ,which lead to a short adjustment stage. The model simulates the experience model as Figure 5.

Compared with Nolan Model, ITAM Model simulates “a slight decrease and a later rebound” process in the adjustment stage. However, Nolan Model describe a “slowly increasing ” process.

4. EMPIRICAL Result

In order to bring forward a complete model test ,except for the 2.4 test, the research go through substantial research data of enterprise .The research consequence supports ITAM Development Regular Pattern ,which the model describe.

With the restrictions of the actual conditions ,the questionnaire of the research gain numerous fractional data which contains time record from different enterprises. These data can describe the state of each variable in information system which is used by enterprises after a period .

For this reason ,232 effective samples are sort out into statistics in time series in order to be approximately regarded as the upgrade and development of a general IT Application Maturity of Enterprises and the related key influential elements .

Each sample contains the using time of Information System(TS) ,IT Application Maturity (ITAM) and so on .According to the using time of Information System ,the average can be obtained all the samples and it helps to attach the percentile of ITAM in using the Information System in an average level. In order to smooth away the influence of adjacent age error ,the average value is revised by 5(ITAM_M_S is the result of the revision from ITAM_M).As the Table 1 shown.

Table 1: The approximately time series table with same age average on ITAM

TS	ITAM_M	ITAM_M_S	CN
2	60.68	60.28	8
3	58.99	59.41	11
4	57.94	58.85	15
5	59.04	58.5	12
6	59.58	58.23	12
7	56.01	58.5	17
8	58.5	59.86	19
9	65.07	62.1	15
10	65.02	64.47	25
11	62.95	66.68	16
12	69.6	68.68	11
13	70.6	70.08	13
14	69.06	70.67	10

15	71.35	70.68	8
16	73.96	70.15	5
17	62.28	69.4	6
18	69.03	69.08	2
19	64.56	69.89	1
20	75.9	71.5	7
21	83.21	72.35	3
22	66.49	72.6	2
23	72.27	73.03	3
24	71.19	73.93	1
25	82.8	75.41	3
26	72.26	76.43	2
27	89.92	76.64	2
28	75.74	76.64	3

* TS: the time ITS being used CN: the quantity of the samples
ITAM_M: the mean of ITAM ITAM_M_S: the revised mean of ITAM

As the Figure 5 shown , the ITAM mean S make changes with the change of TS. It forms a scatter smoothing curves which shows the feature of S curve clearly in the “TS <=16” part. And in the “TS>16”part ,it also appears S curve. This illustrates that : Firstly ,Enterprise IT Application Maturity which is increasing with following S curve pattern is a popular phenomenon in practice. Secondly, the Information System in enterprises will go through adjustments to a large extent with the development of technology and the business. Generally ,it will come out in about 15-20 years. From the table entry ITAM_M(the average of IT Application Maturity) in Table 1,the 16^{th} and 17^{th} year show a obvious decrease .However ,after this decrease ,it appears a new S-curve developing pattern. Because the total number of samples in “TS>16” part is not large enough and almost the overall ages only contain 1-3 enterprises’ samples, the individual error may occur. In this circumstance, although the pattern follow S curve ,it show the slight flutter. In spite of this ,the obvious decrease in 16^{th} and 17^{th} supports that speculation of Discontinuous points. According to the theory of Nolan Six Stage Model, enterprises who start to apply Information System always take it into action in the certain Functional departments or modules (such as Finance Module).While using the Information System ,a adaptation stage takes shape. In this stage ,the application maturity may decrease and rebound. And later ,it will appear to increase fast with the promotion of Information System in more departments and modules. To the late stage, the integration of the system is completed which means the Stability. However ,with the development of technology or the big change in business, the Original system is not able to support the new business. Therefore, a proper adjustment to a large extent is necessary, which leads to a new S-curve increasing process. With the first introduction of new Information System ,the integration is generally formed. By means of a proper design of the whole system ,it appears a smooth operation. the IT Application Maturity obviously increase. Then lots of Personalized Service can be put forward to support more details. This is the process of Nolan Six Stage Model including the introduction、Dissemination、controlling、integration 、formation and promotion

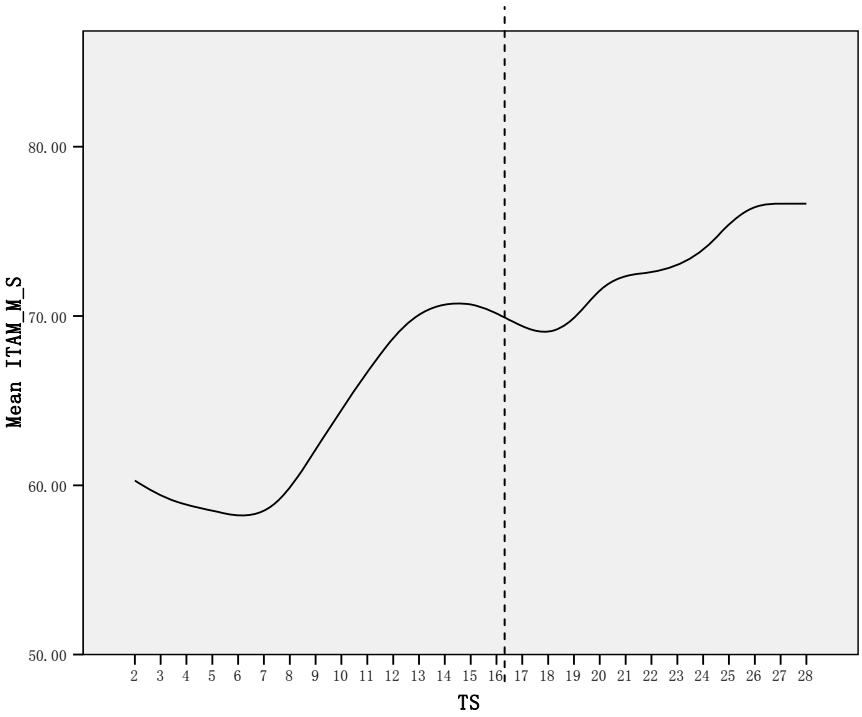

Figure 6

Guangdong Province is chose to be the Key areas for researches. It contains half of the total samples. The total Sample can be sort into two parts: From Guangdong Province and From Other Province except for Guangdong Province. The revised consequence is shown as Table 2 below .

Table 2 : the same using ages Mean distribution of Enterprise IT Application Maturity

T	ITAM_GD_M	ITAM_GD_M_S	N	T	ITAM_NGD_M	ITAM_NGD_M_S	N
2	62.79	61.06	4	2	58.58	60.71	4
3	56.94	59.66	8	3	64.44	60.71	3
4	60.88	58.77	8	4	54.57	60.71	7
5	57.62	58.38	8	5	61.87	60.21	4
6	59.07	58.28	6	6	60.09	59.01	6
7	54.51	58.86	8	7	57.34	58.11	9
8	59.95	60.71	9	8	57.19	57.91	10
9	67.61	63.18	11	9	58.1	58.58	4
10	65.39	64.84	12	10	64.36	61.46	9
11	65.07	65.5	9	11	60.22	66.33	7
12	67.49	66.12	4	12	70.81	70.1	7
13	64.52	67.54	5	13	74.4	71.21	8
14	67.38	70.03	6	14	71.57	70.66	4
15	79.69	72.26	3	15	66.35	69.58	5
16	77.09	72.91	3	16	69.26	69.04	2
18	69.85	72.73	1	17	62.28	69.41	6
19	64.56	72.64	1	18	68.21	70.88	1
20	74.38	73.33	2	20	76.51	72.72	5
21	83.64	76.18	2	21	82.36	73.45	1

23	68.43	79.81	1	22	66.49	73.05	2
25	88.08	81.24	2	23	74.19	72.12	2
27	86.48	81.06	1	24	71.19	71.45	1
28	75.74	80.75	3	25	72.23	72.64	1
				26	72.26	77.92	2
				27	93.36	87.16	1

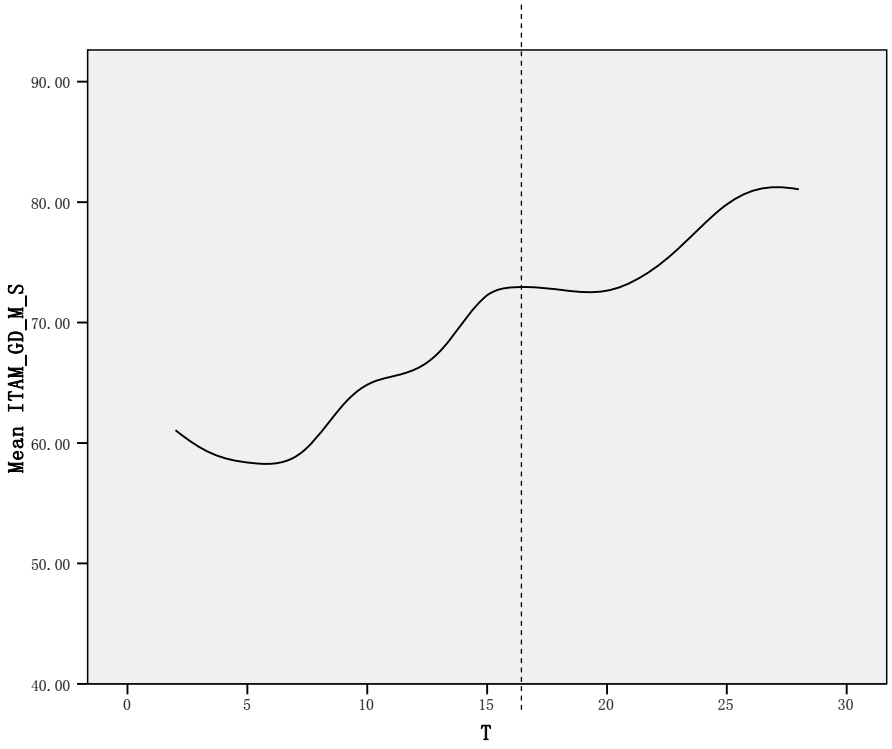

Figure 6: the ITAM time series of Guangdong Province enterprises

The ordinate is the ITAM_GD and the abscissa is T in Table 2 left.Figure 5 can be obtained. It statistically describes the development circumstance of using ages of IT Application Maturity in Guangdong Province.

As the figure shows , choose the 16th year to be the boundary, the pattern appears to be a curve which is formed by two S curves. To some extent , it is close to the model of Nolan Six Stage. The figure 6 also illustrate the rapid decrease of ITAM_GD_M in 16th and 18th year.

Other province except for Guangdong Province Correspondingly show the similar pattern. Choose the 16th year to be the boundary, the left S curve is obvious and the right pattern also appears to be an S-curve increasing tendency .From the figure 7, the rapid decrease of ITAM_NGO_M in 15th and 17th is shown out.

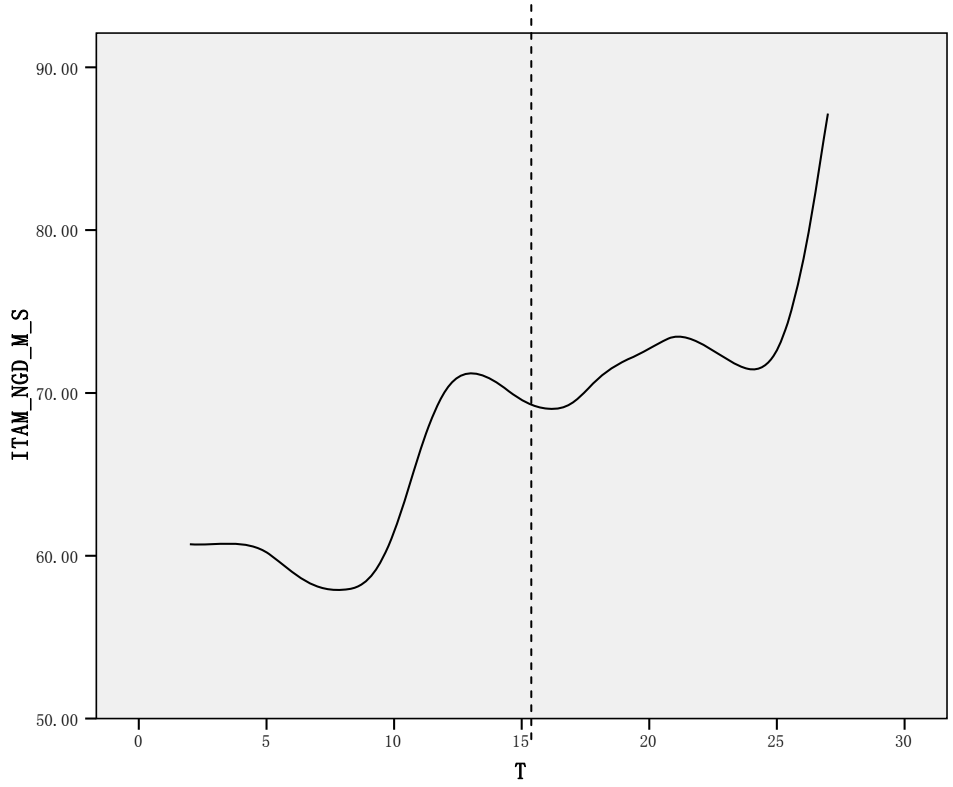

Figure 7: the ITAM time series of Non-Guangdong Province enterprises

5.CONCLUSION

ITAM Model can bring forward a clear and overall explanation of Nolan Stage Theory which is put forward by lots of experience. To some extent ,it proves that the model can be supported by the experience Indirectly.

The research of 232 Single-handed data test the ITAM model and Nolan Stage Theory. By means of establishing the time series ,mean distribution and smooth treatment, including both the total data and the assorted data from Guangdong Province and other province, obviously show the S curve and regular pattern of ITAM. What's more, the Under- bending process proves the Usefulness of the model.

The obvious adjustment in about 16^{th} year appears the same alternating pattern with Nolan Model which strongly support the Nolan Model once more. And the value of the model can be be reflected on the explanation of experience and the Nolan Model.

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