System Dynamics Modeling Of All Element Innovation*

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Abstract: The innovation management is the key activity for enterprises and it plays a significant role in pursuing core competence and sustainable profit. To achieve high performance, enterprises no longer merely rest on technology innovation but call for innovation synergy between both technology and non-technology elements including organization, strategy, culture, market, etc. The All Element Innovation (AEI), one aspect of TIM theory, aims at providing facilitating method for encouraging and regulating innovation of all synergic elements. In this paper, the system dynamics model of AEI is established to study the impact of the portfolio of innovation elements on enterprise's innovation performance. By simulation and policy analysis of the SD model, the interaction and dynamic characteristics of AEI is successfully worked out. The simulating results indicate that, for single element, culture and strategy influence the performance most significantly. In addition, the portfolio of culture and strategy, strategy and organization have the most profound effect on performance. Furthermore, we discover that the innovation performance with multiple coordinated elements is obviously higher than that with single or a few elements, thus confirming that heightened performance depends on synergic innovation process with multiple innovation elements involved.

Keyword: System Dynamics, All Element Innovation, Portfolio, Policy Analysis

INTRODUCTION

To achieve high performance, enterprises nowadays have to apply innovation not only in technology but in all directions. The innovation is so important and pervasive that enterprises rely heavily on it to enhance the competence and performance persistently. They spare no effort in impelling innovation on organization, strategy, service, culture, market and so forth. These innovations can be described as the essential elements in the framework of All Element Innovation (AEI), which is a part of TIM theory and is characterized as the synergic innovation between all the elements.

The system dynamics, which combines both quantitative and qualitative analysis, appeals to be a powerful tool in understanding the behavior of a system by constructing the model of the interaction among all variables and computer simulation.

Based on theoretical analysis and investigation of many typical enterprises, we develop the system dynamics model of All Element Innovation and try to answer the following question: How the different portfolio of innovation elements influences enterprise's performance?

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THE STRUTURE OF SD MODEL

The All Element Innovation is a complicated system with numerous factors and multiple information feedback。 Moreover, the mechanism of the system is determined by intricate interaction among series of factor. On the basis of our research, we have studied the synergic relationship between the innovation elements involved in the SD model, which serves to better design and understand the dynamic model. For example, culture innovation will breed a positive environment that encourages innovation and praises the outstanding employee [Thornberry 2003], thus propelling the technology innovation during everyday work; All Involvement Innovation consolidates the foundation of technology innovation because every employee is considered as an innovator so that their initiative is stimulated[Tucker 2002].

The logical structure of SD model we established separated mainly into eight subsystems. That is, innovation performance subsystem, strategy innovation subsystem, organization innovation subsystem, culture subsystem, technology innovation subsystem, market innovation subsystem, all involvement innovation and innovation capability subsystem. These factors interact with each other and influence the enterprise's performance by innovation integration. **Figure 1** shows the logical structure of the model. The brief casual-effect relation with main negative feedback loop is demonstrated in **Figure 2.**

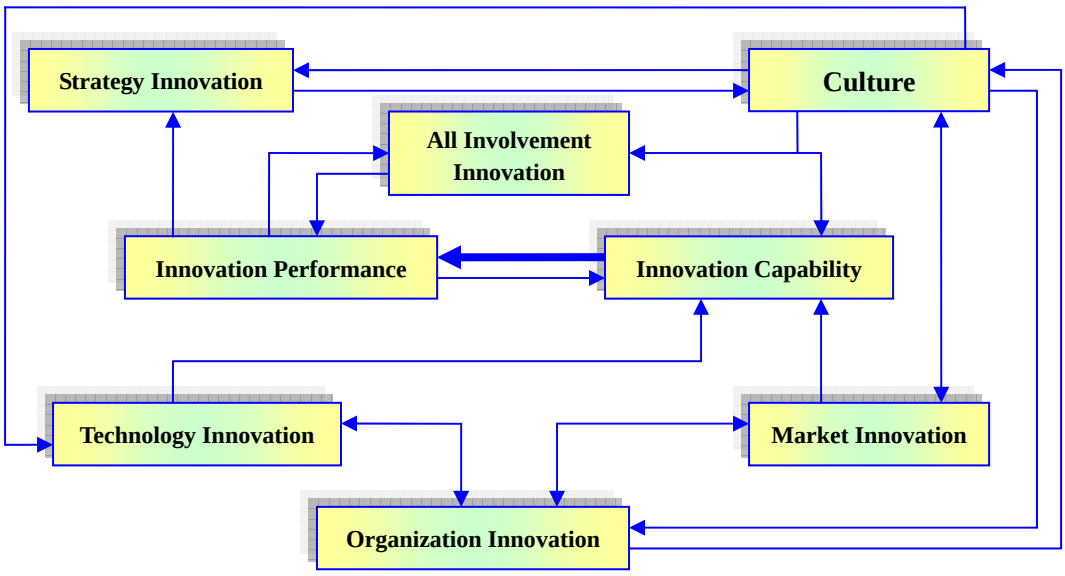

Figure 1: *The logical structure of SD model*

Figure 2: *Simple illustration of causal-effect relation on AEI*

The SD model contains 4 main negative feedback loops:

1) characteristics of top-management innovation culture — flat organization structure/process reengineering — factor of organization innovation — speed of information feedback—extent of culture interplay—characteristics of production line employee innovation culture—employee's deep understanding and implementation of TI strategy—factor of strategy innovation—effectiveness of strategy implementation
2) characteristics of middle-management innovation culture—value of mutual interplay—mutual interplay behavior—extent of culture interplay
3) sense of innovation—investment on technology innovation—TI performance
4) Investment on technology innovation—increase of innovation activity—increase of the percentage of innovation resource allocation—accumulation—facility-installation per employee—production capability—rate of production—sale revenue

VALIDITY TEST

Firstly, we simulate the development of a large-scale manufacturing enterprise H. As a result, the model works well. In addition, we use the data of sale and its rate of increase for reference mode. The error between real and simulating result are less than 3% (see **Table 1**). Therefore, the model is certainly effective and applicable as is anticipated.

Table 1 *The simulating results of enterprise's sale and its rates of increase*

Year	1988	1989	1990	1991	1992	1993	1994	1995	1996
Sale (Million$)	241.8	604.6	1209.2	6046	12091	19347	30955	51995	74970
Real rate of increase (%)	100.00	60.01	50.00	80.00	50.00	37.50	37.50	40.47	30.65
Simulating rate of increase (%)	102.5	62.3	47.2	78.3	48.7	40.3	40.2	38.3	31.9
Error	2.50	2.31	-2.76	-1.70	-1.33	2.76	2.69	-2.21	1.30
Year	1997	1998	1999	2000	2001	2002	2003	2004	
Sale (Million$)	130592	195889	324063	490931	727932	870617	967335	1168148.6	
Real rate of increase (%)	42.59	33.33	39.55	33.99	32.56	16.39	10.00	17.19	
Simulating rate of increase (%)	40.3	36.2	41.9	36.1	34.2	18.1	12.9	20.0	
Error	-2.25	2.88	2.37	2.14	1.60	1.73	2.89	2.77	

POLICY ANALYSIS

Consider the modeling objective as well as the question we are trying to answer in the beginning: How is the impact of different portfolio of innovation elements on the dynamic characteristics of performance? We design several portfolio scenarios of different innovation elements to assess to what extent the amount of elements appearing in innovation process influence dynamic characteristics of performance.

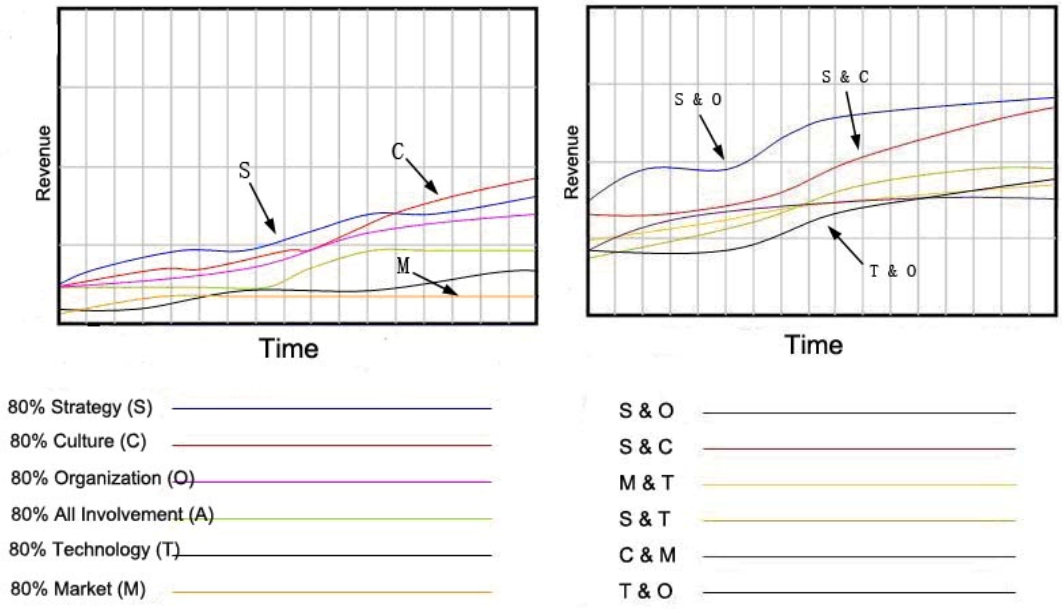

Figure 3 *(a) Single element impacts on performance*
(b) Two synergic elements impact on performance

Figure 3(a) illustrates dynamic change of performance when increasing the ratio of single innovation element. Based on the tendency indicated by curves, it's obviously that strategy and

culture plays the most significant part in performance. Additionally, contrast with strategy, the influence of culture is greater than that of strategy in later stage. On the contrary, the performance that merely depends on technology and market is unsatisfied as is predicted. Furthermore, we acquire that, compared with other elements, the effect of all involvement is moderate

Figure 3(b) illustrates the dynamic change of performance with synergy of two innovation elements at the same time. Based on the tendency denoted by curves, portfolio of strategy and organization influence performance most considerably, followed by portfolio of strategy and culture, market and technology, strategy and technology, culture and market, technology and organization. By comparing these curves, we obtain that portfolio of organization and strategy is superior to that of culture and strategy when strategy is the dominant element; portfolio of market and technology is superior to that of strategy and technology, together with organization and technology when technology is the prominent element. In sum, the performance shown in **Figure 3(a)** is superior to that in **Figure 3(b)**, which confirms that the increase of innovation element helps to improve performance dramatically.

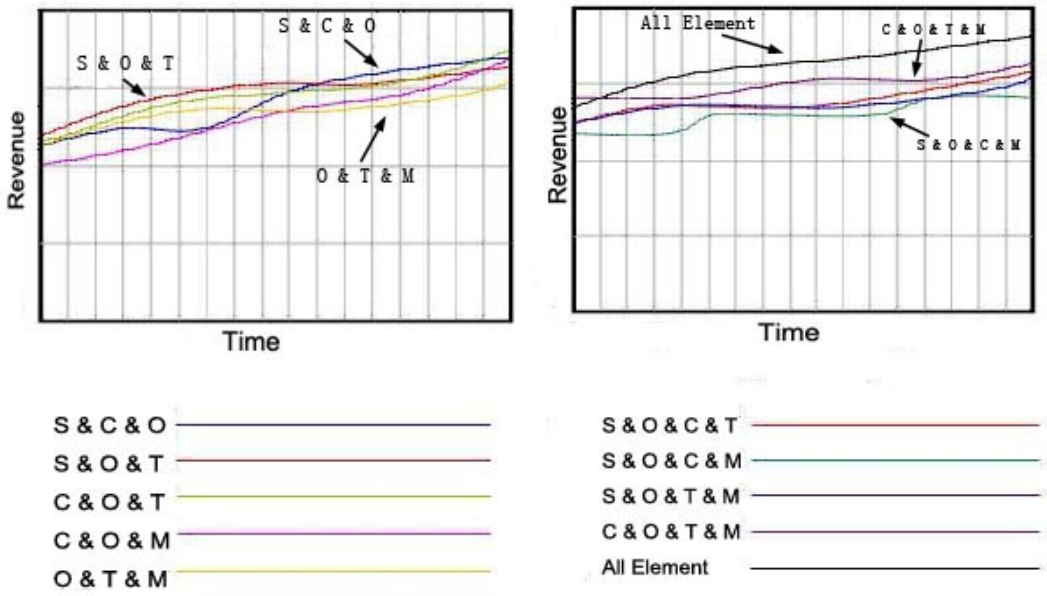

Figure 4 *(a) Three elements impacts on performance*
(b) For and multiple elements impact on performance

Figure 4 illustrate the dynamic change of performance with synergy of three, four and multiple elements. According to the curve, the portfolio of strategy, culture and organization is superior to the other scenarios. Noticeably, the initial point of curve in **Figure 4(b)**, in which four elements are involved, is obviously higher than any other curve in position. Comparing **Figure 4** with **Figure 3**, nearly all influences exerted by portfolio of three and four elements is greatly superior to that of single or two elements. Moreover, the top-level curve in **Figure 4(b)** illuminates the optimal performance when All Element Innovation is implemented. **Figure 5** summarizes the output of the SD simulation with different portfolio of innovation elements.

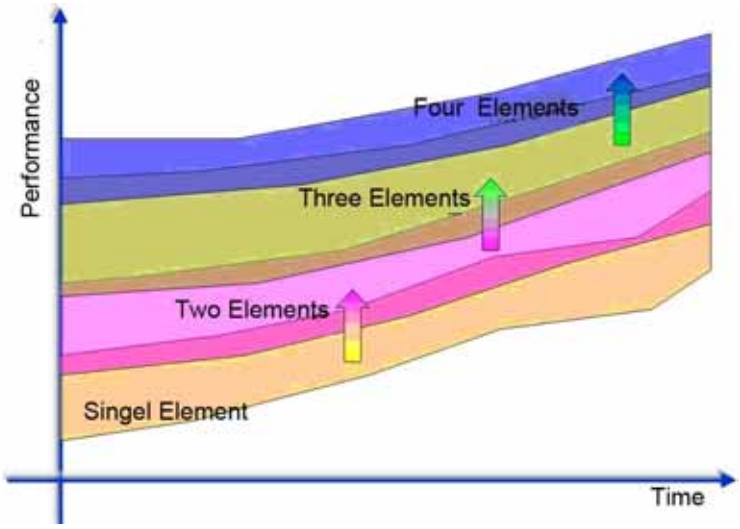

Figure 5 *Sketch map of simulation result with synergic innovation elements*

Taking above simulation result into account, we could safely arrive at the conclusion that if enterprises are keen to succeed in acquiring excellent performance, it is necessary to introduce new management pattern with the participation of synergic innovation elements and strengthen the concept of All Element Innovation. Even though in the infant stage of enterprise development, during which it's incapable to apply all the element, enough attentions should be paid on the construction of non-tech elements, such as strategy, culture and organization. In this way, the enterprise will develop with coordinated innovation between tech and non-tech innovation elements, making persistent achievements in performance.

CONCLUSION

Synthesizing our previous research with the mechanism of the interaction between different innovation elements, this paper proposes the system dynamic model of All Element Innovation. From the simulation of a large-size manufacturing enterprise H, our model is demonstrated to be effective and valid. Furthermore, we design various portfolio scenarios of innovation elements. We then range the influence of single element by descending order: strategy, culture, organization, extent of All Involvement, technology and market. Meanwhile, when multiple elements operate coordinately, the performance improves considerably.

Additionally, this paper has testified the systematic function of All Element Innovation: Improvement in performance is not only dependent on technology innovation, but also a synergic process with multiple elements involved. Single element or technology innovation cannot afford to create excellent innovation performance. Hence, it's crucial for enterprise to concentrate more on the synchronous development of strategy, culture, organization and other non-tech elements. Only in the way could enterprises accomplish ideal innovation performance in the long run.

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