Organizational Adaptative Behavior: The Complex Perspective of Individuals-Tasks Interaction

Jiang Wu[1], Duoyong Sun[2], Bin Hu[1], and Yu Zhang[3]

[1] School of Management, Huazhong University of Science and Technology
1037, Luoyu Road, Wuhan, China, 430074
jiangwu.john@gmail.com, bin_hu@mail.hust.edu.cn
[2] College of Information System and Management, National University of Defense Technology, Changsha, Hunan, China, 410073
duoyongsun@gmail.com
[3] Computer Science Department, Trinity University
One Trinity Place San Antonio, TX, USA, 78212-7200
yzhang@cs.trinity.edu

Abstract. Organizations with different organizational structures have different organizational behaviors when responding environmental changes. In this paper, we use a computational model to examine organizational adaptation on four dimensions: Agility, Robustness, Resilience, and Survivability. We analyze the dynamics of organizational adaptation by a simulation study from a complex perspective of the interaction between tasks and individuals in a sales enterprise. The simulation studies in different scenarios show that more flexible communication between employees and less hierarchy level with the suitable centralization can improve organizational adaptation.

Keywords: Organizational Adaptation, Simulation.

1 Introduction

Nowadays, rapid technological changes, extensive globalization, and intense competition have created significant pressures on organizations. To build an agile organization, one of the most essential issues is how to build an organization that can respond rapidly to the changing business environment. Organizational researchers have long recognized the value of formal models—mathematical, logical, computational—for examining organizational behavior in general and organizational adaptation in particular [2-7]. However, it is still challenging to identify the organizational adaptation and examine the suitable organizational structure that adapts to the environment change.

Research into organizational adaptation is a complex issue because the relationships are intricate, multiple participants are involved during interacting over time and interactions are nonlinear. To study the nonlinear phenomena, there are difficulties to uncover by the classical inductive case methods and to examine them by standard statistical techniques. Computer-based simulation can be used for theory development and hypothesis generation [10]. Simple, but non-linear processes often underlie the team and group behavior. Computational analysis enables the theorist to think through

J. Zhou (Ed.): Complex 2009, Part I, LNICST 4, pp. 28 – 38, 2009.

the possible ramifications of such non-linear processes and to develop a series of consistent predictions. Simulations are also particularly valuable when we seek to explain longitudinal phenomena that are challenging to study using empirical methods because of their time and data demands [4].

Particularly, agent-based simulations can give insights into the "emergence" of macro level phenomena from micro level actions and enable examination of how sensitively the simple rules affect the final results using sensitivity analysis[11].OrgAhead [12] is one of the first computational models used to study organization adaptation, and it focuses on organizational learning designed to test different forms of organizations under a common task representation. Subsequently, Epstein built an organizational adaptation model in which individual agents endogenously generate internal organizational structure to adapt optimally to dynamic environment [13].

In this paper, we propose a new computational model of organizational adaptation that expands Epstein's model so as to be suitable to explore the different dimensions of adaptation—Agility, Robustness, Resilience and Survivability. In this paper, an organization, termed adaptive, can generate new strategies and/or reconfigure its structure to potentially achieve even higher performance [3]. However, a robust organization is able to sustain high levels of performance in dynamic environments without having to change its structures. Robustness involves the ability of the system to survive variations in structural/internal parameters without disrupting its behavior. This would relate to loss of nodes in the company, cost of loss and cost/delay in replacing the nodes. This does have an effect on the agility as a secondary consideration. In this paper, we use an agent-based computational model to address the issue of organizational adaptation. We consider the hierarchy, span of control and communication culture among employees as the representation of organizational structure. The internal environment changes with the hiring or firing employees, and the external environment changes with increasing or decreasing sales opportunities. We assume the enterprise in this paper is a sales company whose major tasks are to recognize and grasp sales opportunities. Thus, the central issue is to build a simulation model on the interaction between individuals and tasks so as to regard it as a test-bed to examine the "fast", "stable", "large" and "long" dimensions of organizational adaptation. Also, we use cumulative bank balance related to revenue, cost and profit as the main measurement to observe the dynamics of organizational adaptation. Our objective is to find insights about organizational adaptation from the simulation study on interaction between organization and task.

The paper is structured as follows. In Section 2, we propose a new computational model that is used to examine the different dimensions of organizational adaptation. Section 3 specifies the design of our virtual experiments. In Section 4, through a series of virtual experiments (simulations), we observe the organizational agility, robustness, resilience and survivability. Section 5 concludes this paper.

2 The Computational Model

Modeling Agility, Robustness, Resilience and Survivability of Organizational Adaptation System (MARRS) is fundamentally expanded from Epstein's organizational adaptation model[13]; But our computational model (MARRS) is designed especially

for examining four dimensions of organizational adaptation. MARRS is an agent-based simulation model and developed using Netlogo[1]. MARRS provides a design/analysis toolkit in which the policies (or traditions) governing the generation of structure and allocation of resources within a self adaptive self organizing multi-agent system of systems can be explored, modeled and/or designed. The tool provides to the designer/analyst the ability to both models how well a particular organization's management policy will fare in one or more alternative environmental dynamics contexts.

As shown in Fig. 1, in the output panel, the red dots represent sales opportunities that move from left to right and can be controlled by the "Opportunity" parameter set. When the organization faces sales opportunities, the managers in organization assign workers to recognize and grasp sales opportunities that are represented by white dots. The opportunities that cannot be intercepted are represented by yellow dots. Enterprise organization is represented by squares in Fig. 1, and it is a structure of hierarchy. The workers are located in the zero level in the hierarchy and in charge of recognizing sales opportunities; the managers are located in the 1~5 levels, and assign tasks to workers and manage task schedules; the managers on the higher level will lead the managers on the lower level. The blue links between employees in Fig. 1represent the span of control for each manager, and the managers on the higher level have larger span of control. The managers on the first level have span of control 2^1=2, the managers on the second level have span of control 2^2=4 and so on. When the organization responds to the change of environment, managers can communicate with the managers on the same level, and exchange workers to schedule tasks; or turn to the managers on the higher level who will be in charge of the tasks assignment. Like other agile enterprises, this organization's structure will adapt based on hierarchy level, span of control and communication mechanisms.

To respond to sales opportunities, workers cannot move to other locations by themselves and must be led by the direct managers on the higher level. Managers can take measures according to the management thresholds from T_{min} *to* $T_{max.}$ The following four mechanisms are employed to adapt to the changes of the business environment:

(1) **Task Scheduling Mechanism:** managers can manage the workers in his own span of control. They can place the workers who are free at time *t* into "Free List" and the workers who will meet sales opportunities at time *t+1*into "Anticipation List". Managers will randomly assign the workers in "Free List" into "Anticipation List" to adapt to the change of environment at time *t+1*.

(2) **One-level Communication Mechanism:** in the range of their memory length, managers can calculate the lost sales opportunities percentage P_i in their span of control: P_i=*lost_opportunities / memory_length*. If $P_i > T_{max}$, the manager *i* demands workers to recognize sales opportunities: $D_i=(P_i-T_{max})\times(1\text{-}demand\_inertia)$; if $P_j < T_{min}$, the manager *j* supplies workers to managers who demand workers: $S_j=(T_{min}-P_j)\times(1\text{-}supply\_inertia)$. The managers who have demands communicate with other managers on the same level to obtain the supplied workers.

(3) **Upward Communication Mechanism:** if manager *i* has exhausted all the supplies from the managers on the same level, and the manager *i* still holds the status of

[1] Epstein's model is based on Ascape(http://ascape.sourceforge.net/), but our new model for different dimensions of organizational adaptation is based on Netlogo(http://ccl.northwestern.edu/netlogo/) . They are different agent-based platforms.

$P_i > T_{max}$ after "*upward_inertia*" time period, the manager *i* will turn to the direct manager on the higher level. The maximum upward level is controlled by "Max Level" parameter setting.

(4) **Downward Communication Mechanism:** if manager *j* still holds the status of $P_j < T_{min}$ after "*downward_inertia*" time period, the manager *j* will authorize the managers on the lower level to take in charge of task scheduling between workers in the range of his span of control.

The bank accounting balance is used to generate the measurements that examine the four dimensions of organizational adaptation. As shown in the output graph of Fig. 1, "Salary" and "Accounting" parameter settings can control budget and cost. The cost includes salary and transaction cost. The salary of busy employees and salary of free employees are different. Managers who actively manage workers at time *t* obtain more salary than managers who are free at time *t*. The busy managers are paid a bonus in addition to the basic salary.

The parameters of this model include four categories: opportunity generation parameters, worker and manager parameters, coordination parameters and accounting parameters. The category of coordination parameters is very important because these define the organizational structure. Demand Inertia is the willingness to ask for help from your trading partner workers and ranges from 0 (never willing) to 1 (always willing). Supply Inertia is the willingness to provide help to your trading partner workers and ranges from 0 (never willing) to 1 (always willing). Max-Hierarchy determines how many levels of the hierarchy on maximum and also includes the different "span of control" on the different level.

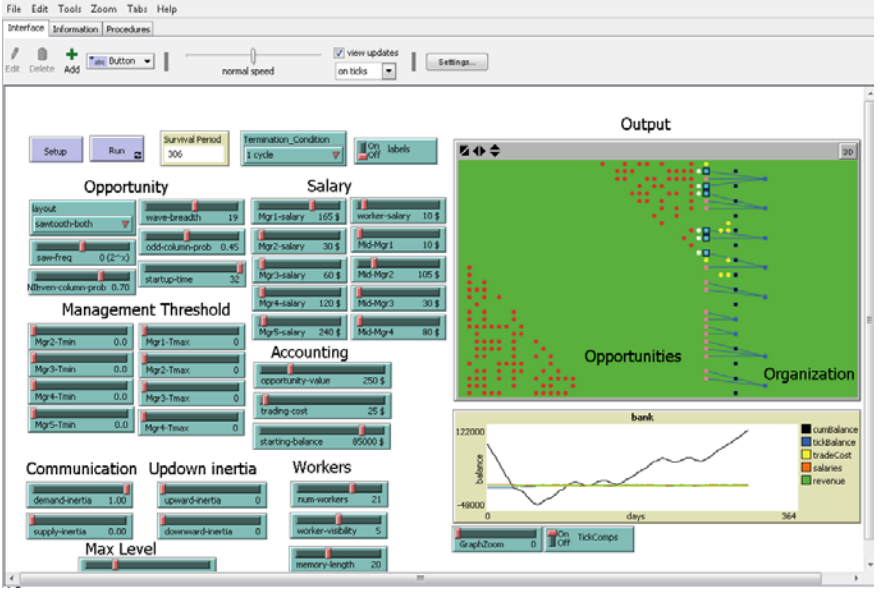

Fig. 1. MARRS—Organizational Adaptation Simulation System

3 Simulations Design

The simulation model can be regarded as the test-bed to alter parameters according to our requirements and to observe the resulting behaviors. From the findings of virtual experiments, potentially useful implications for practitioners can be revealed. As shown in Table 1, we design a series of virtual experiments in order to examine the Agility, Robustness, Resilience and Survivability of organizational adaptation. The different combinations of Demand Inertia and Supply Inertia represent different communication cultures among workers. Specially, we focus on the three different conditions of communication: free trade, medium trade and no trade. In the condition of free trade (Demand Inertia=1, Supply Inertia=1), workers can communicate with each other very freely and do not have inertia between their interactions. In the condition of medium trade (Demand Inertia=0.5, Supply Inertia=0.5), workers faces some pressures to supply or demand help from other workers, and they should keep balance in the communication. In the condition of no trade (Demand Inertia=0, Supply Inertia=0), the culture is very dull, people don't communicate with each other, there is no chance to exchange the labors, and workers have the highest priority of finishing their own tasks (standing always in the same department and finishing the assignments from his/her manager). There are 3×3×5 = 45 (see Table 1) conditions for the virtual experiments; we ran every virtual experiment independently for 100 runs by Monte-Carlo simulation procedure (Carley 1995). During simulations, we keep other parameters at their default values, as described in.

Table 1. Simulations design of organizational structure change for adaptation

Parameters	Range
Demand Inertia	0, 0.5, 1
Supply Inertia	0, 0.5, 1
Max-Hierarchy	1, 2, 3, 4, 5

3.1 Measurements of Agility, Robustness, Resilience and Survivability

In the evolutionary process during simulation, we need to measure four dimensions of organizational adaptation. Agility is measured by velocity, which represents how fast the organization adapts to changes in the environment (includes the internal environment and external environment). As shown in Fig. 2 (1), y axis represents the bank balance, and x axis is the tick time during simulation. Velocity is the average speed of organization balance changing for the period T. Fig. 2(2) shows the measurement of Robustness, which represents the organization's ability to maintain the expected objective in business in spite of some vibrations due to the change of environment. We use standard deviation to measure Robustness. Resilience is the organization's tolerance to adapt to a large change of environment and keep the expected objective in the evolutionary process. Magnitude, as illustrated in Fig. 2(3), measures Resilience of organizational adaptation. This magnitude is the maximum number of workers who were fared when organization can still obtain positive profit, or the maximum opportunities were reduced when organization can still accumulate positive profit. We have

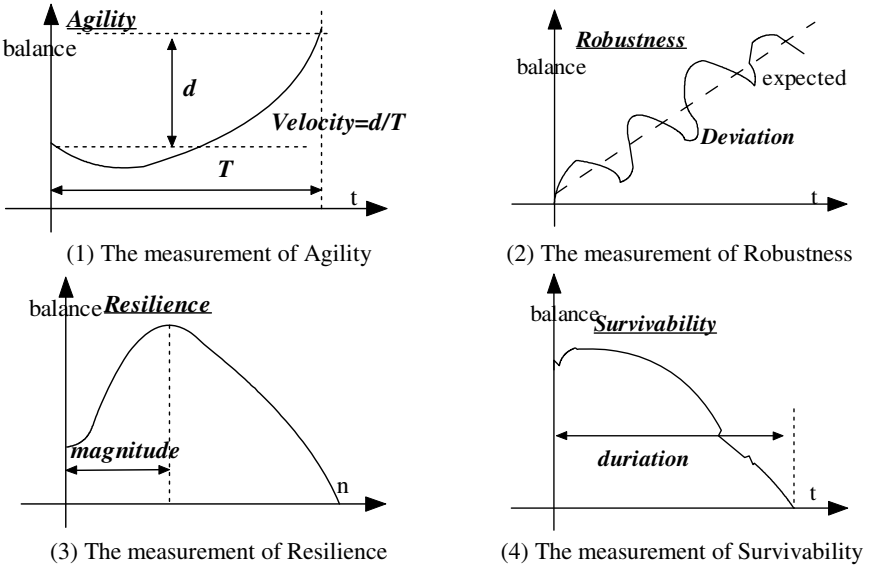

Fig. 2. The measurements of different dimensions of organizational adaptation

assumed that organization will bankrupt if its bank balance is negative. Thus, as shown in Fig. 2(4), we use duration to measure the survivability. In practice, some companies have a wonderful visionary approach which enables them to adapt remarkably well, continue to survive and possibly never die [14].

4 Simulation Studies

We first run the simulations according to Table 1 under the different dimensions of organizational adaptation. Through simulations, we examine the genome of organizational structure (the value combination of max-hierarchy, demand-inertia and supply-inertia) of Robustness, Agility, Survivability and Resilience of the organization. Because every condition is needed to run independently for 100 repetitions, the results presented in the following are the average cumulative balance of all the repetitions.

4.1 The Study of Robustness

To examine the Robustness of organizational adaptation, we design a scenario that the wave-breadth of opportunities can change from 16 to 8 for one time cycle of 100 ticks, which represent the external environment change periodically. This scenario describes situations in which the sales environment changes according to the needs of the market, which usually changes periodically due to the ebb and flow of supply-and-demand. We keep the number of workers a constant value 16 and examine the robustness under different organizational structures (the combination of hierarchy,

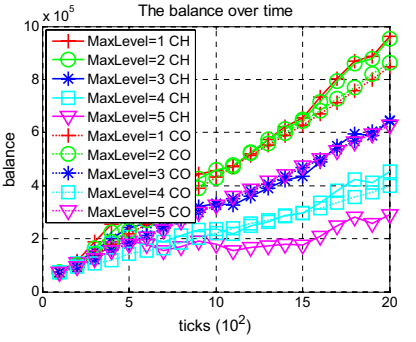

Fig.3(1)

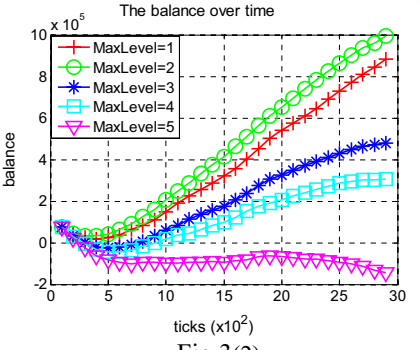

Fig.3(2)

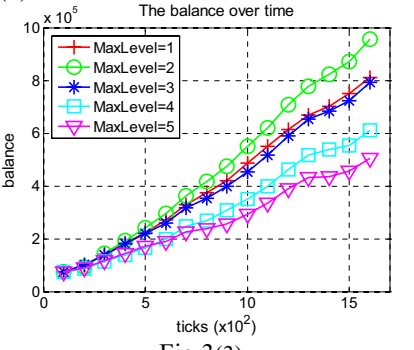

Fig.3(3)

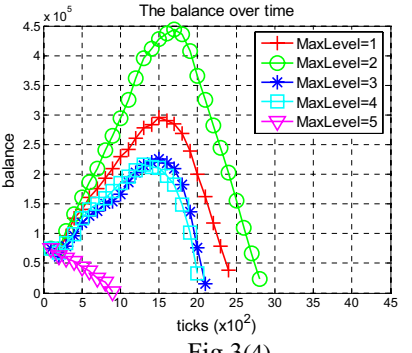

Fig.3(4)

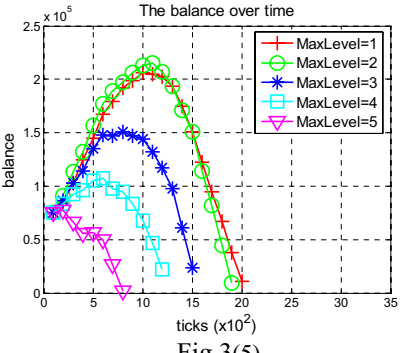

Fig.3(5)

Fig. 3. Results of different dimensions of organizational adaptation in medium trade

demand inertia and supply inertia). As shown in Fig. 3(1), the curves with the legend "CH" represent the scenarios of opportunities change, and these scenarios compare to the other category of scenarios with the legend "CO" (the wave-breadth is a constant 16 for all the time). The Monte Carlo simulation results of the "CO" scenario are expected output and its deviations between output results of "CH" scenarios are organizational Robustness. The smaller deviation represents the higher Robustness.

In practice, more communication and more hierarchy means the organization is more robust. This conclusion has real world implications: to appropriately respond to the change of environment, timely communication can improve the organizational ability of the risk-averse. The communication among workers needs to be spontaneous, but meanwhile this communication must be limited to achieving the unitive purpose generated by the manager in the hierarchy, and if not, this communication is may be counterproductive. Also, greater hierarchy centralization produces a larger span of control and the command transferred to workers is more authoritative and direct. In this way, the organization can avoid the information distortion that occurs during the process of transferring command across a broader, more decentralized hierarchy. In conclusion, the centralization (high hierarchy and large span of control) and flexible communication mechanism (less demand-supply inertia) are significant to improve the organizational Robustness.

4.2 The Study of Agility

To examine the Agility dimension of Organizational Adaptation, we design two types of scenarios to represent the change of the internal environment and the external environment respectively. *(1) Number of Workers* increase from 3 to 32 every 100 ticks (hire new employee gradually) and set the wave-breath=16 as a constant value when running the business. Other parameters are set according to default values. *(2) Wave-Breadth* increase from 16 to 32 every 100 ticks (the opportunities increase gradually) and set number of workers = 12 as a constant value when running the business. Other parameters are set according to default values. The Agility is the average velocity that is equal to the final cumulativeBalance divided by the ticks period, we examine the impact of hierarchy level and communication (trade) on the Agility. The results are the average values of numerous independent Monte Carlo simulations. The dynamics of the output result are shown in Fig. 3(2) and Fig. 3(3).

As shown in Table 2, by analysis of SPSS, we obtain results: under the change of the internal environment, demand-inertia, supply-inertia and the level of hierarchy affect the Agility negatively; under the change of the external environment, demand-inertia and supply-inertia affect the Agility negatively, but the maximum level of hierarchy affects the Agility positively.

Table 2. The correlation analysis result by SPSS

Measurements	demand-inertia	supply-inertia	max-level
Agility(In)	-.478**	-.458**	-.298*
Agility(Out)	.074	-.465**	-.499**
Robustness	.065	-.347*	.354*
Survivability(In)	-.503**	492**	-.134**
Survivability(Out)	-.484**	-.434**	-.254**
Resilience(In)	-.507**	-.336*	-.086
Resilience(Out)	-.476**	-.458**	-.318*

* Correlation is significant at the 0.05 level.

** Correlation is significant at the 0.01 level.

In practice, in order to accommodate the quick change of internal and external environment, the enterprise needs to maintain a kind of flat organizational structure. More flexibility is needed by the managers on the low level, because these managers don't have a large span of control and they can guide the workers more carefully, and meanwhile the flat organizational structure can avoid the unnecessary transaction cost when communicating between the members in the hierarchy. However, we must notice another point that more hierarchy can keep a more stable business running which prevents bankruptcy in turbulent business environments. When the external environment is rapidly changing, enterprises need additional hierarchy to address attrition and more emphasis needs to be placed on communication. Demand-supply inertia should be minimized, and with the free trade atmosphere information will flow smoothly to improve the quality of responding to environmental demands. In conclusion, flat organizational structure (lower hierarchy and smaller span of control) and flexible communication mechanisms (less demand-supply inertia) are significant to improve the organizational Agility.

4.3 The Study of Survivability

Assessment of survivability of the organization was based on financial viability which is measured by the bank balance over a time period of ticks. If the bank balance fell at or below zero then the organization did not survive, as it was out of business. If the organization maintained a positive bank balance throughout the timeframe then it was designated robust for this study. The period duration is used to measure survivability. To examine, we designed two scenarios: (1) *Number of Workers* decreasing from 20 to 2 every 100 ticks (fire the employees gradually), which represents the change of internal environment. We keep external opportunities environment unchanged (wave-breadth = 12); (2) *Wave-Breadth* decreasing from 16 to 2 every 100 ticks (the opportunities decrease gradually), which represents the change of the external environment. We keep the internal human resource environment unchanged (Number of Workers=8). The dynamics of cumulative bank balance for the above two scenarios are shown in Fig. 3(4) and Fig. 3(5) respectively.

The analysis result by SPSS in Table 2 shows that maximum level of hierarchy and supply, demand inertia affect survivability positively no matter what kind of the change of environment. Thus, the organization with more communication among workers and less hierarchy (smaller span of control) has stronger survivability. It is obvious that flexible communication and flat organizational structure allows organizations to survive longer.

4.4 The Study of Resilience

To examine the Resilience of organizational adaptation, we also design two scenarios that are the same as previous section. The first scenario (see Fig. 3(4)) is used to examine the Workers Resilience to internal environmental change: How many persons can leave and the organization still be profitable and survive? The second scenario (see Fig. 3(5)) is used to examine Opportunities Resilience to external environmental change: How much can the opportunities decrease and the organization still be profitable and survive? To calculate the resilience, we first smooth the curves firstly and

then find the inflection of the curve by calculating the gradients along the curve. The correlation analysis result by SPSS for worker resilience and opportunity resilience are shown in and respectively. The analysis results show that demand, supply inertia and hierarchy all affect organizational resilience negatively, which means that more flexible communication and less hierarchy can improve the resilience of organizational adaptation.

In practice, the flat organizational structure and flexible communication among workers allows the organization to withstand larger changes in the external and internal environments.

5 Conclusions

In this paper, we have expanded Epstein's organizational adaptation computational model [13] to propose a new computation model to examine four dimensions of organizational adaptation: Robustness, Agility, Resilience and Survivability. Using a Netlogo agent-based simulation platform, we ran Monte Carlo simulations on this computational model and designed five types of scenarios to run virtual experiments of examining the four dimensions of organizational adaptation.

Through simulation study, we concluded that besides improving Robustness, more flexible communication and lower hierarchy (smaller span of control) can promote the Agility, Resilience and Survivability of organizational adaptation. That is, flat organizational structure and flexible communication mechanism (less demand-supply inertia) are significant to improve the organizational Agility, Resilience and Survivability. However, for improving Robustness, the centralization (high hierarchy and large span of control) and flexible communication mechanism (less demand-supply inertia) are significant. Thus, in agile enterprise, the flat organizational structure and flexible communication is necessary, but meanwhile the organization need to keep a suitable centralized command transferring structure to run business under the right vision, strategic direction of organization designed to maintain ongoing competitiveness [14].

Acknowledgments

We specially thank Joshua Epstein for his lecture on Organizational Adaptability in the Santa Fe Institute's 2008 Complex Systems Summer School. We will thank Kathleen M. Carley (CASOS, CMU) for her support to our research. For valuable comments and discussions, we thank Catherine Spence, Steve Hall, Brad Jones and Brian Hirshman. The authors gratefully acknowledge China Scholarship Council to provide scholarship for my visiting Carnegie Mellon University. This work was funded by the China National Natural Science Fund (No. 70671048). This work was also partially supported by the Santa Fe Institute whose research and education programs are supported by core funding from the USA National Science Foundation and by gifts and grants from individuals, corporations, other foundations, and members of the Institute's Business Network for Complex Systems Research.

References

[1] Anderson, P.: Complexity Theory and Organization Science. Organization Science 10(3), 216–232 (1999)
[2] Foisel, R., Chevrier, V., Haton, J.P.: Modeling adaptive organizations. In: Proceedings of International Conference on Multi Agent Systems, 1998 (1998)
[3] Levchuk, G.M., Meirina, C., Pattipati, K.R., Kleinman, D.L.: Design and analysis of robust and adaptive organizations. In: 2001 IEEE International Conference on Systems, Man, and Cybernetics (2001)
[4] Carley, K.M.: Computational organizational science and organizational engineering. Simulation Modelling Practice and Theory 10(5-7), 253–269 (2002)
[5] Carley, K.M., Svoboda, D.M.: Modeling Organizational Adaptation as a Simulated Annealing Process. Sociological Methods Research Sociological Methods & Research 25(1), 138–168 (1996)
[6] Dessein, W., Santos, T.: Adaptive Organizations. Journal of Political Economy 114(5), 956–995 (2006)
[7] Handley, H.A.H., Levis, A.H.: A Model to Evaluate the Effect of Organizational Adaptation. Computational & Mathematical Organization Theory 7(1), 5–44 (2001)
[8] Davis, J.P., Eisenhardt, K.M., Bingham, C.B.: Developing theory through simulation methods. Academy of Management Review 32(2), 480–499 (2007)
[9] Baligh, H.H., Burton, R.M., Obel, B. (eds.): Devising Expert Systems in Organization Theory: The Organizational Consultant (1990)
[10] Carley, K.M.: On generating hypotheses using computer simulations. Systems Engineering 2(2), 69–77 (1999)
[11] Nigel, G.: How to build and use agent-based models in social science. Mind and Society 1(1), 57–72 (2000)
[12] Lee, J.-S., Carley, K.M.: OrgAhead: A Computational Model of Organizational Learning and Decision Making. Carnegie Mellon University, School of Computer Science, Institute for Software Research International, Technical Report CMU-ISRI-04-117 (2004)
[13] Epstein, J.M.: Generative social science: studies in agent-based computational modeling. Princeton University Press, Princeton (2006)
[14] Collins, J.C., Porras, J.I.: Built to Last: Successful Habits of Visionary Companies. HarperCollins Publishers (1997)