Proceedings of the 2010 Winter Simulation Conference
B. Johansson, S. Jain, J. Montoya-Torres, J. Hugan, and E. Yücesan, eds.

MODELING AND SIMULATION OF TEACHERS OCCUPATIONAL STRESS DIFFUSION IN CHINA

Tianyin Liu
Bin Hu

Huazhong University of Science and Technology
School of Management
Wuhan, Hubei 430074, PRC

ABSTRACT

In this paper, we present occupational stress diffusion model, which are significant for the research on simulation in Chinese teachers healthcare. Our approach is an agent-based simulation implemented by using AnyLogic 6 and MATLAB 7.0. Then virtual experiments are designed, and some results are concluded. The threshold value exists in organizational work control and occupational stress management in a social network is significant and efficient. Simultaneously, we need to focus on the changing of organization stress structure and take suitable measures to maintain middle level stress state, so as to keep teachers healthy physically and psychologically, individuals active in work and organization stable.

1 INTRODUCTION

Investigation shows 80 percent of Chinese teachers often feel heavy occupational stress, and about 75 percent are in subhealthy state of chronic fatigue, furthermore, more than one third of teachers have apparent physiological reaction (Pan 2003). In terms of the concept of **occupational stress**, there exits many definitions (Sun 2007). Some scholars believe that job stress is a stimulated variable. Some regard it as environmental variable. Others take it as an interactive variable between individuals and environment. It mainly includes stressor, intermediate variable and stress response. Some experts think that **teacher stress** is an emotional experience caused by working, which directly impacts on one's psychology, reflects to one's physiology, and reacts in one's behavior. **Teachers' occupational stressor** means their stress source which changes stress intensity related to teaching or teaching context of the individual. There are three aspects of it. The first aspect deals with school organizational factor, such as mission requirements, role demands, role ambiguity, role confliction, work overload and organization change. The second involves individual factor, for example, individual ability, individual expectation, character feature and relationship among the groups. The third relates to environmental factor, i.e., uncertainty of economics, politics and technology.

With regard to **occupational stress theory**, Karasek (1979) advocated JDC (Job Demands-Control/Decision Latitude) Model, which involved two features in work context, i.e. job demand and job control. Job demand is usually defined as psychological stressor, such as short work time, more and difficult task. Also, Job control (or job decision latitude) includes two dimensions: skill discretion and decision authority. Then Cooper, Sloan and Williams (1988) further demonstrated OSI (occupational Stress Indicator) Model. Afterwards, researchers added Social Support dimension into JDC Model, and put forward JDCS (Job Demand-Control-Support) Model (Johnson and Hall 1989; Isabel, Bravo and Jose 2001).

The next study by Robbins (1997) is on Stressor-Stress experience-Stress effect Model. As a result, we make references to the models above and observe new occupational stress model.

Concerning diffusion models, there are a lot of classic models that describe the spreading of information, disease, innovation or product. At present, because of the complexity of network structure and diffusion mechanism, the research on diffusion dynamics and control policies of complex networks (Erdös and Rényi 1959, 1960, 1961; Milgram 1967; Barabási and Albert 1999; Barabási, Albert, and Jeong 1999; Albert, Jeong, and Barabási 2000;) is still in exploring stage, which has not formed a complete theoretical system so far (Newman 2003). It is well known that viruses spreading models (Pastor-Satorras and Vespignani 2001, 2002; Moreno, Pastor-Satorras, and Vespignani 2002; Boguñá and Pastor-Satorras 2002; Boguñá, Pastor-Satorras, and Vespignani 2003a, 2003b; Lloyd and May 2001; Olinky and Stone 2004) are researched on and applied more widely among them, including SIS (Susceptible-Infected-Susceptible) model and SIR (Susceptible-Infected-Recovered) model etc. However, it is not a suitable way to utilizing viruses spreading models above for solving occupational stress diffusion. Consequently, we make references to the mechanisms in the independent cascade model (Goldenberg, Libai, and Muller 2001) and the threshold model (Granovetter 1978). In the independent cascade model, Goldenberg, Libai, and Muller simulated the talk of network and Word-of-Mouth information diffusion through the strong ties among members of the same network and weak ties interaction with individuals belonging to different network. They found the influence of weak ties on the information diffusion is almost as strong as the influence of strong ties. In the threshold model, each node in the network has a threshold that is typically drawn from some probability distribution; it also assigns connection weights on the edges of the network. A node converts its state if a sum of the change of stress intensity of the individual is greater than the threshold. Also agent-based simulations are tools to model real societies as artificial societies and are regarded as test-beds for studying complex phenomena(Wu, Hu, Zhang, and Fang 2008; Wu, Hu, Liu, and Carley 2008).

Therefore, our approach in this paper is an agent-based simulation implemented by using AnyLogic 6 and MATLAB 7.0. We observe and study on the following issues: What is occupational stress diffusion model? How do organizational size, complex networks type and initial distribution of organization stress impact on the evolution process of occupational stress diffusion from the organizational viewpoint? What suitable policies are needed to follow in the process of spreading work stress? In addition, what is the relationship between the change of occupational stress state and stress diffusion?

2 OCCUPATIONAL STRESS DIFFUSION MODEL

In occupational stress diffusion model, we make references to the mechanisms in the independent cascade model (Goldenberg, Libai and Muller 2001) and the threshold model (Granovetter 1978). The difference between early models and ours is that stress intensity of one individual (or node, agent) may change itself after diffusing stress (i.e., when one individual outputs stress, its stress intensity will decrease; when one inputs stress, its stress intensity will increase). In contrast, an individual maintains its state once becoming informed in classical virtual advertising models, and moreover, we utilize four state variables rather than two variables. As shown in Figure 1, we observe the occupational stress diffusion model which includes four subfigures.

In Figure 1, w_i (i=1, 2, 3) is the spreading influence coefficient that an individual will affect another one to spread work stress, and $w_1<w_2<w_3$, $w_i \in (0,1)$. There are four types of stress state. L state means the state of low stress intensity. S state means that of middle stress intensity. I state means that of high stress intensity. R state means that of heavy stress intensity.

2.1 In node L perspective

$$\Delta C_{j_{LS}}(t) = 1-(1-w_1)^{S_j(t)}(1-w_2)^{I_j(t)}(1-w_3)^{R_j(t)} \tag{1}$$

$\Delta C_{j_{LS}}(t)$ is the change of stress intensity of the individual *j* becoming S state from L state at time *t*; $S_j(t)$ denotes the amount of S state individuals directly linking to the individual *j*; $I_j(t)$ denotes the amount of I state individuals directly linking to the individual *j*; $R_j(t)$ denotes the amount of R state individuals directly linking to the individual *j*; $L_j(t)$ denotes the amount of L state individuals directly linking to the individual *j*.

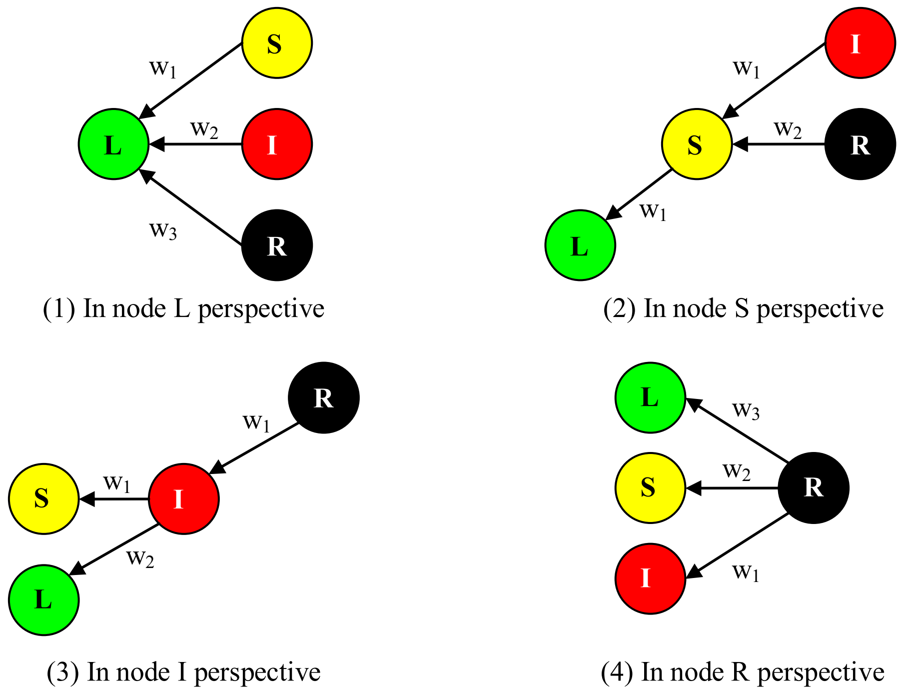


Figure 1: Occupational stress diffusion Model

When the L state individual receives stress from higher stress state individuals, its stress intensity will increase at one certain speed. If $\Delta C_{j_{LS}}(t)$ is greater than the spreading threshold U_j, the individual *j* will become S state from L state, otherwise, it keeps the former state. Table 1 may interpret this threshold. The spreading threshold is a random number drawn from a uniform distribution: $U_j \in U(T, 1)$, and T is the diffusion threshold that can be globally changed by stress control and will affect all the persons in the social network.

2.2 In node S perspective

$$\Delta C_{j_{SL}}(t) = 1-(1-w_1)^{L_j(t)} \tag{2}$$

$$\Delta C_{j_{SI}}(t) = 1-(1-w_1)^{I_j(t)}(1-w_2)^{R_j(t)} \tag{3}$$

If $\Delta C_{j_{SL}}(t) > \Delta C_{j_{SI}}(t)$, and $\Delta C_{j_{SL}}(t)$ - $\Delta C_{j_{SI}}(t)$ >U_j, then, the individual *j* will become L state from S state, otherwise, it keeps the former state.

If $\Delta C_{j_{SL}}(t) < \Delta C_{j_{SI}}(t)$, and $\Delta C_{j_{SI}}(t)$ - $\Delta C_{j_{SL}}(t)$ >U_j, then, the individual *j* will become I state from S state, otherwise, it keeps the former state.

2.3 In node I perspective

$$\Delta C_{j_{IS}}(t) = 1-(1-w_1)^{S_j(t)}(1-w_2)^{L_j(t)} \tag{4}$$

$$\Delta C_{j_{IR}}(t) = 1-(1-w_1)^{R_j(t)} \tag{5}$$

If $\Delta C_{j_{IS}}(t) > \Delta C_{j_{IR}}(t)$, and $\Delta C_{j_{IS}}(t)$ - $\Delta C_{j_{IR}}(t)$ >U_j, then, the individual *j* will become S state from I state, otherwise, it keeps the former state.

If $\Delta C_{j_{IS}}(t) < \Delta C_{j_{IR}}(t)$, and $\Delta C_{j_{IR}}(t)$ - $\Delta C_{j_{IS}}(t)$ >U_j, then, the individual *j* will become R state from I state, otherwise, it keeps the former state.

2.4 In node R perspective

$$\Delta C_{j_{RI}}(t) = 1-(1-w_1)^{I_j(t)}(1-w_2)^{S_j(t)}(1-w_3)^{L_j(t)} \tag{6}$$

If $\Delta C_{j_{RI}}(t)$ is greater than the spreading threshold U_j, the individual *j* will become I state from R state, otherwise, it keeps the former state.

3 VIRTUAL EXPERIMENTS DESIGN AND RESULTS

Agent-based modeling is a metaphor that is based on the characteristics and behaviors of the individuals, and establishes individual characteristics and behaviors in the model. The individuals are mapped as agents, individual characteristics as the attributes, and individual actions as the behaviors of the agent (Macal and North 2005). The nodes in the computational model of social networks are the agents that represent persons in real social networks. The agents will interact with each other to spread stress according to the occupational Stress Diffusion Model. The model is simulated using Monte-Carlo simulation procedure (Carley 1995); it is an interactive process in the internal procedure; for a new run, all the parameters and status must be initialized again. The simulation is implemented by using AnyLogic 6 and MATLAB 7.0.

Occupational stress evolution in a social network is shown in Figure 2. It is an initial stress state distribution graph in a middle level stress organization network. Consequently, the number of S state individuals (yellow nodes) occupies 60 percent of the total.

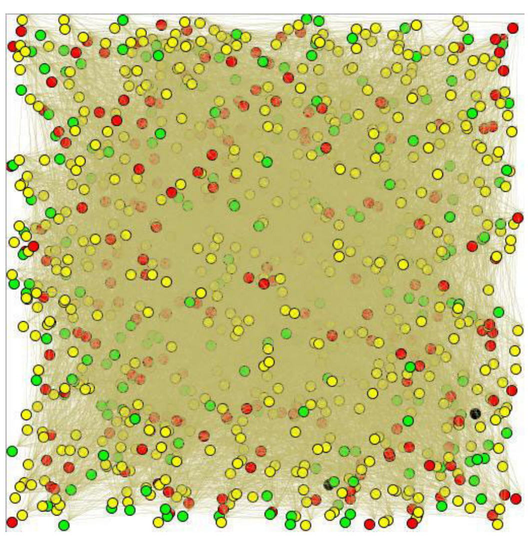


Figure 2: Occupational stress evolution in a social network

As shown in Table 1, we design five input parameters to control the run of the simulation model. Also as shown in Table 2, the simulation system can result in five output measurements that are used to observe the dynamics of occupational stress diffusion.

Table 1: Input parameters of the simulation model

Input Parameters	Value	Explanation
Node Size	1000	The total number of persons in the social network
Diffusion Threshold	T=0.1,0.2,…,0.9	T is used to limit spreading threshold that is uniform distribution: Threshold ∈ U(T, 1)
Network Type	Random Networks, Small World Networks, Scale Free Networks	Different network structure in the real world
Influence Coefficient	$w_i \in (0, 1)$, i=1,2,3 and $w_1<w_2<w_3$	Different occupational stress influence ability, related to the distance of two stress state hierarchy
Initial Stress Distribution	L_NO∈(0, 1), S_NO∈(0, 1), I_NO∈(0, 1), R_NO∈(0, 1), and L_NO+S_NO+I_NO+ R_NO=1	The initial stress distribution in the social network

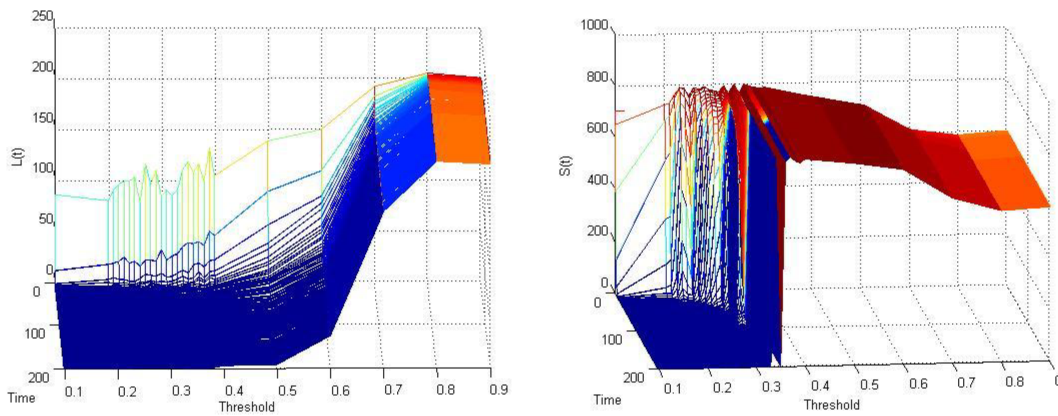
Table 2: Output measurements of the simulation model

Output	Explanation
Cascading Time	The consuming time in the cascading during diffusion; cascade once, Cascading Time increase one
L(t)	The total number of L state persons at time t
S(t)	The total number of S state persons at time t
I(t)	The total number of I state persons at time t
R(t)	The total number of R state persons at time t

3.1 Diffusion threshold vs. occupational stress diffusion

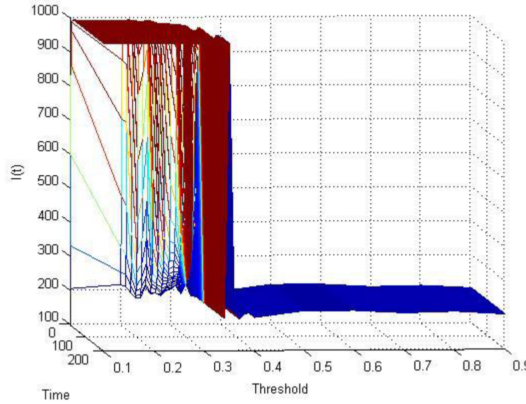
Figures 3 (a) and (b) show the landscapes of viral occupational stress diffusion in random networks with the different threshold Node. Size=1000, w_1=0.05, w_2=0.09, w_3=0.12, time=100, L_NO=0.2, S_NO=0.6, I_NO=0.198, R_NO=0.002.

It is shown that stress control is a suitable policy to adjust the number of L, S and I state individuals. There is a threshold value between 0.3 and 0.4, and the result implies that occupational stress management in the organization is important and efficient.

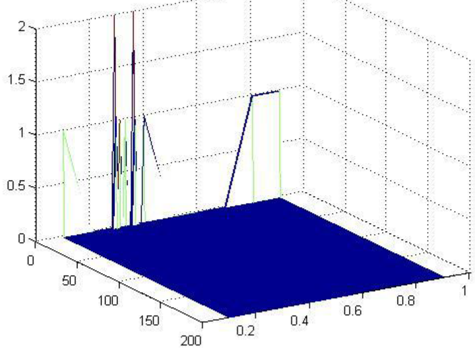


(1) Threshold vs. L(t) (2) Threshold vs. S(t)

Figure 3(a): Diffusion threshold vs. occupational stress diffusion in states L and S.



(3) Threshold vs. I(t)

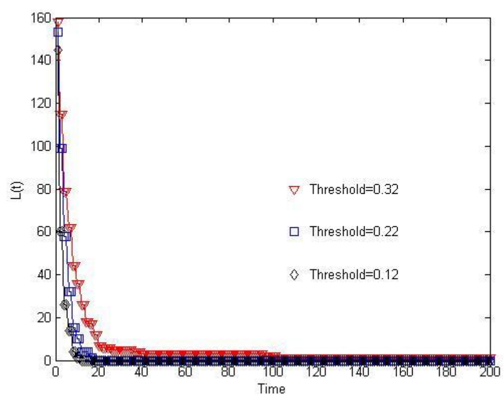


(4) Threshold vs. R(t)

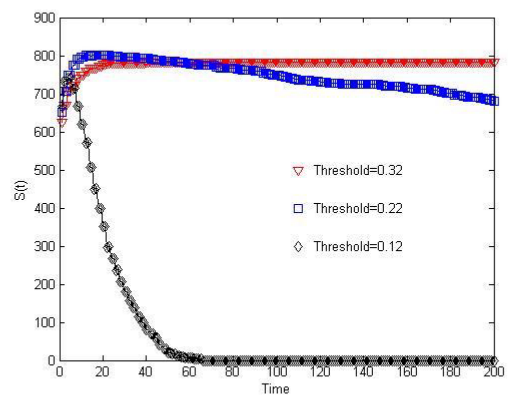
Figure 3(b): Diffusion threshold vs. occupational stress diffusion in states I and R.

3.2 Network topological types vs. occupational stress diffusion

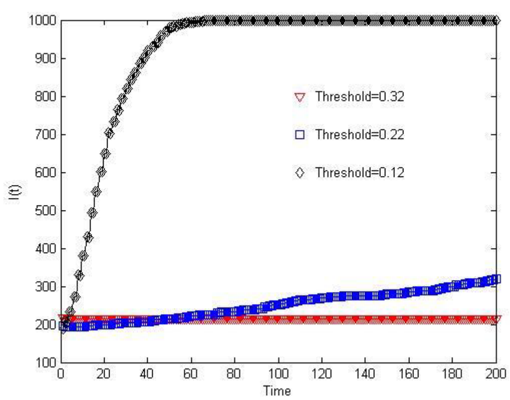
Figures 4 and 5 show the landscapes of viral occupational stress diffusion in small world networks and scale free networks with the different threshold Node. Size=1000, w_1=0.05, w_2=0.09, w_3=0.12, time=100, L_NO=0.2, S_NO=0.6, I_NO=0.198, R_NO=0.002.



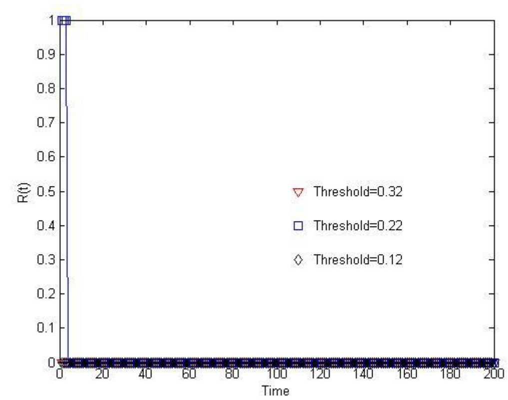
(1) Small world networks vs. L(t)



(2) Small world networks vs. S(t)



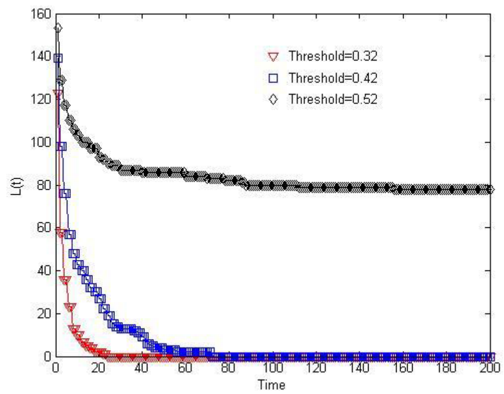
(3) Small world networks vs. I(t)



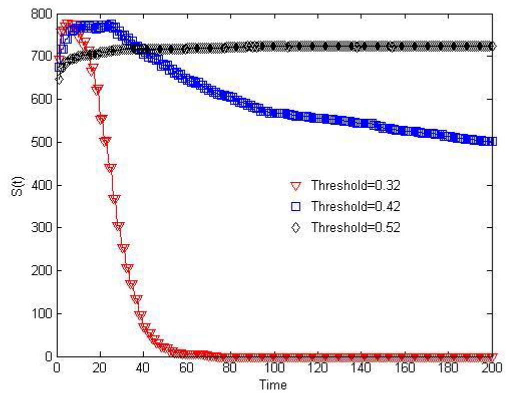
(4) Small world networks vs. R(t)

Figure 4: Small world networks vs. occupational stress diffusion

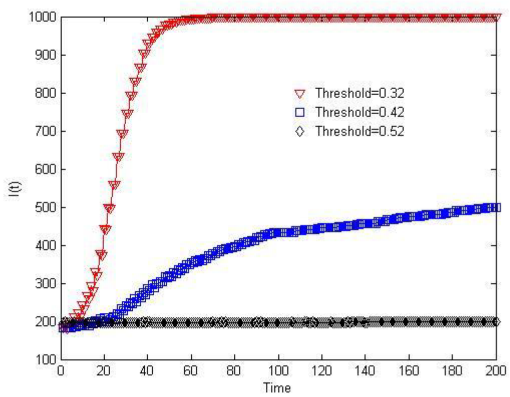
It is shown that the same rule exits in the three classic types of complex networks, but there is difference on threshold value. Therefore, we need to concern the changing of organization stress structure.



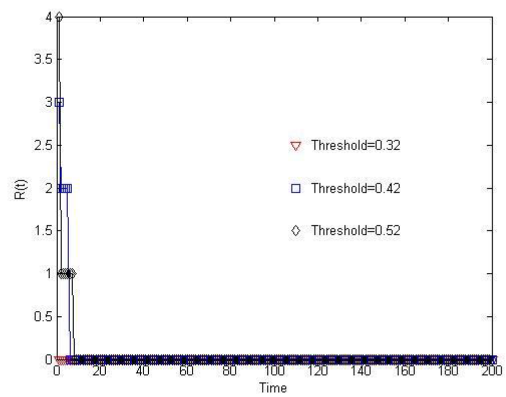
(1) Scale free networks vs. L(t)



(2) Scale free networks vs. S(t)



(3) Scale free networks vs. I(t)



(4) Scale free networks vs. R(t)

Figure 5: Scale free networks vs. occupational stress diffusion

3.3 Initial stress distribution of the organization vs. occupational stress diffusion

Figure 6 shows the landscapes of viral occupational stress diffusion in random networks with the different initial stress distribution. Size=1000, w_1=0.05, w_2=0.09, w_3=0.12, time=100, Threshold=0.32.

In Low Stress Organization, L_NO=0.6, S_NO=0.2, I_NO=0.198, R_NO=0.002.

In Middle Stress Organization, L_NO=0.198, S_NO=0.6, I_NO=0.2, R_NO=0.002.

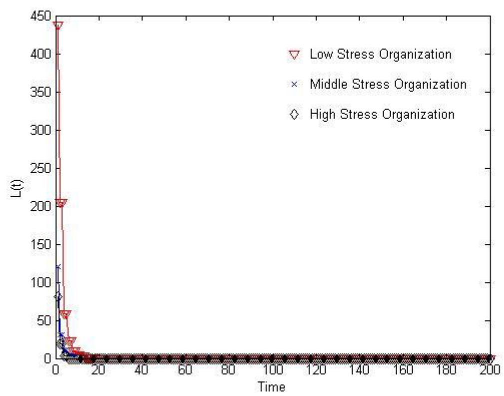
In High Stress Organization, L_NO=0.198, S_NO=0.2, I_NO=0.6, R_NO=0.002.

It is shown that the higher occupational stress intensity of the organization, the faster the speed of the global achieving equilibrium, and the result implies that Middle Stress Organization is of great benefit to maintain organizational stability and active attitude of individuals.

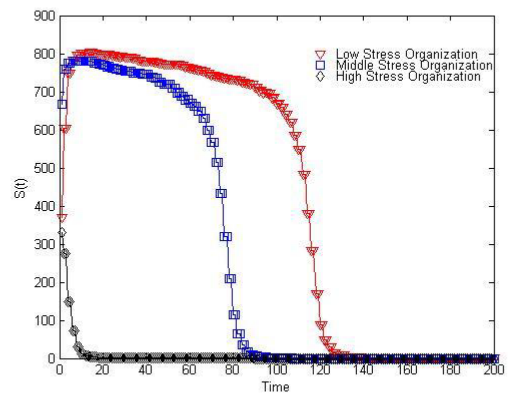
4 CONCLUSION

Some conclusions could be drawn from the above results.

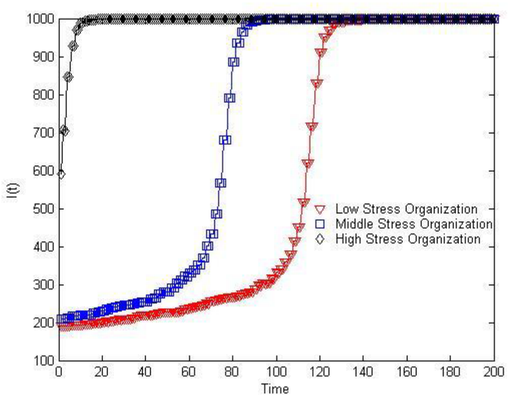
There does exit stress management threshold -- a key model parameter, diffusion threshold T, which can be globally changed by teachers stress management and will affect all the teachers in the university. The effect of occupational stress management is to improve the spreading tolerance of all the teachers, that is, to increase diffusion threshold T. When T is smaller than one value (e.g. 0.3), the stress state of most teachers in one social network will change to I state, i.e., high occupational stress state. The tolerance of all the teachers in one university is low, and so is the stress management level of the organization. This is a true portrayal of the present situation in China, and statistical data also shows it. More seriously, many teachers from Chinese universities even know nothing about stress management or ignore it. When T is larger than one value (e.g. 0.4), the stress state of most teachers in one social network will change to S state, middle occupational stress state, which is appropriate for one university. With the increase of T, individual quantity of S state will slow down, and reach a balanced value. It is obvious that a few individuals of S state have changed to those of L state at low stress. Simulation data shows that the greater stress management intensity is not the better, and the one slightly larger than threshold is regarded as the best. Many countermeasures can be chosen: to gradually promote Employee Assistance Program (EAP) in Chinese universities, proclaiming the importance of stress management, collecting and monitoring the related data of occupational stress; to improve working conditions; to enhance the management of tasks and role requirements; to improve interpersonal demand management; to offer guidance for teachers career planning, etc.



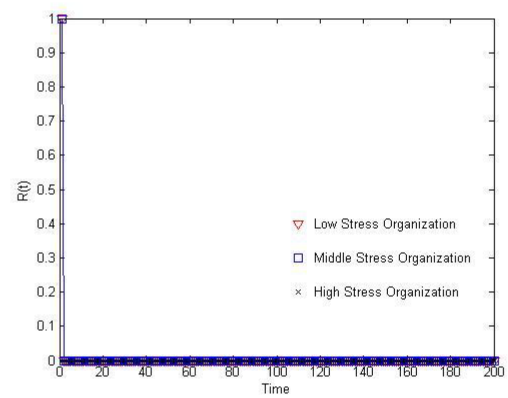
(1) LMH stress organization vs. L(t)



(2) LMH stress organization vs. S(t)



(3) LMH stress organization vs. I(t)



(4) LMH stress organization vs. R(t)

Figure 6: Low, middle and high stress organization vs. occupational stress diffusion

Simultaneously, we need to focus on the changing of organization stress structure and take suitable measures to maintain middle level stress state, so as to keep teachers physically and psychologically healthy, individuals active in work and organization stable. The threshold of small world networks is similar to that of random networks, while that of scale free networks is far larger than them. Therefore, small world networks structure is the best for college organizations with large Clustering Coefficient and small Average Path Length (APL). Many countermeasures can be chosen: to create people-oriented university culture; to strengthen cooperation on teaching and scientific research; to construct a harmonious campus, etc.

Certainty of reaching equilibrium levels demonstrates that low stress organization has stronger robustness than high stress organization. University should try to reduce their teachers' stress and build a beautiful, free and harmonious campus at low stress.

One shortcoming of the model is the inability to account for varying direction of stress diffusion between individuals. Further studies on occupational stress diffusion will be summarized in next paper.

ACKNOWLEDGMENTS

This work has taken place in the research group for Complex Management Systems at the Modern Management Institute, School of Management, Huazhong University of Science and Technology. It is supported by the Chinese National Nature Science Fund (No. 70671048) and the Project of Hubei Provincial Department of Education (No. 20070347, No. B20104406). The authors would like to thank Jiang Wu and Fei Niu et al. for their comments and suggestions on early versions of this paper.

REFERENCES

Albert, R., H. Jeong and A. L. Barabási. 2000. Attack and error tolerance of complex networks. *Nature*, 406: 387-402.

Barabási, A. L., and R. Albert. 1999. Emergence of scaling in random networks. *Science*. 286: 509-512.

Barabási, A. L., R. Albert and H. Jeong. 1999. Mean-field theory for scale-free random networks. *Physics A*. 272: 173-187.

Boguñá, M., and R. Pastor-Satorras. 2002. Epidemic spreading in correlated complex networks. *Phys. Rev. E*. 66: 047104(1-4).

Boguñá, M., R. Pastor-Satorras, and A. Vespignani. 2003a. Epidemic spreading in complex networks with degree correlations. *Physics and Astronomy*. 625: 127-147.

Boguñá, M., R. Pastor-Satorras, and A. Vespignani. 2003b. Absence of epidemic spreading in scale-free networks with degree correlations. *Phys. Rev. Lett.*, 90: 028701(1-4).

Carley, K.M. 1995. Computational and mathematical organization theory: Perspective and directions. *Computational & Mathematical Organization Theory* 1(1): 39-56.

Cooper, C.L., S.J. Sloan and S. Williams. 1988. *Occupational stress indicator management guide*. NFER-Nelson, Windsor.

Erdös, P., and A. Rényi. 1959. On random graphs. *Publications Mathematical* 6: 290-297.

Erdös, P., and A. Rényi. 1960. On the evolution of random graphs. *Publications of the Mathematical Institute of the Hungarian Academy of Science* 5: 17-61.

Erdös, P., and A. Rényi. 1961. On the strength of connectedness of a random graph. *Acta Mathematical Sciential Hungary* 12: 261-267.

Goldenberg, J., B. Libai, and E. Muller. 2001. Talk of the network: A complex systems look at the underlying process of word-of-mouth. *Marketing Letters* 3 (12) :211-223.

Granovetter, M. 1978. Threshold Models of Collective Behavior, *The American Journal of Sociology*. 83 (6):1420-1443.

Isabel, R., M. J. Bravo and M. P. Jose. 2001. The Demand-Control-Support model, locus of control and job dissatisfaction: a longitudinal study. *Work & Stress* 15(2) :97-114.

Johnson, J.V., and M. E. Hall. 1988. Job Strain, Work Place Social Support, and Cardiovascular Disease: A Cross-Sectional Study of a Random Sample of the Swedish Working Population. *American Journal of Public Health*, 78:1336-1342.

Karasek, R. A. 1979. Job demand, job decision latitude and mental strain: implications for job edesign. *Administrative Science Quarterly*, 24 :285-308.

Lloyd, A. L., and R. M. May. 2001. How viruses spread among computers and people. *Science*, 292: 1316-1317.

Macal, C. M., and M. J. North. 2005. Tutorial on Agent-based Modeling and Simulation. In *Proceedings of the 2005 Winter Simulation Conference*. eds. M. E. Kuhl, N. M. Steiger, F. B. Armstrong, and J. A. Joines, 2-15. Piscataway, New Jersey: Institute of Electrical and Electronics Engineers, Inc.

Milgram, S. 1967. The small world problem. *Psychology Today*. 2: 60-67.

Moreno, Y., R. Pastor-Satorras. and A. Vespignani. 2002. Epidemic outbreaks in complex heterogeneous networks. *Eur. Phys*. J. B, 26: 521-529.

Newman, M. E. J. 2003. The structures and functions of complex networks. *SIAM Review*, 45: 167-226.

Olinky, R., and L. Stone. 2004. Unexpected epidemic thresholds in heterogeneous networks: The role of disease transmission. *Phys. Rev. E*, 70: 030902(1-4).

Pan, X., Z.-L. Quan, and Y.-Y. Qian. 2003. Relation between Mental Health and Occupational Stress among College Teachers. *Chinese Journal of Health Education*, 19(10): 792-793.

Pastor-Satorras, R., and A. Vespignani. 2001. Epidemic spreading in scale-free networks. *Phys. Rev. Lett*. 86: 3200-3203.

Pastor-Satorras, R., and A. Vespignani. 2002. Epidemic dynamics in finite size scale-free networks. *Phys. Rev. E*, 65: 035108(1-4).

Robbins, S. P. 1997. Organizational Behavior: concepts, controversies and applications(7th ed.). Prentice Hall Inc. *Renmin University of China Press*. 474.

Sun, L.-Z., X.-W. Shen. 2007. A Review of Research On the Occupational Stress in Western Countries. *The Border Economy and Culture*, 43(7): 74-76.

Watts, D. J. and S. H. Strogatz. 1998. Collective dynamics of small world networks. *Nature*. 393: 440-442

Watts, D. J. 1999. Small Worlds: The Dynamics of Networks Between Order and Randomness. *Princeton University Press*.

Watts, D. J., P. S. Dodds and M. E. J. Newman. 2002. Identity and search in social networks. *Science*. 296: 1302-1035.

Wasserman, S. and K. Faust. 1994. Social Network Analysis: Methods and Applications (Structural Analysis in the Social Sciences) *Cambridge University Press*, Cambridge.

Wu, J., B. Hu, T.-Y. Liu, and K. M. Carley. 2008. Empirical Data Driven Simulation on the Diffusion of an E-commerce System. *World Congress on Social Simulation 2008* (WCSS-08). George Mason University, Fairfax, July 14-17.

Wu, J., B. Hu, J.-L. Zhang, and D. Fang. 2008. Multi-agent Simulation of Group Behavior in E-Government Policy Decision. *Simulation Modeling Practice and Theory*, 16(10): 1571-1587.

AUTHOR BIOGRAPHIES

TIANYIN LIU is a Ph.D. candidate in School of Management, Huazhong University of Science and Technology, currently also an Associate Professor of School of Computer Science in Huangshi Institute of Technology, PRC. His research interests include System Simulation, Complex System and Management Information System. His email is <tianyin_L@163.com>.

BIN HU is a Professor, Director of the Modern Management Institute, School of Management, Huazhong University of Science and Technology, P.R.C. He received his Ph.D. in Management Science and Engineering from Huazhong University of Science and Technology, PRC (1999). His research interests include Management System Simulation, Decision Support System and Artificial Intelligence. His research papers have been published in many Chinese journals and international journals. His email is <bin_hu@mail.hust.edu.cn>.