MODELING GOVERNMENT CREDIT INFORMATION SYSTEMS DIFFUSION IN CHINA: A SYSTEM DYNAMICS APPROACH

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Abstract

This paper examines the usage and diffusion of Government Credit Information Systems (GCIS) in district-level governments in Shanghai. The diffusion of GCIS was studied from a process-oriented perspective. A System Dynamics (SD) model is developed to simulate the relationships of technological, organizational and environmental, and institutional factors on GCIS diffusion under different management policies. A holistic view on the feedback loops, the consequently nonlinear behavior pattern of GCIS usage, and its diffusion in Shanghai government agencies is examined.

Our research model and results suggest that workload faced by GCIS users and the tolerable maximum workload have a high impact on GCIS usage, task volume brought by GCIS, work pressure and the perception of technological factors. Different combination of work intensity and the tolerable maximum work intensity significantly influence the system usage. The contribution of our study lies in revealing that the diffusion of GCIS requires a systematic consideration of the business development plan, the GCIS user's workload and the organization's business environment. Flexible managerial incentive strategy will enhance user's work efficiency, thus lead to effective diffusion of GCIS in organizations. The theoretical and practical implications of this study are discussed.

Keywords: Government Credit Information Systems, System Dynamics, Simulation.
1 INTRODUCTION

Credit is the basis of market economy (Calvo & Frenkel 1991). Nowadays, Government Credit Information System (GCIS) spreads widely in Shanghai city, for the purpose of integrating and sharing credit-related data that distributed in different government agencies, with the expectation that information silos are eliminated, all kinds of information resources are effectively integrated and shared, and cross-boundary, cross-departmental and inter-level business collaboration are achieved (Liu & Li 2009a). Therefore, government agencies are increasingly investing in GCIS in order to support credit information sharing.

Since 2003, Shanghai has established the “three-year action plan for social credit system construction of Shanghai” for two terms (2003 - 2005, 2006 - 2008). Thus, the GCIS in district-level government agencies of Shanghai diffused rapidly. However, the current potential benefits from GCIS are still considered to be low and intangible (Liu & Li 2009b). For example, at the stage of post-implementation, lots of GCIS has not been fully utilized; the diffusion of GCIS has not achieved the desired level (Liu & Li 2009b). Appropriate policies are therefore in demand so as to achieve sustained and effective adoption of GCIS.

In order to explore the diffusion of GCIS and its impact on government agencies, this study set up two research objectives: (a) developing a system dynamics (SD) model to analyze the behavioral characteristics of GCIS diffusion over time, and (b) computing different scenarios to study the impact of management policies on the diffusion of GCIS in district-level governments of Shanghai. In the next section, theoretical background is presented, following by research methods which illustrate the development of qualitative and quantitative models, and the simulation design. Manipulation scenarios are based on the actual operation of GCIS in district-level government agencies of Shanghai. Results and discussions are provided.

2 THEORETICAL BACKGROUND

System Dynamics (SD) method, initially developed by Jay Forrester in 1956, is widely used to describe and analyze complex systems, while simulate system behaviour qualitatively and quantitatively, which emphasizes on conceptualization, formulation and simulation (Richardson 1996). This method holds the view that a system’s basic structural unit is feedback loop. A system structure model is built from the system's micro-structure, which describes the logical relationship of system elements by means of causal loop diagram (CLD) and flow diagram, so that the quantitative relationship between system elements can be represented by differential equations. Hence, simulation can be implemented to analyze periodic, long-term, multi-variables, non-linear, and time-varying scenarios that often face the problem of lacking real data (Li 2009).

SD method has been successfully applied in diverse information systems (IS) research areas, topics and levels, such as IS development, information technology (IT) and individuals as well as groups and organizations, and IT and markets (Rodrigues & Williams 1997; McCray & Clark 1999; Marquez & Blanchard 2006; Sidorova et al. 2008). However, classical technology diffusion modelling approaches often run the risk of failing to give a fully dynamic picture of technology adoption in an industry. It must be emphasized that a qualitative model should be developed under theoretical structural validation (Forrester & Senge 1980), which helps to build a bigger dynamic picture to capture the main elements in the system.

Since the adoption of GCIS is related to the attributes of the system as perceived by potential adopters, we identify variables in qualitative model and adopt measurements in quantitative model by incorporating theoretical perspectives such as Technology Acceptance Model (TAM), Technology, Organization, and Environment (TOE) framework, and institutional theory.

For technological context, TAM proposed that perceived usefulness and perceived ease of use have a significant positive impact on new technology adoption (Davis 1989). Further, perceived relative...
advantage, perceived information matching, and perceived compatibility have positive impact on user’s attitude to adopt new systems. (Tian 2008). For organizational and environmental context, TOE framework posits that the support from high-level managers will positively affect the user's attitude and perception towards the system; meanwhile, the level of IS diffusion has a positive impact on the relative advantages and information matching (Tian 2008). For institutional context, it is predicted by institutional theory (DiMaggio & Powell 1983) that, either the increasing of GCIS use time or the decreasing of volume of business to handle by GCIS, will lead to the reduction of the pressure users faced. And if the users face increasing pressure, they would take the initiative to increase the use of GCIS, thereby enhancing the GCIS diffusion level.

Lastly, we select the users’ work efficiency as a measure of GCIS diffusion extent based on previous research (Liu & Li 2009b). If the system users have a stronger willingness to use GCIS, the working efficiency will become higher accordingly; it also reflects a higher degree of systems diffusion.

Details regarding the data collection, model building analysis and results are elaborated upon in the following sections.

3 RESEARCH METHODS

During the last two years, we have documented several cases of GCIS implementation and operation in Baoshan, Minhang and Xuhui District of Shanghai (Liu & Li 2009a; Liu & Li 2009b). We also obtained data through interviewing GCIS users of those districts. Iterative steps are used to create, validate and simulate our SD model.

Our research contains three stages. In the first stage, we identified variables and relationships among them based on literature review to develop Causal Loop Diagrams (CLD). Then, surveys and interviews carried out in previous study helped us to validate the variables and draw a parsimonious model (Liu & Li 2009b). In the second stage, we converted the CLDs to a stock and flow diagram. To validate the quantitative model, we used the data of system behaviour over time that we had previously recorded (Liu & Li 2009b). In the third stage, we simulated GCIS diffusion in different scenarios through manipulation of managerial policy portfolio. Modelling and Simulation were implemented with software Vensim PLE Version 5.8d.

3.1 Qualitative model development

A qualitative model is developed based on six sub-processes in GCIS diffusion process. They are GCIS usage, task volume, technological factors-related processes, organizational factors-related processes, institutional factors-related processes, and time of GCIS usage. TAM and TOE framework are included in CLD, to explain how different factors affect GCIS systems use. Professionals, consultants, GCIS users were interviewed to provide comments on the CLDs, while adjustments were made to strengthen the validity of the model through several rounds of communication. This was an iterative process so that the qualitative model can better reflect the complex dynamics of real system.

Established Causal loop Diagram (CLD) is shown in Figure 1. Reinforcing loops are labelled as “R” in figure 1, and balancing loops are labelled as “B”. Positive linkage lines between variables are denoted as “+”.

Some variables, such as time of credit system use, incoming business, can be easily measured in the real system environment. While the other variables are mostly latent variable, reflecting the user's attitude, intention, etc. Variables shown in grey squares in Figure 1 are exogenous (variables manipulated by the authors), the other variables are endogenous (variables determined by the system).
3.2 Quantitative model development

The quantitative model, i.e., the stock and flow diagram is translated from CLD by identifying levels, rates and auxiliary variables derived from qualitative model. Task volume, pressure, level of IS diffusion, and perceived technical factors are selected as level variables, reflecting the status of the system. Figure 2 shows the flow diagram of GCIS diffusion. The definition of variables appeared in the model are presented in Table 1.

Figure 2. Flow diagram of GCIS diffusion

The initial parameters of base model are from the records of real GCIS operation, and empirical data obtained from the user interview. The validation of the model includes dimensional consistency.
Dimensional consistency of the model was checked with the "Units Check" function of Vensim software. The structure assessment and the face validity check of the model were conducted by using data from the user interview in previous study (Liu & Li 2009b). The causal relations were developed on the basis of available knowledge about the real system, and provided a sort of "empirical" structural validation. TAM and institutional theory served as a "theoretical" structural validation (Forrester & Senge 1980).

<table>
<thead>
<tr>
<th>Variable</th>
<th>Definition</th>
<th>Units</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Task volume</td>
<td>Task volume with GCIS per week</td>
<td>Count</td>
<td></td>
</tr>
<tr>
<td>IS diffusion</td>
<td>Work efficiency of GCIS-related within organization</td>
<td>Count/Week</td>
<td></td>
</tr>
<tr>
<td>Pressure</td>
<td>The extend of user’s pressure due to GCIS use</td>
<td>1-5 Likert scale</td>
<td></td>
</tr>
<tr>
<td>Perceived technical factors</td>
<td>User perceived technical factors due to GCIS use</td>
<td>1-5 Likert scale</td>
<td></td>
</tr>
<tr>
<td>Incoming business</td>
<td>Incoming business to be finished by GCIS per week</td>
<td>Count</td>
<td></td>
</tr>
<tr>
<td>Tolerable business</td>
<td>User’s tolerable business per week</td>
<td>Count</td>
<td></td>
</tr>
<tr>
<td>Time of GCIS use</td>
<td>User’s time of GCIS use per day</td>
<td>Hours</td>
<td></td>
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</tbody>
</table>

*Table 1. Variables used in the SD Flow diagram*

### 3.3 Simulation Design

To compare how different management policies affect GCIS use, we design a set of nine simulation runs (Table 3). Initial parameters values of the base run were gathered from GCIS users. By changing the intensity of work (i.e., the variable "incoming business"; L=300, N=400, H=500) and tolerable intensity of work (i.e., the variable “tolerable business”; L=300, N=400, H=500), different business situations are simulated. Based on the simulation runs, the changes of level variables that reflected the whole model state was observed.

<table>
<thead>
<tr>
<th>Simulation</th>
<th>Intensity of work</th>
<th>Tolerable intensity of work</th>
<th>Simulation</th>
<th>Intensity of work</th>
<th>Tolerable intensity of work</th>
<th>Simulation</th>
<th>Intensity of work</th>
<th>Tolerable intensity of work</th>
</tr>
</thead>
<tbody>
<tr>
<td>SIM 1</td>
<td>N</td>
<td>N</td>
<td>SIM 4</td>
<td>L</td>
<td>N</td>
<td>SIM 7</td>
<td>H</td>
<td>N</td>
</tr>
<tr>
<td>SIM 2</td>
<td>N</td>
<td>L</td>
<td>SIM 5</td>
<td>L</td>
<td>L</td>
<td>SIM 8</td>
<td>H</td>
<td>L</td>
</tr>
<tr>
<td>SIM 3</td>
<td>N</td>
<td>H</td>
<td>SIM 6</td>
<td>L</td>
<td>H</td>
<td>SIM 9</td>
<td>H</td>
<td>H</td>
</tr>
</tbody>
</table>

*Table 3: Different simulation scenarios of management policies (N = normal; L = low; H = high; Initial parameters values of the base run: Task volume = 10, IS diffusion = 20, Pressure = 1, Perceived technical factors = 1)*

Week is selected as time interval, which can better capture the changes of the GCIS diffusion according to user interview and our observations. Initial time is 0, length is 12, and step is 0.25. In real system, GCIS users worked under moderate work intensity, so SIM 1 is assigned as the base run (Table 3). Primary input for model parameters and relations is from user provided data. Eight scenarios are computed by changing base run conditions shown in Table 3.

### 4 SIMULATION RESULTS

The result of the base simulation run (SIM 1) is shown in Figure 3. The result shows that, as the level of GCIS diffusion (the curve marked with "1") increases, and business volume needed to be handled (the curve marked with "2") decreases over time. Accordingly, the user perceived pressure (the curve marked with "3") and the level of technological factors (the curve marked with "4") gradually increase.
Figure 3. Results of the base run

The results of different simulation scenarios listed in Table 3 are shown in Figure 4 a, b, c, and d respectively. The numbers on the curves represent nine different simulation scenarios.

Figure 4. Results of different simulation scenarios

Figure 4(a) shows the different level of GCIS diffusion under 9 simulation scenarios. Curve 3, 4 and 6 split from other 6 curves after week 8. In other words, in scenario SIM 3, SIM 4 and SIM 6, the level of GCIS diffusion is lower. The common feature of SIM 3, SIM 4 and SIM 6 is that the actual work intensity is relatively lower than tolerable work intensity.

Figure 4(b) shows the different level of business volume to handle under 9 scenarios. All curves of task volume grow first, and then display a downward trend. At the beginning, SIM 3, 4 and 6 are obviously higher than others, which means when work intensity is lower than tolerable work intensity, GCIS users have to handle more work. Such situation implicates that accumulation of business tasks occurs due to low level of user's work efficiency.

In Figure 4(b), curve 8 lies in the bottom, which means the SIM 8 has the least business volume to handle. At this moment, work intensity is the highest and tolerable work intensity is lowest. It indicates that, although the tolerable work intensity is low and work intensity is high, in order to complete their work, users have to spend more time using GCIS, resulting in decreasing of task volume.
Figure 4(c) shows the differences of the pressure user faced under different simulation scenarios. In general, the pressure faced by users shows an upward trend over time. At the later period, the pressure of SIM 3, 4 and 6 is less; when work intensity is below tolerable work intensity, GCIS users face less pressure. This result is consistent with our intuitive experience.

Figure 4(d) shows the differences of user perceived technical factors under different simulation scenarios, and the differences are slight. From the whole, user perceived technical factors is constantly improving as the use of GCIS.

5 DISCUSSION

5.1 Implications for GCIS usage

Our method emphasizes the importance of analyzing GCIS diffusion from a process-oriented perspective. With the simulation of GCIS diffusion in a SD model, it is more visible to identify the situations which have greater impact on GCIS usage over time.

The results indicate that as time proceeds, the diffusion of GCIS is gradually improved. However, improvement level of GCIS diffusion alters when work intensity level differs. Higher work intensity leads to a higher level of GCIS diffusion and vice versa. However, higher work intensity has also led to the accumulation of task volumes. Since organization’s goal is to obtain a higher level of system diffusion, it will inevitably result in higher work intensity that could decline users’ enthusiasm. Thus, managers are suggested to consider work intensity, task volume, and user workload simultaneously.

In addition, our results show that technological and environmental factors can significantly affect the effective usage of GCIS. In simulation results, pressure user faced, technology advantage, and technology compatibility gradually accumulate over time, but the increase of users’ perception of these factors is relatively slow. It reminds the policy makers to be aware of both the benefits of technology and the risks of users’ resistance to adopt. A variety of incentives can be implemented so that user’s pressure can be reduced. Thus, the diffusion of GCIS will achieve a more satisfactory level in a relatively short period of time.

5.2 Implications for IS research

In IS adoption/diffusion research, it is difficult to directly measure latent variables, and there often existing more complex relationship such as correlation, causal relationship and so on. SD method is a tool to deal with causal relationship between latent variables. It’s suggested to make more applications of SD on situations when latent variables are hard to measure, since “leaving such variables out of models just because of a lack of hard numerical data is certainly less scientific than including them and making reasonable estimates of their values” (Forrester 1980; Sterman 1991).

As for the limitations of this study, we still have some considerations when generalizing the results. First, our study is based on the scope of district-level government in Shanghai, so is the simulation model. Second, the simulation makes a reasonable abstraction and simplification to real GCIS systems. However, even if there are some variations between the modelled and the actual behaviours, a simulation model can still provided valuable suggestions on system usage (Kanungo 2003).

6 CONCLUSION

Drawing upon TAM, TOE frameworks, institutional theory, SD simulation, and grounding our research in practice, we developed a SD model to examine the impact of technological, organizational and environmental, and institutional factors on GCIS diffusion in Shanghai under different scenarios.

Our research model and results suggest that workload faced by GCIS users and the tolerable maximum workload has a high impact on GCIS use. The first 7 to 9 weeks after the implementation
of GCIS tend to increase user’s task volume, cause a lot of work pressure, and lead to negative perception of technology. Different combination of workload and the tolerable maximum workload will influence the diffusion of GCIS. It is important for the decision makers to handle user pressure in that period. A reasonable business development plan and the GCIS user’s workload should be designed carefully by assessing organization's business environment. Flexible managerial incentive strategy will enhance user's work efficiency and promote the GCIS diffusion to a desired level in organizations. Our results contribute to the IS research with SD that examines the phenomena of GCIS use and its diffusion impacts in district-level governments of Shanghai.

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