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MODELLING MEANING, NOT VARIABLES: TOWARDS AN INTERPRETATIVE MODELLING OF SYSTEM DYNAMICS

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Abstract

This study suggests a rethinking of qualitative system dynamics modelling. The results highlight that "interpretative modelling" is a useful way to enhance the use of system dynamics when encountering a situation coloured by social, cultural and political factors. The paper examines the problem embedded in the current use of system dynamics and proposes a three-level analysis (process, influence diagram and frame) to show how interpretative modelling can be attempted. It argues that, for qualitative inquiries, researchers need to consider interpretative modelling that emphasises more on surfacing meaning rather than on building variables.

Keywords: interpretative modelling, knowledge elicitation, process theory, influence diagrams and frame analysis

Introduction

Since its inception, system dynamics researchers have developed a strong pool of knowledge to understand better non-linear problems though quantitative simulation of feedback loops. Recent developments in this field come to recognize the limit of quantification and propose to use qualitative methods (e.g. combine system dynamics and soft system method) to produce policy insights (Coyle and Alexander, 1997). However, scant attention thus far is paid to examine the underlying worldview rooted in both use of system dynamics.

This study therefore aims to explain why current applications of system dynamics are entrapped by a *positivistic* worldview, an assumption which seeks to generalize "objective" theories through testable hypotheses. As shown in this study, researchers may inevitably oversimplify the organizational realities by embracing the *positivistic* assumption. Three major problems are addressed: (1) the problem of knowledge elicitation (Does the system dynamics model represent the "real" problem under investigation? Or does it merely reflect the modellers' bias?), and (2) unit of analysis (Should researchers focus on finding *constructs* for hypotheses-testing? Or should they analyse the *meaning* of participants' mental models?). These two problems seek to sensitise researchers to a social-scientific modelling of system dynamics.

The paper thereupon proposes an analytical framework seeking to respond partially to these three challenges. The framework assumes an interpretative worldview and considers a three-level analysis with a combinational use of process theory, influence diagrams and frame analysis. An in-depth field study of IT failure is used for illustration. First, the sequences of events are traced to offer a *process story*, identifying the patterns that explain how problems emerge and evolve over time. Secondly, these process patterns are used to build a *system dynamics model*, with a focus on "meaning" (how participants perceive these problems). Thirdly, a *frame analysis* is used to examine how the mental models (of participants) contribute to the problems exhibited in the system dynamics model. Finally, the limitations of this three-level method are reflected.

Conceptual Basis

Although more and more researchers begin to employ qualitative system dynamics to understand policy dilemma (e.g. Sterman et al., 1997), few critically examine the underlying assumption of system dynamics method. A common understanding of qualitative system dynamics is to include "soft" constructs such as trust, leadership, and motivation. System dynamics researchers rarely consider the "worldview" behind the use of non-linear modelling. It is also the dominant view that a rigorous, scientific system dynamics study must be accompanied by statistical justification and correct mathematic formula embedded in the model. This view of qualitative system dynamics is nonetheless bias, if not wrong. The qualitative research discipline of organizational science might be useful to provide some hints to system dynamics researchers.

To provide a conceptual basis for this proposal, one question is proposed to offer a lead for the intellectual debate: i.e. *should system dynamics be described as a hard/deterministic system approach?* The purpose of this discussion is not to provide the "right" answer of what qualitative system dynamics should be. Instead, it aims to suggest an alternative way to consider a qualitative method of deploying system dynamics.

Should system dynamics be described as a hard/deterministic system approach?

The question is to revisit Lane's (2000) defence on system dynamics as a deterministic system approach. Lane (2000) argues that researchers mistreat system dynamics as a hard science because there is a lack of theoretical understanding. There are four major "accusation" of system dynamics modelling. First, system dynamics is a naïve method in assuming that future events can be prophesised. Second, system dynamics assumes complete control of the decision of human agents. Third, system dynamics assume that there are only cause-effect laws, ignoring issues derived by human subjectivity. Fourth, system dynamics is just another form of system engineering which is operationally austere and coercive. Lane (2000: 18) concludes that the misunderstanding is due to poor communication between system dynamicists and other system practitioners.

Although Lane (2000) argues in length to counter these accusations, unfortunately, few qualitative researchers might agree with his view. The reason is neither about the methodology adopted nor the measurement taken. The poor communication perhaps lies in the paradigmatic gap between a positivistic and interpretative worldview (for detail description of paradigm and worldview, see Blaikie, 1993; Burrell and Morgan, 1979). In order not to fall into abstract debates, I will try to illustrate this paradigmatic gap by discussing three issues relating to system dynamics modelling. I will then revisit why current system dynamics is considered as under positivistic paradigm.

The first issue is related to the problem of knowledge elicitation. This is to ask: does the system dynamics model represent the "real" problem under investigation? Or does it merely reflect the modellers' bias? Often, it is the trained system dynamics modellers (or consultants) who will interview informants and decide what the problem is about, although they claim to be neutral. One manager from client site (a petroleum company in UK doing system dynamics exercise) interestingly called it "Apotheosis of Model Building". This refers to the criticism of the God-like role of researchers as modellers. In most situations, although statistical justifications have demonstrated the objectivity of the model, it nevertheless assumes that modellers have a final decision on which variable should be included and which causal relationships should be specified. Most experienced managers would wonder how one could play the role of God in deciding what should be the "final model", even the method of group model building is used (Vennix et al., 1996). In a real life context, this is often a matter of power struggle between modeller and key stakeholders. As this is not merely a technical but also a social issue, it frequently requires reconciliation rather than measurement.

Moreover, there is another issue of inter-subjectivity (Mitchell, 1983). The system dynamics modellers bring in a subjectivity based on their expertise background (e.g. if the modeller is from technology discipline, he/she will tend to consider solution from a technology viewpoint). The informants interviewed, from different departments, also bring with them different kinds of subjectivity, if not mention the vested interest. The interaction of modellers and informants again create inter-subjectivity. In this case, will the mathematic formula truly reflect the complex interaction of subjectivity involved? Therefore, system dynamics can be considered as a "hard science" if it fails to address the issue of knowledge elicitation from a qualitative angle.

The second issue is about the unit of analysis. This is to ask: Should researchers focus on finding *constructs* for hypotheses-testing? Or should they analyse the *meaning* of participants' mental models? A typical process of system dynamics modelling includes: (1) defining the problem by collecting data, (2) defining constructs to represent the problem, (3) formulating hypothesis about the reciprocal causal relationship among the constructs, (4) building and optimising the model, (5) analysing problem through simulating the system dynamics model, and (6) identifying an optimal solution through simulations. Such a build-test-solution process seems too good to be true. We might wonder: how can this systematic build-test-solution process guarantee an "optimal answer"? Most companies encounter complex problem coloured by organisational politics, culture, and power. It requires researchers to investigate qualitative concepts such as "trust" and context-sensitive constructs such as "leadership" (a leader will influence how a problem can be solved in an organisation). Without getting an in-depth understanding of the issue under investigation, researchers might in fact come to a solution that oversimplify the problem. In particular, it would be difficult to get an in-depth understanding if researchers do not understand the problem perceived by the stakeholders. Without recognising this, researchers might create a model that has no meaning to the context-specific problem.

Should system dynamics be described as a hard/deterministic system approach? The answer I am afraid is "yes". According to the yardstick of social science, the current system dynamics modelling effectively embrace a "positivistic worldview", a paradigm (way of thinking) that consider the world as ordered universe made up of atomistic, discrete and observable events. The positivism view regards true knowledge to be represented by universal laws: i.e. only which can be observed can be regarded as truth science (Blaikie, 1993). It holds that knowledge is derived from sensory experience by means of experimental analysis. Science is to gain predictive and explanatory knowledge of the external world. In contrast, interpretivism view sees "reality" (true science) as the product of processes by which social actors together negotiate the meanings for actions and situations (Blaikie, 1993). "True knowledge" thus is be derived from the everyday social world in order to grasp the socially constructed meanings, and reconstructs these meanings in social scientific language.

According to Waring (1996), hard systems approach relates to those situations in which human behaviour is perceived to play a minor role, even though many people may be involved in the system. People are assumed to be objective in any situation. Hard systems approach refers to attributes perceived to be quantifiable, predictable and relatively undisputed. It involves a set of tacit assumptions on the part of problem-solvers, which may be summarised as followers:

- The existence of the problem may be taken for granted.
- The structure of the problem can be simplified or reduced so as to make its definition, description and solution manageable.
- The reduction of the problem does not reduce the effectiveness of the solution.
- An optimal or superior solution does exist
- The selection of the optimal solution is through a rational process of comparison.

These assumptions indicate that a hard system view of problem-solving involves a very detailed examination of the system experiencing the problem. For hard systems analysis to be effective, there will also have to be a large measure of agreement concerning the overall goal. The role of human actors is assumed to be that of passive objects amongst whom consensus exists. The major criticism of hard systems thinking concerns its deterministic view of social systems which sees individuals performing deliberate acts and imparting subjective meanings. Indeed, if we take a laymen approach to look at system dynamics, we might wonder how valid is it by building a mathematic formula or assigning a 1-10 scale to constructs such as “love”. Perhaps, we want to know more about the *meaning* of love rather than *measuring* the quantity of love.

Therefore, even soft system method or soft OR is used to support system dynamics modelling (e.g. Coyle and Alexander, 1997; Lane, 1994; Lane and Oliva, 1998; Rosenhead, 1989), it still does not change the positivistic assumption. Not until this paradigmatic issue is addressed, researchers might not be able to communicate to each other about what is the true model to represent the true knowledge of the selected phenomenon. To explore how qualitative system dynamics can work, we need a new way to experiment with system dynamics and take a new perspective to consider the influence of human actors. The next session makes such an attempt.

Research Method

Case Selection

The case is an international firm – FoodInc (disguised name) – in a consumer product industry based in Asia. The selection of this case is based on the principle of theoretical sampling (Eisenhardt, 1989; Yin, 1989) for two reasons. First, FoodInc has continuously invested millions of dollars working with various consulting firms on large-scale IT-enabled change projects. However, the top management remains baffled by the dilemma of ineffective investment in IT-enabled change. Secondly, these changes have resulted in the resignations of many senior staff, and the problems at the operational level seem to be escalating. Divisional managers in general feel that the company's overall capability in dealing with these problems has gradually dwindled. Thus, the case provides a rich context for studying IT failure characterised by high causal and human-induced complexity. In this case, the critical events within the organization (based on the Diary Division) are used as the focus of analysis.

Data Collection

The data collection traced the developmental path of IT introduction, following interviews from front-line staff to the top management team and tracing the value chain activities horizontally (i.e. from R&D to customer service). The overall interview scheme is illustrated in Table 1. The data collection is designed to trace the change incidence retrospectively, including a real-time intensive field visit (spanning one month from August to September 1997), a series of follow-up semi-structured interviews, and another site audit (spanning three weeks in April 1998). In addition, during the site visit, the researcher also attended many of the departmental lunch meetings in order to appreciate the problem and context. Informal talks to product managers and front-line staff also helped to understand the organizational climate that contributed to the IT failure.

	R&D	Production	Sales/Retailers	Headquarters
Management team				8
Divisional Managers	1	2	3	
Middle Managers	1	4	15	
Frontline workers	1	6	28	
Sub-total	3	12	46	8
Total				69 persons

TABLE 1. Interview Scheme for Data Collection

Two main sources of information were collected. First, process data were collected with reference to content and context over time (Pettigrew, 1990, 1997). This is mainly concerned with retrospective tracing of different change initiatives. Secondly, data concerning the subjective interpretations of key stakeholders actors was collected, including the perceptions of the top management, Strategic Planning Division (SPD, a key policy designer), IT Division, and product managers (they are users mostly based in the Diary Division). This data was used to understand how conflicting frames lead to resultant actions (Schön and Rein, 1994). Data were gathered through semi-structured interviews (around 2 hours for each interview), participant observation in internal meetings, document study (internal archives and consultancy reports), and two group interviews.

Data Analysis

Based on interpretivism tradition (Walsham, 1995), three particular techniques are used in the data analysis: processual analysis (Pettigrew, 1990, 1997), system dynamics and frame analysis (Schön and Rein, 1994). First, processual analysis involves the use of ethnographic narratives to capture the organisational dynamics and a process map to understand how problems evolve and accumulate over time. The detail documentation of ethnographic narratives is provided in a working paper (Hsiao, 2000), while the paper sums up only the key events in the case analysis.

Second, influence diagram is used for system dynamics modelling (Coyle, 1996; Wolstenholm, 1990) to understand the underlying causal pattern of change. However, it should be noted that the modelling process used in this study is slightly different from the current quantitative (e.g. Sterman, 1989) and qualitative approach of modelling (e.g. Wolstenholm, 1990). The quantitative modelling approach, in principle, follows the positivist paradigm and emphasizes the measurable factors of a system, without paying sufficient attention to the complexity of human interaction. This approach is more concerned with the production of a universal framework for prescribing remedial actions. For example, if analysts control the "morale factor" in the system dynamics model, the system performance will achieve certain optimal outputs.

On the other hand, qualitative modelling stresses the collection of behavioural data, which aims to understand how the dynamics of the problem evolved. Nevertheless, the current qualitative approach seems to focus more on the construction of a system dynamics model and less on the description of problem in organizations. This study attempts to adopt qualitative modelling approach by incorporating a "thick description" of the social dynamics involved (Geertz, 1973). The purpose is to examine the detail of human interactions in the context of IT-mediated organizational change. In this way, the influence diagram model is used mainly as an interpretative device to add to the explanatory power of the case study. This feedback loop analysis, provided by influence diagram modelling, offers an effective way of representing the reciprocal relationships of the problem under investigation.

Third, the analysis revisits the processual data and system dynamics model in order to reflect on how problems are caused by the conflicting frames of human actors. This helps to understand the root cause of IT failure in this particular case. The research framework shown in Figure 1 explains three levels of analysis in this study.

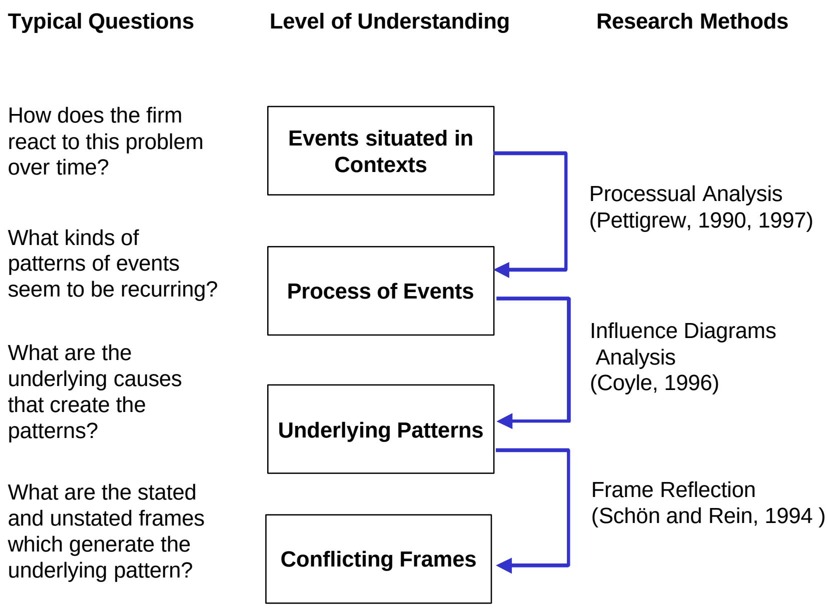

FIGURE 1. The Research Framework for Data Analysis (based on Kim 1992)

Validation Issues. The issue of validity raised in this study is complex. It involves modelling subjective cognition, which gives rise to the problem of inter-subjectivity. In order to minimise the impact of the researcher's own bias and key actors' "attributional egotism" effect (see Brown, 1998: 52, which refers to the phenomenon wherein actors offer self-serving explanations for events, attributing favourable outcomes to their own effects, and unfavourable outcomes to external factors), reflective interviews and group meetings were used to incorporate key actors' comments. Triangulation is also achieved through the use of multiple informants (in different divisions and ranks) and data sources (retrospective vs. real-time data and field data vs. archive data). In addition, some key informants were interviewed 2-3 times to examine the coherent of their claims. Their personal career in the company is mapped and compare to the overall process of change. This helps to validate their accounts of change events.

However, the researcher retains the final decision about mapping the change process and model building, with reference to the hidden agendas informed by site visits and informal conversations. Five guiding questions are repeatedly raised in different ways to informants in order to achieve data triangulation (Forrester, 1993). These questions are: (1) What was done in various kinds of past problems? (2) What are the self-interests of social actors? (3) Where are the influential power centres in the organisation? (4) What could be done in various hypothetical situations that have never happened? (5) What is being done to help solve the serious problems facing the company?

Case Analysis

Context

The case is based on the study of IT failure in a consumer products company – FoodInc (with its headquarters based in Taiwan). The globalisation challenge has brought about a series of changes in FoodInc. Since its establishment in 1967, the company has grown into an international organization which employs 6,200 people in the core businesses, owns 52 factories around the world, and has strategic alliances with over 70 internationally known firms (up to 1997). Its business scope ranges from animal foods (e.g. stock-feed), consumer foods (such as plain flour, meat, frozen foods, and beverages), chain stores, distribution, construction, electronics, semiconductors, and financial services to leisure enterprises.

The company's aim was to integrate its core competencies to achieve successful globalisation. The management team intended to upgrade the legacy information systems in order to support future business growth. With the assistance of various consulting firms, FoodInc invested in a series of IT initiatives during the period 1989-1998. Internally, the firm had two key change agents – SPD (Strategic Planning Division) and Information Division – to facilitate the transformation for over 72 business divisions. However, these initiatives were not entirely beneficial; rather, they seemed to create more trouble throughout the organization. The empirical investigation is mainly based on the introduction of IT in Dairy Product Division.

Process

The events are summarized into 11 episodes to illustrate the *meaning* interpreted by key stakeholders in the implementation process (see Table 2). In each episode, the emerging conditions of context (first column) are explained and the dominant actors' perceptions are "interpreted" (second column). This reflection of the *frame* of references of social actors helps to understand why particular actions are resulted (third column). The purpose of this analysis is to show that reciprocal causality is derived not necessarily as "rational". The structural constraints may be "irrational" and "emotional". Finally, the outcome of these frame-induced actions is provided in the fourth column. The 11 episodes help to enhance our understanding of the situations in the context of IT failure in FoodInc. The process story is to assist the building of system dynamics model. However, the qualitative system dynamics model is used more as an *interpretative device* to deepen the understanding of IT failure problem, rather than a predictive model to forecast behaviour under structural control.

Episode	Contexts and situations	Dominant actors' perceptions	Resulting actions	Outcome
1	The outsourced ISD project was abandoned (1985). Operational bottleneck was seen as a key issue.	SPD: ISD must be managed in-house.	IT Dept. was expanded (became ID). The WANG system was used for hardware platform and COBOL language was used for ISD.	Users complained that the problem stemmed from the new IS. Operational bottleneck was still unresolved. ID gained more power over SPD.
2	The top team pressured SPD to resolve operational bottleneck. Users' complaints were mounting.	SPD: Users' complaints are only temporary. ID: We must prove our worth; IS would work well within the parameters of a coherent IT infrastructure.	SPD concentrated on pushing ISD schedules. ID concentrated on hardware and software integration for ISD, paying more attention to system coherence.	Users' complaints were continuously aroused. There was still no sign of productivity improvement.
3	A new CEO proposed an initiative: to transform the old hard-work culture into a smart-work culture (1989).	SPD/ID: Smart-work culture could be achieved by introducing smart machine (i.e. the IS).	SPD urged ID to expand the local exploitation of IS into a company-wide implementation.	Users became less tolerant and more resistant to the IS. ID expedited the ISD schedule but did not consider the redesign of the outmoded process.
4	Users' resistance was mounting. CEO pressured SPD and ID to deliver results.	SPD: Something must be done to show ways of implementing "smart-work". ID: To smooth complaints, we must first gain users' confidence. Users: ISD only means more workloads.	SPD installed groupware to demonstrate how smart-work could be achieved. To gain sympathy from users, ID developed a data-mining system to help users retrieve data from POS. Users considered groupware was a distraction from their work.	The use of groupware further promoted hostility and distrust among users toward SPD. However, the feeling was not recognized by SPD. ID was tied up in fixing the problems generated by system breakdowns. Under the pressure to develop several software applications at the same time, the workload of ID staff increased and IS quality suffered.
5/6	Old culture persisted in FoodInc. Users' skepticism towards smart machine was rising. There was a lack of senior product managers in the consumer goods industry in the Asia Pacific region.	User: The IS was not useful; it is merely doing the wrong thing faster. SPD/ID were spending money on entertainment. ID: Better technology was needed.	Users (product managers) were engaged in product failure problems. ID focused on system coherence and upgraded IT infrastructure (1993/94); later, ID was engaged in data conversion and software redesign.	Another round of ISD interviews added to users' workloads. As the workloads were increased consistently and the career systems remained, many product managers left and joined FoodInc's competitors. Conflict and distrust between users and SPD/ID were aroused.
Conventions: SPD = Strategic Planning Division; ID = Information Division; IS = Information Systems; ISD = Information Systems Development; IT = Information Technology.				

Table 2. Tracing the Frame-induced Conflicts in FoodInc.

Episodes		Dominant actors' perceptions	Resulting actions	Outcome
7		ID: We needed to demonstrate our technical competence to gain user confidence. User: IS would not solve productivity problems; PC-based application is a better solution.	ID decided to shun Window-based applications because of system consistency (1992); ID later concentrated on system migration (1993-94). User started to use end-user applications (e.g. Excel).	Users decided to ignore ID's ISD efforts.
8		User: We did not get any productivity improvement from the ISD. ID: Why didn't they appreciate the importance of system coherence? We need to enhance communication.	User decided to bypass ID and hire its own programmers; Divisional directors sent junior staff to deal with the irritation of ISD. ID began several user-communication programs; later, ID was again engaged with the tasks of data conversion.	Distrust arose between users and ID. System quality suffered further because of poor user inputs; most users gave up the use of IS in response to the outbreak of system problems.
9	. ERP systems were populated in the various industries in the Asia Pacific Region.	SPD: The previous IS failure was due to changing user demands; ID was not capable of dealing with it.	SPD: decided to transfer built-in best practice via ERP systems (1997) and; SPD set up committees to get top management support. Users felt they were not involved in designing the systems. ID conducted a series of communication programs to gain user support.	The rising conflicts resulted in users' resistance to the ERP implementation.
10	Users distrusted ID's competence in delivering viable IS and doubted SPD's intention to introduce ERP systems.	SPD: Best practice transfer would solve all the technical problems and smooth the complaints from users. Users: SPD is squandering money on projects that are incapable of producing major results. Our concern is to resolve product-related problems.	SPD pushed the use of ERP software aimed at reengineering supply chain processes and transferring best practices. Users decided to concentrate on product-related problems and ignored IT-related tasks.	The overall organizational climate was filled with conflict, distrust and de-motivation. Product managers' workloads increased, resulting in staff turnover. The product managers had indignant feeling towards IT consultants.
11	The increasing staff turnover caused the loss of organizational knowledge. The concept of e-Business became a new trend, replacing ERP.	SPD: We needed something new and interesting to engage users. Users: These smart machines (ERP and e-Business) were just expensive calculators.	SPD decided to introduce e-Business to enhance the ERP-based reengineering project. Users turned into clandestine resistance; they wanted to protect their "trade secrets" from being computerized into e-Business.	As more and more senior staff left, the operational problems continued. Conflict and distrust persisted in the organizational climate. The use of IS, under the banner of "smart-work-via-smart-machine", was suffocated.

Table 2: Tracing the Frame-induced Conflicts in FoodInc (continued).

Structure

In FoodInc's case, a system engineer may attribute IT solution backfire to poor system development. A product manager may blame retailing policies and ineffective processes. On the other hand, the SPD may prioritise the need to align IT and business strategy. An organizational development consultant may emphasize the resolution of conflicts between SPD and business divisions in order to smooth the implementation of change. Each cause-and-effect inference is right, but the dilemma lies in the synthesis of all. For instance, if the IT manager implements a better software engineering method, this may speed up the system development cycle; but it may also cause an increase of staff workload, leading to more staff turnover and internal conflicts. In addition, the technical difficulties may increase, and systems may become even unstable. Furthermore, if the SPD introduces better consultants to assist the strategic planning, this may provide a coherent design for integrating IT and business strategy; but it may also escalate the internal conflicts and delay the remedies in distribution channel, given the context in FoodInc.

Analysing the Underlying Pattern. To provide a viable process theory, analysts need to reflect upon the recurring patterns of events. This requires an examination of the processual data presented in the case and identifies the reciprocal effects of the context-specific constructs. Feedback loops are used to illustrate the problem of IT solution backfire from a systemic perspective.

The IT Solution Loop. In the early stage, FoodInc's inefficient processes incurred operational bottlenecks and an increase in operating costs. To regain competitiveness, the SPD initiated a series of IT-enabled change which included distribution information systems, the WANG hardware systems, in-house developed software, a major upgrade in IT infrastructure (into Oracle RDBM platform), and supply chain management. The "IT Solution Loop" (see Figure 2) represents this feedback effect. IT-based solutions are applied to improve operational bottlenecks. If operational bottlenecks remain, more IT solutions are needed.

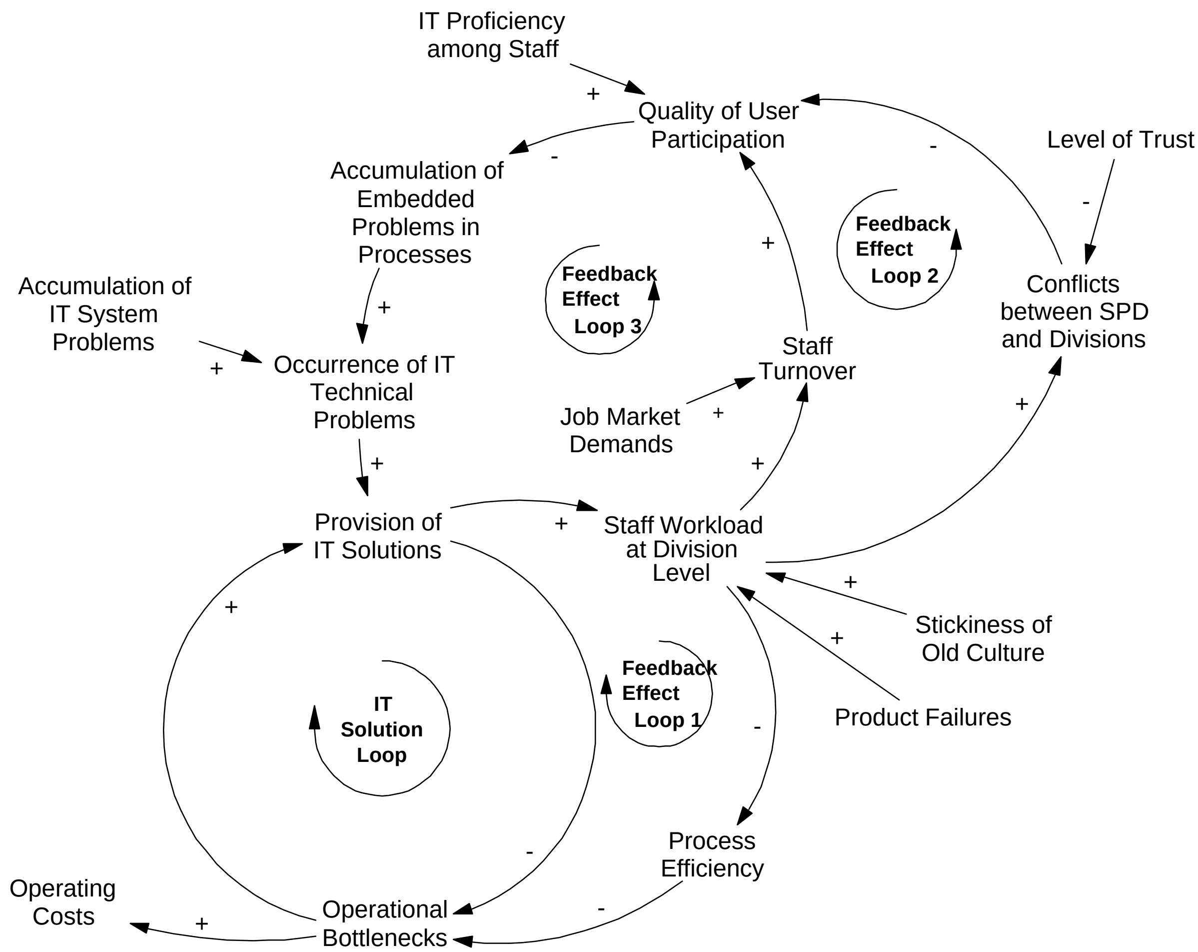

FIGURE 2. The Dynamics of IT Failure in FoodInc.

The First Feedback Effect. The provision of IT solutions unexpectedly increases the staff workload at a divisional level (see “Feedback Effect Loop 1” in Figure 2). The level of workload is initially maintained by the firm’s ineffective work practices, which. include, for example, tedious meetings held regularly at a divisional level and outmoded administrative processes (e.g. product managers have to share a fax machine to receive and send orders). The result of the continuous provision of IT solutions is that product managers have to deal with both their ineffective routine tasks and the added IT-related jobs. Meanwhile, the level of workload is sustained by two key contextual factors – the old way of working and constant product premature death (see the two factors “Stickiness of Old Culture” and “Product Failures”). In consequence, such an accumulated workload invariably decreases the process efficiency in operations, leading to more operational bottlenecks.

From the SPD's standpoint, the remaining bottlenecks demand more IT solutions. For example, this may mean shifting from IT outsourcing to in-house design, and introducing a third party consultancy. This effect forms a reinforcing loop (see Feedback Effect Loop 1) that perpetuates operational bottlenecks, urging the SPD to implement more IT solutions. Inevitably, this initiates another cycle of workload increase, further process inefficiency and more operational bottlenecks.

The Second Feedback Effect. "Feedback Effect Loop 2" explains a second reinforcing effect of the IT-induced dilemma, which explains the conflicting perceptions between the user side and the supply side. The increased workload leads to rising conflicts and accumulated distrust between the SPD and users. In addition to the lack of IT-related knowledge of users, the poor quality of user participation also worsens the problem. This results in more embedded problems of ineffective processes. Once these problems are designed into the information system, they lead users to report system unreliability as a result of technical IT problems. They also lead the Information Division to interpret these problems as system incompetence, thus leading to more changes of IT infrastructure. In addition, frequent changes of IT infrastructure in the name of system coherence mean more work on system migration (e.g. on translating data structure from COBOL to RDBM), and this leads to an accumulation of further IT problems (see the factor "Accumulation of IT Technical Problems"). Altogether, the SPD and the Information Division feel a stronger need to resolve the technical problems by providing more IT solutions.

Another unintended consequence is the internal conflict among business divisions (the user side), the Information Division (the supply side) and the SPD (the mastermind side). Initially, referring to the "Feedback Effect Loop 2", the effect of the increase staff workload (at the divisional level) leads to an increase of conflict between the SPD and users. This has a second reinforcing effect on the staff workload, the conflicts between SPD and business divisions, the quality of user participation, the accumulation of embedded problems in processes, and IT technical problems, thereby perpetuating the system instability. In general, users feel that the SPD's fruitless IT solutions jeopardize their performance in sales and interrupt their routine work. Moreover, the continuous failure of IT solutions results in a distrust of the SPD's competence in introducing information systems (see the factor "Level of Trust"). A major consequence of this is that it invites more conflicts and users are less willing to participate in the design of information systems (see the factor "Quality of User Participation"). The decreasing quality of user involvement leads to two major problems.

1. Because users (in particular the senior product managers) are not fully involved in redesigning processes, they provide only partial information to system

analysts. Many problems are still embedded in these ineffective processes. When system analysts fail to incorporate these problems into process redesign, these problems are less detectable. As a result, these process-based problems are translated into technical problems (see the factor "Accumulation of Embedded Problems in Processes"). From a user's perspective, information systems are not reliable and their instability becomes ever more difficult to tolerate.

2. When users later find that IT consultants are paid astronomically and SPD staff have abundant resources (to travel abroad, for example), their commitment turns sour. This leads to their alienation from subsequent projects. Users come to provide system analysts with the wrong specifications to sabotage the whole IT initiative.

There is another noteworthy contextual factor: the "Proficiency of IT among Staff". In FoodInc, most staff lack IT-related training. This makes it more difficult for users to articulate their real information needs. Users can only explain old processes (how things have already been done) to system analysts rather than persuade them to consider the underlying policies (such as the retailing policy). Furthermore, the participation of novice staff also undermines the quality of system development. However, system analysts assume that users can objectively and correctly articulate their system requirements. These specifications, once designed into various information systems, will only automate the incorrect administrative processes, thus causing further IT-related problems. Moreover, system analysts have to spend more time dealing with these IT-related problems, rather than investigating the fundamental process-related issues. As a result, when information systems are used in divisions, users often find that they are unstable, and hence more "IT-related" problems are discovered. Again, users then report these IT-related (technical) problems to system analysts for further improvement. This then urges the SPD to provide more IT solutions.

The Third Feedback Effect. The increased workload at the divisional level also has a third reciprocal effect on FoodInc's IT dilemma (see "Feedback Effect Loop 3"). The increase of staff workload makes employees suffer from demoralization and family pressures. As the job market offers more attractive packages, more and more senior staff are turning to competitors. The turnover of senior staff means losing organizational knowledge, which is equivalent to the loss of years of industrial experience in handling the supply chain, product management and relationships with retailers. The pressure of senior staff turnover and the accumulating workload force divisional managers to start sending junior staff to participate in user requirement meetings in order to alleviate staff turnover and allocate resources to more urgent problems – product failures stemming from ineffective departmental coordination.

Hence, solutions that fail to recognize the reciprocal nature of change may lead to more undetected problems, thus merely shifting problems from one part of the system to another. In some situations, a solution may become a problem of its own; at worst, a problem may become buried in the historical context when those who handled the first problem were replaced by those who inherited the new problem (Morecroft, 1985; Senge, 1990).

Moreover, understanding the nature of reciprocal causality may often develop counterintuitive insights by observing the social dynamics in terms of feedback behaviour (Morecroft, 1985; Richardson, 1991). For example, the enhancement of user participation may eventually accumulate embedded problems in processes if users have little IT knowledge. The introduction of another strategic exercise by consultants may only make product managers more resistant to any changes that are brought in by the SPD. The introduction of IT solutions may lead to a heavier workload rather than resolving the operational bottlenecks, if the problem of the old culture and product failures is not considered. By appreciating the reciprocal causality of a problematic situation, analysts can effectively reflect on the complex interaction of problems and sources of dilemmas, thereby producing enduring improvements.

Outcome

There are four major indicators of understanding the IT dilemma in FoodInc. First, the top management were puzzled by the enormous investment in IT and consultancy services, which seemed to have little positive impact on the firm’s performance. In the light of the conflicts among the policy designer (SPD), the IT provider (Information Division) and users (various divisional managers), the top management seemed to lose confidence in implementing more changes. In 2001, the company try to implement another software in the hope of using a better technology to resolve the adoption barriers.

The second condition was the high turnover of senior staff. As the number of resignations increased, divisions faced major sales difficulties and suffered from low morale. This in turn tended to cause further resignations. Divisional managers were very worried about such a vicious circle. The third symptom related to a more intangible measure of conflict and morale. The conflict between SPD and divisional managers seemed to escalate because the two parties disagreed about the allocation of resources. More and more divisional managers were seeking to implement changes by themselves, thereby neglecting those organized by the SPD. The fourth problem was in fact even more worrying. The technical difficulties of the IT systems seemed to rise steadily. The unsuccessful investment in IT-enabled change led to a loss of top management support.

Increasingly, there were signs of a significant rise in the workload of senior staff, the level of inter-departmental conflicts, and operating costs. The management team believed that immediate remedies must be sought to resolve operational bottlenecks, and thus promote productivity.

Discussion: Hard SD vs. Soft SD, a New Perspective

The discussion addresses two objectives: 1) to explore the practicality of applying soft SD (system dynamics) and 2) to summarise the differences between solving 'dynamic' issues through hard SD and soft SD from the author's viewpoint. The purpose of the discussion is to suggest ways to bridge the classical use of positivistic SD to that of interpretative SD modelling (see also Dyer and Wilkins, 1990).[1]

	Hard/Positivistic SD	**Soft/Interpretative SD**
Data Acquisition	measurable hard variables (e.g. inventory and revenue) quantification in the relationships of variables	non-measurable soft variables (e.g. motivation and competitiveness) alignment among the interactive feedback loops
Model Construction	models the world focuses on hard facts/*constructs*	models individual perception focus on subjective meaning/*stories*
Model Analysis	conducts hypothesis testing to reach policy recommendation	identifies dominant logic to obtain in-depth understanding and leverage points
Ultimate Concerns	generalisable laws aims to achieve optimum portfolio of solutions	transferable insights aims to achieve intellectual efficiency

Figure 2. The differences between positivistic and interpretative SD modelling.

The first aspect explores the practicality of qualitative SD application. The use of system dynamics in this project leads to several implications for management. These may be discussed in turn as follow:

1. Soft SD is an effective way to enhance *group intelligence* (GI). The synergy between individuals can be increased significantly using system dynamics model to trigger strategic debates. In the focus group session with informants representing

[1] The use of term (qualitative and quantitative) can be confusing. Here I will use soft SD to refer to interpretative SD and hard SD to refer to positivistic SD.

different interested parties, the SD model helps to consolidate controversial views which are implicitly embedded among the informants. To discuss safety issues in a feedback loop manner helps informants to challenge their existing mental perceptions. One interesting anecdote describes a debate between an pilot and a aircraft designer. They start with serious argument, accusing each other of causing threats to safety to and later explore the idea that the problem exists in the 'structure' rather than with people. On such an occasion, a group of intelligent experts may reach an unintelligible conclusion. Qualitative SD can thus be very useful in bringing together diverse viewpoints.

2. The strategic debates based on the mental model promote *consensus* which in turn enhances the quality of decision making. Informants become more tolerant on controversial issues through the process of revealing their disagreements. Thus, an airline manager, through the focus group process, recognises the need to implement remedial policies to deal with pilot subculture problems. Before reaching such a consensus, although he reads articles regarding similar issues, he does not actually recognise that the problem is caused by the subculture, but in stead emphasises human errors.

3. Qualitative system dynamics provides to be an effective way for identifying the source of organisational dysfunction. This is especially true when several stakeholders are involved in the process. The managerial errors caused by the interaction of the pilot community, airline companies, aircraft manufacturers and government agents have previously been discussed but not recognised. The dysfunction in the structure can be identified through the qualitative SD model in order to explore the 'helpless' syndrome (like beer game) caused by the overall system structure.

4. The *visualisation* of SD models helps to increase the capacity of mental information processing. Because human brains are not able to process too many interwoven relationships at the same time, the visualisation used by the system dynamics method can assist the appreciation of complex problems.

5. Qualitative system dynamics asks a different type of question, exploring subjective meaning rather than quantifiable measurement and evaluation. The criteria of an effective use of qualitative system dynamics depends on the insight that can be provided by the modelling, but not on the facts derived from the building of equations and figures. As Richmond (1993) suggests, problems can always be quantified but can rarely be measured. Modellers need to use mediating variables to study the system behaviour indirectly.

The second aspect concerns the difference between quantitative and qualitative approaches to SD modelling. This has been a paradigmatic debate in SD field. The emphasis of the dominate quantitative SD approach is on experiments with quantifiable variables, using historical data as reference modes to create equations embedded in models, and thus to simulate behaviour. Quantitative SD modelling is recognised as the most convincing approach for management decision makers (see, for example, the work of Coyle, 1996; Roberts, 1978; Forrester, 1961). However, as Wolstenholme (1990) suggests, in order to relate SD to a wider audience, the subject of qualitative system dynamics needs to be further developed in order to capture generic insights from many SD models in a condensed qualitative form. This qualitative form offers a powerful means to disseminate insights and enhance learning in relation to complex situations. The Table below compares these differences in terms of data acquisition, model construction, model analysis and ultimate concerns. Although Figure 8 does not aim not to explain the whole spectrum of differences, it may nevertheless provide a reference point for bridging these two approaches in future research.

The third aspect relates the learning of system dynamics to the wider field of OR. At first, it was not clear to the author have the ‘hard’ OR modelling techniques might be related to the of ‘soft’ ones. During the process of research, however, the author found that it was useful to understand these relationships in terms of the nature of problems: hard vs. soft and static vs. dynamic. Hard problems refer to problems which are structured and can be well-defined: for example, the material requirement problem in production systems. Soft problems refers to problems which are ill-defined and cannot be measured in a clear way as they also involve a lot of external factors (such as oil crisis, recession or the break of war). For example, the measure of competitiveness in firms is regarded as a ‘soft’ variable. On the other hand, the difference between the nature of static and dynamic problems relates to their inherent complexity and effects over time. For a static problem the effect of feedback depends on the portfolio of input variables and the formulae built in the process mechanism. The complexity is linear and can only be traced over a specific period of time. For dynamic problems, the effect is often interwoven between the interdependent variables and cannot be discerned easily. This kind of problem is often controversial and conflict-based. In Figure 9 the framework is proposed to explain this concept. Although the framework requires further refinement, it serves as a basis for discussing the implications of OR according to the varying nature of problems. It also offers a reference point for identifying the appropriate OR techniques to be applied to the right type of problem.

Conclusion

The paper attempts to offer a new perspective of using soft system dynamics. It proposes a synthetic method based on interpretative paradigm by employing process and frame analysis. In this way, system dynamics model is used more as an interpretative device which aims to convey meaning rather than merely the constructs. The article proposes a different approach: (1) acknowledge an interpretative paradigm, (2) conduct ethnographic data collection, (3) see processual patterns of SD from events, (4) incorporate *meaning/stories* into the structure, and (5) seek not an optimal solution but maximum understanding. In this way, the paper suggests that SD has much to offer to qualitative research discipline as a new way to understand problems characterized by dynamic causal relationships. Lastly, it should be noted that such an interpretative modeling aims to complement, and not replace, current system dynamics practices.

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