Title	Putting General Systems Sciences To Practical Use : Methodological Issues, And the Case of Business Process Engineering
Author(s)	Sato, Ryo
Citation	
Issue Date	2005-11
Type	Conference Paper
Text version	publisher
URL	http://hdl.handle.net/10119/3931
Rights	©2005 JAIST Press
Description	The original publication is available at JAIST Press http://www.jaist.ac.jp/library/jaist-press/index.html, IFSR 2005 : Proceedings of the First World Congress of the International Federation for Systems Research : The New Roles of Systems Sciences For a Knowledge-based Society : Nov. 14-17, 2141, Kobe, Japan, Symposium 7, Session 3 : Foundations of the Systems Sciences Models and Applications

Putting General Systems Sciences To Practical Use: Methodological Issues, And the Case of Business Process Engineering

Ryo Sato
Department of Social Systems and Management, University of Tsukuba
Tsukuba, Ibaraki 305-8573, Japan
rsato@sk.tsukuba.ac.jp

ABSTRACT

Making a business process is the target of information systems methodologies. A business process is intangible system that human beings make artifically to satisfy some goals. It is a human activity system [1], contains formal components such as datamodel and information systems, and is subject to achievement of its goal. Since it is artificail and contains human activities, the natural science cannot be directly applied to. The aim of business process engineering is to analyse and synthesize such business processes, but the current status of its development does not have engineering precision yet. Fundamental examination of the nature of business process and appropriate methodology was required.

This paper is threefold. First, the nature of research of social systems as artificail systems will be clarified. Referring Simon[2] and Yoshida[3], huge difference between natural and social sciences will be reconsidered, and then a firm epistemological basis for research of intangible and artificial systems is set. The point is the true meaning of social laws. Secondly, a methodology for integration of researches for practical research product will be formulated based on Yoshikawa et.al [4] and Gibbons [5]. Thirdly, the development of business process engineering is shown as sample application of the second order methodology, inidicating the role of general systems research in the development is also indicated. Future research areas are also shown to be huge vacuum and are worth exploring.

Keywords: second order methodology, symbolic program, business process engineering

1. INTRODUCTION

In current human societies artificial systems are becoming much more important. Not only computers or skyscrapers but also concepts and methodologies are artificial systems that are needed to be designed. General systems researches (GSR, for short) seem to be a suitable device for that kind of knowledge societies, but there is merely a successful story that GSR played a certain important role. Frequently-asked questions for GSR might be "What is GSR?; What is output of GSR?; How do you apply GSR to?" Since the result of general systems research is abstract and interdisciplinary, it is said to be difficult to show the concrete outputs.

This paper will provide a methodology to put general systems sciences to practical use. Then it will be applied to business process engineering in the sense that the development of business process engineering is positioned from viewpoint of that methodology (Fig. 1).

<table>
<tr><td colspan="2">Businees Process Engineering</td><td>another area</td><td>...</td></tr>
<tr><td colspan="4">second order methodology for integration</td></tr>
<tr><td>Disciplined Specific Researches</td><td colspan="3">General Systems Research</td></tr>
</table>

Fig.1. Second-order methodology for practical use

Though there are many important systems researches on artificial systems, we are not brave enough to survey most of them. A quite limited number of systems researches are referred [6,7,8,9,10,11].

2. RECONSIDERING ARTIFICIAL SOCIAL SYSTEMS AS TARGET OF GSR

We need to start reconsideration of general systems research of artificial systems, especially that of artificial social systems. Simon [2] and Checkland [1] had clarified characters of artificial systems and human activity systems. Artificial systems have goals. In order to attain the goals, the target system is analyzed and designed. Such activities are common in engineering. Simon pointed out the following issues on artificial systems [2].

(1) Artificial systems are synthesized by man.
(2) Artificial systems have similar function with real systems, but internal mechanism may be quite different.

(3) Artificial systems' characteristics are functions, goals, and adaptation.
Artificial systems are designed to have necessary functions to achieve goals. The internal mechanism of the systems should be sufficient to work in the systems' environment. Certain environmental conditions for an artificial system are satisfied by a mechanism, and it is called adaptation.

Social systems are a kind of artificial systems, because they are not natural but man-made. Social systems are made of rules, while natural systems consist of real physical elements. Yoshida had pointed out that the "laws in social systems" are quite much different from those in natural sciences. The laws in social systems are not physical objects but logical mechanisms [3]. Such laws condition purposeful human behaviors. Most of so-called social sciences have focused on such laws. The existence of equilibrium of a market in microeconomics does not say anything about physical laws of the set of carbohydrate substances that make up human bodies in the market. Instead of gravity or thermodynamic and chemical equilibrium, the economic rules of transaction lead us to an economic equilibrium. Such kind of laws and rules are often called social mechanisms, and economists are working to find better mechanisms, examining, for example, possible properties or regulations of competition in market.

Yoshida says, this recognition that social laws are exactly rules and logical mechanisms brings us a clear understanding about the distinction of laws in natural and social sciences. Yoshida called such rules symbolic programs. They are usually expressed in forms of equations with mathematical symbols, and of text with linguistic symbols, which govern behavior of human individuals.

Yoshida's distinction of laws is quite fundamental. The design of social systems is actually that of rules. We argue in this paper that since social systems are also artificial, they have the characteristics of artificial systems given by Simon. He discussed that human logic will play an important role in selecting optimal implementation in possible ones. That will hold true in the case of symbolic programs.

3. DISCIPLINE FORMATION OF RESEARCHES AND PRACTICAL USE

GSR is also a discipline or an academic area. This section describes that both facts that any research activity has inevitable tendency to form a discipline and that the use of GSR can possibly remedy the situation.

3. 1. Discipline Formation

When a research has focused on a specific issue and developed a paradigm and exemplars, then a set of researches of similar kind forms an academic displace. This "enclosure of knowledge by a discipline" seems inevitable based on the following observation.

Observation 1 [4]: Electric Engineering has Ohm's law and Mechanical Engineering does Hook's law. The former tells us the relation among electric resistance, voltage and electric current, while the latter describes the relation among spring constant, displacement, and force. Both describes respective part of nature, but they are independent each other. In general, once laws are established, they become independent, because a law is a complete set of knowledge to describe an issue concerned. Academic disciplines make nature separete. More generally, disciplines make a system separete.

Observation 2 [5]: Education provides students with disciplined academic issues, and the contents of education are firm. Otherwise, students cannot focus on main topics. Furthermore, the physical and institutional stability is necessary. This human organization is called a university or a school. Within a disciplined education people can be effectively educated, develop their ability to define and solve problems from discipline's point of view. That is, such training can provide people with opportunity to be a specialist and then to get a job. Camaraderie among students is also cultivated.

3. 2. Mode 2 and Second Order Basic Research

It is hard or ambiguous how different disciplines can be integrated. Since each specialized education inevitably tends to form a discipline, and since it is a major way for youngsters to get jobs, we see many specialists in the world. Furthermore, since disciplines are mutually independent, specialists can communicate less. In business world, cooperation among specialists is universal. Otherwise, they lost in their business. When economy is boom, companies have enough capacity to train people for their strategic goals. If economy experienced recession for long long time, the society needs good account of universities' education in a way the public can accept. This pressure goes to on research organizations such as universities and research institutes, because they are funded from the society. Research and education in universities are becoming to subject to be more practical than ever before.

Yoshikawa et.al. pointed out that it is beneficial for research activities to be practical [4]. According to them, basic researches are classified into two categories. The basic researches of first category are, in a sense, usual researches or of normal science in Thomas Kuhn' term. A research of that category tries to find new facts, new theory, and undiscovered laws for interesting phenomena within a well-developed conceptual framework. Results of such researches are published in academic journals, and usually that's it.

The basic researches of second category have clear social/business goal to be developed. The development of first humanoid robots, drug discovery and liquid crystal television are examples. Such a basic research tries to make combination of existing results of many researches. Since a practical (social, business) goal requires many researches though considerations and experiments with trial and error method. For example, assume that you were a control engineer and would like to develop a new robot. You certainly know a theory of optimally control of motion. But that is not enough. You need good connectors to prevent disconnection, and light weight battery. You need to know fascinating design of body and safety standard if it aims to be a toy for kids. (Babies lick anything around them.) Project management also seems to be called for. While struggling to integrate these different activities, you may find a new and promising research area. That area might open novel design method of a set of mobile robots that did not formulated before. With some new concepts and frameworks and applications, a new active discipline may be formed. This point distinguishes basic researches of second category from simple application-oriented research. Practical researches may bring new directions into researches.

A similar kind of researches are observed by Gibbons [5], where they call such researches are in mode 2. Researches in mode 1 are usual researches.

4. INTEGRATION OF DISCIPLINES: SECOND ORDER METHODOLOGY

4. 1. Selection of Researches by a Society

The basic researches of second category need integration of disciplines. If two electric cables pulls each other by strong electromagnetic force, certain mechanical strength of the cables and supporting plank are necessary. Electromagnetics with Ohm's law should be integrated with Hook's law to get a better design. As Simon indicated, depending on the goal of an artificial system concerned, there may be quite different design of wiring so that interaction of two cables is resolved.

Yoshikawa et.al. [4] shows interaction between researches and society in Figure 3. They insist that it is not an easy task for a research to be concretized and accepted in a society.

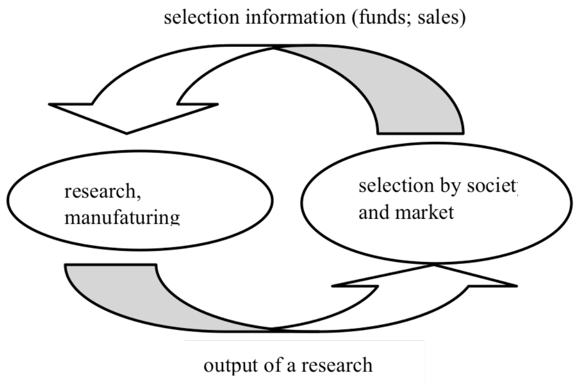

Fig.3 Feedback interaction between research and society (adapted from[4])

The output of a research has two facets. It is a technical artifact on the one hand and a society focuses on the value and meaning of the output, on the other. If the society finds the output to be an enhancement of people's lives or business activities or an intellectually valuable concept, then the research may find a chance to continue in the society. In this sense, researches are selected by the feedback mechanism in a society at large.

If a research output is a design of artificial system, then the internal structure to implement the functions of a system is not unique. Many technical possibilities usually exist. Moreover, a society has many values to be filled for an artificial system. Then, many disciplines are necessary to develop a socially acceptable output of a research. This situation is much complicated, because disciplines are mutually independent. Therefore, when integration of different disciplines is undertaken, we need a discipline or a framework, even if explicit or implicit, to integrate those disciplines.

4. 2. Second Order Methodology For Integration

Yoshikawa's second order basic research and Gibbons' interdisciplinary research has something in common on an issue how to put researches to practical use. They can be summarized as follows.

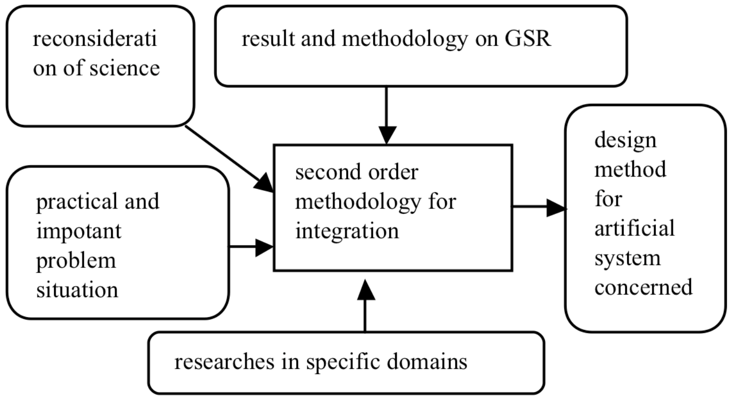

Fig. 4. Second order methodology

(1) Both authors use the term, 2 or 2nd. It suggests that traditional or usual researches are neither sufficient nor suitable in current societies.

(2) Researches have to have a clear goal. Then, they need to make an artificial system with internal mechanism to attain the goal.

(3) A methodology to integrate different methodologies is called for. That methodology will help a research produce a practical output.

(4) Any research should show its product to be interpretable and understandable by a society so that the society will give some feedback.

(5) It is important for a research to communicate with other researches to be practical and effectively used together.

A research methodology with these characteristics is called a second order one. GSR can play a role to guide a research to be second order basic research by guiding the underlying methodology of the research to be a second order methodology (Fig. 4)

problem situation	specific disciplines	specific models of disciplines	mechanisms defined in GSR	resultant models in BPE
insufficient model building	control engineering	state, feedback	state, state transition mechanism	business transaction system (multicomponent DEVS with a data model)
	discrete-event system	DEVS	canonical form, minimal realization	universality, uniqueness
		Petri net		max-plus equation
semantics of diagrammatic tools	Information systems methodology	diagrammatic tools	state transition mechanism	business transaction system
		organizational coordination	2 level coordination model	task system
	database	data model	state	business transaction system
lack of design of performance	operations management	Little's law	optimal behavior	business transaction Petri net
	production	MRP, Kanban,TOC	optimal behavior	business transaction Petri net
		lead time	optimal behavior	max-plus equation
		Production management system	state transition mechanism	--
share and use of information in SCM	operations management	Supply chain management	state transition mechanism	BTS+?
ubiquitous network	operations management,	--	--	--

Fig. 5. Development of BPE

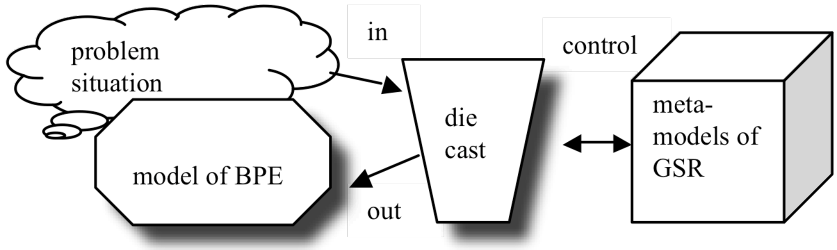

Fig. 6 Development of BPE

5. APPLICATION TO BUSINESS PROCESS ENGINEERING

This section provides an overview of business process engineering (BPE, for short) as an application of the concept of second order methodology. Three practical and important problems of BPE as described below have been clarified.

(1) A model of business process for engineering precision was needed.
(2) Semantics of diagrammatic tools of information systems methodologieswas not available.
(3) The design of dynamic performance and properties for abusiness process was neither possible not related to operations management.

In the following Section 5.1, the current contents of BPE is overviewed in a table and explained. In section 5.2 we show how a second order methodology to put the research to practical use by using the GSR's concept of state transition mechanism and 2 level organizational coordination.

5.1 Approach to and Contents of Business Process Engineering

In order to develop BPE, the result of mathematical general systems has been employed, which is summarized in Figure 5 and 6.

A business transaction system is a discrete-event model of business process with information system. It has intrinsic structure that can be drawn with a diagrammatic tool de-fined below, and also has precise state transition mecha-nism.

Definition. Activity Interaction Diagram (AID) [12]
An activity interaction diagram is a diagram that has three kinds of components. They are activities, queues, and connecting arrows. Activities should be connected with queues, and vice versa. That is, in the graph theoretic sense, an AID is a directed bipertite graph.

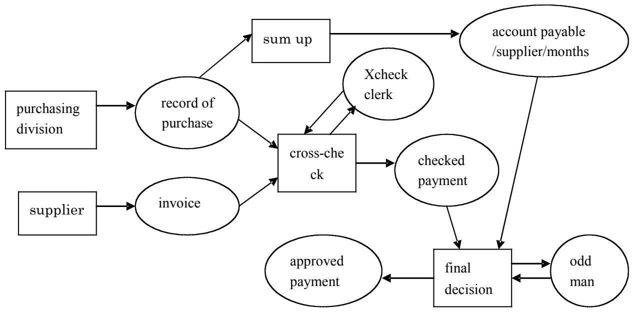

Fig.7. Approval of trade account payable

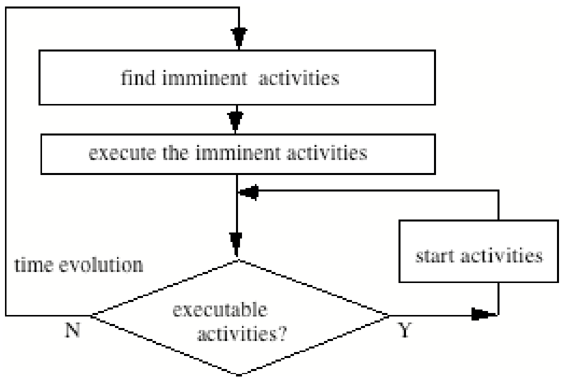

Fig.8. Flowchart for the processing of a dynamic structure

A business process for approval of trade account payable is depicted in Figure 7. The intrinsic meaning of Figure 7 is as follows.

(1) The purchasing division records the transactions for purchase.
(2) Suppliers send us invoices based on past purchase.
(3) The record and invoice are cross-checked by a responsible clerk.

(4) After cross checking, payment is requested for final decision.
(5) The odd man decides the validity of the payment and suitable bank account for the payment.
(6) After the decision, approved payments are sent to treasurer who will remit the amount or make bills due in certain days/months (that is, sight).

The time evolution of the discrete-event system depicted in an AID follows the flowchart in Figure 8. An activity that has incoming queues is called an internal transaction, while one with no incoming queues is called an external transaction. In Figure 7, "supplier" and "purchasing division" are external. The other activities are internal.

The dynamics of a system can be described by its state tran-sition when the system has a state transition function. As is shown in [8], a system that is depicted as an AID is a discrete-event system. Table 1 shows a time evolution of the approval process of trade account payable, starting from time zero with an initial condition. Table 1 is called a state transition table. The first row of Table 1 shows the following: "time" shows clock. The "supplier" shows data for supplier activity. The "invo" is used as an abbreviation of invoice to show the invoices currently accumulated in the system. The "PurcDiv" is purchase division. The "recPurch" is an abbreviation of record of purchase. The "XchkClk" shows the available number of the clerks for cross check, and "Xcheck" the activity of cross check. The "chkdPymnt" is an abbreviation of checked payments. The "oddMan" is the number of avail-able odd man who is responsible for checked payment to be approved payment. Odd man's activity is called final decision that is shown as "finDec" in Table 1. The second line shows several numbers, corresponding to each on activities. For example, 15 for supplier means that it takes 15 time units for suppliers to issue a new invoice. In the same way, it takes 7 time units for the purchase division to issue a new record of purchase, 10 time units to cross check a payment, and 29 time units to make final decision on a checked payment.

At time 220 the value for supplier attribute is (1, 210). It means that a supplier had started preparing one invoice at time 210. Since 15 time units are needed to complete the activity, that invoice will be input into the business process at 225. Both of the values (1, 217) for "PurcDiv" and (1, 203) for "finDec" have the same meaning. The value "-Xck-" for "Xcheck" means that there exists no cross check activity. The value 0 for "invo" means that there is zero invoices at 220, while 115 for "recPurch" shows that there are 115 records of purchase wating for cross checking. According to the flow chart in Figure 3, the values at the line for 220 changes to the next line at time = 224.

Notice that the contents of connecting queues of an AID are modeled as simple objects. That is, in the ap-proval process of trade account payable, only the number of accumulated invoice are concerned and processed in turn. In general, suppliers supplies different materials with various amount, preparation and processing of them needs various length time, and also objects in invoice queue should be described by some attributes to characterize each invoice. A data model is used as a logical design of a set of data in a business transaction system.

time	supplier	invo	PurcDiv	recPurch	XchkClk	Xcheck	chkdPymnt	oddMan	finDec	apprvPymnt
ta	15		7			10			29	
220	(1,210)	0	(1,217)	115	1	-Xck-	10	0	(1,203)	7
224	(1,210)	0	(1,224)	116	1	-Xck-	10	0	(1,203)	7
225	(1,225)	1	(1,224)	116	1	-Xck-	10	0	(1,203)	7
225	(1,225)	0	(1,224)	115	0	(1,225)	10	0	(1,203)	7
231	(1,225)	0	(1,231)	116	0	(1,225)	10	0	(1,203)	7
232	(1,225)	0	(1,231)	116	0	(1,225)	10	1	-finDec-	8
232	(1,225)	0	(1,231)	116	0	(1,225)	9	0	(1,232)	8

Table 1. Part of state transition table for approval process of trade account payable

supplier	invo	PurcDiv	recPuech	XchkClk	Xcheck	chkdPymnt	oddMan	finDec	apprvPymnt
(1,210)	0	(1,217)	115	1	-Xck-	10	0	(1,203)	7

Table 2. A state of approval process of trade account payable

Figure 9 is a data model [19,20] (or, a class diagram without methods) of the data in the approval of trade account pay-able. It describes the logical structure of data that is im-plemented as a set of tables like Figure 5 (on next page) in a database management system.

A business transaction system is a discrete-event sys-tem with AID and a data model. Though the mathematical definition of the state transition function of a business transaction system is provided in Sato and Praehofer [12], it is nothing but the flow chart in Figure 8, and, produces the state transition table. So, if we provide a suitable and correct data model for Figure 7, then the approval business process in Figure 7 becomes a business transaction system. Since a data model can be realized in tables and then form a file system as a whole, the state transition table is analyzed in the same way as Table 1.

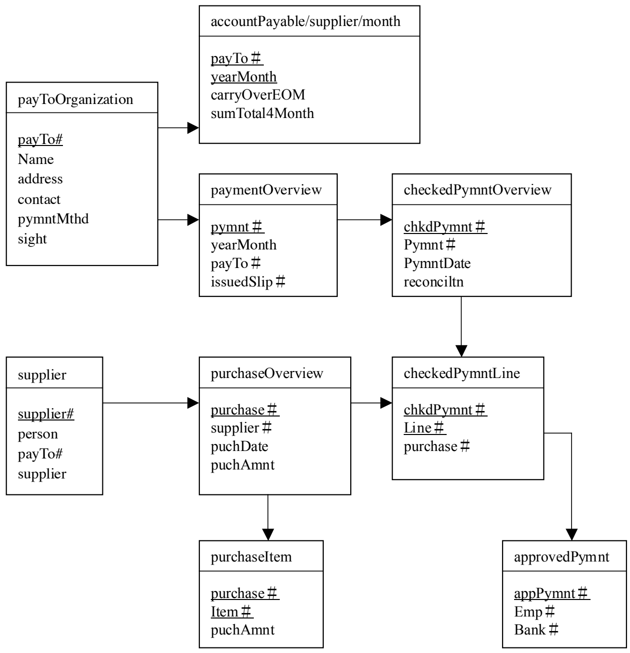

Figure 9. A data model for the data in approval process of trade account payable

A company-wide information systems, such as ERP, provides data sharing function. It has been shown that data sharing actually provides a coordination mechanism among organizational activities [18]. That is, from the coordination point of view, data sharing through information system is nothing but a behavioral coordination. The analysis and design of information system virtually determine the business process, because it is a control device of the process. Thus, information system methodology should be enhanced to deal with organizational global goal.

5.2 Second Order Methodology of BPE

The way to apply the result of general systems research to BPE is not unique. We discuss below how the application of GSR can have the respective characteristics of second order methodology shown in Section 4.2.

(1) In business tradition, modeling business process does not need to be engineered or designed. BPE is a current trend to develop a mathematical systems theory of business processes, which should have many reference of practical problem situation.

(2) The goal of BPE is to develop a synthesis method with rigorous models and equations for analysis and design of business processes. Since the importance of business process is widely accepted in business world, there already exist some informal or diagrammatic models without mathematical mechanism. Therefore, ambiguity in defining and formulating target business process could not be resolved with respect to engineering precision.

(3) The concept of state and state transition function in GSR has been used to make the concept of business transaction system (BTS, for short). By providing the mechanism of state transition, the data model was brought from database area and integrated into part of a BTS [12]. When analysis of dynamic property (e.g., lead time and inventory) of business process is concerned, an isomorphism between a BTS and a specific sort of Petri net is established [13]. That isomorphism leads us to Little's law [21] on lead time of the business process, and opened an opportunity to provide "business transaction equation", which is an application of max-plus algebra [14]. (The development of max-plus equation for business processes has not been developed yet.) In this way, as a result of GSR, the state concept had provide a firm and mathematically clear understanding in modeling business process by integrating disciplines of discrete-event systems and Petri nets. Development of business equation is not accomplished well. It just started.

(4) Since BTS of BPE is defined by both static diagrammatic structure and the dynamic state transition mechanism with the set-theoretic formalism, mathematical proof is possible by stating issues properly. Systems engineers employ many diagrammatic tools in information methodologies. We could have provided rigorous meaning of a few of such tools, and then provided a guideline to model business processes with those tools [15]; nevertheless, many important tools have still remained to be proved.

(5) Since one of the basic philosophy of GSR is to communicate different areas by providing isomorphy among them. In BPE, BTS could serve as a platform, in the sense that if you established an isomorphy between BTS and your tool, and if other person did the same between BTS and another tool, then you tool and the other tool can be compared and examined, if you wish,

in rigorous way of mathematical proof. This situation helps us communicate other researches.

6. CONCLUSION

This paper provided the second order methodology of BPE. In order to have such a methodology, the nature of artificial systems was reconsidered based on Simon, and Yoshida's concept of symbolic program is referred. The concept of Yoshikawa's second order basic research is found to be suitable for GSR to be practical. That methodology is characterized as second order methodology of GSR. Since business processes are artificail, and a symbolic program that requires second order methodology of GSR, current BPE could have been developed.

Still we have many topics to be attached in BPE [17]. If we can develop BPE further and further to de able to design business process as like usual machines or logical circuits, then we will see totally different society of smooth business processes. The second order methodology based on GSR will have been a key to enhance BPE.

Spirit of GSR has been simple, I believe. If you have an important, fecund but undeveloped area in business or science, try to develop models and implementation methodology. It is not difficult to notice the existence of such areas that is waiting for us to be researched and developed. Such area usually has many jargons and business users, and the most-used tools will be diagrams because of lack of foundation. Besides BPE, innovation management seems to be still such an area, and [18] is an attempt of application of GSR. Philosophy and resultant logical mechanism of general systems research can, hopefully, guide us to use second order methodology.

REFERENCES

[1] Peter Checkland, Systems thinking, systems practice, John Wiley & Sons, 1981.
[2] Simon, H.A. The science of Artifical, 2nd ed. MIT Press, 1981.
[3] Yoshida, Tamito, "Second major revolution of science and its phylosophy", http: //www.copymart.jp/ iiasap/itiran_1.html. (in Japanese)
[4] Yoshikawa, H. and Naito, K., Philosophy of Industrial and Scientific Technology, Tokyo-daigaku-syuppankai, 2005. (in Japanese)
[5] Gibbons, M. et.al. The New Production of Knowledge, SAGA publishing, 1994.
[6] Mesarovic, M. and Takahara, Y., Mathematical foundation of general systems theory. Academic, 1975.
[7] Mesarovic, M. and Takahara, Y., Abstract systems theory. Lecture Notes in Control and Information 116. Springer, 1989
[8] Zeigler, B.P., Theory of modelling and simulation. John Wiley, 1976
[9] George J. Klir (edts.), Trends in general systems theory,Wiley, 1972,
[10] Wymore, A.W., Model-based Systems Engineering, CRC Press, 1993.
[11] Pichler, F., On the use of structured methodologies in General Systems Research, in "Systems Methodology in Social Science Research", Kluwer-Nijihoff Publishing, 1982.
[12] Sato, R. and Praehofer, H., "A discrete event model of business system - A systems theoretic foundation for information systems analysis: Part 1". IEEE Trans. Syst, Man, Cyber 27-1:1-10, 1997.
[13] Sato, R. "Integrating two dynamic models of business-logistics plant". In: Pichler F, Moreno Diaz M, Kopacek, P (Eds) Computer Aided Systems Theory - EUROCAST '99. Lecture Notes in Computer Science, vol. 1798:259-273. Springer, 2000
[14] Sato, R. "On control mechanism of business processes". Journal of Japan Society for Management Information 8-1:17 - 28, 1999
[15] Ryo Sato: Discrete-Event Semantics for Tools for Business Process Modeling in Web-Service Era, Tag Gon Kim (Eds.), Artificial Intelligence and Simulation: 13th International Conference on AI, Simulation, Planning in High Autonomy Systems - AIS 2004, Lecture Notes in Computer Science, vol. 3397, pp 635-644, Springer, 2005.
[16] S. Takahashi, K. Kijima, R. Sato (Eds.), Applied General Systems Research on Organizations, Springer, 2004.
[17] Sheer, W.A., Business Process Engineeirng, 2nd ed., Springer, 1994.
[18] Kijima, K. and Tschirky, H., Enterprise Science for Technology-intensive Company and its Elaboration by Systems Thinking, Proceedings of Pacific-Asia Conference on Information Systems, 16pages, CD-ROM, Seoul, Korea, 2001.
[19] Chen, P.P.: “The entity-relationship model -- Toward a unified view of data,” ACM Trans. Database Syst. vol. 1, no. 1, pp.9--36, 1976.
[20] Hotaka, R., Database systems and data model, ohom-sya, 1989 (in Japanese)
[21] Little, J.D.C., "A proof for the queuing formula: $L = \lambda W$," Operations Research, 9, 383-387, 1961.