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**Integrating Information Systems Methodologies into an Engineering Discipline:  
Methodological Issues, And the Rise of Business Process Engineering**

Ryo SATO

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UNIVERSITY OF TSUKUBA  
Tsukuba, Ibaraki 305-8573  
JAPAN

# **Integrating Information Systems Methodologies into an Engineering Discipline: Methodological Issues, And the Rise 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 with information systems is the target of information systems methodologies. A business process is intangible system that human beings make artificially to satisfy some goals. It is a human activity system [1]. It consists of human activities, contains formal components such as datamodel and information systems, and is subject to achievement of its goal. Since a business process 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 with information systems, though the current status of its development does not have engineering precision yet. This paper gives fundamental examination of the nature of business process, and then proposes a model of business process for integration of related issues such as information systems, operations management, and human organizations.

This paper is threefold. First, the nature of research of social systems as artificail systems will be clarified based on general systems research. Referring Simon[2] and Yoshida[3], huge difference between natural and social sciences will be reconsidered, and then an epistemological basis for research of intangible and artificial systems is set. Secondly, a methodology for integration of researches will be formulated based on Yoshikawa et.al [4] and Gibbons [5]. The role and power of general systems research for integration is also examined. Thirdly, the on-going development of business process engineering is shown as sample application of integration-oriented methodology. A model of business process with information systems is formualted. Also, the function of information system is shown to be both state transition and organizational coordination.

**Keywords:** artificial systems; symbolic program; business process engineering; business transaction system; information systems; data model; coordination.

## **1. INTRODUCTION**

In current human societies artificial systems are becoming much more important. Not only computers and skyscrapers but also concepts and methodologies are artificial systems. Profound characteristics of artificial systems are that are needed to be designed. Systems approach and general systems research (GSR, for short) seem to be a suitable conceptual device as general meta-principle for design. But there is merely a successful story that GSR played a certain important role in integration. 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 inevitably abstract and interdisciplinary, it is said to be difficult to show the concrete outputs.

In this paper GSR will be applied to business process engineering (Fig. 1). The concept of state transition mechanism is used to integrate many models and issues that were developed in independent engineering areas.

Business Process Engineering			
Methodology for Integration (General Systems Research)			
data model	information systems methodologies	business process models	operations management

Figure 1. Methodology for Business Process Engineering

Though there are many important systems researches on artificial systems, we are not brave enough to survey most of them. A 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 for 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 laws (i.e., social rules), while natural systems consist of real physical elements. Yoshida had pointed out that the "laws in social systems" are 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 on the set of carbohydrate substances that make up human bodies in the market. Instead of gravity or thermodynamic and chemical equilibrium, the social/business rules of economic 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 of competition or regulations 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 form of equations with mathematical symbols, or of text with linguistic symbols, which govern social 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 also in the case of symbolic programs.

### **3. DISCIPLINE FORMATION OF RESEARCHES AND INTEGRATION OF DISCIPLINES**

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 in Basic Research**

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 discipline. 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. In this way, academic disciplines make nature separate. More generally, disciplines make a system separate.

*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. Second Order and Mode 2 Basic Research**

It is hard or ambiguous to plan 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 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's 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 achieve. The development of humanoid robots, drug discovery, liquid crystal television and information systems are examples. Such a basic research tries to make combination of existing results of many researches. Since a practical (social and/or business) goal requires many researches though considerations and experiments with trial-and-error method.

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

The basic researches of second category or of mode 2 need integration of disciplines. If two electric cables pull each other by strong electromagnetic force, for example, 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 interplay 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.

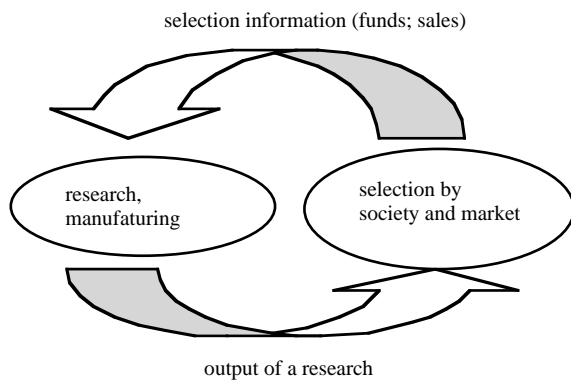


Figure 3. Feedback interaction between research and society (adapted from [4])

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.

### 3.3. Information Systems

Many kinds of documents, diagrams, and models are produced through information systems development. Those products of information systems methodology virtually decide the way business process and information systems work, and then a kind of symbolic program. In this sense, business consultants and IT workers have produced laws of business process. Since information systems are not only topics for academic research but important and indispensable elements in business and then it was easy to be invested for implementation, many methodologies and specifically focused disciplines. Discipline formation is usual tendency of human society as we discussed in section 3.1. Unification of methodologies, such as UML, is rare to see. Not only methodologies and concepts are plenty but also we have many products and implementation of information systems. We have many softwares for browsing web. A company develops and sells sales management software and customer relationship management one independently, while other vender supplies an integrated company-wide software such as an enterprise resource planning

package with SOA related components. Those softwares come up with seemingly different and independent concepts, and it difficult to communicate each other. What we have as a result of this business activity is many diagrammatic tools and concepts behind. So, the situation is quite similar when general systems movement is called for. If we could build a precise and integrative definition and its logical implications, then, hopefully, that theory would provide a language for interdisciplinary communication, preventing us from misunderstanding and misleading.

Yoshikawa's second order basic research and Gibbons' interdisciplinary research has something in common on an issue how to integrate disciplines. The points are summarized as follows.

- (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. This holds true also in information systems area.
- (4) It is important for a research and discipline of information systems to communicate with other to be practical and effectively used together. That will encourage future development in theory and practice.

Here, GSR can play a role of a meta-methodology to guide a research to integrate related issues (Fig. 4). According to Mesarovic and Takahara [6], systems theory has to reflect the "invariant" structure of different real systems, i.e., those that remain invariant for similar phenomena from different fields (disciplines).

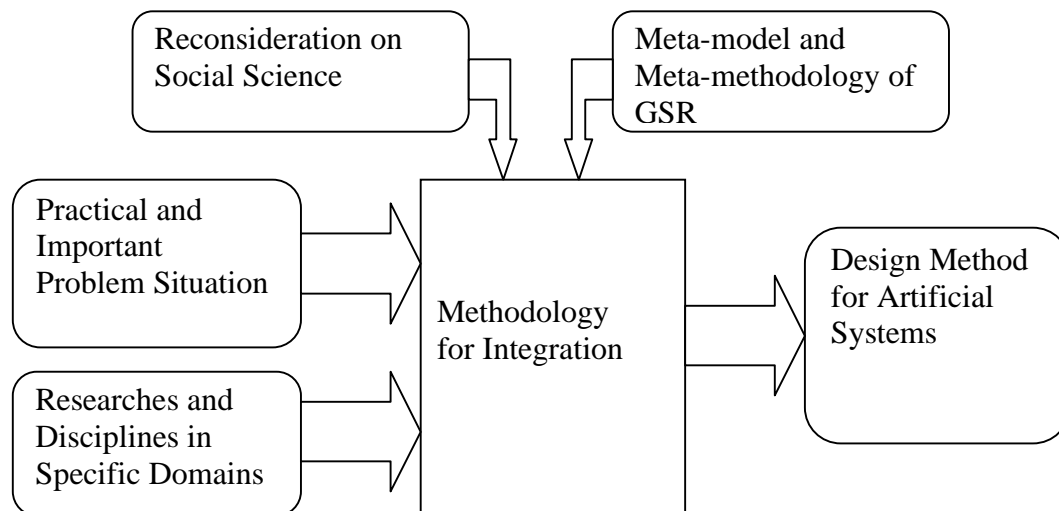


Figure 4. Methodology Integration for artificial systems

problem situation	specific disciplines	specific models in 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 planning and control	MRP, Kanban	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	inventory control; operations management	Supply chain management	state transition mechanism	business transaction system and planning system
information system's contribution to organizational goal	organization theory	organizational coordination	coordination principle	2-level organization with information systems

DEVS: discrete-event systems specification [8]; MRP: material requirements planning; SCM: supply chain management

Figure 5. Development of BPE

#### 4. DEVELOPMENT OF BUSINESS PROCESS ENGINEERING

This section provides an overview of business process engineering (BPE, for short) as an example of integration of information systems and methodologies.

Information systems have been designed and implemented for many years. Related concepts and methodologies have been also proposed and used. Logical mechanism of business transaction is virtually and strongly influenced by such implementations of information systems and concepts. Those activities certainly built societies laws as Yoshida pointed out.

ERP (enterprise resource planning packages) came up with reusability of a standard software by many different companies, though software engineering is still trying to provide software components that can be used as like standard parts in manufacturing. Since there are many new



challenges (possible goals) in business and IT, such as SOA, RFID (radio-frequency IDentification), optimization of distribution, SCM, and so on, and since artificial systems inevitably have many possible designs and implementations, this kind of pluralism will never stop and need not to stop. At the same time, we need integration for sound development.

Now we point out four issues for business process engineering (BPE, for short) as follows.

- (1) A model of business process for engineering precision was needed.
- (2) Semantics of diagrammatic tools of information systems methodologies was should be available.
- (3) The design of dynamic performance and properties for a business process should be possible and be related to operations management.
- (4) Effectiveness of IS with respect to organizational goal should be clarified.

Our basic strategy for those issues is to formulate a model of business process with information systems, and use it as a mathematical platform to answer questions.

In the following Section 5.1, the current contents of BPE is overviewed in a table and explained. In section 5.2 we summarize how the GSR's concept of state transition mechanism and 2 level organizational coordination are used in integrating information systems issues.

## 5.1 Discrete-event Model of Business Process Engineering

In order to develop BPE, the result of mathematical general systems has been employed. The current situation is summarized in Figure 5.

A business transaction system is a discrete-event model of business process with information system. It has both static and dynamic structures. The former is intrinsic structure that can be drawn with a diagrammatic tool defined below, while the latter a precise state transition mechanism.

*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. 6).

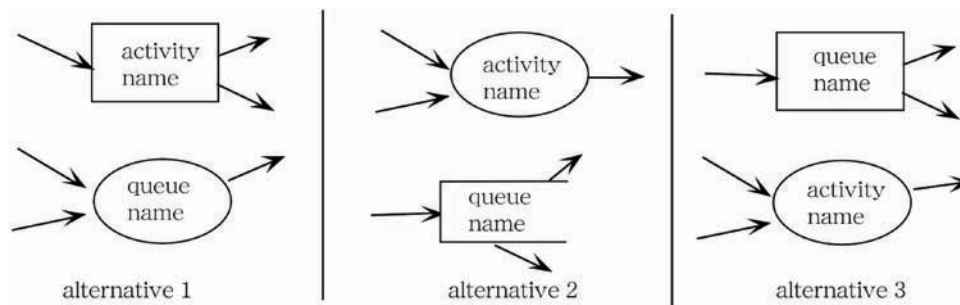


Figure 6. Components of activity interaction diagrams

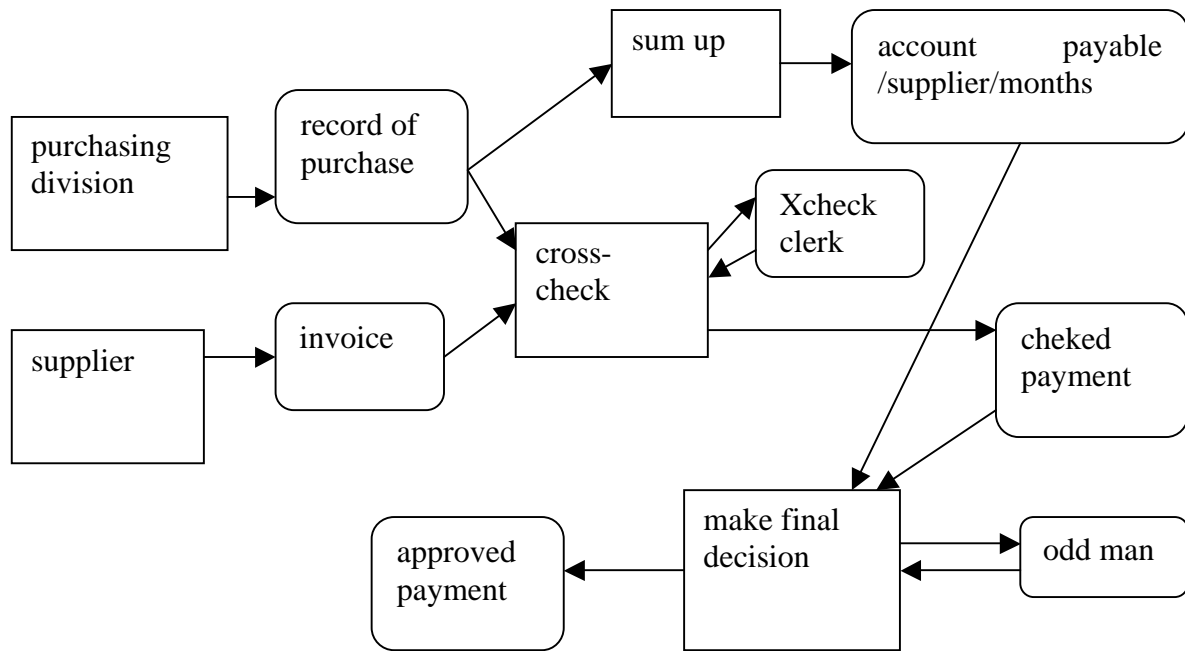


Fig.7. Approval of trade account payable

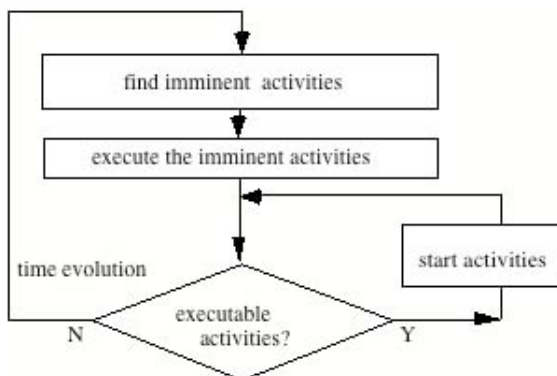


Fig.8. Flowchart for the processing of a dynamic structure

An example of AID is depicted in Figure 7. It is a static structure of a business process for approval of trade account payable. 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 is defined as a state transition function with set theoretic notation [12]. The definition of the function is explained by the flowchart in Figure 8. An activity that has incoming queues is called an internal transaction, while one with no incoming queues 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 transition 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 available 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 waiting 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 approval 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

A business transaction system is a discrete-event system with AID and a data model. The mathematical definition of the state transition function of a business transaction system is provided in [12]. It produces a state transition table for an initial condition. 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 is a data model [19,20] (or, a class diagram without methods) of the data in the approval of trade account payable. An arrow represents a referential relationship among entity types. It describes the logical structure of data that is implemented as a set of tables like Figure 10 in a database management system.

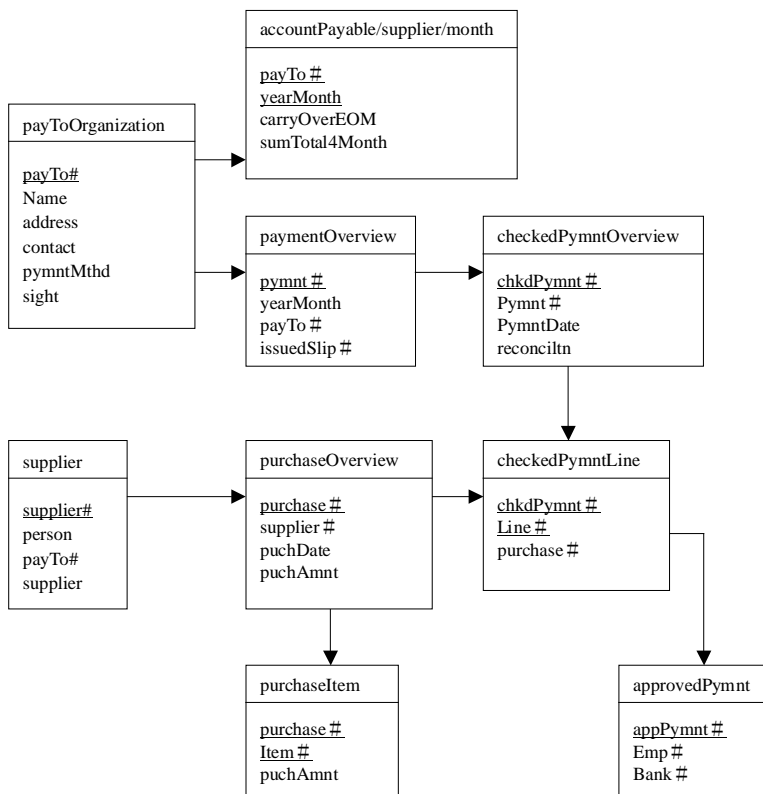


Figure 9. A data model for the data in approval process of trade account payable

time=220

supplier	purchDivision	XcheckClerk	oddMan
(#1282981, 210)	(#9328178, 217)	-	(#100186, 203)

(A supplier is preparing No.1282981 slip. PurchaseDivision started preparing to a record of No.9328179. )

(The odd man started No. 100186 at t= 203)

paymentOverview			
pymnt #	yearMonth	payTo #	issuedSlip #
83258	20XX/02	2031	342032
83243	20XX/02	14	2, 250, 000

purchaseOverview			
purchase #	supplier #	puchDate	puchAmnt
9328145	546	20XX/02/09	231, 000

purchaseItem		
purchase #	Item #	puchAmnt
9328145	010	200, 000
9328145	020	31, 000

checkedPymntOverview			
chkdPymnt #	Pymnt #	PymntDate	reconciltn
100185	83243	20XX/02/25	2, 250, 000
100186	83258	20XX/02/25	320, 000

checkedPymntLine		
chkdPymnt #	Line #	purchase #
100185	010	9328139

approvedPymnt		
appPymnt #	Emp #	Bank #
100183	1022	1458176

accountPayable/supplier/month			
payTo #	yearMonth	carryOverEOM	sumTotal4Month
2031	20XX/01	33, 500	220, 525
1095	20XX/01	23, 500	908, 000

t=224

supplier	purchDivision	XcheckClerk	oddMan
(#1282981, 210)	(#9328179, 224)	-	(#100186, 203)

Data for No.9328178 was added. PurchaseDivision is now preparing to a record of No.9328179.

purchaseOverview			
purchase #	supplier #	puchDate	puchAmnt
9328145	546	20XX/02/09	231, 000
9328178	72	20XX/01/17	145, 700

purchaseItem		
purchase #	Item #	puchAmnt
9328145	010	200, 000
9328145	020	31, 000
9328178	010	30, 150

t=225

supplier	purchDivision	XcheckClerk	oddMan
(#1282981, 210)	(#9328179, 224)	-	(#100186, 203)

A supplier had sent an invoice that is recorded as No. 83259 in the information system.

paymentOverview			
pymnt #	yearMonth	payTo #	issuedSlip #
83258	20XX/02	2031	342032
83259	20XX/02	2031	1282981

t=225

supplier	purchDivision	XcheckClerk	oddMan
(#3522, 225)	(#9328179, 224)	(#100187, 225)	(#100186, 203)

(XcheckClerk started to cross-check payment and purchase. Purchase No.s 9328145 and 9328178 are combined into the payment I

checkedPymntOverview			
chkdPymnt #	Pymnt #	PymntDate	reconciltn
100185	83243	20XX/02/25	2, 250, 000
100186	83258	20XX/02/25	320, 000
100187	83259	20XX/02/25	581, 000

checkedPymntLine		
chkdPymnt #	Line#	purchase #
100185	010	9328139
100187	010	9328145
100187	020	9328178

t=231

supplier	purchDivision	XcheckClerk	oddMan
(#3522, 225)	(#9328180, 231)	(#100187, 225)	(#100186, 203)

(purchaseDivision recorded No. 9328179 and its items.)

purchaseOverview			
purchase #	supplier #	puchDate	puchAmnt
9328145	546	20XX/02/09	231, 000
9328178	72	20XX/02/17	350, 000
9328179	72	20XX/02/19	50, 000

purchaseItem		
purchase #	Item #	puchAmnt
9328145	010	200, 000
9328145	020	31, 000
9328178	010	350, 000
9328179	010	9, 000
9328179	020	41, 000

t=232

supplier	purchDivision	XcheckClerk	oddMan
(#3522, 225)	(#9328180, 231)	(#100187, 225)	(#100185, 232)

(The odd man finished the approval of No.100186. Then started No. 100185.)

approvedPymnt		
appPymnt #	Emp #	Bank #
100183	1022	1458176
100186	1022	9088190

Figure 10. State transition of business transaction system

Fig. 10 shows that a state transition of the business transaction system is the same as Table 1. Notice that contents of a file system do not assume uniformity of rows. That is, the file system can describe arbitrary variety of possible invoices or payments. (It is still assumed that the processing time of activities is the same as Table 1 for comparison purpose.)

#### 4.2 Design of Dynamic Property of Business Process

We can think of the total operation of an organization as a queuing system for inventory control. Little's theorem [21] says  $W = TL$  holds, meaning that average lead time is equal to (average interval between arrivals)  $\times$  (average inventory) in stationary operation. Though a business process with a file system has much more complex queues than ordinary queuing network, this analogy is applicable to a business process to investigate dynamic properties. The higher demand is, the shorter the interval between arrivals is. Smaller inventory means shorter lead time. So, if we could have a less inventory operation for high demand, then the lead time becomes shorter. That is, we could have higher through-put. Therefore, if the lead time and inventory of business process in stationary operation can be analyzed and the structure of business process could designed to have such organizational operation, then we can adopt the lead time of a business process as an organizational goal. So far, we have shown that cyclic behavior is a key to design dynamic characteristics of a business process [14], by applying the max-plus theory of timed Petri nets [23] define and evaluate the effectiveness of information systems, these kind of dynamic property of a business process should be incorporated in information systems methodology.

#### 4.3 Coordination of Organization via Information Systems

The effectiveness of information systems is becoming more and more important. The basic function of information system is to provide data sharing. But what is needed is a conceptual basis on which we can position the function of information systems in an organization even if its business process is often formed across corporate boundaries using SOA or e-market places

Business transaction system is a model of business process with information systems. The file system of a business transaction system is used as part of the state space. This situation is shown in Figure 3. Since the business transaction system in Figure 7 has seven queues of objects, we need to store transaction data in tables for "record of purchase", "invoice", "available cross-check clerk", "account payable per month for respective suppliers", checked payment", "available odd man", and "approved payment".

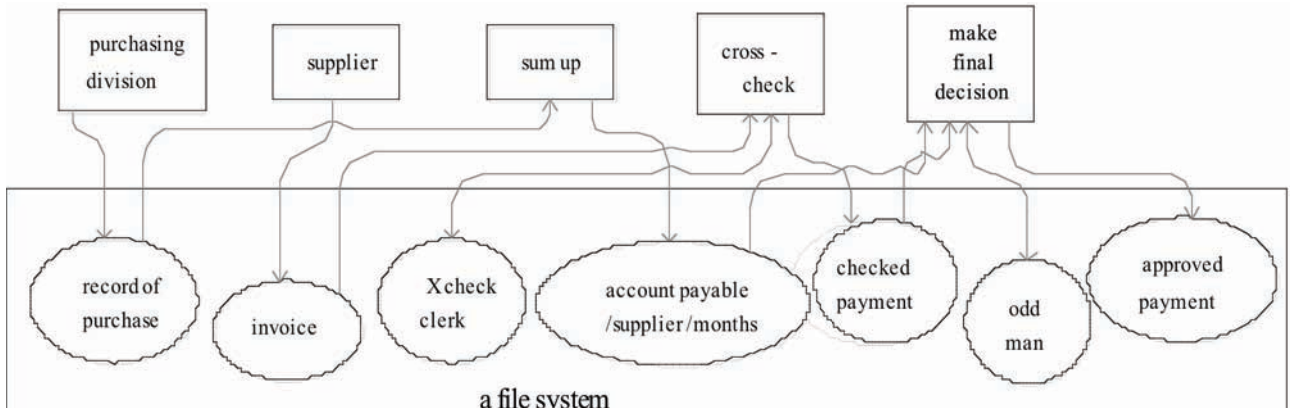


Figure 11. File system of a business transaction system

An invoice should be sent to a customer who procured some goods from a supplier, while any supplier must not send any invoice to our company if we did not buy any goods yet. This kind of integrity is represented by referential key and maintained in a file system. Both conceptual design of data by a data modeling facility, and its implementation into a database management software are called a file system.

Sato and Praehofer[12] proved that the dynamics of a business process is decided by combination of file system and elapsed time from the time when current value of the file system was set. That is, the combination is a state space of a business process. Once we know what consists of a state space, doing optimal operation of a business is nothing but building a management structure that will produce optimal state trajectory from a certain point of view.

The basic structure of organization is depicted in Figure 12 [7, 16, 22]. We focus on the process level (i.e., operational level) of an organization that is a realization of the state transition function  $\delta$  of a business transaction system.

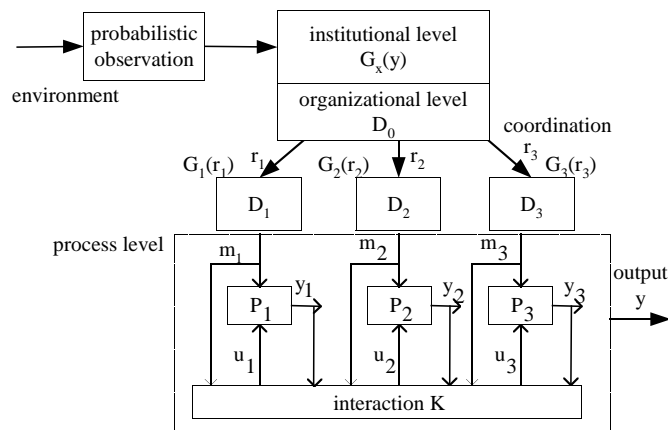




Figure 12. Basic structure of organization

Operation of a sub process  $P_i$  is measured by a performance function  $G_i$  and optimal manipulation is decided by the corresponding decision unit  $D_i$ . The coordination variable,  $r_i$ , is used to resolve mutual interaction among activities in divisions. Since the optimality here is local, organization-wide optimality is not assured of. Let us take a production process as an example. Based on inventories of raw materials and forecast of demands made by other department, production department decides production plans and release of production orders that are manipulation variables (inputs) of the production process. The output is amount of products, production lead times, and/or production cost. In order to attain “best operation” of production process, some decisions are made on manipulation variables based on the logical and physical relations among input and output variables. In a similar way, process of other department like procurement or sales, is operated. The decisions on respective operations are called as divisional plans which are mutually affected with respect to budget and human resources.

### Coordination and coordinability

According to Takahara [22], the point is that coordinabilities are not necessarily filled, depending on specific structure that is used to define specific tasks. This is called coordinability problem. Our business transaction system should also be examined to see what coordinability holds true while the other do not. The concept of coordinability will be defined properly.

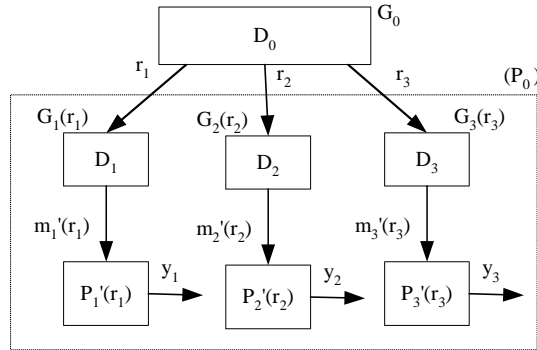


Figure 13. Coordination organization

Figure 13 shows an image of coordination organization for the task system in Figure 12. Interaction among sub processes virtually may disappear by introducing suitable coordination variable. Thus, decision subunits,  $D_1, D_2$ , and  $D_3$ , can do optimal decision based on respective local conditions. For example, a decision unit  $D_1$  makes an optimal decision, evaluating its performance by function  $G_1(r_1)$ , where  $G_1(r_1)$  is a modified evaluation function when given a coordination value  $r_1$ . This kind of localization is of great importance from information processing capacity view point.

### Definition. Behavioral coordinability [16, 22]

A coordination organization is said to *satisfy behavioral condensability* if and only if there exists a coordination value  $r$  such that divisionally (locally) optimal

If behavioral coordinability is satisfied in a coordination organization, then for a coordination variable,  $r$ , the optimal decisions of subunits bring the same value of interaction with the coordination variable. Since a business transaction system has a state transition function  $\delta$ , and since the process of the business transaction system is defined from its state transition function, the task transaction system satisfies behavioral coordinability for arbitrary coordination variable.

The second concept of coordinability is of importance for organizational goal that is defined below.

**Definition.** *Soundness condition of coordination organization [16,22]*

A coordination organization with a global evaluation function  $G_x$  is said to *satisfy soundness condition* if and only if for arbitrary coordination value,  $r$ , the following holds true: If the upper unit (management) evaluated the value,  $r$ , as the most preferable, then the set of optimal decisions made by infimal units (divisions or workers) is a global optimal solution with respect to  $G_x$ .

If an organization does not have a global evaluation function (organizational goal)  $G_x$  then we cannot discuss whether the soundness condition could be met or not. Even if a global evaluation is defined, if a goal has no relation to its behavior, then it is quite difficult to examine soundness condition on an organization. As long as a business transaction system is concerned, we do not need any global goal. Since a business transaction system has a file system of an information system, and since business process works without global goal, it is rare to see soundness condition is met in a business process.

Assume we have global goal like “any process goes as long as our firm can survive.” This global goal is met if we have a business process that enables us to run a company. In such a case, if we can make ends meet then we can say that the company satisfies soundness condition.

The analysis and design of information system virtually determines the performance of a business process, because it is a control device of the process. Thus, information system methodology should be enhanced to deal with organizational global goal. Otherwise, the resultant deployment of information systems such as ERP (enterprise resource planning package), Web servers, RFID, and/or SOA, does not necessarily assures of a business success.

## 5. CONCLUSION

This paper has discussed two issues. First, the nature of artificial systems was reconsidered based on Simon, and Yoshida's concept of symbolic program is referred. According to Simon and Yoshida, we have clarified that activities (research, design, programming, implementation, maintenance) on information systems are nothing but building social laws. Information system certainly has the characteristics of artificial system. It means that implementation of an information system is by no means unique. This pluralism holds true even in concepts, research topics, and methodologies.

Secondly, in order to integrate some information methodologies and concepts for effective advancement in business processes, we showed the development of business process engineering as an application of (mathematical) general systems research.

Two issues on business process engineering were introduced: business transaction system and coordination mechanism through information systems.

#### Business Transaction Systems:

The way to apply the result of general systems research to business process engineering is not unique. We discuss below how the application of GSR can have the characteristics of methodology for integration.

- The goal of business process engineering 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 practical and diagrammatic models without mathematical mechanism. Therefore, ambiguity in defining and formulating target business process could not be resolved with engineering precision.
- 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 [23] for business processes has not been well 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.
- Since BTS 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.
- One of the basic philosophies of GSR is to communicate different areas by providing isomorphy among them [6]. In business process engineering, 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 disciplines.

#### Coordination Theory of Organization:

Starting from the concept of business transaction system, two level coordination model for business

operation was formulated. A coordination organization with BTS provided by mathematical organization theory [7, 16, 23] has been used.

From the result of this analysis of coordination function of information systems, we conclude as follows.

- A company-wide information system, such as ERP, provides data sharing function. The paper showed that data sharing actually provides a coordination mechanism among organizational activities. That is, from the coordination point of view, data sharing through information system is nothing but a behavioral coordination.
- In the management level of an organization, financial indices such as profit and cost are often referred. They are important evaluation factors but not goals from which we can draw hints for process improvement [2]. The art of management is in the definition of operation and operational goals for the company's business process. In order to establish a novel business process for complex and many sort of products with less inventory, introducing e-commerce, SCM, CRM, SOA and other business processes are being tried. The resultant business process can go beyond organizational boundaries, forming a huge virtual organization. It is not trivial for such an organization to find a goal that should be pursued by operating the whole business process. If the goal has unclear relation to its operation, the organization does not satisfy soundness condition. That is, a set of solutions that are optimal in departments of organizations does not necessarily imply the whole optimality. The theory asserts that overall goal should be detailed so as to give operational goals.

Still we have many topics to be developed in business process engineering. If we can expand business process engineering further to be able to design business process as like usual machines or logical circuits, then we will see totally different society of smooth business processes. The integrative 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 and success stories because of lack of foundation. Besides business process engineering, 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 integrative methodology.

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