A Methodology for Integrating Business Process and Simulation for Business Process Redesign

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Abstract

IDEF0 is the IEEE standard for functional enterprise modeling and has been used for business process modeling or process mapping in US and Europe. But it does not reflect the potential benefits of modeling and simulation of the dynamic aspects of an enterprise or a system. On the other hand, simulation tools concentrate mostly on the simulation of material flows and are difficult to include information flows and control flows. Additionally, the simulation models that include elements such as queues, event generators and process nodes is a visual interactive representation for the model builder, but is inconvenient for the domain expert. In an attempt to fill that void, we provide an integration of business process and simulation models in this paper. An enhancement of the IDEF0, called parameterized IDEF0, is proposed and its conversion mechanism to network simulation model is developed. Using this methodology, business process models for alternative systems can be evaluated and compared through simulation on time, cost, and quality metrics. As an application of the proposed methodology, economic evaluation of EDI (Electronic Data Interchange) for time-based BPR (Business Process Redesign) is demonstrated. In addition to BPR, the developed methodology may be further integrated with ABC (Activity Based Costing), TQM (Total Quality Management), and economic evaluation of information systems.

Key Words: Business Process Modeling; Simulation; BPR

1. Introduction

IDEF0 is the IEEE standard for functional enterprise modeling (IEEE Computer Society, 1998) and has been used for business process modeling or process mapping in US and Europe. It has become extremely useful during the domain analysis (or knowledge

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acquisition) process as a means of communication between users and system developers because the notation is quickly understood by the domain experts. The IDEF0 diagram captures the flows of information, material, and control very succinctly in one diagram, and also the relationships between processes and functions in the organization. One of the limitations of IDEF0 is the inability to specify dynamic and behavioral information. But it is generally recognized that IDEF0 is well suited for documenting the flows in a simulation model (Oscarsson and Moris, 2002). It does not cover all the aspects of the model documentation and do not say much about low-level logic, structure or dynamics. It cannot handle parallel processes well, but it plays an important role in giving an overall understanding of the simulation model. The quality of being comprehensive and broadly used among engineers makes the IDEF0 model documentation a good choice (Oscarsson and Moris, 2002).

Simulation can refer to a range of model types from spreadsheet models, system dynamic simulations and discrete-event simulation modeling. A discrete-event simulation model is one in which the state of the model changes at only a discrete set of time points (Greasley, 2003; Schriber and Brunner, 1996). It has been applied extensively to manufacturing (Hlupic, 1999), but its application in service process design is becoming more widespread (Aguilar et al., 1999; Greasley, 2003; Profozich, 1998). Examples of use include telecommunication service (Dennis et al., 2000), banking (Verma et al., 2000) and hotel management (Aksu, 2001). The primary shortcoming of existing simulation tools is the lack of suitable concepts that describe the manufacturing enterprise at the appropriate level of abstraction. Usually, it is very difficult to include information and control flows together with material flows. Additionally, the simulation models that include elements such as queues, event generators and process nodes is a visual interactive representation for the model builder or decision maker (Bell et al., 1999), but is inconvenient for the domain expert (Mujtaba, 1994). In order to fill that void, this paper presents an integration of the business process and simulation models. An enhancement of the IDEF0, called parameterized IDEF0, is proposed, and its conversion mechanism to network simulation model is developed. Using this methodology, process models for alternative systems can be evaluated and compared through simulation on time, cost, and quality metrics.

BPR (Business Process Reengineering) has led to the widespread analysis of business processes using techniques such as flow charts, process maps and simulation software (Cheung and Bal, 1998; Jaklic et al., 2002). Aguilar et al. (1999) indicate how simulation could provide support in BPR. Researchers have differing opinions of the usefulness of business process simulation or simulation software in the context of BPR projects. For example, Petrozzo and Stepper (1994) outline how business process simulation helps understanding of process dynamics while Peppard and Rowland (1995) are wary of the use of simulation analysis in the redesign stage due to the potential time and cost involved in building the model. Greasley (2003) discusses the benefits and limitations of business process simulation and outlines what contribution a BPR approach can make to the successful use of the simulation technique.

This paper is organized into the following: In section 2, the parameterized IDEF0 is presented. In section 3, the conversion mechanisms of the parameterized IDEF0 into the network simulation model are constructed. Section 4 presents an application of the developed methodology to the economic evaluation of BPR alternatives. Finally, conclusions and further research are addressed.

2. Parameterized IDEF0

The original IDEF0 building block shown in Fig. 1 does not reflect the potential benefits of modeling and simulation of the important dynamic aspects of an enterprise or a system. In order to incorporate such aspects and simulate IDEF0 models, we must parameterize the model. This shall be done by reflecting back on the purpose and context of the model. The corporate strategy and the metrics needed to achieve the corporate goals are often stated in cost reductions, time reductions, quality improvement, and so on. It is never stated in number of systems installed or number of networked workstations. Thus, the translation must be made to go from strategy to systems. The mechanism for this is the parameterized IDEF0 model.

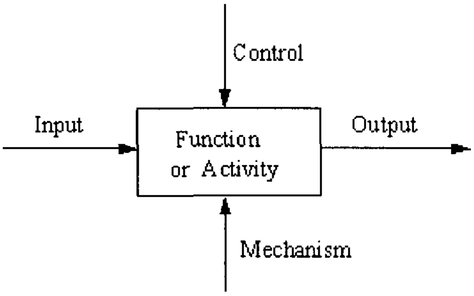

Fig. 1 IDEF0 building block

The building block of the parameterized IDEF0 is shown in Fig. 2. Inside each function box, function-processing time, activity cost for ABC (Activity Based Costing), and error rate are specified. The flow time and branching condition of each input, output, and control flows are attached next to them in parentheses. Different types of orders belong to control flows, but they are depicted separately as heavy lines only if they represent the simulation entities flowing through the whole system with attribute values to be collected at the end of simulation. As are the orders, if materials represent the simulation entities, they are represented as heavy lines to differentiate them from other input flows. Output flows become either simulation entities or other types of entities. Functions are not always activated if all inputs, controls, and resources are present. Some functions are processed only at a predetermined time. These periodic functions are activated by the periodic condition or the arrival of time-event, which is shown as a dotted line in the Fig. 2. The mechanism in the IDEF0 is specifically replaced by resource type and resource capacity. In order to avoid confusion, hereafter the term mechanism will refer to the conversion mechanism into simulation.

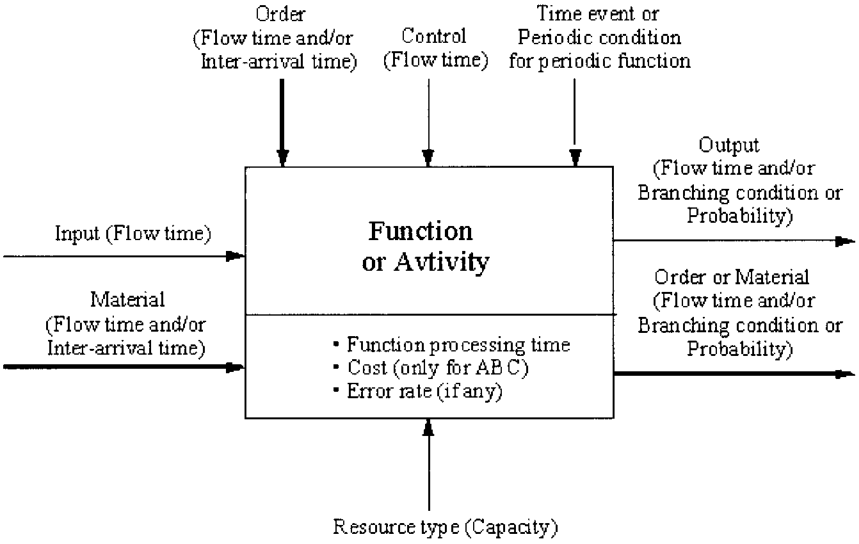

Fig. 2 Parameterized IDEF0 building block

2.1 Assigning time parameters

In today's competitive world, time is becoming the equivalent of cost and quality. To analyze where time is really spent, we must model time on the functions and information or material flows. The required time parameters for simulation purposes are:

- Processing time for each function or activity;
- Information or material flow time (from request to arrival) between functions;
- Inter-arrival time of external entities (e.g., customer order) into the system to be modeled and simulated;
- Other times affecting the path of entity flow through the system (e.g., order due date);
- Time event or periodic condition for periodic functions (e.g., arrival of the last day of a month for a routine maintenance, once a weak for material requirement planning).

2.2 Assigning cost parameters

If activity based costing is realized in the enterprise to be modeled, cost for each function can be attached to each function box. Otherwise, the specification of required cost data depends on the performance measures evaluated from simulation. For example, if a company's main concern is to reduce inventories and their costs, the following data need to be specified:

- Average carrying cost for finished goods per unit per year;
- Average carrying cost for raw materials per unit per year.

In addition, the following non-cost data are sometimes necessary to evaluate the inventory reduction:

- Average quantity of finished goods per order;
- Maximum quantity of finished goods per order;
- Average quantity of raw material per order;
- Maximum quantity of material per order.

2.3 Assigning quality parameters

If we apply TQM (Total Quality Management) and continuous improvement, all the functions ought to have some measure of quality assigned to them, and this should be monitored and displayed on the model. One of the most easily identifiable quality parameters is error rate. It represents the total count of entities flowing through the rework and scrap functions.

2.4 Additional parameters needed for simulation analysis

Besides the time, cost, and quality parameters, the following data are often required for simulation:

- Resource type and resource capacity, i.e., the number of resources (e.g., headcounts, number of machines, etc.);

- Branching condition or probability.

3. Conversion of Parameterized IDEF0 into Simulation Model

In this paper, we use the SLAMII (Pritsker, 1986) as a network simulation model. A precise conversion mechanism must be defined to convert the parameterized IDEF0 model into a consistent SLAMII network simulation model. Proposed conversion mechanism consists of nine types of Generic Building Blocks (GBBs) of the parameterized IDEF0 and corresponding SLAMII models. Each of them is explained below.

3.1 Creation of the simulation entity

An external entity arriving and proceeding through system is the simulation entity in the SLAMII network model. This entity is either a type of order or a type of product (or material). It is easily created using CREATE node of the SLAMII. This translation is presented in the GBBs shown in Fig. 3.

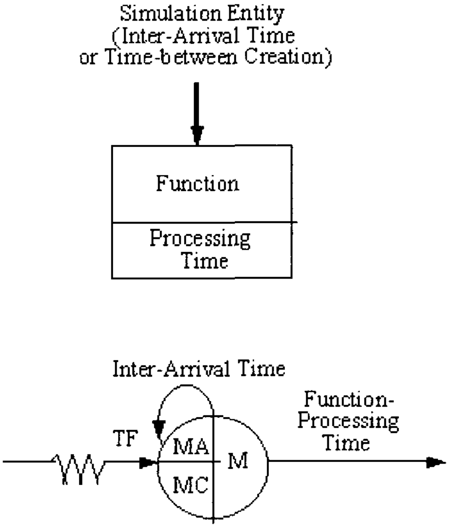

Fig. 3 Creation of simulation entity in the parameterized IDEF0 and SLAMII

3.2 A type of order or material flow as the simulation entity

If a type of order or material arrives at the function box and the corresponding SLAMII model Fig. 4, it waits until the required units of resources are available. After capturing the resources, it goes through the function spending the assigned processing time, and then, frees the resources and travels to another function box during the flow time.

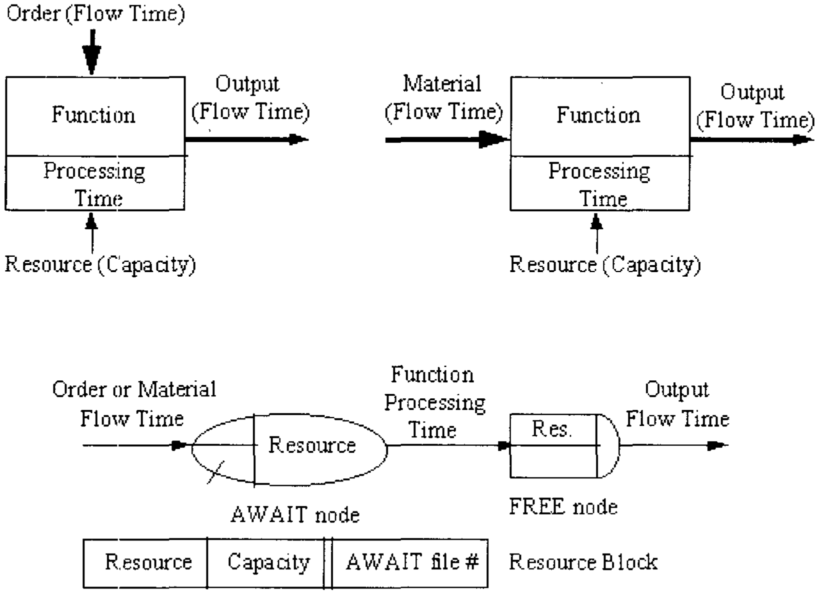

Fig. 4 A type of order or material flow in the parameterized IDEF0 and SLAMII

3.3 Multiple inputs and controls flowing into the function box

Fig. 5 shows a case of an order (i.e., a simulation entity) together with a control and an input. In order to activate the function, all the required orders, controls, and resources must be present. But their arrival times at the function box are different. Therefore, they have to wait until all of them arrive at the function box. This mechanism can be represented by ASSEMBLY Queue Selection Rule shown in the Fig. 5. The ASSEMBLY rule involves the combining of two or more entities into an assembled entity. In this rule, the selection process requires that at least one entity be in each QUEUE node before any entity will be routed to a service activity (or function). In the case of the Fig. 5, three QUEUE nodes for the order, the control, and the input, respectively, are set up in front of the SELECT node using ASM (ASSEMBLY) Queue Selection Rule. Here a problem caused by the differences between parameterized IDEF0 and SLAMII is encountered. The parameterized IDEF0 represents each order, control, and input as a separate flow. But SLAMII can represent only a simulation entity as a flow. In other words, other types of flows, except for a simulation entity cannot be represented as separate flows. As a solution to this problem, the simulation entity (i.e., order flow in the Fig. 5) is divided into three different flows in the SLAMII. They represent order, control, and input flows, respectively. These divided flows are then assembled into one simulation entity again through the SELECT node. The divided flows affect only the waiting mechanism, while keeping the concept of a single simulation entity flow.

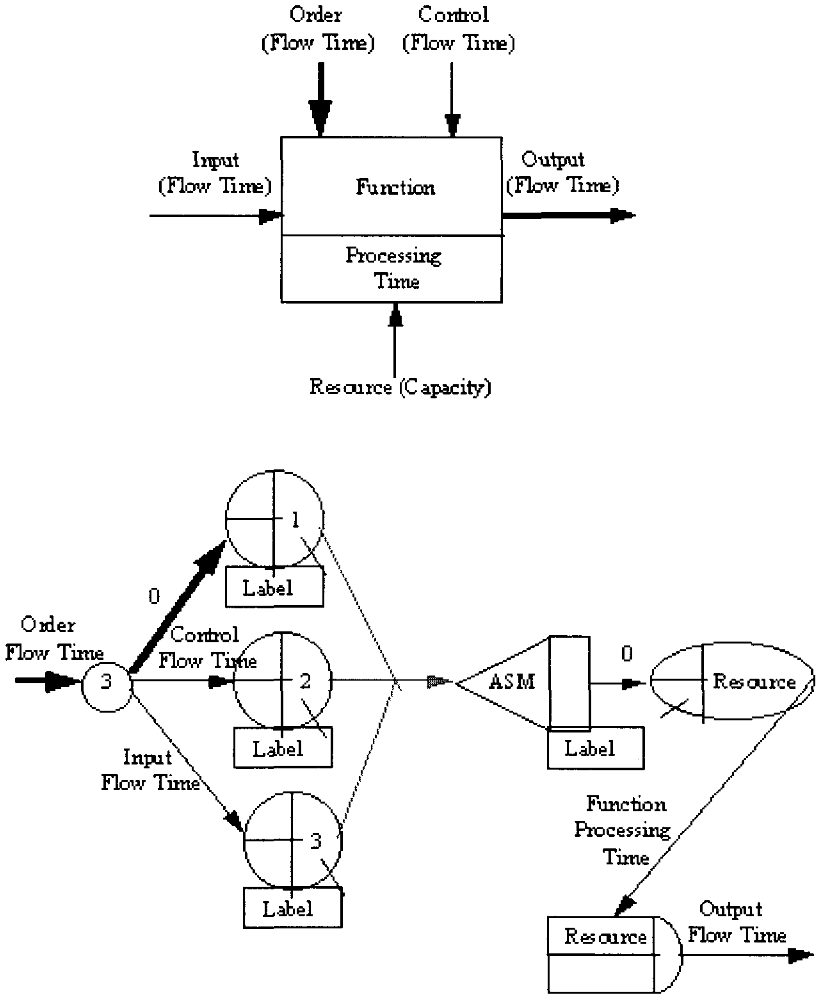

Fig. 5 Multiple flows of inputs and controls in the parameterized IDEF0 and SLAMII

4.4 A function box without resources

So far, we have focused on the input and control flows. Resources must also be addressed. If there are no resources at the function box, the conversion mechanism is very simple. The arrived order can be directly processed without waiting for the resources. This case is illustrated in Fig. 6.

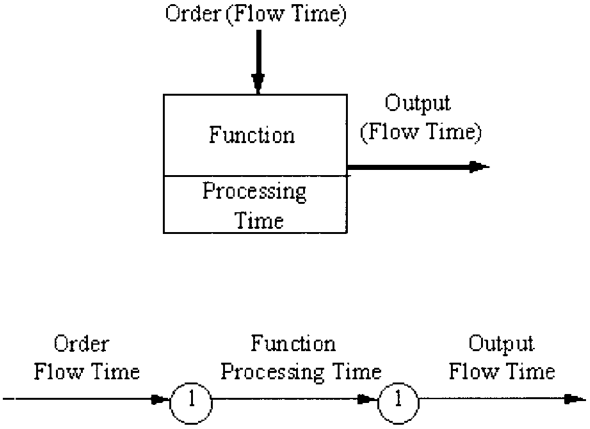

Fig. 6 A function box without resources in the parameterized IDEF0 and SLAMII

3.5 A function box with multiple types of resources

Assume that there are two types of resources at the function box in Fig. 7. Then the arriving entity must wait until the required units of both resources are available

3.6 Multiple types of outputs with unconditional branching from function box

Until now, we have considered the case of only one type of output emanating from the function box. In this subsection, multiple types of outputs with unconditional branching are translated to the SLAMII. For example, two types of outputs in Fig. 8 are translated to the two branches unconditionally, passing through GOON node. In this case, an order flow processed by the function is divided into the two identical order flows that will visit different function boxes.

3.7 Multiple types of outputs with conditional branching from function box

If the branches of outputs are conditional or probabilistic, the order leaves the function box through only one branch among them. This case is illustrated in Fig. 9.

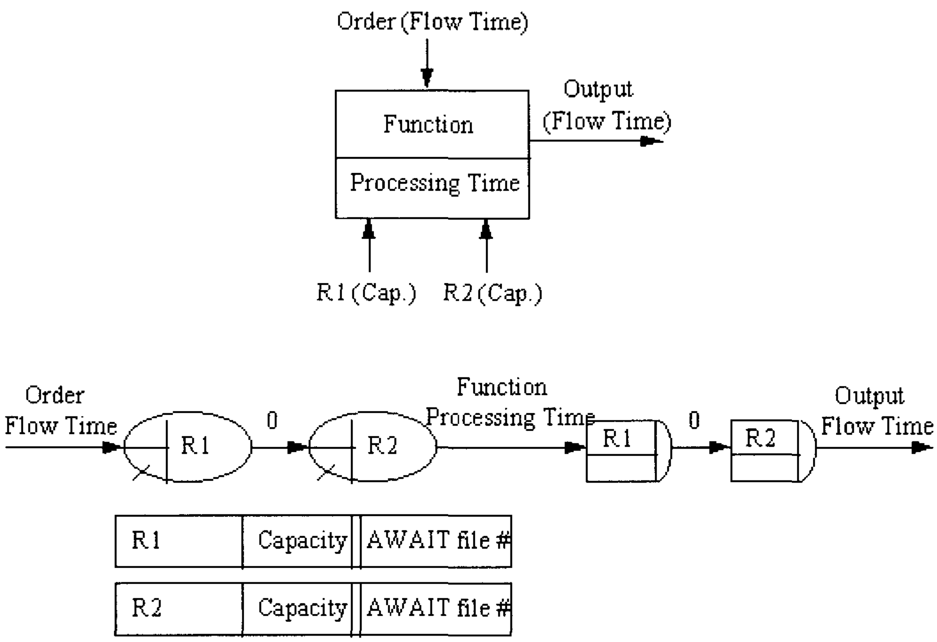

Fig. 7 A function box with multiple types of resources in the parameterized IDEF0 and SLAMII

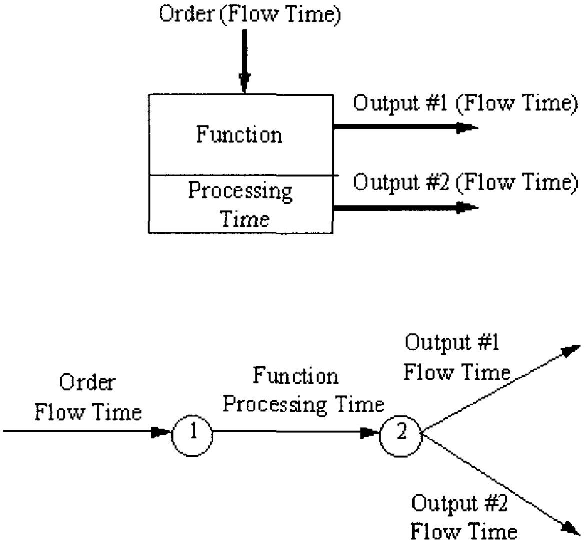

Fig. 8 Multiple types of outputs (unconditional branch) in the parameterized IDEF0 and SLAMII

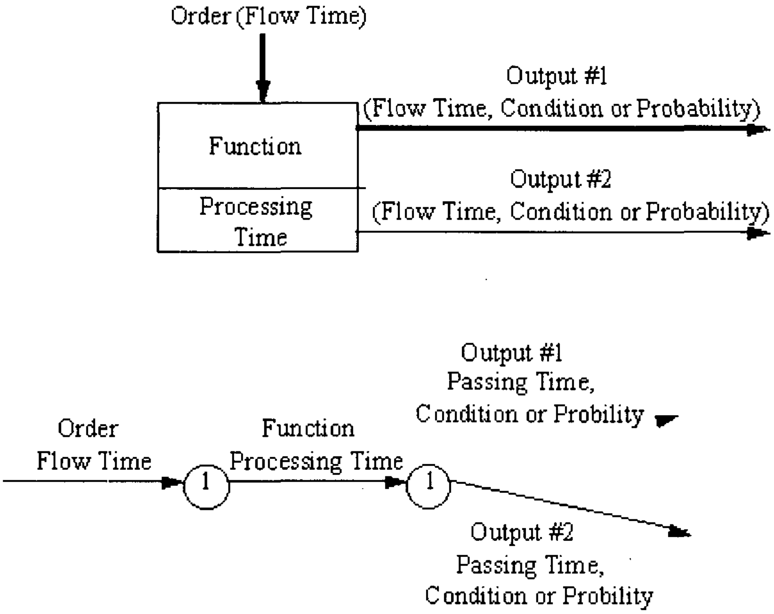

Fig. 9 Multiple types of outputs (conditional branch) in the parameterized IDEF0 and SLAMII

3.8 Periodic function

Functions are not always activated if all inputs, controls, and resources are present. Some functions are processes only at a predetermined time. These periodic functions are activated by the periodic condition or the arrival of time-event, which is shown as a dotted line in Fig. 10. For example, it is assumed that a function is activated once a week. In the SLAMII model of the Fig. 10, this periodic condition is converted by a global variable XX(1) and ASSIGN node. First, the arriving entity waits for the arrival of the specified time at the QUEUE node. Then, when the time arrives, the entity leaves the QUEUE node and starts to be processed. The time is reset automatically at the ASSIGN node.

3.9 Cost data

Cost data other than function- or activity-related costs are not really represented on the parameterized IDEF0 diagram, but they are needed to calculate the required cost metrics. What kinds of cost data are needed depends upon the desired cost metrics. In the SLAMII, cost data can be defined by assigning necessary costs to global variables in the ASSIGN node. This is shown in Fig. 11.

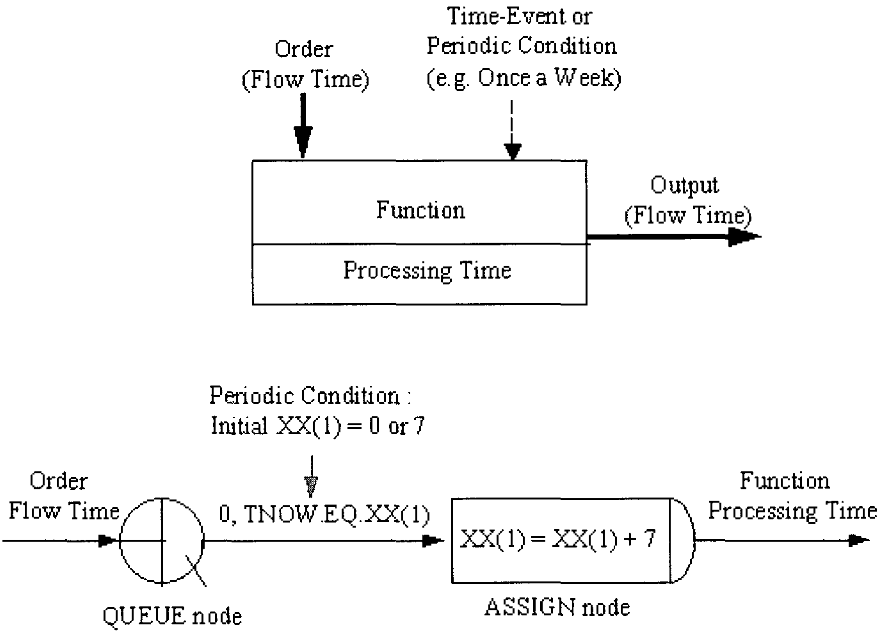

Fig. 10 Periodic function in the parameterized IDEF0 and SLAMII

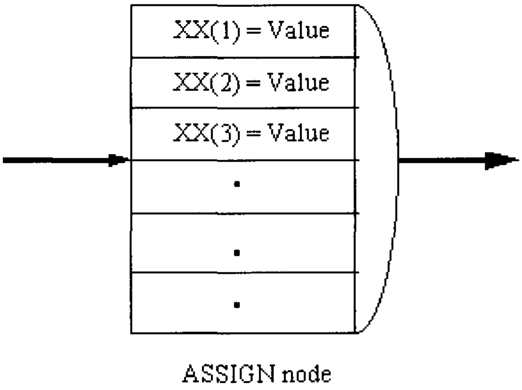

Fig. 11 Cost data in the SLAMII

4. An Application of the Economic Evaluation of BPR

On-time delivery and reducing inventory costs are two factors that are traded off in many manufacturing organizations. Customers become dissatisfied if the time from placement of an order to receipt of shipment is too long. At the same time, a global manufacturing enterprise can have significant amounts of money tied up in inventory that is in the wrong place or in the wrong product, while the long delivery time translates into large order backlogs. This dilemma is one of the primary concerns of most enterprises (Mujtaba, 1994).

Manufacturing companies usually have three types of order-fulfillment strategies: Make-To-Stock (MTS), Assemble-To-Order (ATO), and Make-To-Order (MTO). MTS holds both finished goods and raw material inventories, ATO that is often considered as a variation of MTO keeps raw materials (including subassemblies and components) only, while MTO assumes ideally zero inventory. All of them have work-in process inventories. In their philosophies, MTS aims at on-time delivery, but it requires higher needs for inventories. On the contrary, MTO aims at lowest inventory, but it reduces delivery speed. Most companies are neither strictly MTS nor MTO, but have elements of both (Turbide, 1993).

One of the solutions to this dilemma is time-based BPR. Time compression (e.g., reducing cycle time from order receipt to shipment) simultaneously achieves better on-time delivery and less inventory costs. An example that is presented in this paper shows such a simultaneous improvement. Stalk and Hout (Stalk and Hout, 1990a; Stalk and Hout, 1990b) state that one of the core concepts in structuring work for time compression is the main sequence comprising those activities that directly add customer value in real time. Customer orders flow directly through the main sequence. They show an example of the main sequence for a manufacturing industry. Incidentally, it corresponds to the order-to-fulfillment (or order receipt-to-shipment) process. The parameterized IDEF0 can represent the customer order flow through the main sequence, and then it can be translated into the SLAMII simulation network showing the consistent order flow. These proposed constructs provide a means to perform the time-based BPR because they model business processes with time parameters and simulate the time-varying behavior of the processes.

Although many people have proposed different processes of BPR, they have the following common steps:

- Identify current processes (or As-Is system);
- Identify redesign or improvement opportunities;
- Design new processes (or To-Be system);
- Evaluate and justify the alternative systems.

The parameterized IDEF0, together with consistent SLAMII simulation, provides tools for process modeling and performance evaluation required for those common steps. Ardhaldjian and Fahner (1994) also discuss the use of simulation in BPR, especially in the As-Is modeling (as a tool for understanding) and To-Be alternatives (as a tool for comparison). Application of the proposed constructs to the time-based BPR is shown in the following example in the order-to-fulfillment process. The purposes of this example are:

- to demonstrate and validate the proposed constructs;
- to show that cycle time compression simultaneously improves on-time delivery and inventory cost savings.

4.1 As-is system

In general, the order-to-fulfillment in a manufacturing company consists of the five generic processes along the main sequence (i.e., value-added customer order flow) at the highest level. These processes are order processing, production planning and purchasing, materials inventory processing, production, and shipping and warehousing. The same processes are illustrated as the main sequence by Stalk and Hout (1990a, 1990b). But more detailed or different identification of the processes is always possible, depending on the level of abstraction. Fig. 12 exhibits an As-Is parameterized IDEF0 model including those processes. Resources are ignored in this model. Heavy lines represent customer order flows (i.e., the paths of the simulation entities) according to the types of order-fulfillment (i.e., MTS, ATO, and MTO). As Turbide (Turbide, 1993) addressed, most companies have a mixed form of the three types of order fulfillment. Since deterministic average times, except inter-arrival time and due-date, are assigned and no waiting times for resources are included, each order cycle time of the MTS, ATO, and MTO can be hand-calculated by following the order flows on the diagram. If either time assignment is probabilistic or resources are modeled (and thus waiting time is included), order cycle times can be obtained only after simulation runs. The precalculated cycle times in this example are: 18 days for MTS, 32 days for ATO, and 56 days for MTO. The assumption of the company's policy on the order fulfillment is as follows: If the time allowance from due-dates of customer orders is less than 18 days, the orders become lost sales. If the allowance is greater than or equal to 18 days and less than 32 days, orders are satisfied by the direct shipping from finished-goods stock (i.e., MTS). If the allowance is greater than 32 days, orders become backorders. Furthermore, if the allowance is greater than or equal to 32 days and less than 56 days, the backorders are satisfied by ATO beginning with subassembly or component inventory. Finally, if the allowance is greater than or equal to 56 days, the backorders are produced by MTO. Exponential distribution is chosen for the inter-arrival time assuming that the arrival of a customer order is independent of the arrival of other customer orders (Pritsker, 1986).

The mean value of 0.5 days for the inter-arrival time is assigned after some simulation trials. Due-date is arbitrarily assigned by uniform distribution from 5 to 90 days.

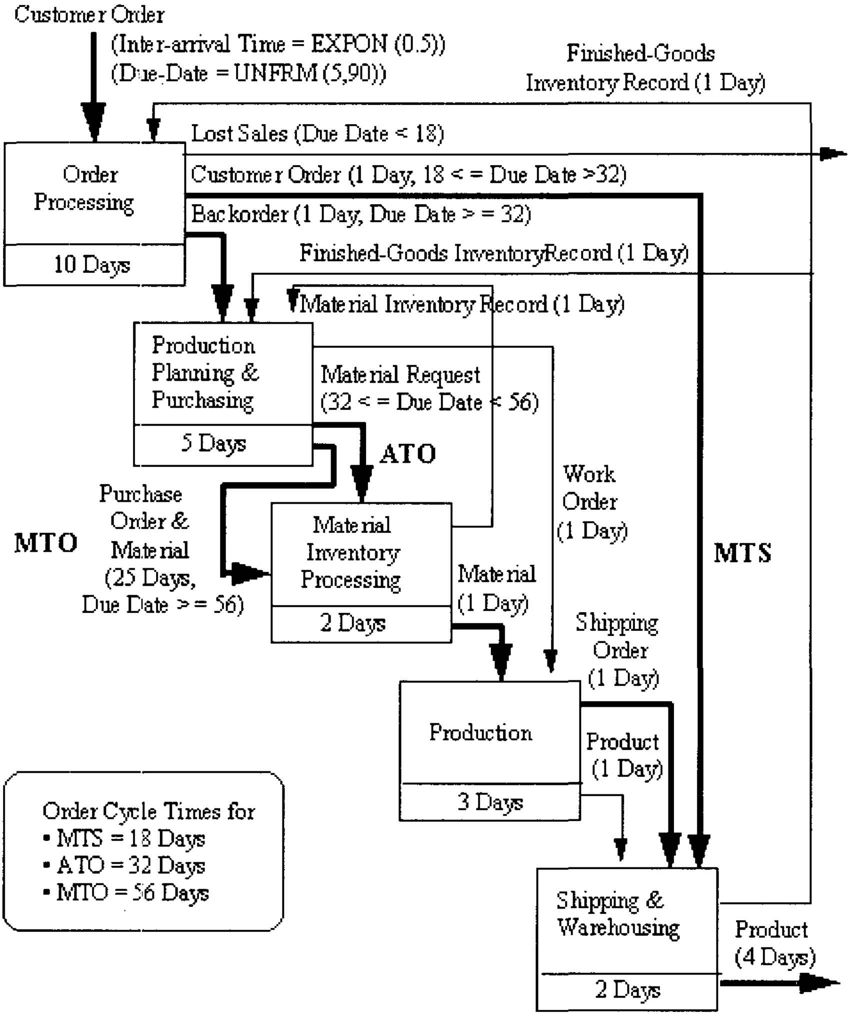

Fig. 12 Parameterized IDEF0 model of the as-is system

Performance measures on the on-time delivery and inventory costs should be specified before converting the parameterized IDEF0 model into simulation. As a measure of the on-time delivery, order fill-rate is selected because it is the most widely used measure for customer satisfaction (Lee and Billington, 1992; Vollmann et al., 1992). It is defined as the percentage of the orders shipped prior to due-date (i.e., the percentage of on-time delivery). As the measures of the inventory costs, average annual holding costs of finished-goods and raw-materials are selected. Although the cost of WIP (Work-In-Process) exists in the system, it is ignored because of the difficulty of identification. Additionally, average annual lost-sales cost is included for the economic evaluation. Surely many other costs exist in the enterprise, and more costs included provide more realistic information on the cost savings from the alternative system. The cost metrics selected in this example are defined as follows:

- Average annual holding cost of the finished-goods
  = (Avg. inventory held/yr.)(Avg. holding cost/unit/yr.)
  = (Avg. annual demand+Avg. safety stock)(Avg. holding cost/unit/yr.)
  = ((No. of MTS orders/yr.)(Avg. quantity/order)+
  (No. of MTS orders/yr.){(Max. quantity/order) - (Avg. quantity/order)}
  (MTS cycle time/2))(Avg. holding cost/unit/yr.)

In this equation, the formula for the average safety stock is derived from the following concise form (Dervitsiotis 1981):

Average annual safety stock = (Dmax - D)L/2, where Dmax = maximum demand rate per year
D = average demand rate per year
L = supply lead time or order cycle time

- Average annual holding cost of the raw-materials
  = (Avg. inventory held/yr.)(Avg. holding cost/unit/yr.)
  = (Avg. annual demand+Avg. safety stock)(Avg. holding cost/unit/yr.)
  = ({No. of (MTS+ATO) orders/yr.}(Avg. quantity/order)+
  (No. of (MTS+ATO) orders/yr.){(Max. quantity/order) - (Avg. quantity/order)}
  {(MTS+ATO) cycle times/4})(Avg. holding cost/unit/yr.)

The same safety stock formula as the finished-goods is used in this equation.

- Average annual lost-sales cost
  = (No. of lost orders/yr.)(Avg. profit/order)

Even though defining lost-sales cost is different between companies, the above equation is used in this example.

Assume that the necessary data for the above three equations are as follows:

- Average quantity of the finished-goods/order = 100 units/order
- Maximum quantity of the finished-goods/order = 500 units/order
- Average quantity of the raw-materials/order = 500 units/order
- Maximum quantity of the raw-materials/order = 2,500 units/order
- Average holding cost of the finished-goods/unit/year = $10/unit/year

- Average holding cost of the raw-materials/unit/year = $2/unit/year
- Average profit/order = $10,000/order

Now it is time to translate the parameterized IDEF0 into the SLAMII network model using the conversion mechanisms developed in the previous section. Fig. 13 shows the converted SLAMII network model of the As-Is system.

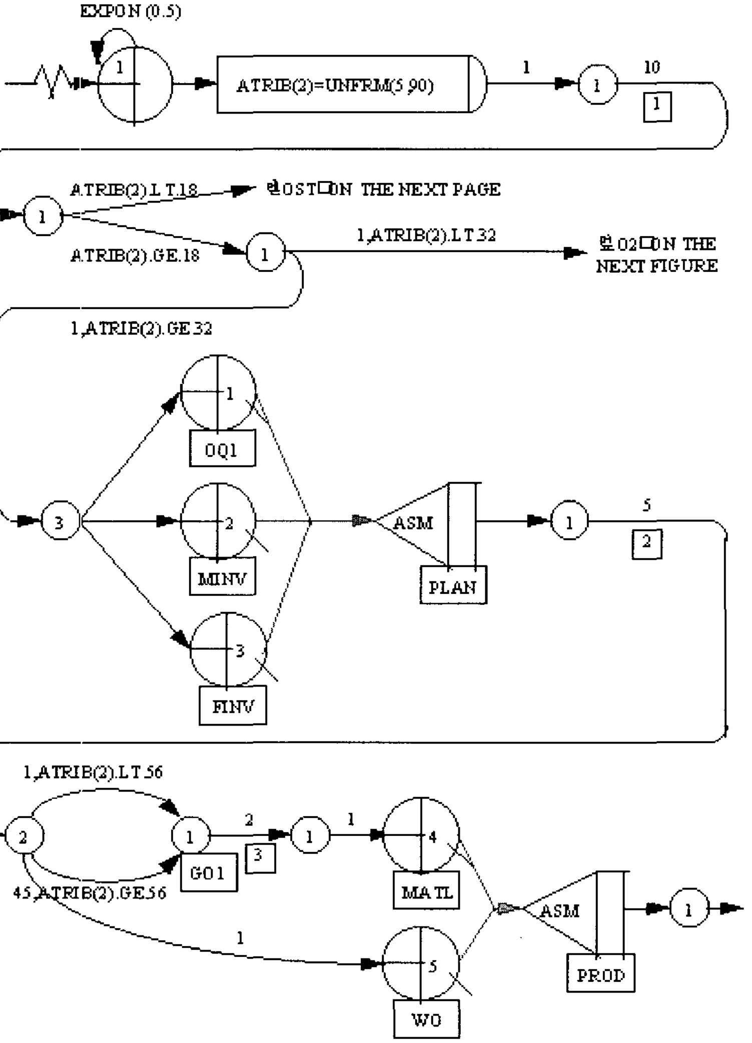

Fig. 13 SLAMII network model of the as-is systems (continued on next page)

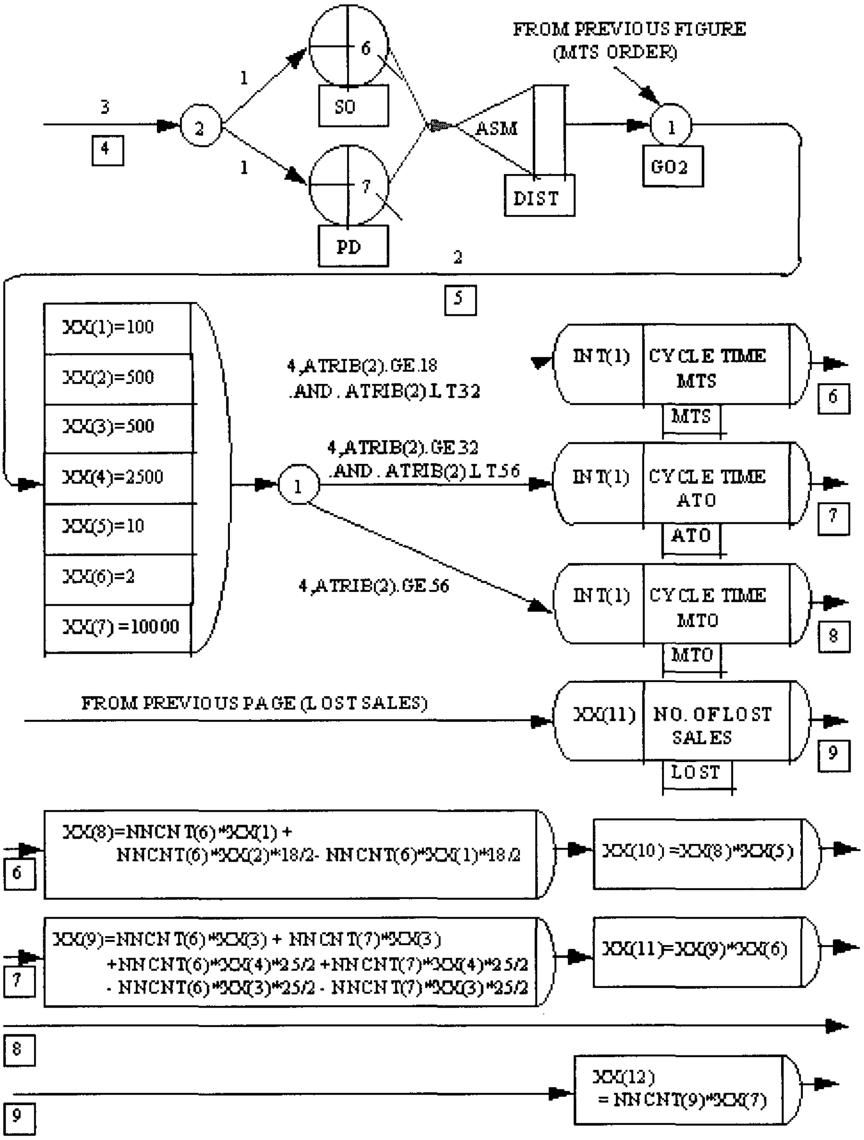

Fig. 13 SLAMII network model of the as-is systems (continued from previous page)

Table 1 shows the simulation results of the As-Is system. The results validate that the conversion of the parameterized IDEF0 to SLAMII is correct because order cycle times of the MTS, ATO, and MTO from simulation are the same as the precalculated values in the parameterized IDEF0. These same values result from the fact that resources are ignored in the modeling and simulation for the simplification of the example. The purposes of this example are:

- to demonstrate and validate the proposed constructs;
- to show that cycle time compression simultaneously improves on-time delivery and inventory cost savings.

Table 1. Simulation results of the as-is system

Performance Measures	Average	Standard Deviation	Minimum	Maximum
MTS cycle time per order	18 days	0 days	18 days	18 days
ATO cycle time per order	32 days	0 days	32 days	32 days
MTO cycle time per order	56 days	0 days	56 days	56 days
Average cycle time per order	39.1 days	15.8 days	18 days	56 days
Holding cost of finished goods/yr	\$ 1.55 m*	\$ 0.89 m	\$ 0.04 m	\$ 3.07 m
Holding cost of raw materials/yr	\$ 4.89 m	\$ 2.51 m	\$ 0.51 m	\$ 9.69 m
Lost-sales cost/yr	\$ 0.44 m	\$ 0.25 m	\$ 0 m	\$ 0.87 m
Total cost per year	\$ 6.88 m	-	-	-
No. of MTS orders fulfilled/yr	83	-	-	-
No. of ATO orders fulfilled/yr	107	-	-	-
No. of MTO orders fulfilled/yr	149	-	-	-
Total no. of orders fulfilled/yr	339	-	-	-
No. of lost orders/yr	87	-	-	-
Order fill rate	20 %	-	-	-

*Dollar unit is million.

If resources are included, waiting times will increase the cycle times and more realistic simulation results will be given. But this preliminary simulation without resource specification can provide a means to validate the conversion process. In other words, if a simulation run without resources produces the same cycle times as the precalculated ones, the conversion is correct. Then resources are added into the model, and we can obtain more reliable information on the cycle times and variable waiting times from the simulations.

4.2 Alternative to-be systems

Giaglis et al. (1999) present a practical application of business process simulation in an inter-organizational process design setting, where more than one organization initiated a joint effort to change their relationships and communication schemes within the pharmaceuticals industry. The authors discuss the unique characteristics and requirements associated with inter-organizational simulation modeling and argue for the need to develop special-purpose simulation environments that will address business process simulation requirements (Paul et al., 1999).

One of the technologies used to implement inter-enterprise integration is EDI, which eliminates uncontributing time between companies. EDI is a useful tool for the time-based BPR (Borthick and Roth, 1993). As an alternative To-Be system in this example (To-Be #1), EDI between customer and supplier is proposed. Fig. 14 shows the parameterized IDEF0 model of the new EDI system with the estimated times reduced after its implementation. In this figure, only changed data are represented to highlight the differences from the As-Is system in the Fig. 12.

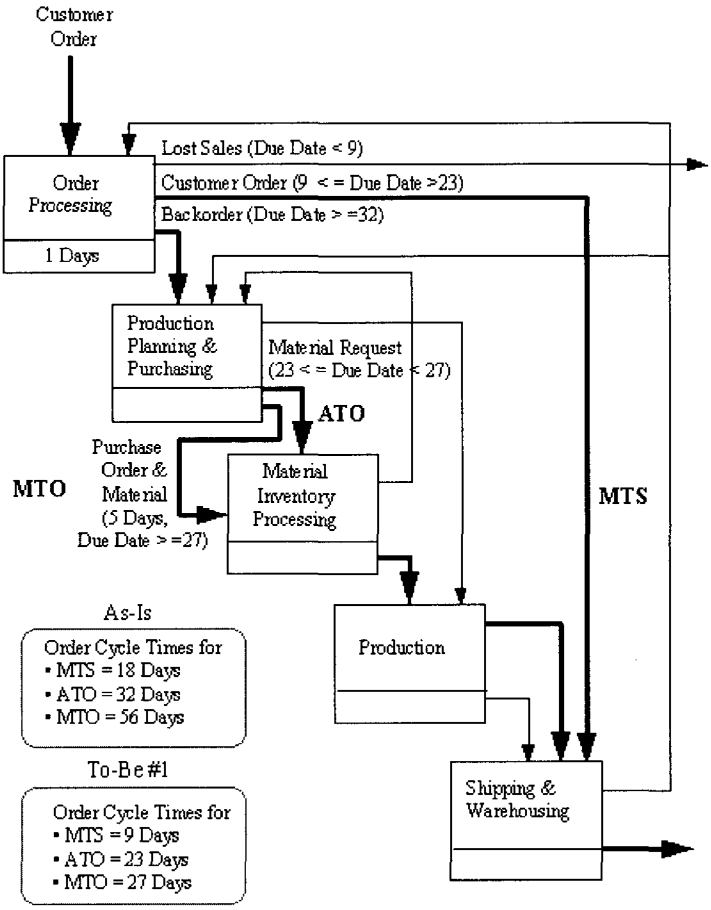

Fig. 14 Parameterized IDEF0 model of the to-be #1

The second alternative To-Be system (To-Be #2) represents the implementation of both intra- and inter-enterprise integration. The reduced times of this alternative are realized by the integrated database and EDI.

The simulation results of the three alternative systems are summarized in Table 2. This shows that reducing cycle time gives significant improvements in both inventory costs and on-time delivery (or order fill-rate). Reducing cycle time also gives other important cost savings in addition to the inventory savings. Those other savings are well described in literature (e.g., Borthick and Roth, 1993). To justify the implementation of the alternative systems, these cost savings should be compared with the cost of implementing and maintaining the system. Note, however, that if the other cost savings are not included in the analysis, it is possible for the system to be unacceptable from a financial viewpoint. Thus, all costs need to be included to justify investments in the project (Borthick and Roth, 1993).

Table 2. Summary of the simulation results

Performance Measures	As-Is	To-Be #1	To-Be #2
MTS cycle time per order	18 days	9 days	5.52 days
ATO cycle time per order	32 days	23 days	10.1 days
MTO cycle time per order	56 days	27 days	15.2 days
Average cycle time per order	39.1 days	22.9 days	14.0 days
Holding cost of finished goods/yr	$ 1.55 m*	$ 0.86 m	$ 0.20 m
Holding cost of raw materials/yr	$ 4.89 m	$ 2.53 m	$ 0.58 m
Lost-sales cost/yr	$ 0.44 m	$ 0.15 m	$ 0.03 m
Total cost per year	$ 6.88 m	$ 3.15 m	$ 0.81 m
No. of MTS orders fulfilled/yr	83	89	29
No. of ATO orders fulfilled/yr	107	30	43
No. of MTO orders fulfilled/yr	149	297	387
Total no. of orders fulfilled/yr	339	416	459
No. of lost orders/yr	87	29	5
Order fill rate	20 %	93 %	99 %

*Dollar unit is million.

5. Conclusion

This paper presents an approach to the integration of business process and simulation models. An enhancement of the IDEF0, called parameterized IDEF0, is proposed, and its conversion mechanism to SLAMII network model is developed. Using this methodology, business process models for alternative systems can be evaluated and compared through simulation on time, cost, and quality metrics. As an application of the proposed methodology, economic evaluation of EDI time-based BPR is demonstrated. This example shows that reducing order cycle time in order-to-fulfillment process simultaneously achieves better on-time delivery and less inventory costs. In addition to BPR, the developed methodology in this paper may be further integrated with ABC, TQM, and economic evaluation of information systems. Greasley (2001) provides more details of the use of the simulation in conjunction with the ABC technique.

Further research is required: Firstly, SLAMII simulation cannot support the hierarchical modeling of the parameterized IDEF0. At the moment, only a few simulation tools that fully support hierarchical decomposition and design modularity are available (Paul et al., 1999). Secondly, the parameterized IDEF0 cannot model the synchronization and concurrency of functions or processes. Extending the research of this paper into IDEF3 process modeling technique or Petri Nets is required to incorporate those mechanisms. Zakarin and Kusiak (2001) extend IDEF3 methodology by including quantitative information, improve IDEF3 process analysis and reengineering capability, and facilitate the formulation of a simulation model. Finally, development of the software for automatic conversion from the parameterized IDEF0 model to the network simulation model is needed because the use of general-purpose simulation languages requires a great deal of skills and effort.

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References

1. Aguilar, M., Rautert, T. and Pater, A.J.G. (1999), Business Process Simulation: A Fundamental Step Supporting Process Centered Management, Proceedings of the 1999

Winter Simulation Conference, SCS, pp. 1383-1392.
2. Ardhaldjian, R. and Fahner, M. (1994), Using Simulation in the Business Process Reengineering Effort, Industrial Engineering, July, pp. 60-61.
3. Bell, P.C., Anderson, C.K., Staples, D.S. and Elder, M. (1999), Decision-Makers' Perceptions of the Value and Impact of Visual Interactive Modelling, Omega, Vol. 27, No. 2, p. 155.
4. Borthick, A.F. and Roth, H.P. (1993), Accounting for Time: Reengineering Business Processes to Improve Responsiveness, Journal of Cost Management, Vol. 7, No. 3, pp. 4-14.
5. Cheung, Y. and Bal, J. (1998), Process Analysis Techniques and Tools for Business Improvements, Business Process Management Journal, Vol. 4, No. 4, pp. 274-290.
6. Dennis, S., King, B., Hind, M. and Robinson, S. (2000), Applications of Business Process Simulation and Lean Techniques in British Telecommunications PLC, Proceedings of the 2000 Winter Simulation Conference, Orlando, Florida, pp. 2015-2021.
7. Giaglis, G.M., Paul, R.J. and Doukidis, G.I. (1999), Assessing the Impact of Electronic Commerce on Business Performance: A Simulation Experiment, Electronic Markets, Vol. 9, No. 1, pp. 25-31.
8. Greasley, A. (2001), Costing Police Custody Operations, Policing: An International Journal of Police Strategies & Management, Vol. 24, No. 2, pp. 216-227.
9. Greasley, A. (2003), Using Business-Process Simulation within A Business-Process Reengineering Approach, Business Process Management Journal, Vol. 9, No. 4, pp. 408-420.
10. Hlupic, V. (1999), Discrete-Event Simulation Software: What the Users Want, SIMULATION, Vol. 73, pp. 362-370.
11. IEEE Computer Society Software Engineering Standards Committee (1998), IEEE Standard for Functional Modeling Language - Syntax and Semantics for IDEF0, IEEE Std. No. 1320.1-1998.
12. Jaklic, J., Stemberger, M.I., Kovacic, A. and Vuksic, V.B. (2002), Evaluation of Alternative E-Business Models by Business Process Simulation Modeling, Proceedings of the WSEAS International Conferences - Simulation, Modelling and Optimization (ICOSMO), Skiathos, Greece, pp. 1301-1306.
13. Lee, H.L. and Billington, C. (1992), Managing Supply Chain Inventory: Pitfalls and Opportunities, Sloan Management Review, Spring, pp. 65-73.
14. Mujtaba, M.S. (1994), Simulation Modelling of A Manufacturing Enterprise with Complex Material, Information and Control Flows, International Journal of Computer

Integrated Manufacturing, Vol. 7, No. 1, pp. 29-46.

15. Oscarsson, J. and Moris, M.U. (2002), Documentation of Discrete Event Simulation Models for Manufacturing System Life Cycle Simulation, Proceedings of the 2002 Winter Simulation Conference, San Diego, CA.
16. Paul, R.J., Giaglis, G.M. and Hlupic, V. (1999), Simulation of Business Process, American Behavioral Scientist, Vol. 42, No. 10, pp. 1551-1576.
17. Peppard, J. and Rowland, P. (1995), The Essence of Business Process Re-engineering, Prentice-Hall, Hemel Hempstead.
18. Petrozzo, D.P. and Stepper, J.C. (1994), Successful Reengineering, Van Nostrand Reinhold, New York, NY.
19. Pritsker, A.A.B. (1986), Introduction to Simulation and SLAMII, John Wiley; Systems Publishing Corporation.
20. Profozich, D. (1998), Managing Change with Business Process Simulation, Prentice-Hall, Englewood Cliffs, NJ.
21. Schriber, T.J. and Brunner, D.T. (1996), Inside Simulation Software: How It Works and Why It Matters, Proceedings of the 1996 Winter Simulation Conference, SCS, pp. 23-30.
22. Stalk, G. Jr. and Hout, T.M. (1990a), Competing Against Time: How Time-Based Competition Is Reshaping Global Markets, Free Press.
23. Stalk, G. Jr. and Hout, T.M. (1990b), Redesign Your Organization for Time-Based Management, Planning Review, Jan./Feb, pp. 4-9.
24. Turbide, D.A. (1993), MRP+: The Application, Enhancement, and Application of MRPII, Industrial Press Inc..
25. Vollmann, T.E., Berry, W.L. and Whybark, D.C. (1992), Manufacturing Planning and Control Systems, Irwin.
26. Zakarin, A. and Kusiak, A. (2001), Process Analysis and Reengineering, Computers & Industrial Engineering, Vol. 41, pp. 135-150.