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On Role of Planning and Control Components in Mutually Connected Business Processes

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Abstract

Mutually connected business processes have both logistics process and planning and control components. The Little's theorem describes that for a queuing system in stationary situation, average demand rate multiplied by average number of inventory is average lead time. This paper shows what role a planning and control component plays in forming such a dynamic property of a business process as a whole. Some relation among lead time, planning cycle and release of orders will be considered. It is shown that "slow planning" leads the whole connected business process to slow behavior with thick inventory.

Keywords

Mutually connected business process, planning component, slow planning, dynamics of business process

1. Introduction

Information systems exist not in a vacuum for *per se*. It plays both roles of operating system of complicated combination of human business activities and hardware and control system of the combined process. As an operating system of such a business process, information system should provide neat mechanism that can handle and record tremendous amount of day-to-day transactions. As a controller with a business process, it is indispensable to achieve customers' satisfaction and adaptation to business environment. If a travel company, for example, cannot have any access to a reservation system, it would not survive. A reservation system provides necessary data that controls flow of business activities. Furthermore, business needs many firms, and then it forms a huge business process. Taking a look at mutual business connection among companies in textile-related industry in Japan, we see that many firms are operating. According to a report by Textile and Clothes Information Centre in Japan (1998) the area of production and wholesale of cotton spinning, silk, and synthetic fibres has 2,137 firms; that of yarn has 7,960; that of textile has 49,664; that of clothing has 283,292. As a whole they sold around 500 trillion $ in 1994, that is one tenth of Japanese GDP.

They are connected by supplier-consumer relationship. Each has its own optimal operation. And they are calling for whole planning and control mechanism. The fashion-business-architecture (FBA), developed by the Japan Department Stores Association and Japanese Apparel Industry Council (2001), is an example developed from such needs. The FBA aims to establish a control mechanism through a form of business protocol for contract.

Like this, planning and control is getting much more important in business operation to attain lean inventory, yet satisfying customers' and other stakeholders' requirements. Sharing information these days is easier and detailed than former days, thanks to the development of information technology. Ubiquitous computing and network accelerates the movement. Radio frequency identifications (RFID) and micro equipment developed by nano-technolgy will bring us much more "deep data" so that we see more possibility for developing accurate and fine-tuned operation of the business process as a whole. Most data in logistics can be stored in an item with such small devices. A stock keeping unit (SKU) seems to become an item, instead of a set of same items. But effective use of such information is not trivial. It is a challenge for planning and control of business process operation.

The number of IT/IS-oriented students are declining in major universities in USA, according to Informationweek[Nikkei Compueter, NikkeiBP, p24-25, 2003]. In the current situation, if we do not develop a design framework for information system and business process, the academic and business area of information systems might be shrinking. People will see IS people playing with gadget such as network and computer softwares. If so, youngsters may not come into the IT/IS area, IS-related research area would be small, and then the chance for society to be wealthy and convenient with highly functional business processes and information systems. Thus, we need a kind of grand theory that covers information system and business process.

We consider, in this paper, basic mechanism of planning and control of business process. Taking planning and control function as a business process, we will show relation between the lead time and planning cycle of a business process. This result gives some insight into the control of mutually connected organization, that is, the management of supply chain of diverse organizations.

2. Integration of Production and Supply Chain Planning

Supply chain process can be described by a similar structure with production process, using the concept of distribution product (Tanaka 1988). A distribution product is defined by a distribution bill of materials (a distribution BOM, for short) in Fig. 1. Usually three levels will suffice to define a distribution BOM. Level 0 corresponds to delivered products at customers (retailers or shops). Level 1 corresponds to a distribution centre that is linked to customers who will be delivered from the distribution centre. There might exist some depot's between a distribution centres and customers. The geographic locations of depot's and distribution centres decide the logical link between them, and then the relation is fixed. So, we do not need to include such depot in distribution BOM. In Figure 1, A2 at level 1 represents that two items of product A is planned to be delivered from the distribution centre 2. The number 5 at the upper right of A2 means quantity per unit of parent. That is, the order S requires 5 items of product A. Level 2 corresponds to warehouse of factories.

Usual materials requirements planning (MRP) set lead times of operations in routings (Silver, Pike&Peterson 1998, Vollmann, Berry&Whybark 1997). Since work-in-process (WIP) inventories form queues waiting for operations, the plans resulted from MRP calculation become infeasible when the sum of queuing time and processing time is bigger than predefined lead times. One way to avoid this inconvenience is to use bottom-up calculation based on schedule with Gantt charts. Each necessary operation will be deployed in a possible position of the chart, and then feasible plan with necessary queuing time. That is, planning is incorporated with scheduling. So-called advanced planning system (APS software) can be used to do it.

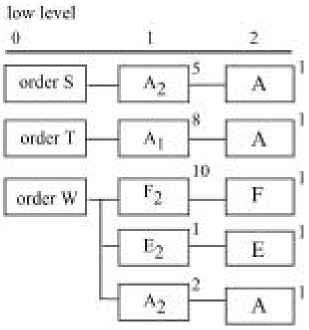

Figure 1. Distribution BOM

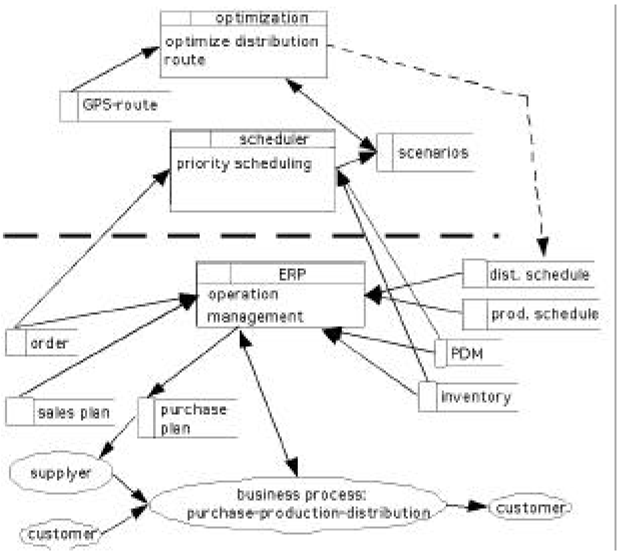

Figure 2. Schema for integrative scheduling

True optimality is hard to calculate for such scheduling because of combinatorial explosion. So, simple backward-and-forward scheduling is usually used.

Fig. 2 is a schema for integrative planning and scheduling of business process. The lower half of the figure depicts implemented process within which transactions are stored in an enterprise resource planning software (ERP), like SAP R/3TM. Production planning and control is also taken place with the data in ERP. The functions in the upper half are responsible to achieve the optimality in scheduling and planning for production and delivery logistics.

Sato and Tsai (2003) developed a real-time production planning and control system that can be extended to integrative scheduling. It does not require WIP for parts but employ buffers for purchase lead time and safety stocks.

3. Modeling Business Process

The product data management (PDM) with BOMs, routings and work centers, which are shown in section 2, certainly provides us with a practical and convenient way to describe business processes. But, in order to deal with dynamic characteristics of business process, we first need a suitable modeling. A business transaction system is a discrete-event model of business process with information system (Sato&Praehofer 1997). It has intrinsic structure that can be drawn with a diagrammatic tool defined below, and also has precise state transition mechanism.

Definition 1. Activity Interaction Diagram (AID) (Sato&Praehofer 1997)

An activity interaction diagram is a diagram that has three kinds of components. They are activities, queues, and connecting queues. Activities should be connected with queues, and vice versa. That is, in the graph theoretic sense, an AIC is an alternative directed graph.

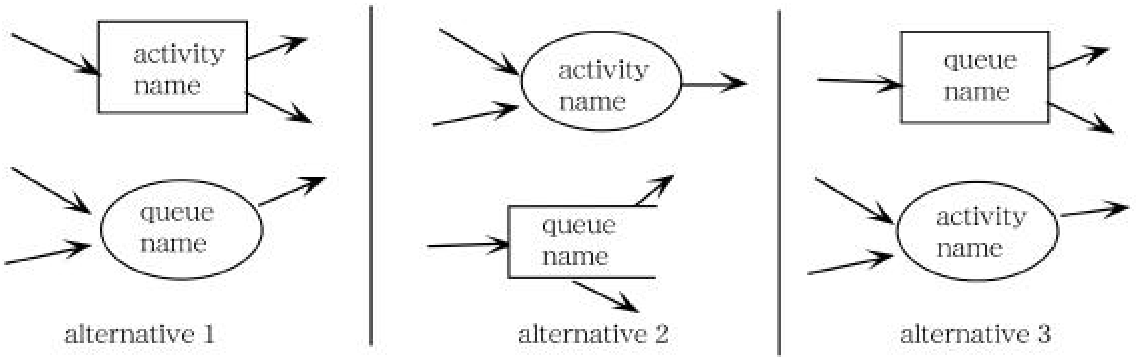

Figure 3. Components of activity interaction diagrams

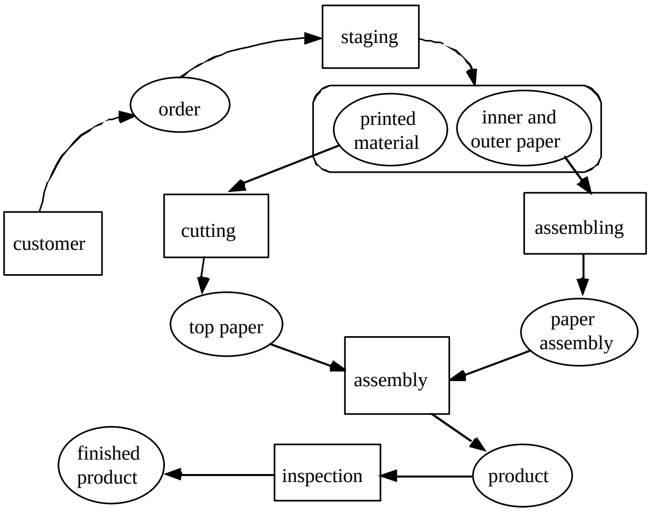

Figure 4. Assembly process

There are several ways to draw an AID as shown in Figure 3. An assembly process is depicted as Figure 4. Orders come into the process from customers, and are accumulated in the order-queue. The worker who is assigned to staging processes customer orders, one by one. The outputs of staging are small material and big material, which will make respective queues. Small material is input of assembly for small part. After assembly, the activity produces small part. The other portion of the assembly process works in similar way.

An important issue in business process engineering is to establish a way to trace the behavior of a business process. Evaluation of business operation and planning based on that are only possible when such method is developed. Since any dynamic system can be described by its state transition when the system has a state transition function, we need to have that function for a business transaction system.

Business transaction system has the state transition function of which structure is common in other dynamic systems such as continuous systems described by differential equations and discrete-time systems described by difference equations. In the case of business transaction systems, the behavior is described by the set of the activities and queues within the system, since they consist of the state space of a business transaction system. Figure 5 shows a state transition table of the assembly process with a given set of operation parameters. The point is that such dynamic behavior is precisely provided for a business transaction system based on its discrete-event nature. In the following, a business process and a business transaction system are used interchangeably.

time	Cust	OrdQ	Stg	MaSQ	AssS	MaBQ	AssB	SPtQ	BPtQ	Ass	PrdQ	Isp	PWH
0	odNo 1(4)	0	-stg-	0	-SAm-	0	-BAm-	0	0	-Asm-	0	-Ins-	0
4	odNo 2(4)	1	-stg-	0	-SAm-	0	-BAm-	0	0	-Asm-	0	-Ins-	0
4	odNo 2(4)	0	1(5)	0	-SAm-	0	-BAm-	0	0	-Asm-	0	-Ins-	0
8	odNo 3(4)	1	1(1)	0	-SAm-	0	-BAm-	0	0	-Asm-	0	-Ins-	0
9	odNo 3(3)	1	-stg-	1	-SAm-	1	-BAm-	0	0	-Asm-	0	-Ins-	0

Figure 5. State transition of assembly business process

4. Dynamic Change of Lead Time and Queue Formation

Before we go to investigate the dynamics of logistics process of a business transaction system with planning component, we observe business system without planning. It provides us with fundamental dynamics of business processes. We focus on the relation between the cyclic behavior and lead time of a business transaction system. A simplified assembly process depicted in Figure 6 is used for that purpose.

Assume that process is in stationary operation so that we can think of average of some aspects of a system. Let W be the average lead time, T the average number of items in the system, and L the average time interval of arrival of items (Figure 7). Then, the Little's theorem (Little 1961) describes the fundamental relation between three indices of the process

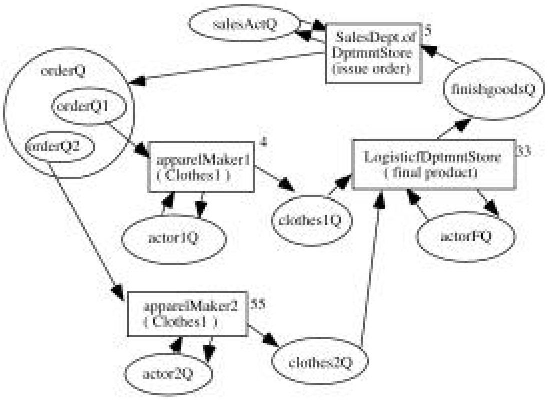

Figure 6. Simplified apparel process

as follows. (Technically speaking, the equation with these three probabilistic variables holds true almost everywhere in the sense of probability theory.)

$$W= TL$$

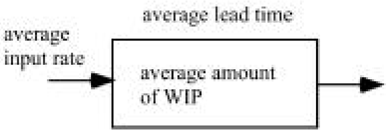

Figure 7. Little's theorem

A path in a business process (i.e., a business transaction system) is a sequence of arrows in its activity interaction diagram (following the direction of each arrow). If a path starts from an activity comes in the same activity, then it is called a cycle, or a circuit. A critical cycle is a cycle that has the maximum average processing-time per one peace of objects. Materials, data of requests, persons, and anything that is waiting to be processed, are example of such objects.

If arbitrary two activities in a business process have a connecting path starting from each activity, then the process is said to be strongly connected. Figure 3 is strongly connected, while figure 2 is not.

If a business process will not be in dead locked, then it is said to be live. Formally, the process is live if and only if its state transition will not stop and all of its activities will start and stop again and again.

Now, we drastically simplify business process so that we can analyze its basic behavior. From now on, we assume that only one kind of product is produced and sold to customers. That is, we assume that all products in orders are identical, and then, we only focus on the number of products in an order. This assumption allows us to consider similar situation to the Little's theorem. The point in this research is that we can analyze internal mechanism in addition to the fact that is stated by the Little's theorem. It has been shown that the class of this kind of business processes are isomorphic to a class of certain kind of Petri nets (Sato 200a, 200b).

Theorem 1 (Sato 1999)

Every strong and live (simplified) business process has periodic behavior. That is, in a long run, its state transition becomes periodic with a period.

Theorem 2 (Sato 1999)

If a process behaves periodically, then the number of items that are processed by each activity on a circuit is the same.

Theorem 3 (Sato 1999)

If a process is strongly connected, then the number of items contained in a circuit of the process remains the same at any progress of state transition.

Let the number of input items to an activity within a period be k, its period S, and the number of items in a circuit L. Then we have that W = L*(S/k), according to the Little's theorem. Table 1 shows the simulation result, where the respective number of workers assigned for activities are three.

number of items in a cycle: L	period: S	number of input items in a period: k	average interval of arrival: S/ k	lead time:
2	96	2	96/2	96
5	96	5	96/5	96
6	57	3	57/3	114
25	57	3	57/3	475

Table 1. Simulation result

5. Issues on Dynamics of Business Process with Planning Components

Figure 8 shows a business process within which a planning component is introduced. Notice that almost all information on the queues and activities within the business process is the input of the planning and control component. The function of the planning component is modeled twofold. First it will get data of current status, and secondly, it releases production orders at appropriate times.

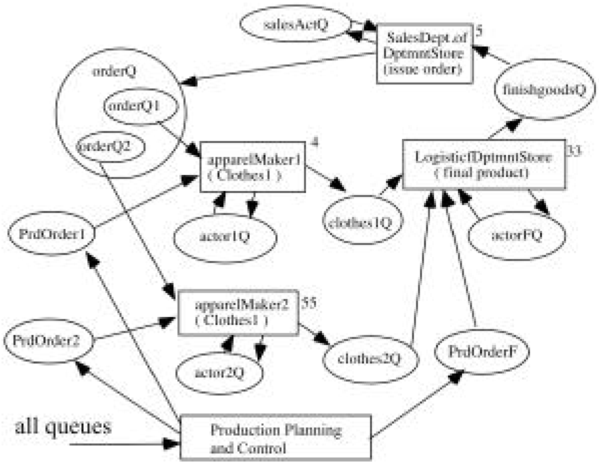

Figure 8. Simplified assembly process with planning component

Basic characteristics of ideal planning component are as follows.

(1) It releases production orders precisely that are feasible, using Gantt chart technique.

(2) So, if there is no machine break down or delay of suppliers, no queue of orders will be formed and then lead time will be the same as planned. Uncertain change in planned lead times of activities caused by unexpected queue formation is main source of the variable and unexpected lead time of the whole production process.

Even if we have an ideal planning component, there is a huge room in selecting evaluation attribute for schedule. Examples are makespan, inventory level, service level on due date, and so on.

Applying theoresms 1 through 3 to a business process with an ideal planning component, we have the following.

Theorem 4

Assume a business process satisfies the following operational

- Each activity has one work resource to perform.
- Planning period is longer than duration of activities.
- One kind of finished product that has parts is manufactured.
- A routing (a set of production processes) for the product is fixed.
- The production for the product goes as planned.

Then the followings hold.

(1) In a steady operation, the whole process shows periodic behavior.

(2) Even in that case, some activities have inventories in front of them.

(3) There are critical cycles. The part of business process, which forms a critical cycle, varies depending on the number of objects in the whole process.

(4) If there are many items, the planning component and its resource forms a critical cycle. That is, it will be the bottle neck of the whole process. To avoid this, you need frequent update of planning.

In the rest of this section, we state conjectures on dynamic properties of business processes with planning components.

Assume that a mutually connected business process operates as follows.

- Many companies, like the textile industry, are involved in the whole business process.
- Demand rate for finished products is constant.
- Many products with respective routings are manufactured.
- Production goes as planned.
- Due dates of customer orders can be confirmed based on the capacity of the process.
- The whole process contains many companies. Each has its own planning system.

Case 1: Modest demand

The critical cycle would be formed across firms. That is, a chain of many companies forms a critical cycle. The whole lead time depends on the demand rate.

Case2: Excessive demand

The critical cycle would be formed in a firm within the whole process. Especially, the planning system and planning component of that firm can be a critical cycle of the whole process, depending on the rate how much frequently updates production plans.

6. Conclusion

This paper first put a framework of business process engineering with respect to analysis of dynamic behavior. Network of business processes is a multicomponent DEVS (Zeigler 1976, 1984) called a business transaction system, or simply, a business process. It is known that the lead time of a whole business process is not the sum of lead times of component processes, and that critical cycles play important role.

This paper has shown that both character of ideal planning component in business process and the effect of planning cycle on dynamics of the resultant business process (Theorem 4). An important implication from the theorem is that if the process is governed by "slow planning" mechanism, then it leads the whole connected business process to slow behavior with thick inventory.

Using APS (advanced-planning-system software) for supply chain planning and control seems to be effective, though it is often said that a planning system for a group of firms may be difficult to be effective.

Based on the consideration in this paper, we can say that scheduling with exact feasibility is inevitable to attain effective operation in ubiquitous computing and network era.

Acknowledgement

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