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시간과 능력을 고려한 공급사슬 경영에서의 생산-분배 계획을 위한 시뮬레이션과 최적화모델의 적용

Production-distribution Planning in Supply Chain Management Considering Processing Times and Capacity Using Simulation and Optimization Model

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ABSTRACT

Analytic models have been developed to solve integrated production-distribution problems in supply chain management (SCM). As one of major constraints in analytic models, capacity, which is the total operation time in this paper has mostly been known or disregarded assuming infinite capacity. Also, as major factors, machine processing time to fabricate or assemble a part or product at a certain machine center in production system and vehicle processing time to deliver a product to a customer by a certain vehicle in distribution system have been fixed and regarded as a static factor. But in the real systems significant differences exit between capacity and the required time to achieve the production-distribution plan and between processing time and consumed time to process a part or product. In this paper, capacity and processing times in the analytic model are considered as dynamic factors and adjusted by the results from independently developed simulation model, which includes general production-distribution characteristics. Through experiments, we obtain the more realistic solutions reflecting stochastic natures by performing the iterative analytic-simulation procedure.

1. INTRODUCTION

SCM is the management of material, information and fund flows through the supply chain such as vendors, manufacturing plants and distribution centers. SCM is not far from the management of general manufacturing and distribution system. But it has a broad scope that includes sub-suppliers, suppliers, internal operations, intermediate storage point, retailers, and customers. Therefore, production and distribution plan in SCM is needed to be solved in the integrated way.

In SCM, the production-distribution planning is one of the most important problems. The production planning is the design of process and management of entire manufacturing process, such as material handling, scheduling and inventory control, *etc.* The distribution planning is the process determines how products are retrieved and transported from the factory or warehouse to customers. One of major constraints in the model of production-distribution planning problems is capacity. Capacity is regarded as total operation time of system in this paper. One of major factors in the analytic model is processing time that is the time to produce unit product or distribute unit product. We consider two processing times: machine processing time and vehicle processing time in this research. Capacity and processing time are closely related with each other and they affect the optimal production-distribution plan significantly.

In this paper, we propose an integrated analytic model for production-distribution under SCM environment and consider capacity and processing times in this model as stochastic factors and adjust these factors by the proposed specific process according to the results from independently developed simulation model, which includes general production-distribution characteristics. Based on this procedure we obtain the proper capacity to satisfy the customer demand and provides more realistic solutions for production-distribution planning under SCM environment.

2. BACKGROUND

Analytic models have been developed to implement SCM in real logistic world. There are a few researches which have been studied recently for finding optimal production-distribution planning considering capacity.

In the most of analytic models, capacity which is the total operation time for production-distribution system has mostly been known and fixed. But for the real systems, capacity should not be considered as a static factor. Because production-distribution chain can produce a wide variety of dynamic behaviors such as machine and vehicle breakdowns, repair times, queuing, transportation delay, traffic congestion which can not be simply considered as fixed values. Assigning fixed value to capacity may fail to represent the system in reality. It may be ended up with non-realistic production and distribution plan which is far away from the realistic one.

As major factors in production-distribution planning problems, machine processing time to fabricate or assemble a part or product at a certain machine center in production system and vehicle processing time to deliver a product to a customer by a certain vehicle in distribution system have not been considered in the dynamic way. They are fixed and regarded as static factors in many researches. But in the real systems significant differences exit between processing time and consumed time to process a part or product. Assigning fixed value to processing time also may fail to describe realistic system. It may conclude with non-realistic plan which is not the same as the realistic one. In order to estimate exact capacity to cover the demand and obtain optimal production-distribution plan based on this capacity, processing times and capacity which affect the plan should be considered dynamically.

A simulation model is a dynamic or an operating model of a system or problem entity that resembles the operating behavior system or problem entity and contains its functional relationships. It can describe the system in detail with realistic situation and is preferred when an analytic solution can not give proper values for performance evaluations.

3. PROBLEM DESCRIPTION

To illustrate modeling of the production-distribution planning problem in

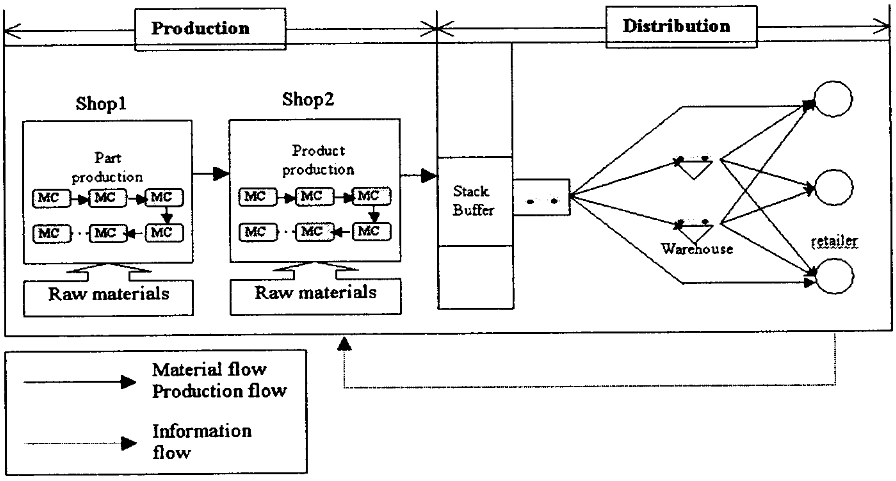

Figure. 1. A Proposed System

SCM, we consider a multi period, multi product, multi shop production and distribution problem where each shop in production model produces several products and these products are distributed to retailers within the given period. The structure of a multi period, multi product, multi shop production and distribution system is described in Figure 1.

The first shop of production system produces *n* different products that are used in the production of *m* different products at the second shop of production system. An example is a general manufacturing system where the first shop consists of fabricating machines machining a number of different types of parts and the second shop contains assembling machines that use the parts in producing several types of products.

The distribution system contains the stack buffer where all products produced in production system are temporarily stored and intermediate warehouses storing all kinds of products and retailers that are the origin of demand. Products are transported in unit size from the stack buffer either to warehouses or to retailers directly or moved from warehouses to retailers to satisfy their demand. The problem is to meet the production and distribution requirements at minimum costs of production, distribution and inventory, subject to various resource constraints.

The production and distribution system are interrelated with each other. The amount of demand from the distribution system is the production quantity that the production system should produce. And all products produced in production system should be transported to retailers or stored at storage points in distribution system. As can be seen from Figure 3, two sub-systems in production system, shop1 and shop2, are closely related with each other. The production rate of shop2 affects the production rate of shop1. In other words, the amount of parts produced in shop1 is decided by the amount of products produced in shop2. Raw material requirements for parts and products are also decided by the amount of products to be produced in shops. In the design of the model, we set the following assumptions: the customer demand is known and time-variant, Backlogging of demand is not allowed, all costs are given, production and distribution capacities which are adjusted through simulation are initially given. Through this model, we decide production-distribution plan that is when and which product, how much of it should be produced and should take which route to retailers and store how much of products at which storage point to minimize the total cost within a certain period

4.MODEL DEVELOPMENT

In the analytic model, decision variables which are the quantity of product produced and the distributed are definitely affected by processing times and capacity. There are two types of processing times in the proposed system; machine processing time and vehicle processing time, machine processing time is the time to fabricate or assemble a part or product in production system and vehicle processing time is the time to deliver a product to warehouse or customer in distribution system. Capacity is the total operation time for production-distribution system. All products should be produced and distributed within the capacity. Therefore, the amount of products produced and distributed at each system in each period is affected by both processing times and capacity. In these formulations, processing times and capacity are initially given and then, adjusted by the result of simulation which accommodate the real manufacturing environment. We formulate this whole situation as a linear program.

5. THE SOLUTION METHOD

Assigning processing times and capacity in the analytic model is a difficult task. Because the consumed time to realize the production and distribution plan are complex and non-analytic functions of decision variables which represent stochastic natures in real systems. It is therefore proposed to use a simulation model to accommodate real processing times and capacity in the analytic model. We regard the flow time that is overall time that all products spend in the system from simulation model as the required capacity to produce and distribute all products. We run the analytic-simulation model iteratively until the difference in total flow times between two models is small enough to be accepted. If the difference in flow times of the analytic model and simulation model is close enough, we regard the analytic model reflects the realistic situation through the simulation model.

The procedure is consists of the following steps:

Step 1. Obtain production and distribution plans from the analytic model using assumed data of processing times and capacity.

Step 2. Calculate flow time (FLP) by the analytic formulation. FLP is the sum of the total time simply calculated by multiplying the processing time for a unit of product by the number of that product.

Step 3. Input the production and distribution plans to the independently developed simulation model and simulate (make 15 replications for each iteration) the system subject to realistic operational policies.

Step 4. Obtain processing times for each machine (MPT) and each vehicle (VPT) and flow time (FSIM) from simulation model.

Step 5. If the rate of difference in flow time of FLP and FSIM is close enough (within the rate between 0.01-0.02 in this paper) hen go to step 7. Otherwise go to step 6. Difference rate is calculated by following formulation.

$$\frac{|FLP - FSIM|}{FSIM}$$

Step 6. Adjust processing times and capacity constraints for the analytic model based on the simulation results (MPT, VPT, FSIM) from step 4 and regenerate production and distribution plans and go to step 3.

Step 7. Production and distribution plans obtained by the analytic model may be considered to be optimal solutions.

Step 8. Stop.

This solution procedure is illustrated by a flow diagram in Figure 2.

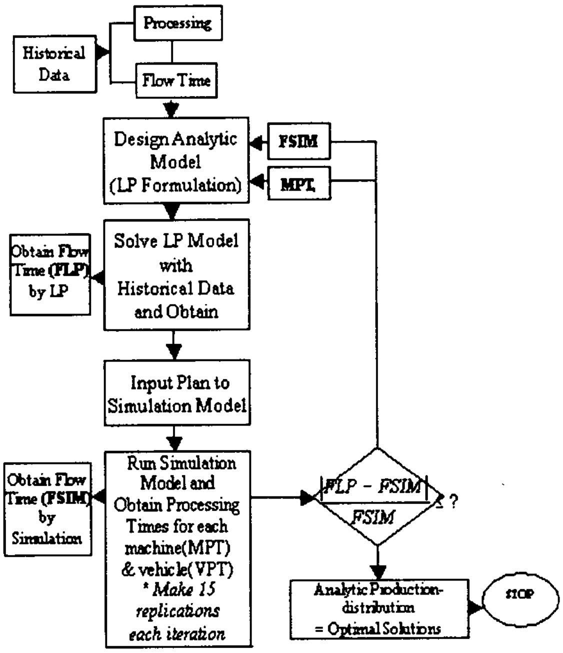

Figure 2. An Iterative Solution Procedure

6.EXPERIMENTS

The iterative analytic-simulation approach is applied to a cost minimization problem of the production-distribution system. The production system consists of 2 shops, each shop having 3 machine centers, each machine center having 1 machine. Parts and products are moved between machine centers by non-accumulating belt conveyors.

The distribution system comprises of 1 stack buffer and 2 warehouses and 3 retailers. Products are transported along the routes by the unit vehicle which can load one unit of finished product. The stack buffer and each warehouse have a unit vehicle. For purposes of simplicity we consider only one period. Capacity of the system is initially 14440 minutes. This means that all products that are required from retailers should be produced and distributed within 14440 minutes. The process routings and initial process times in production system and distribution times according to routes are shown in Tables 1-3. We assume that available quantity of raw materials and product holding capacities at the stack buffer, warehouses and retailers are sufficient.

For simulation, we consider random processing times and random machine/vehicle operations: each machine processing time and vehicle processing time to produce or

Table 1. Production Process Routings

Shop1		Order			Shop2		Order		
Part (i)	1	MC1-1	MC1-2	MC1-3	Product(j)	1	MC2-1	MC2-3	MC2-2
	2	MC1-1	MC1-3	MC1-2		2	MC2-1	MC2-2	MC2-3

Table 2. Processing Times in Production

Machine center (u)		1	2	3	Machine center (v)		1	2	3
Part (i)	1	1	1	1	Product (j)	1	3	6	4
	2	1	1	1		2	4	7	5

Table 3. Processing Times in Distribution

From \ To	Warehouse 1	Warehouse 2	Retailer 1	Retailer 2	Retailer 3
Stack	15	20	40	35	50
Warehouse 1			25	30	25
Warehouse 2			30	25	20

distribute each part or product follow exponential distribution with mean of its own static value given in Table 2, and MTBF and MTTR for each machine and vehicle follow exponential distributions with mean of 500 and 2 minutes respectively where MTBF is Mean Time Between Failure and MTTR is Mean Time To Repair.

The difference in flow times between FLP and FSIM are given in Table 4 and depicted in Figure 3. As can be seen from Figure 4. The difference in total flow times steadily reduced reaching a minimum in iteration 20 whose difference rate is only 1.217%. Note that, starting from quite poor estimates of flow times, the difference rate is approximately 5% at 4th and 5th iteration, probably acceptable for planning purpose. As can be seen from the Table 4, optimal capacity to satisfy the demand is 20450 minutes. This value is very different from initially given capacity for analytic model. In order to produce and distribute required demand, 6010 minutes of additional capacity is needed. Based on this optimal capacity, we obtain optimal production-distribution plans which are shown in the last column of Table 4.

7. CONCLUSIONS

In this paper, we consider processing times and capacity in production-distribution planning problem as stochastic factors to obtain more realistically feasible plans under SCM environment. We propose LP formulation for an integrated production-distribution system and design an iterative method combining the analytic and simulation model to solve the problem. The iterative method uses advantages of both modeling methods while avoiding demerits of both methods.

The iterative method provides more realistic optimal solutions with respect to the analytic model for the integrated production-distribution planning that are quite different from the initial analytic solutions.

Table 4. Difference Rates in Total Flow Times of Analytic and Simulation Model

Iteration Number	Flow Times		Difference Rates (%)
	FLP	FSIP	
Initial Data	14440	24255	40.466
1	20233	22307	9.298
2	20555	22009	6.606
3	20952	22250	5.834
4	21332	22502	5.200
5	21982	23104	4.856
6	22119	23056	4.064
7	22207	21462	3.471
8	20718	20057	3.296
9	20449	19892	2.777
10	19721	19231	2.548
11	19454	19004	2.368
12	19429	18993	2.296
13	19217	19892	3.393
14	19803	20371	2.788
15	20057	20974	4.372
16	20453	21252	3.760
17	20809	20511	1.453
18	20673	20402	1.328
19	20533	20885	1.685
20	20702	20453	1.217
Optimal Production-distribution Plan with the Capacity of 20th iteration : X1=580 ,X2 =870, Y1=75, Y2 =70, L-P1:80, L-P2:0, L-Q1:25, L-Q2:0, L-Q3:40, P1-Q1:30, P1-Q2:50, P1-Q3:0, P2-Q1:0, P2-Q2:0, P2-Q3:0, X1 = amount of part1, X2 = amount of part2, Y1 = amount of product1, Y2 = amount of product2, L-P: amount of product delivered from stack to warehouses (1,2), L-Q: amount of product delivered from stack to retailers (1,2,3), P-Q: amount of product delivered from warehouses (1,2) to retailers (1,2,3), I = initial values from given data			

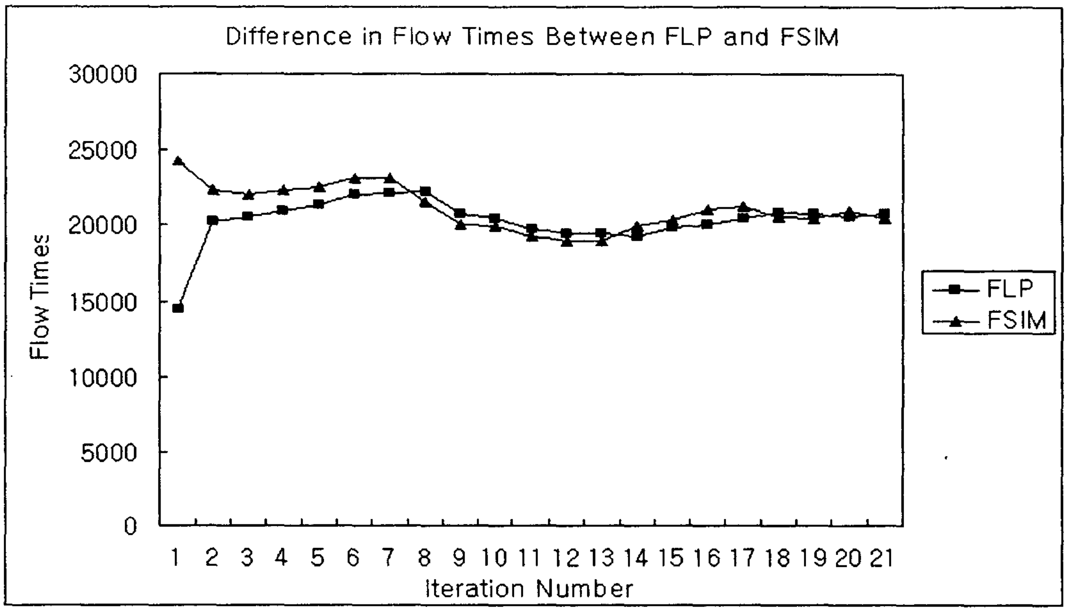

Figure 3. Difference in Flow Times Between FLP and FSIM

We also present an efficient algorithm that can find realistic and optimal capacity for production and distribution.

Formulating more realistic analytic model and simulating more complicated and realistic situations for obtaining more feasible solutions are proposed as further research areas.

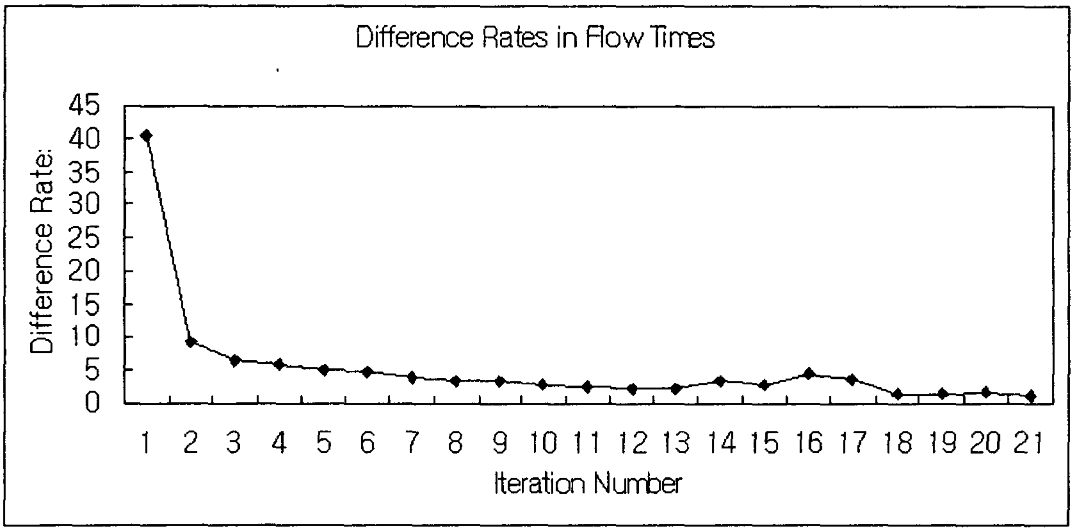

Figure 4. Difference Rates in Flow Times

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