

Studies on the Priority Rule for Production Planning in MRP system

Daiju NAKAGIRI and Sennosuke KURIYAMA

MRP システムにおけるプライオリティ指標を用いた生産計画に関する研究

中桐大寿・栗山仙之助

[Abstract] As for the conventional study of MRP system, the critical ratio rule has taken the remaining time until due date into consideration has been commonly utilized for a characteristic of the operational priority rule. In this paper, a characteristic of new priority rule was proposed in order to remove the defect of the critical ratio rule. To put it concretely, both of backorders and outstandings were introduced into this priority rule as a substitution for considering the due date. The superiority of the proposed rule over the critical ratio rule was proved by the use of the model experiments.

1. Preface

MRP system is widely noticed as one of the most advanced methods of production control in the recent days of jobbing production (multi-item, small-sized production) with the diversification on the part of customers' needs [1]. In this system, required materials are supplied according to the aggregate production planning, which results in not only effective utilization and smooth supply, but also raised production process and high productivity. Just in time supply of required materials is an important factor of production management for the discussed system. As for this study, the critical ratio rule taking the remaining time until due date into consideration is used for the operational priority rule [2] [3].

But since backorders and stock on orders were not considered, the lack of accuracy in schedule is not avoidable when the operational priority is decided [4].

In this study, a new priority rule is proposed in order to remove the defect of the critical ratio rule. The new priority rule is utilized under the consideration of backorders and stock on orders in the MRP system dealing with the part explosion in the production planning. Furthermore, the superiority of the proposed rule over the conventional rule is proved by the use of the model experiment.

Received September 6, 1993

2. Requisite for the model

The MRP package in this paper, as shown in Figure 1, consists of three functions; total required quantity calculation, available stock quantity calculation and order quantity calculation. [5] In order to perform these three functions the MRP package requires a master production schedule along with a bill of materials and a bill of stock condition.

Figure 2 shows the relations as to how parent material u_j is made by materials w_1, w_2, \dots, w_j of kind j_i out of kinds l and n kind of parent product P_i is made by materials u_1, u_2, \dots, u_m of kind i_m from kind of m manufactured in that way.

Table 1 shows the bill of materials of parent product P_i and Table 2 shows the bill of materials of child part u_j .

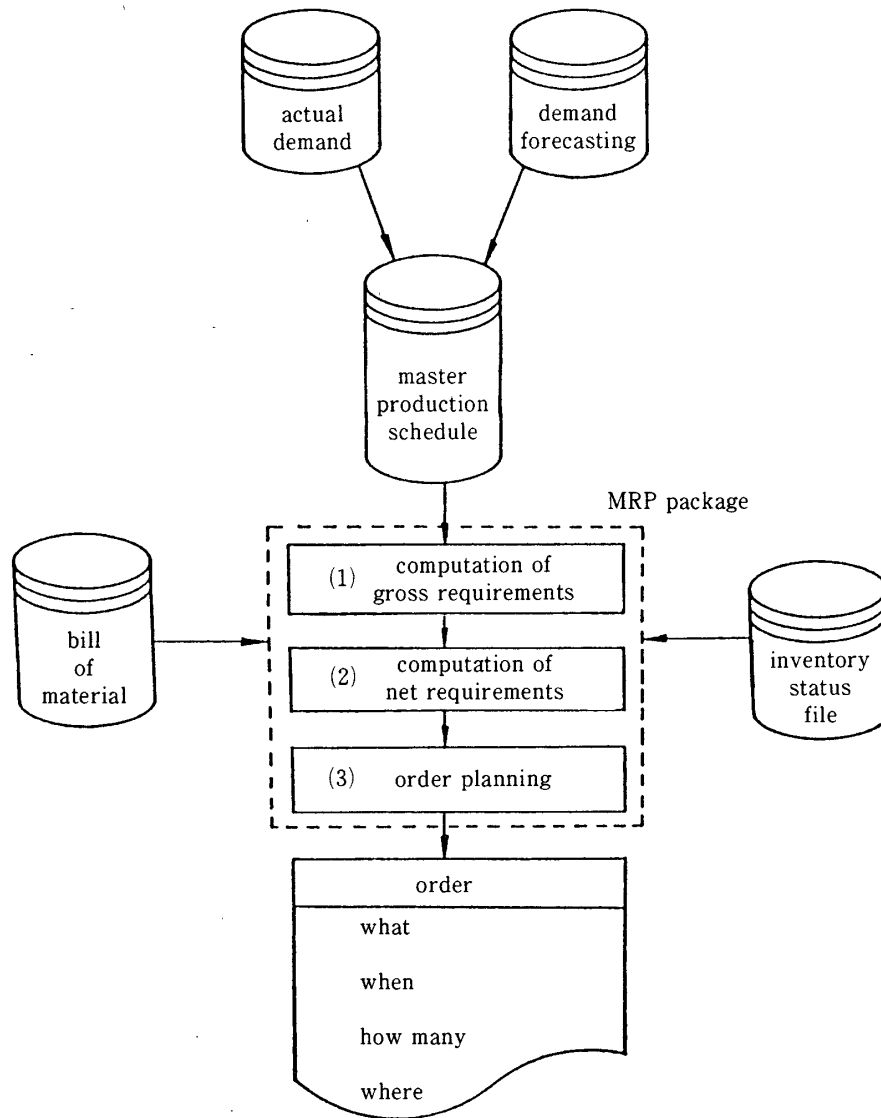


Fig. 1 MRP package

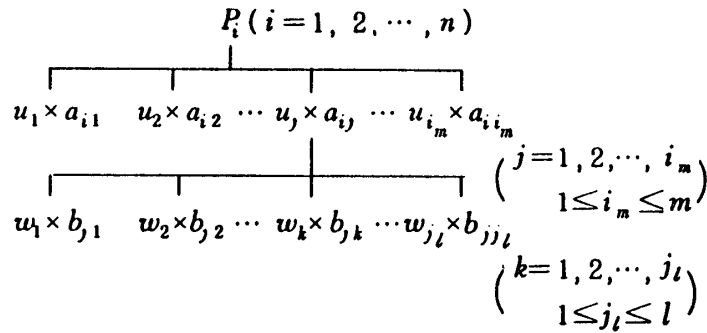


Fig. 2 Bill of Material

Table. 1 Bill of materials of parent product P_i

		final products					
		P_1	P_2	...	P_i	...	P_n
component materials	u_1	a_{11}	a_{21}	...	a_{i1}	...	a_{n1}
	u_2	a_{12}	a_{22}	...	a_{i2}	...	a_{n2}
	\vdots	\vdots	\vdots		\vdots		\vdots
	u_j	a_{1j}	a_{2j}	...	a_{ij}	...	a_{nj}
	\vdots	\vdots	\vdots		\vdots		\vdots
	u_m	a_{1m}	a_{2m}	...	a_{im}	...	a_{nm}

Table. 2 The bill of materials of parent part u_j

		component materials					
		u_1	u_2	...	u_j	...	u_m
materials	w_1	b_{11}	b_{21}	...	b_{j1}	...	b_{m1}
	w_2	b_{12}	b_{22}	...	b_{j2}	...	b_{m2}
	\vdots	\vdots	\vdots		\vdots		\vdots
	w_k	b_{1k}	b_{2k}	...	b_{jk}	...	b_{mk}
	\vdots	\vdots	\vdots		\vdots		\vdots
	w_l	b_{1l}	b_{2l}	...	b_{jl}	...	b_{ml}

In this study the following five points are considered as a model supposition :

- (1) Applying MRP to jobbing production, the production form of the final product is based on the production to order system.
- (2) The production of materials consists of the mixture of the production to order system and the stock considering in-process after the final order quantities are fixed.
- (3) The change of production planning (Production Replanning) is made according to the priority rule.
- (4) A master production schedule consists of both the quantities of fixed orders and the

quantities of sales prediction .

- (5) It is supposed that the trouble during the production process does not delay the inspection of material purchases.

3. Model Formula

The order quantities of material u_j is obtained from the following formula which is considered parent product P_i according to Table 1.

$$Nu_{jt} = \sum_i a_{ij} \cdot R_{p_{it}} \quad (1)$$

$$Au_{jt} = Iu_{jt} + Ou_{jt} - Fu_{j,t-1} \quad (2)$$

$$Uu_{jt} = Nu_{jt} - Au_{jt} \quad (3)$$

where,

- Nu_{jt} : total quantities of material u_j during period t
- a_{ij} : required quantities of material u_j used per product P_i
- $R_{p_{it}}$: quantities of product P_i on the master production schedule during period t
- Au_{jt} : available stock quantities of material u_j during period t
- Iu_{jt} : stock quantities of material u_j during period t
- Ou_{jt} : backorder quantities to be delivered during period t
- $Fu_{j,t-1}$: balance of reserve quantities of material u_j during the latter part of period $(t - 1)$
- Uu_{jt} : order quantities of material u_j during period t

In order to formulate the new priority rule according to the master production schedule regarding material u_j shown in Table 3, $Wu_{jt} (t = 1, 2, \dots, T)$ shows the accumulation of t for $Nu_{jt} (t = 1, 2, \dots, T)$ and $W'u_{jt} (t = 1, 2, \dots, T)$ shows the result of Wu_{jt} .

- Wu_{jt} : total required quantities of material u_j used for all the products during period t

3-1 New priority rule

The critical ratio rule taking the due date into consideration is used for making the priority in operations and expresses the ratio of the time remained until due date to the planning lead time remained. It wasn't, however, enough as the criterion on the part of a purchaser. It is the main reason that the expecting date of completion made in the master production schedule is corresponding to the last due date. In this paper, the new priority rule is proposed, where backorders for products which must be manufactured by the due date and stock on orders which must be obtained in time for the production are taken into account.

In this model the production for order is made during period t_0 and the production for stock is made during the remaining period $(T - t_i)$.

The priority index (η) considering backorders is defined as follows.

Studies on the Priority Rule for Production Planning in MRP system

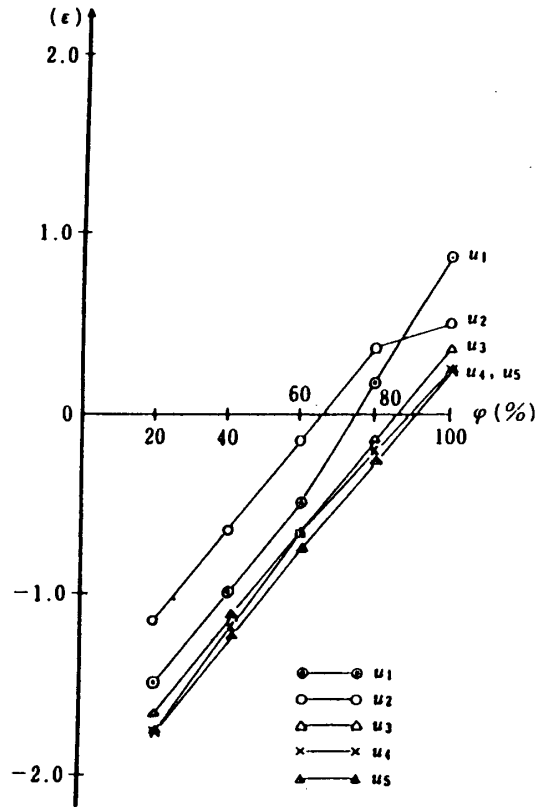


Fig. 3 Relationship between the received order progressive situation rate (ϵ) and the new priority rule (φ)

Table. 3 Master production schedule for the material u_j

period t	1	2	...	t_0	t_1	...	T	
total accumulated required quantities	$W_{u,1}$	$W_{u,2}$...	W_{u,t_0}	...	W_{u,t_1}	...	$W_{u,T}$
total accumulated quantities of delivery	$W'_{u,1}$	$W'_{u,2}$...	W'_{u,t_0}				
stock on orders quantities	$O_{u,1}$	$O_{u,2}$...	O_{u,t_0}				

$$\eta = \frac{W_{u,t_1} - W'_{u,t_0}}{W_{u,T} - W_{u,t_0} - \delta_w I_{u,t_0}} \quad (4)$$

$$\delta_w = \begin{cases} 1 : W'_{u,t_0} > W_{u,t_0} \\ 0 : W'_{u,t_0} \leq W_{u,t_0} \end{cases},$$

where,

t_0 : actual time ($t_0 < t_1 < T$)

W_{u,t_1} : total accumulated required quantities of material u_j during period t_1

W_{u,t_0} : accumulated quantities of delivery goods of material u_j during period t_0

Wu_{jT} : total accumulated required quantities of material u_j during period T

Wu_{jt_0} : accumulated required quantities of material u_j during period t_0

$\delta_w Iu_{jt_0}$: stock quantities u_j during period t_0

And the priority rule (r) considering stock on orders is defined as in the following.

$$r = \frac{Ou_{jt_0}}{Wu_{jT} - Wu_{jt_0} - \delta_0 Iu_{jt_0}} \quad (5)$$

$$\delta_0 = \begin{cases} 1 : Ou_{jt_0} = 0 \\ 0 : Ou_{jt_0} > 0 \end{cases}$$

Ou_{jt_0} : stock on orders quantities u_j during period t_0

The new priority rule (ε) proposed in this research is obtained from formula (4), (5) and is expressed as in the follows.

$$\varepsilon = \eta - r \quad (6)$$

The priority of the operational order is decided according to the material which has a larger ε .

The rate of the received order progressive situation rate of (φ) material u_j is as the follows.

$$\varphi = Wu_{jt_1} / Wu_{jT} \quad (7)$$

The relationship between the received order progressive situation rate (φ) and the new priority rule (ε) is shown in Figure 3. The higher received order progressive situation rate is, the larger an index of the priority rule. It is results in the decision making of giving priority of the operational order to the material which has a bigger index.

3.2 Set of Cost function

The cost (TC) during the planning time remained by the new priority rule (ε) is gained from the follow.

$$TC = \sum_{j=1}^{im} \left[c_1 u_j \sum_{t=t_0+1}^T (t-t_0) (I_{u,t} + QUu_{jt}) + c_2 u_j \sum_{t=t_0+1}^T (Uu_{jt} - QUu_{jt})^+ \right] \quad (8)$$

$$(A)^+ = \max(A, 0)$$

where,

QUu_{jt} : order quantities u_j during period t when using ε

$c_1 u_j$: cost of storage per period

$c_2 u_j$: cost of shortage loss per period

T : planning time

The critical ratio using the priority rule (CR) is expressed as follows.

$$CR = D/L \tag{9}$$

D : the remaining time until the due date

L : the remaining planning lead time

The cost (TC') during the planning time using the priority rule (CR) is gained from the next formula.

$$TC' = \sum_{j=1}^{im} \left[c_1 u_j \sum_{t=t_0+1}^T (t-t_0) (I_{u_j,t} + QU_{u_j,t}) + c_2 U_j \sum_{t=t_0+1}^T (U_{u_j,t} - QU_{u_j,t})^+ \right] \tag{10}$$

$QU_{u_j,t}$: order quantities during period t when using CR

4 Model Experiment

4.1 Purpose of Experiment

This experiment indicates the comparison between the conventional priority rule and the new priority rule considering backorders and stock on order to show the precedence of the new rule.

4.2 Model for Numerical Experiment

The products mentioned in this experiment include five kinds of P_1, P_2, \dots, P_5 and the production quantities as well as the bill of materials are shown in Table 4. Each products consist of five component materials u_1, u_2, \dots, u_5 and each materials have a total of ten kinds of $u_{11}, u_{12}, \dots, u_{52}$. It is supposed that φ shows 20, 40, 60, 80, 100 % and 1000 products are manufactured a week. It is also supposed that used material quantities for one product corresponds to one. Five weeks are given to the planning period. The storage cost, the cost of shortage loss and the stock quantities are shown in Table 5.

4.3 Calculation Process to decide the priority order

The experiment is carried out according to the process mentioned in the previous stage.

Table. 4 Model Experiment

Product	bill of materials					production quantities per period
	u_1	u_2	u_3	u_4	u_5	
P_1	u_{11}	u_{21}	u_{32}	u_{43}	u_{51}	200
P_2	u_{11}	u_{21}	u_{31}	u_{41}	u_{51}	280
P_3	u_{11}	u_{21}	u_{31}	u_{41}	u_{52}	200
P_4	u_{11}	u_{22}	u_{31}	u_{42}	u_{52}	170
P_5	u_{11}	u_{22}	u_{32}	u_{42}	u_{52}	150

Table. 5 Model of the storage cost, the cost of shortage loss and the stock quantities

product	bill of materials					shortage cost					cost of shortage loss					stock quantities				
	u_1	u_2	u_3	u_4	u_5	c_1u_1	c_1u_2	c_1u_3	c_1u_4	c_1u_5	c_2u_1	c_2u_2	c_2u_3	c_2u_4	c_2u_5	$I_{u_1,t}$	$I_{u_2,t}$	$I_{u_3,t}$	$I_{u_4,t}$	$I_{u_5,t}$
P_1	u_{11}	u_{21}	u_{32}	u_{43}	u_{51}	10	20	50	80	90	15	25	55	85	95	10	15	30	45	50
P_2	u_{11}	u_{21}	u_{31}	u_{41}	u_{51}	10	20	40	60	90	15	25	45	65	95	10	15	25	35	50
P_3	u_{11}	u_{22}	u_{31}	u_{41}	u_{52}	10	20	40	60	100	15	25	45	65	105	10	15	25	35	55
P_4	u_{11}	u_{22}	u_{31}	u_{42}	u_{52}	10	30	40	70	100	15	35	45	75	105	10	20	25	40	55
P_5	u_{11}	u_{22}	u_{32}	u_{42}	u_{52}	10	30	50	70	100	15	35	55	75	105	10	20	30	40	55

[Step one] The total required quantities, the available stock quantities and the order quantities are obtained from (1) to (3).

[Step two] Each priority rule is gained from (6) and (9), and the operational order is decided

[Step three] $I_{u,t}$, $QU'_{u,t}$, $QU_{u,t}$ can be obtained from Step two

[Step four] TC and TC' can be obtained (8) and (10)

[Step five] Compared TC with TC' , the operational order is decided according to the priority rule.

[Step six] When $(t_0 + 1)$ is smaller than T , return to Step one in changing $(t_0 + 1)$ to t_0 and in other cases, stop the calculation.

4.4 Result of the experiment and Examination

The total cost using ϵ and one using CR are shown in the Figure 4.

The received order progressive situation rate is 80 %, for example, $u_2 \rightarrow u_1 \rightarrow u_3 \rightarrow u_4 \rightarrow u_5$ is obtained if the material processing order is decided by using ϵ . The cost is 460 (in 1000 yen). In the same way, CR is used, the material processing order is $u_2 \rightarrow u_3 \rightarrow u_1 \rightarrow u_4 \rightarrow u_5$. The cost is 540 (in 1000 yen). Therefore, in this case, 80 (in 1000 yen) cost reduction is possible if the operational order is decided by using ϵ . In other cases, see Table 6. It clearly shows that the new rule reduces the total cost more than the conventional rule.

Figure 4 shows that as for the material with a bigger ϵ the higher the received order progressive situation rate φ is, the lower (cost) is. On the other hand, however, ϵ is high when exceeds 60 % as for the material which has a smaller φ .

In the same way, φ is under 50 %, TC does not change much and does not have influence on it, if the conventional rule is used.

The total cost using ϵ and the total cost without shortage are shown in Figure 5. So, the indicates cost without the shortage is 20 (in 1000 yen) higher than the cost using ϵ . Thus the experiment clarifies the precedence of the new priority rule.

5 Conclusion

This study proposes the new priority rule considering backorders and stock on order based

Studies on the Priority Rule for Production Planning in MRP system

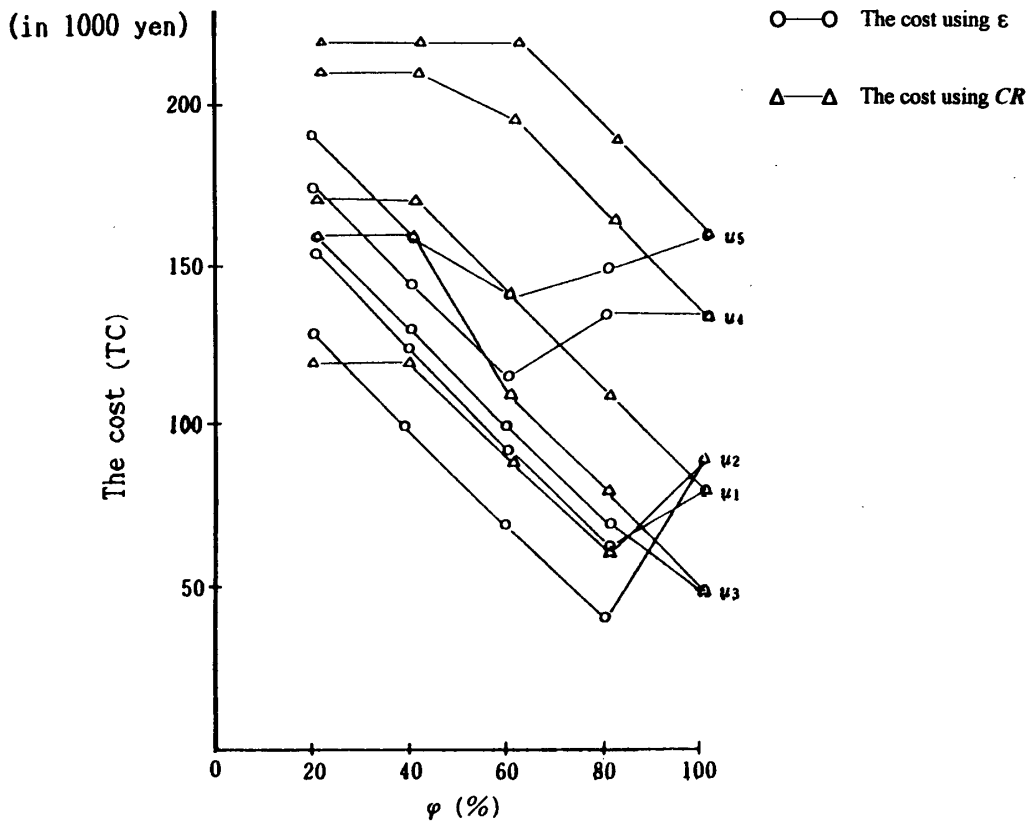


Fig. 4 Relationship between the received order progressive situation rate (φ) and the cost (TC)

Table. 6 Comparison of costs
(in 1000 yen)

φ (%)	Total cost using ϵ	Total cost using CR
20	810	960
40	670	860
60	530	745
80	460	540
100	525	545

on the MRP and the numerical analysis showed the effectiveness. The followings are the results.

- (1) The study indicates the relationship between the new priority rule and progressing condition of orders.
- (2) The new priority rule makes it possible to replan production based on the MRP system more effectively.
- (3) Compared the proposed critical ratio with the conventional critical ratio, it is clear that the proposed rule can reduce the times of due date delay and the times of production replanning on the MRP system.

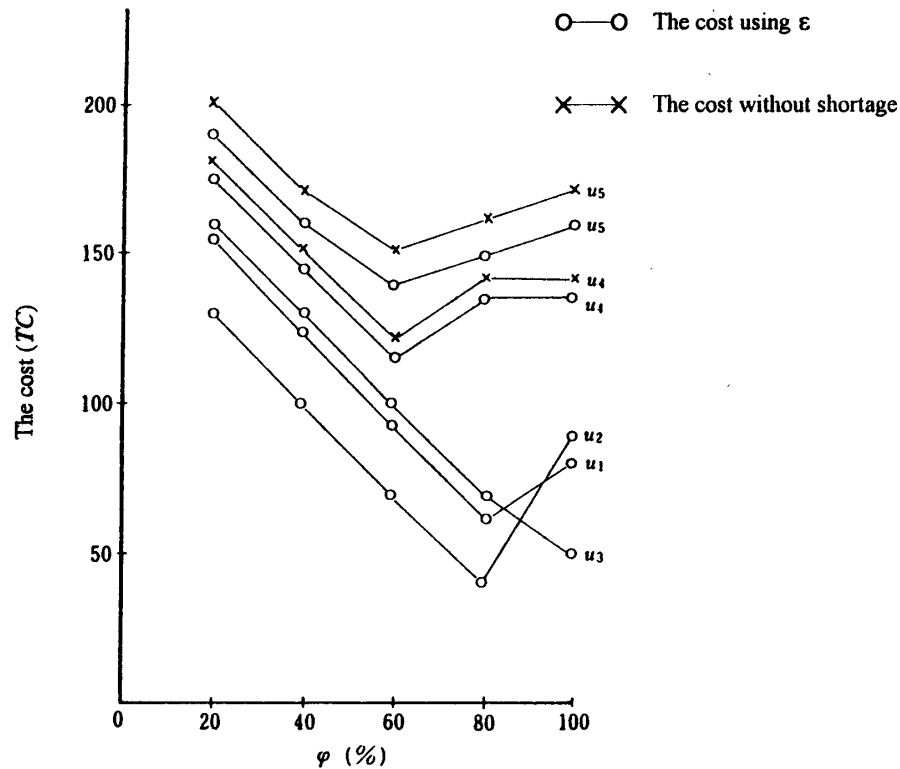


Fig. 5 Relationship between the received order progressive situation rate (φ) and the cost (TC)

Reference

- 1) Daiju, NAKAGIRI., Sennosuke, KURIYAMA., Takio, SHIMOSAKON., Toyokazu, NOSE. and Akinobu, TAKEHIRA.: An application of Markov Process for Inventory Management. Journal of Japan Industrial Management Association, Vol.27, No.1 (1976), 57-62.
- 2) Daiju, NAKAGIRI., Sennosuke, KURIYAMA. and Toyokazu, NOSE.: Optimal Production Planning Using the New Priority Rule , Journal of Japan Industrial Management Association , Vol.35, No.1 (1984), 30-35.
- 3) Daiju, NAKAGIRI., Sennosuke, KURIYAMA. and Toyokazu, NOSE.: A Study of Optimal Ordering Quantity in an Uncertainty Situation, Journal of Japan Industrial Management Association ,Vol.42, No.1 (1991), 8-14.
- 4) Daiju, NAKAGIRI., Sennosuke, KURIYAMA., Toyokazu, NOSE. and Hiromu, SAKAGUCHI.: A Study of the Transportation Lot Size Determination for Distribution Network, Journal of Japan Industrial Management Association, Vol.44, No.2 (1993), 124-130.
- 5) Sennosuke, KURIYAMA. and Toyokazu, NOSE.: Office Automation and Communication on Material Requirements Planning, Japan Society for The study of Office Automation, Vol. 4, No.4 (1983) , 103-107.