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Transition from Make-to-Order to Make-to-Stock for a Most Profitable Production-Sales System*

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Abstract

For Supply Chain Management (SCM) to work effectively, the cooperation between a manufacturing company and retailers in a Supply Chain group is significant. Two typical items in classification of various production-sales systems for a group company composing a Supply Chain are Make-to-Order system and Make-to-Stock system, which are two extremes of production-sales systems. It is presumably difficult for a mathematical model to combine the two extremes of production-sales systems into one model system. We will propose a hybrid model, which covers these two typical systems. In this model, we will solve the problem which is a more profitable production-sales system, Make-to-Order or Make-to-Stock. Using this model, we discuss that a transition of a production-sales system from Make-to-Order to Make-to-Stock takes place, if the group company pursues highest profitability.

Key Words: Transition of Production-Sales System, Make-to-Order, Make-to-Stock

1. Introduction

We will solve a fundamental problem in Supply Chain Management. The patterns of demand from customers have been diverging for various characteristics of product. Manufacturers must respond to demand from customers, competing with competitors in global market. We solve the problem how a manufacturer should cooperate with retailers in order to respond to demand of customers for product.

First, we refer to two typical items in classification of various sales systems for a Supply Chain (See Fig. 1):

1) Direct sales system

In a direct sales system, the manufacturer starts to assemble and produce products, when they receive demand for product from customers.

2) Retailer sales system

In a retailer sales system, a group company of a manufacturer and retailers produce and store products to sell.

What sort of Supply Chain works most effectively for characteristics of products requested from customers? David Simchi-Levi of MIT proposes Portfolio Supply Chain [2]. Dell (PC Maker), for example, started production-sales business in a direct sales system, but

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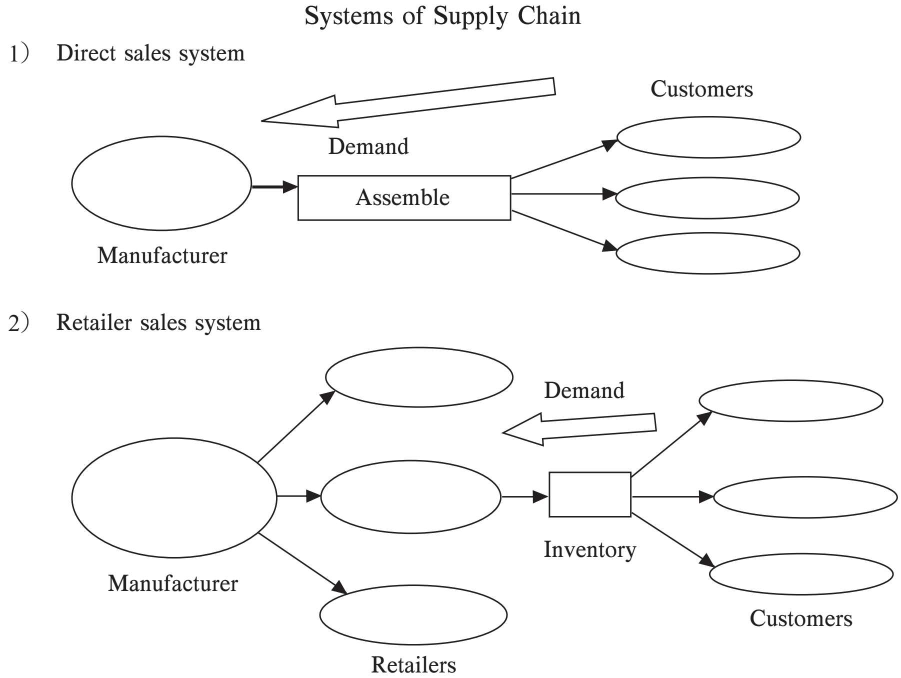

Figure 1 The two typical Supply Chain systems: Direct sales system and Retailer sales system.

now they extend their business toward a retailer sales system. Hewlett-Packard (HP, PC Maker) has developed a portfolio Supply Chain including five models, that is, No-Touch, Low-Touch, Configure-to-Make, High-Value, and Services, classified by characteristics of products and customers. "No-Touch model" sounds strange. So, a little bit of the model is explained. In No-Touch model, HP uses a third party company to produce and sell their product. They only organize the schedules for the third party company to produce and sell the product, so that they do not directly touch the product in the production and sales.

Usually Make-to-Order system and Make-to-Stock system are considered to be two extremes of production-sales systems. So it is presumably difficult to combine the two systems into one model system. In this paper, we will propose a hybrid system, which covers Make-to-Order and Make-to-Stock, and formulate a mathematical model for production-sales profit of the system. Then, we solve the problem which is more profitable, Make-to-Order system or Make-to-Stock system.

The two typical production-sales systems are characterized as follows:

1) Make-to-Order (MTO) system

The manufacturer receives orders to make from customers, and then they start to assemble and produce products. Higher customers' willing to wait for a given lead time favors a MTO system.

2) Make-to-Stock (MTS) system

A group company of manufacturer and retailers produce and store product to sell. Inventory of product is required for a MTS system. Inventory cost, however, reduces production-sales profit.

Customers' waiting allowance and required inventory play a trade-off in an analysis, which is more profitable, MTO system or MTS system (See Fig. 2).

A newly developed product is in high demand for a while after it is put on market. The product loses its reputation, when the product fully prevails over market. Thus, the demand for the product gradually fades away through the life cycle of the product. While cus-

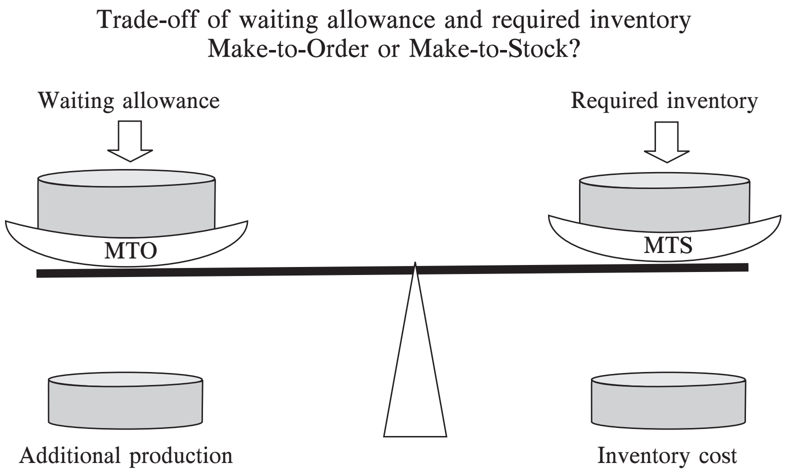

Figure 2 The trade-off of waiting allowance and required inventory between Make-to-Order and Make-to-Stock.

tomers' waiting allowance decreases, a most profitable production-sales system meets with a transition from Make-to-Order to Make-to-Stock during the life cycle of product. Using the mathematical model for production-sales profit, we analyze the transition of a profitable system from MTO to MTS.

In this paper, first we solve a problem, which is a more profitable production-sales system, Make-to-Order or Make-to-Stock. Further, it is discussed that a most profitable production-sales system meets with a transition from Make-to-Order to Make-to-Stock during the life cycle of product.

2. Mathematical model for production-sales profit

In this section, we propose a hybrid model for production-sales systems of Make-to-Order and Make-to-Stock, and formulate a mathematical expression for production-sales profit, which is applicable to a wide range of production-sales systems covering MTO and MTS (See Fig. 3). The hybrid model for production-sales systems is proposed to solve the problem which is a most profitable production-sales system, MTO or MTS. The mathematical expression for profit is formulated in terms of the two parameters for inventory cost and customers' waiting allowance.

The elements to set up the mathematical model of production-sales profit are the following: A retailer starts to sell product holding a quantity I of inventory. The demand d for the product in a unit period fluctuates in a probability distribution. Because of the fluctuation, the demand d in a unit period may exceed the inventory quantity I, resulting in insufficient inventory. In the case of the insufficient inventory, the retailer requests the manufacturer for supplementary supply of product and they ask customers to wait for a given lead time. The percentage of customers willing to wait for the supplementary supply is a significant factor in the mathematical formulation.

We now present the mathematical expression for production-sales profit. The following quantities are taken into account in the mathematical expression.

Gross profit for a unit of product; m = sales price − production cost,
Inventory cost; c,

Percentage of customers willing to wait for a given lead time; y.

The demand d for product in a unit period fluctuates with the probability distribution function $f(d)$. When the inventory quantity I is given, the sales quantity S is expressed as a function of the demand d:

$$S(d) = \begin{cases} d, & d < I, \\ I + (d - I)y, & d < I. \end{cases} \quad (1)$$

The expectation value of production-sales profit is given by [3], [4]

$$\begin{aligned} P(I) &= m \sum_{d=0}^{\infty} S(d) f(d) - cI \\ &= m\left\{N_d - (1-y) \sum_{d=I}^{\infty} (d-I) f(d)\right\} - cI, \end{aligned} \quad (2)$$

with the expectation of demand d in a unit period, $N_d = \sum_{d=0}^{\infty} df(d)$.

Now, we determine the inventory quantity $I = I_0$ that yields the maximum value of the production-sales profit $P(I)$ in eq. (2). Since the mathematical structure of this expression for profit has a singularity at $y = 1 - c/m$, the inventory quantity $I = I_0$ determined for a highest profitability depends on the customers' waiting allowance y.

1) In the case of higher waiting allowance, $y > 1 - c/m$

The production-sales profit $P(I)$ gets a maximum value at the inventory quantity $I = I_0 = 0$ (See Fig. 4). Therefore, a production-sales system without any inventory, i.e., MTO system, is most profitable.

2) In the case of lower waiting allowance, $y < 1 - c/m$

An inventory quantity $I_0 (> 0)$ yields the highest production-sales profit $P(I_0)$ (See Fig. 5). Therefore, MTS production-sales system with inventory quantity $I = I_0$ is most profitable.

Thus, the present mathematical expression for production-sales profit of the hybrid model system in eq. (2) can be used to solve the problem which is more profitable production-sales system, Make-to-Order or Make-to-Stock (See Fig. 3).

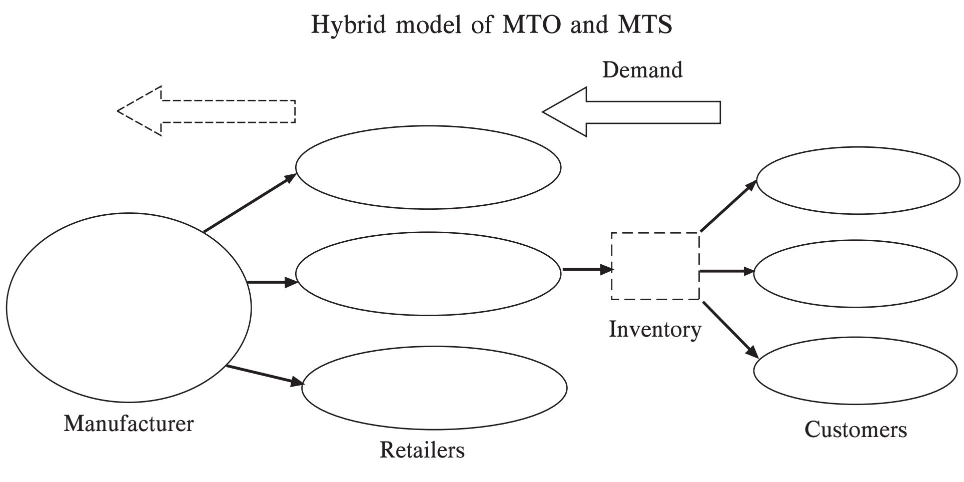

Figure 3 Hybrid model of Make-to-Order and Make-to-Stock. The inventory quantity required for highest profitability determines either Make-to-Order or Make-to-Stock to be a more profitable production-sales system.

3. Numerical calculation in the case of binary distribution of demand d in a unit period

Now, we analyze numerically the transition of a most profitable production-sales system from MTO to MTS. It is assumed that the demand d fluctuates in a binary probability distribution. Number of customers is N and the probability of each customer to buy product in a unit period is p and $q = 1-p$. The demand d for product in a unit period fluctuates with a binary distribution function [5], [6],

$$f(d) = {}_NC_d p^d q^{N-d}. \qquad (3)$$

The numerical results are shown in Figs. 4–8 for the case of the number of customers, $N = 100$, and the average value of the demand d in a unit period, $N_d = pN = 100p$.

Fig. 4 shows the production-sales profit $P(I)$ in the case of a higher waiting allowance, $y = 0.9$. Then, the profit $P(I)$ is a decreasing function of inventory quantity I. Therefore, the profit gets a highest value at the inventory quantity $I = 0$. This case indicates that Make-to-Order system is more profitable than Make-to-Stock system. Fig. 5 shows the production-sales profit $P(I)$ in the case of a lower waiting allowance, $y = 0.3$. Then, the profit $P(I)$ gets a highest value at an inventory quantity $I = I_0 > 0$. This case indicates that Make-to-Stock system is more profitable than Make-to-Order system.

Fig. 6 shows the inventory quantity I_0 required for highest profitability on the plane of inventory cost ratio c/m and customers' waiting allowance y. In the area above the diagonal line, the required inventory quantity $I_0 = 0$, i.e., MTO is favored, and below the diagonal line, the required inventory quantity $I_0 > 0$, i.e., MTS is favored. Fig. 7 shows the contour lines of the highest production-sales profit $P(I_0)$. A straight line at $c/m = 0.3$ is to indicate the

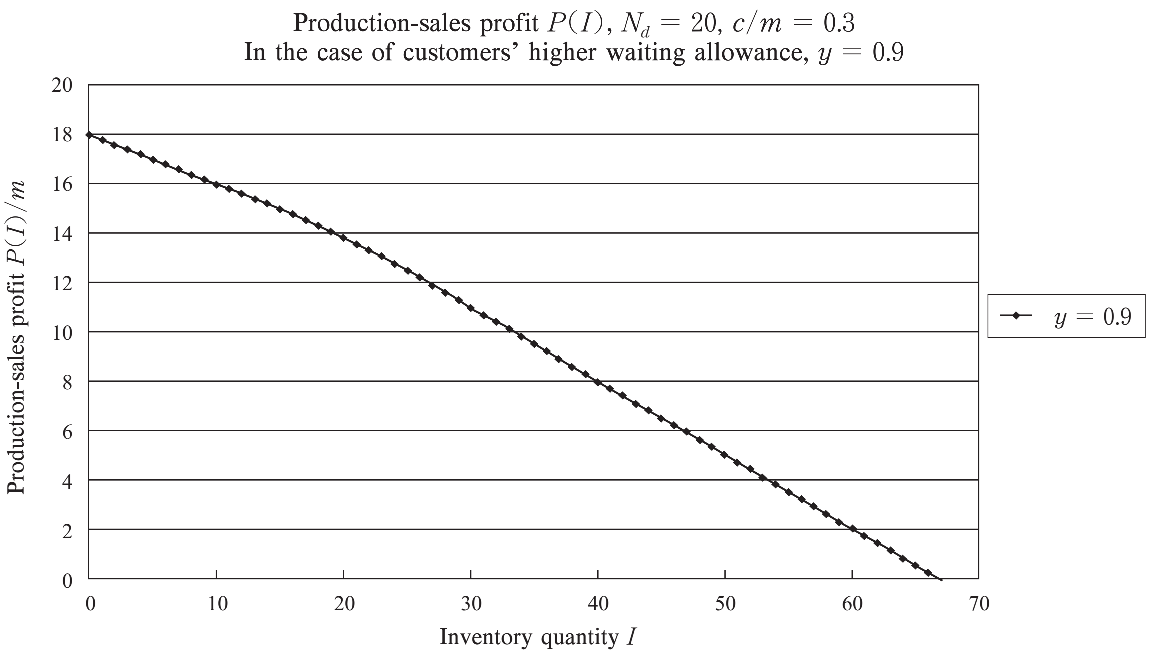

Figure 4 Production-sales profit $P(I)$ in the case of a high customers' waiting allowance, $y = 0.9$. Inventory cost ratio $c/m = 0.3$ and demand d in a unit period $N_d = 20$. The profit gets a maximum value at inventory quantity $I = 0$.

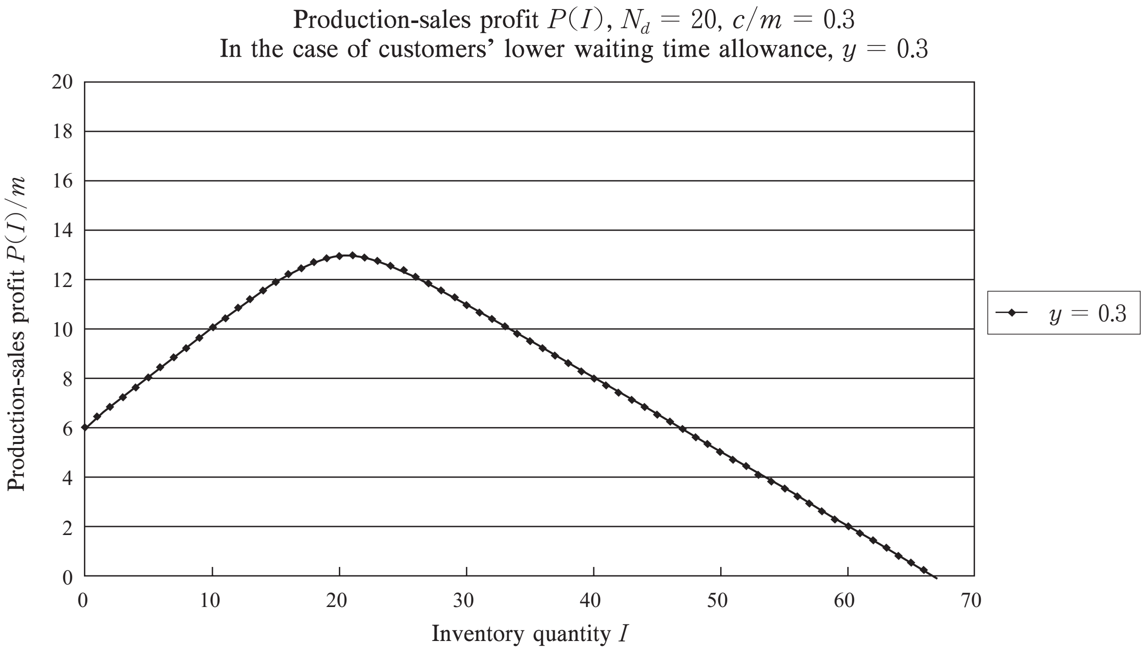

Figure 5 Production-sales profit $P(I)$ in the case of a low customers' waiting allowance, $y = 0.3$. Inventory cost ratio $c/m = 0.3$ and demand d in a unit period $N_d = 20$. The profit gets a maximum value at an inventory quantity I close to 20.

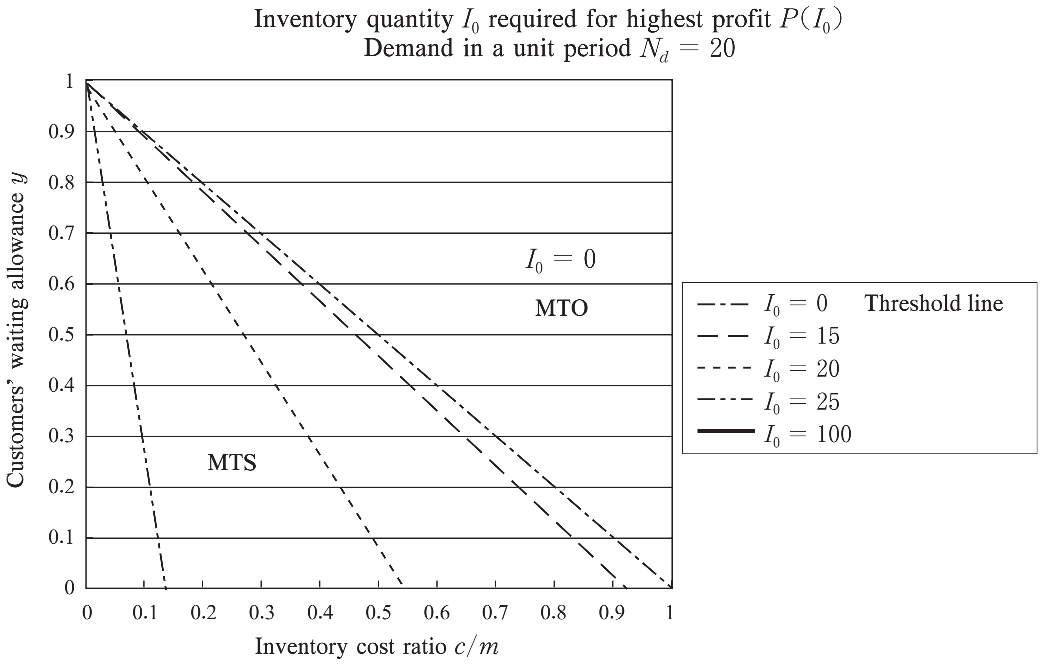

Figure 6 The inventory quantity I_0 required for a highest production-sales profit $P(I_0)$ is shown on the plane of inventory cost ratio c/m and customers' waiting allowance y. The expected demand d in a unit period $N_d = 20$. In the area above the diagonal line, the required inventory quantity $I_0 = 0$, i.e., MTO is favored, and below the diagonal line, the required inventory quantity $I_0 > 0$, i.e., MTS is favored.

highest profit for a given customers' waiting allowance y in the case of inventory cost ratio kept to be $c/m = 0.3$. In this case, a transition from MTO to MTS takes place at a time when the customers' waiting allowance $y = 0.7$, while the customers' waiting allowance y is decreasing.

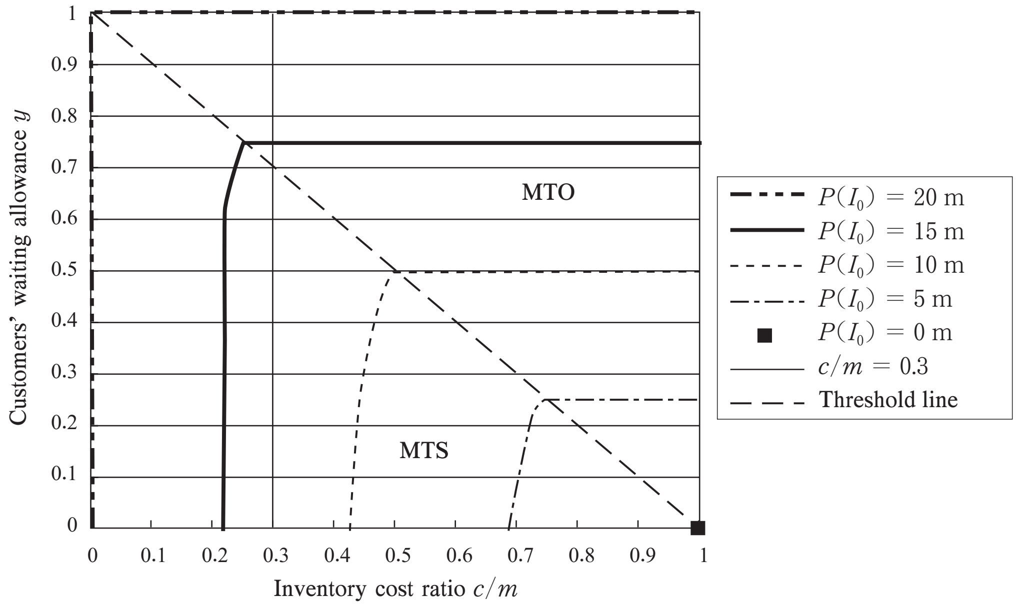

Figure 7 Contour lines of highest production-sales profit $P(I_0)$ on the plane of inventory cost ratio c/m and customers' waiting allowance y. A straight line at $c/m = 0.3$ is to indicate the highest profit for a given customers' waiting allowance y in the case of inventory cost ratio kept to be $c/m = 0.3$.

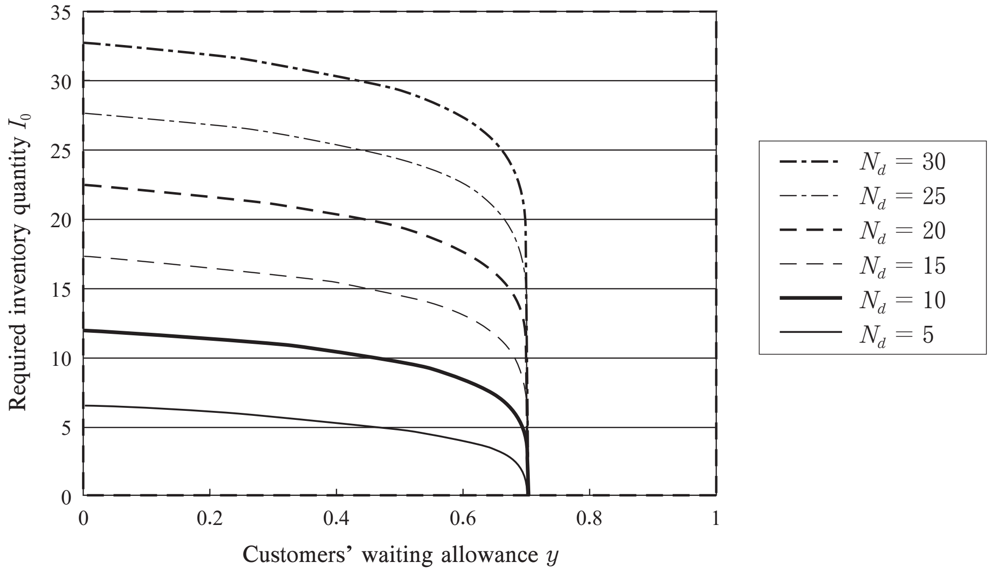

Figure 8 Variation of the inventory quantity I_0 required for highest production-sales profit $P(I_0)$ in the case of inventory cost ratio $c/m = 0.3$. Customers' waiting allowance y is supposed to decrease with time. A transition from MTO to MTS takes place at a time when customers' waiting allowance $y = 0.7$.

Fig. 8 shows the variation of the inventory quantity I_0 required for highest profit $P(I_0)$ in the case of inventory cost $c/m = 0.3$. Customers' waiting allowance y is supposed to decrease with time. A transition from Make-to-Order to Make-to-Stock takes place at a time when the waiting allowance $y = 0.7$. In the Fig., the trade-off property of customers' waiting allowance y and required inventory I_0 is seen with a threshold at $y = 0.7$.

4. Extension of the model to more general cases

We can extend the present mathematical expression for production-sales profit in Eq. (2) to more general cases, by taking into account unsold goods cost, supplementary production cost and soon. These factors can be numerically taken into the already considered parameters of gross profit m, customers' waiting allowance y and inventory cost c. This extension of the expression for profit only modifies the values of these parameters [3], [4]. Therefore the present discussion based on a simple mathematical model is applicable to these more general cases.

5. Concluding remarks

We have shown that, when customers' waiting allowance y is close to 1, MTO system is more profitable and when y is close to 0, MTS system is more profitable. Therefore, while customers' waiting allowance y decreases from 1 to 0, in accordance with the product prevailing over market, a most profitable production-sales system meets with a transition from MTO to MTS. The transition takes place at a time when customers' waiting allowance $y = 1 - c/m$.

Dell recently extends their business model from Direct sales system toward Retailer sales system. The present discussion on the transition from MTO to MTS explains the extension of Dell's business model.

In a quasi-static model, we have solved a problem how a most profitable production-sales system makes a transition. The quasi-static model assumes that the concerned Supply Chain can attain a most profitable system at any time. Apple (Smart phone Maker) performs a speculative production-sales business, casting a considerable quantity of product onto market when they have a newly developed product. They do not seek after quasi-static profitability at the beginning. However, when their business becomes more steady, they may turn to aim at quasi-static profitability.

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