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| Title | 良いサービス品質を達成するための生産と在庫の調整 |
| Author(s) | 島本，泰輔 |
| Citation | |
| Issue Date | 1999-03 |
| Type | Thesis or Dissertation |
| Text version | author |
| URL | http://hdl.handle.net/10119/1270 |
| Rights | |
| Description | Supervisor:Milan Vlach，情報科学研究科，修士 |

# Coordination of Production and Inventory for Achieving Service Quality

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February 15, 1999

**Keywords:** queueing theory, stochastic model, fill rate, stock allocation, priority scheduling.

### Background

While many managers at manufacturing firms pay their attentions to "Customer Satisfaction" today, they are also trying to strengthen the management system for the suppression of inventory cost. Keeping delivery promises is often considered the main performance measure for the quality of customer service. One may consider to hold plenty of stocks for every item to carry out the delivery promises. That leads, however, to an increase of the inventory cost. To satisfy such conflicting objectives at the same time, Sox et al. constructed a production-inventory model based on the classical $M/M/1$ queueing system. They propose to measure the level of service to customer by the fraction of total demand filled within a fixed number of $T$ units of time from the arrival of a customer order. They call this measure the *fill rate* within the service window $T$. Obviously, the fill rate is influenced by basestock (the stocks to be always kept in inventory) levels of individual products. Therefore the problem is to determine these basestock levels so as to maximize the fill rate within $T$ and not to exceed a given limit on the total basestock. Sox et al. consider several production scheduling disciplines. For the First-In-First-Out (FIFO) policy, they present a simple algorithm for optimal allocation of total basestock. For other rules, they estimate the size of possible improvements using the optimal allocation attained for the FIFO policy.

### Objectives and Methods of Research

The model proposed by Sox et al. is easily applicable but it provides optimal or approximate solutions for a rather limited number of practical situations. The main purpose of the thesis is to extend the model so that it is useful for a larger variety of real business situations and test the worthiness of the proposed extensions. To achieve these objectives, the original model of Sox et al. is extended in the following three directions.

First, the original model is restricted to exponential production time distributions. Here a larger class of production time distribution is considered, namely $k$-stage Erlang distributions.

Second, the original model is applicable only to situations with a single-location finished-goods inventory facility. Moreover, it does not permit limits on the individual basestock levels on subgroup of products. The proposed extension includes both the possibility of several inventory facilities and limits on the levels of basestock for subsets of products. The basestock allocation algorithm is considered for such partitioned model.

Third, Sox et al. introduced a priority rule for production, BackOrder-gets-first-Priority (BOP), and improved the fill rate over FIFO within a fixed service window. It is found that BOP is efficient production rule overall, but works negatively on the fill rate in some conditions. The proposed rule, *Modified BOP*, is expected to solve that problem and achieve higher fill rate than BOP.

### Results and Remarks

As a result of the extension of the model with approximated Erlang distribution for production time, it is found that the allocation of the basestocks changes with the value of the parameter $k$ of Erlang distribution. Moreover, the fill rate increases according to the increase of $k$ with fixed number of total basestocks. A larger $k$ means that production time becomes more deterministic—consequently average waiting time decreases[1] , and the fill rate increases. Above results imply that if the probability distribution of actual production time shows a periodical tendency, where the shape of the distribution usually looks like a curve with single peak around average value, using Erlang distribution with adjusted parameter $k$ to the actual distribution is preferable to using exponential distribution.

For the partitioned model, it is found that the optimum basestock allocation is obtained using a greedy algorithm. The algorithm is similar to the one by Sox et al. However, a simple proof, which is not clearly mentioned by Sox et al., is given regarding the optimality of the algorithm.

The simulation result shows that Modified BOP achieves higher fill rate than FIFO or BOP with a fixed service window. This is because that Modified BOP reduces the time losses observed in BOP. BOP shows lower fill rate than FIFO at service window shorter than 1 time unit, but Modified BOP shows the same fill rate to the one with FIFO at the same service window.

### Further Research

The extensions of the model are originally aimed to make the production-inventory model applicable to a larger variety of practical situations. In that sense, there is much room left

[1]In queueing theory, it is proved that average waiting time becomes minimum when production time is deterministic.

for further improvement of the model. For example, the model of this research assumes single production line. Since most actual production facilities have multiple production lines for the specific groups of product items, extension from single to multiple production lines for the model is considered natural. Or the model of this research assumes the same production rate $\mu$ for all product items. The model with different $\mu$'s for the product items seems to be more realistic. Approximated Erlang distribution is used for the probability distribution of production time in this research. From theoretical point of view, using Erlang distribution would be more preferable. It was not possible to formulate mathematical model with Erlang distribution this time because of the difficulty of handling formulas. Different approach is expected to organize the model with Erlang distribution.