KnE Life Sciences
ICoA Conference Proceedings
The 3rd International Conference on Agro-Industry 2016
"Competitive & Sustainable Agro-Industry: Value Creation in Agribusiness"
Volume 2017

Knowledge E
Engaging minds

Conference Paper

Optimal Cycle Service Level for Continuous Stocked Items with Limited Storage Capacity

Kanokwan Singha[1], Jirachai Buddhakulsomsiri[1], and Parthana Parthanadee[2]

[1]School of Manufacturing Systems and Mechanical Engineering, Sirindhorn International Institute of Technology, Thammasat University,Pathum Thani 12121, Thailand
[2]Department of Agro-Industrial Technology, Faculty of Agro-Industry, Kasetsart University, Bangkok 10900, Thailand

Abstract

This paper involves determining an optimal cycle service level for continuously stocked items that explicitly considers storage space capacity. Inventory management is under a continuous review policy. The total inventory management cost consisting of ordering cost, inventory holding cost, shortage cost, and over-capacity cost. Shortage items are assumed to be backlogged. A numerical example is provided to demonstrate the method.

Keywords: Continuous Review; Cycle Service Level; Storage Space Capacity; Over-Capacity Cost

Corresponding Author
Kanokwan Singha
kanokwan.singha@gmail.com

Received: 25 December 2017
Accepted: 5 February 2018
Published: 1 March 2018

Publishing services provided by Knowledge E

Selection and Peer-review under the responsibility of the ICoA Conference Committee.

INTRODUCTION

At present, distributors, wholesalers, and retailers have to manage and control inventories of items that are continuously stocked, such as detergent, soap. An important decision in their inventory management is to set a proper cycle service level in order to optimally meet customer demand. Setting an optimal cycle service level is a trade-off between inventory holding cost, ordering cost, and shortage cost. In addition to these three major cost components, this paper considers explicitly another cost component, which is over-capacity cost. In other words, finding an optimal service level, in this paper, also considers a storage space capacity that is prespecified and limited for an item.

The inventory management system under study is a widely used continuous reviewed (R, Q) policy, where an order quantity Q is placed for replenishment, when the inventory position level is on or below the reorder point R. When demand arrives and items are not available, shortage would occur. Shortage items are assumed to be backlogged, which means that customers are willing to wait for the items. When

How to cite this article: Kanokwan Singha, Jirachai Buddhakulsomsiri, and Parthana Parthanadee, (2017), "Optimal Cycle Service Level for Continuous Stocked Items with Limited Storage Capacity" in *The 3rd International Conference on Agro-Industry 2016 "Competitive & Sustainable Agro-Industry: Value Creation in Agribusiness"*, KnE Life Sciences, pages 82–88. DOI 10.18502/kls.v4i2.1659

items are available, there would be backlog cost charged on a per unit basis. This cost represents the costs of expedite delivery, or some discount given to the customers.

In addition, storage space capacity for an item is limited such that if the item is ordered in a quantity that makes the on-hands inventory exceed the storage capacity, an over-capacity cost would incur on a per unit basis. The over-capacity cost represents the cost of keeping the over-capacity unit at an external storage space. Naturally, a unit over- capacity cost is higher than the unit inventory holding cost at internal storage space. Under this problem setting, it is important that the cycle service level during replenishment lead time is optimally determined.

Numerous research has been studied on continuous review (R, Q) policy, for example, Farvid and Rosling [3]; Kouki et al. [5]; Tamjidzad and Mirmohammadi [7]; Braglia et al.[1]. Farvid and Rosling [3] considered Poisson demand and stochastic lead-times. Tamjidzad and Mirmohammadi [7] considered a single product with stochastic demand and lead time being discrete and constant. Braglia et al. [1] considered a normal demand during lead time and constant lead time. All studies set the objective function to minimize inventory management cost consist of ordering cost, inventory holding cost, and backorder cost. Kouki et al. [5] proposed a single stage perishable product with deterministic lead time to minimize total inventory cost which are fixed ordering cost, holding cost, purchasing cost, and lost sales cost.

Most relevant research studies on the continuous review (R, Q) policy inventory problem that consider limited storage space are Zhao et al. [8], Zhao et al. [9], and Hariga [4]. Zhao et al. [8], Zhao et al. [9] considered single item and multiple items by a continuous review (R, Q) policy with limited storage space with the objective function to minimize the total inventory cost. Hariga [4] proposed a single item (R, Q) continuous review stochastic demand under a space restriction. The study only focused on limited storage space but do not consider over-capacity cost.

Regarding cycle service level, Tajbakhsh [6] proposed a continuous review (R, Q) inventory policy with a service level constraint that the service level is more than 50%. All unsatisfied demand can be backordered. The inventory cost only considered ordering cost and inventory holding.

This paper focuses on finding a method for setting an optimal cycle service level for continuously stocked item under the continuous review (R, Q) inventory policy with storage space restriction. The method aims at balancing between customer service level and inventory cost consisting of ordering cost, inventory holding cost, backlog cost, and over-capacity cost.

NOTATION

The notation used in this paper are as follows.

Q replenishment order quantity, unit

R reorder level, unit

C_h Inventory holding cost, THB/(unit-period)

C_s Backorder cost, THB/unit

C_o Over-capacity cost, THB/(unit-period)

□ Average daily demand, unit/period

L Average lead time, period

W Storage space capacity, unit

CSL Cycle service level

CSL_w Cycle service level considering W

METHODOLOGY

Chopra and Meindl [2] provides a method for setting an optimal service level for continuously stocked item under backlog case. The method is based on the concept that increasing the level of safety stock by one unit, will result in one unit of saving in terms of backlog cost, at a cost of additional inventory holding.

Consider a replenishment cycle with an expected cycle length of $\frac{Q}{\mu}$, the cost incurred from an additional inventory item in the safety stock is equal to $\frac{QC_h}{\mu}$. Potential saving in the backlog cost for one unit is C_s, which occurs with a probability of stockout = 1-CSL. Therefore, the expected savings is equal to (1-CSL)C_s.

By definition, the optimal cycle service level is where the saving from keeping an additional item is equal to the cost that the item incurs. Therefore, equating the saving and the cost would result in the optimal cycle service level according to Eq. (1).

$$CSL^* = 1 - \frac{QC_h}{\mu C_s} \tag{1}$$

Now consider the case where the storage space is limited. The over-capacity cost would incur at the beginning of a replenishment cycle, i.e. the peak of inventory on-hands exceeds the storage space capacity. At the end of a replenishment cycle, the level of inventory on-hands is equal to R-□L, the reorder point minus the average demand during replenishment lead time. At the beginning of a replenishment cycle, the level of inventory on-hands is, therefore, Q+R-□L. With this level, the expected

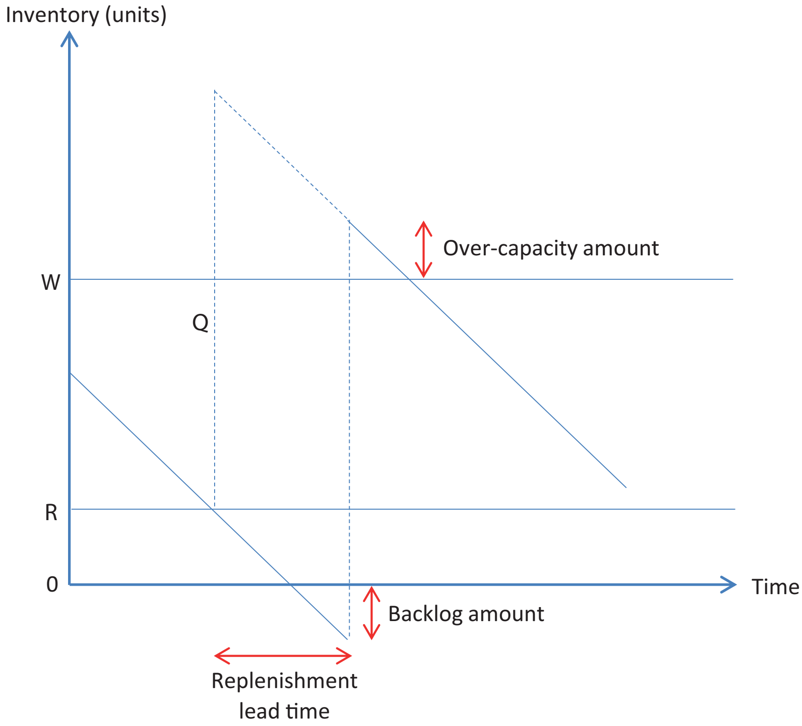

Figure 1: Inventory level in a replenishment cycle.

over-capacity unit at the beginning of a cycle is Q+R-□L-W. Keeping an additional item in the safety stock would raise the inventory on-hands profile by one unit, thus, the expected overstock unit becomes Q+R-□L-W+1. This additional unit would be charged for duration of $\frac{Q+R-\mu L-W+1}{\mu}$. period. The additional over-capacity cost is, therefore, $\frac{(Q+R-\mu L-W+1)C_0}{\mu}$.

With the over-capacity cost, the total cost of keeping an additional item in the safety stock becomes $\frac{QC_h}{\mu}+\frac{(Q+R-\mu L-W+1)C_0}{\mu}$. Setting this cost equal to the saving of one-unit backlog cost, (1-CSL)C_s, the optimal cycle service level under storage space capacity is according to Eq. (2).

$$CSL_W^* = 1 - \frac{QC_h}{\mu C_s} + \frac{(Q+R-\mu L-W+1)C_0}{\mu C_s} \tag{2}$$

Given the value of Q, R, and W, inventory levels, both inventory position and inventory on-hands, in a replenishment cycle, the expected backlog amount, and the expected over-capacity amount are shown in Figure 1.

In addition, the probability of stockout and probability of over-capacity can be shown in Figure 2.

From Figure 2, for illustration purpose, suppose the distribution of demand during lead time is normal. The probability of stockout, which occurs at the end of a replenishment cycle, depends on the value of the demand during lead time. That is,

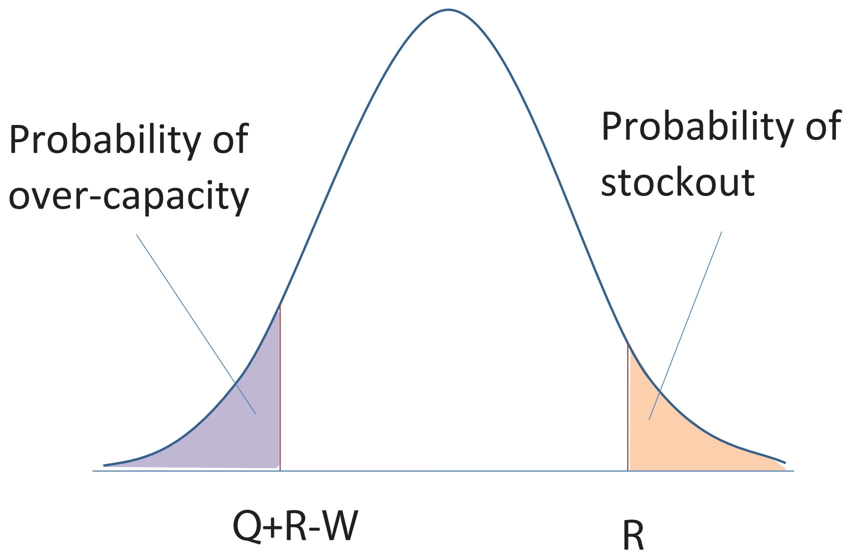

Figure 2: Probabilities of stockout and over-capacity.

Table 1: Data for numerical example.

Parameter	Data	
C_h	0.015	THB/unit/day
C_s	5	THB/unit
C_o	0.2	THB/unit/day
□	110	Units/day
L	2	days
W	3,000	units

it is the probability that the demand during lead time exceeds R at the right tail of the distribution. In addition, the probability of over-capacity that would occur at the beginning of the next replenishment cycle would also depend on the value of the demand during lead time of the previous cycle. It is the probability that $Q+R-$□$L > W$, or □$L < Q+R-W$, i.e. demand during lead time is less than $Q+R-W$ at the left tail of the distribution.

NUMERICAL EXAMPLE

A numerical example to demonstrate the use of Eqs. (1)-(2) to determine the optimal cycle service level with and without storage space capacity. Demand, lead time, storage space capacity, and cost parameters as shown in Table 1.

Table 2 shows the optimal cycle service level when varying Q and R parameters.

Table 2: Optimal cycle service level with and without considering storage space capacity.

	Q = 1,400		Q = 1,600	
R	CSL	CSL_w	CSL	CSL_w
2,000	96.2%	89.6%	95.6%	81.8%
2,200	96.2%	82.3%	95.6%	74.5%
2,400	96.2%	75.1%	95.6%	67.2%
2,600	96.2%	67.8%	95.6%	60.0%
2,800	96.2%	60.6%	95.6%	52.7%

From Table 2, for the given Q of 1,400 and R of 2,000 units, the CSL is 96.2%. This indicates that there is only a 3.8% probability of backlog. When considering storage space capacity, the optimal cycle service level is reduced to 89.6%, i.e. the probability of backlog increases to 10.4%. This is an adjustment to the additional over-capacity cost that is considered. Increasing Q for 200 units to 1,600 units, CSL and CSL_W decrease by 0.6% and 7.8%, respectively. This is as expected, because increasing Q will increase the expected length of a replenishment cycle, which in turn increase the cost of keeping an additional item. With increased cost, while savings remain the same, it is only natural that the optimal cycle service level is decreased. In addition, when the over-capacity cost is considered, increasing Q will also raise the probability of over-capacity, which lead to a more dramatic reduction in the optimal cycle service level.

As R increases, CSL remains the same when the storage space capacity is not considered, because CSL is not a function of R. However, CSL_W decreases significantly according to Eq. (2) and Figure 1 that increasing R would increase the probability of over-capacity and thus the over-capacity cost, which leads to reduction in CSL_W.

CONCLUSIONS

This paper presents a new method for determining the optimal cycle service level for the (R, Q) inventory policy under storage space capacity. The numerical example shows clearly the effectiveness of the method. Further study is to develop a method to determine the optimal inventory policy parameters under storage space capacity.

References

[1] Braglia, M., D. Castellano, M. Gallo. 2016. Approximated Closed-Form Minimum-Cost Solution to the (r, q) Policy with Complete Backordering and Further Developments, *Applied Mathematical Modelling.* 40: 8406–8423.

[2] Chopra, S., P. Meindl. 2016. Determining the Optimal Level of Product Availability. *Supply Chain Management Strategy, Planning, and Operation*. (pp. 13-382 – 13-384). Harlow: Pearson Education Limited.

[3] Farvid, M., K. Rosling. 2014. The Discounted (R, Q) Inventory Model—The Shrewd Accountant's Heuristic. *International Journal of Production Economics*, 149: 17–27.

[4] Hariga, M.A. 2010. A single-item Continuous Review Inventory Problem with Space Restriction. *International Journal of Production Economics*, 128: 153–158.

[5] Kouki, C., Z. Jemaï, S. Minner. 2015. A Lost Sales (r, Q) Inventory Control Model for Perishables with Fixed Lifetime and Lead Time. *International Journal of Production Economics*, 168: 143–157.

[6] Tajbakhsh, M.M. 2010. On The Distribution free Continuous-review Inventory Model with a Service Level Constraint. *Computers & Industrial Engineering,* 59: 1022–1024.

[7] Tamjidzad, S., S.H. Mirmohammadi. 2015. An Optimal (r, Q) Policy in a Stochastic Inventory System with all-units Quantity Discount and Limited Sharable Resource. *European Journal of Operational Research*, 247: 93–100.

[8] Zhao, X., F. Fan, X. Liu. 2007. Storage-Space Capacitated Inventory System with (r, Q) Policies. *Operations Research*, 55: 854–865.

[9] Zhao, X., M. Qiu, J. Xie, Q. He. 2012. Computing (r, Q) Policy for an Inventory System with Limited Sharable Resource. *Computers & Operations Research*, 39: 2368–2379.