Stock rotation policies of medical supplies for emergency response

Quan Zhou, Tava Olsen
University of Auckland, New Zealand
q.zhou@auckland.ac.nz, t.olsen@auckland.ac.nz

Short abstract
To prepare for public emergencies, governments maintain large quantities of medical supplies known as “the reserve”. While medical supplies have a limited shelf life, emergency demand is highly uncertain. This leads to a serious expiration problem in the reserve. Our study proposes to reduce expiration by rotating the reserve items to hospitals' operational use. The approach is to use old reserve items in hospitals, and to replenish the reserve with new items, so we can keep the reserve fresh. We derive the optimal policies for the rotation decision in joint with hospital’s ordering decision. Our results show that rotation could effectively reduce expiration and improve the cost-effectiveness.

Keywords: stock rotation, perishable, long shelf life

Topics: services, humanitarian operations and crisis management

Methodology: quantitative modelling or optimisation

To prepare for emergencies, many countries are holding national medical supplies which we refer as “the reserve”. Governments usually require the reserve to maintain a minimum stock level so that it can meet the surging demand after an emergency (Ministry of Health, 2009). However, the reserve is likely to expire without being used. Though their shelf life could be several years, the likelihood of a large-scale public health emergency is relatively low during that period. So, after several years’ sitting in the reserve, many medical stocks expire before being used. This causes substantial waste to dispose of expired items and replace the reserve with new items when necessary. New Zealand has recently dumped almost 1.5 million doses of expired anti-flu drug, valued as $30 million in original cost and $110 million in retail price (Stuff NZ, 2014). Indeed, expiration is not only limited to New Zealand; many countries are facing serious expiration in the reserve (Whybark, 2007).

Observing that hospitals often hold similar supplies and have a regular demand, we propose to rotate reserve items to hospitals, so as to reduce expiration and use the reserve effectively. That is, to transfer old reserve items and use them in hospitals, and at the same time, to replenish the reserve with new items. In such a way, reserve items can be used before the expiry date, so as to avoid disposing of and replacing expired stocks. Of course, this involves two sets of handling costs and so the extra cost must be weighed against the benefit of avoiding expiration. We need to quantify the costs and the savings from rotation, and so to effectively reduce expiration and wastes.
With this motivation, we investigate an inventory rotation system for perishable items with a long shelf life and a minimum volume requirement. We study the stock rotation policy jointly with the hospital’s ordering policy, analyse the optimal policy structure, and discuss the implications of the analytical results.

**Main results**

Deriving the optimal policy for the joint ordering and rotation decision, we show that rotation could be effective in minimising expiration, especially when the rotation cost is not big and the wastes from expiration are large. Our model shows that the system has a well-structured optimal policy: a policy with two up-to levels, one for ordering and the other for rotation, is optimal if the rotation cost is linear without fixed cost; the optimal policy is an \((s, S)\) type policy for the rotation decision, and an up-to policy for the ordering decision, if there is a fixed rotation cost.

We show that there are three cases for each period: rotate all – the hospital gets all its order from the reserve; rotate some – the hospital orders part from the reserve and part from the supplier; and rotate none – the hospital orders only from the external supplier. It is surprising that the order-up-to level under rotation is the same, no matter whether it is rotating all or some, in the case of linear cost without fixed rotation cost. Because the unit cost involved in rotating is higher, one may expect to order fewer when it is rotating all. In fact, this results from the effect that the ordering and rotation decisions impose on the expected cost-to-go function, as we will show in the analysis.

Further, we show that the critical values are ordered with time. The rotation threshold value, the number of old items that should have been rotated, is increasing with time. Less intuitively, we find that the order-up-to level at the hospital is non-increasing as time elapses. This seems counterintuitive because one may expect to rotate more and thus order more towards the end of the shelf life. The result is driven by the different tradeoffs around the rotation and ordering decisions and can be explained by the underlying cost functions.

**Contributions**

This paper proposes a rotation system to reduce expiration in the reserve, which suggests its practical implications. In terms of theoretical contributions, we consider the perishability of a long-life product which is traditionally assumed to be non-perishable. Our work contributes to the literature in two key aspects. First, it provides operational insight for reserve stock rotation. To the best of our knowledge, so far there are no operational guidelines for such a rotation system; it is not clear how effective a rotation system could be or how to implement such a system. Second, it derives the optimal policy structure for rotating long-lifetime perishable inventory. While it is very difficult to find the optimal policy for fixed life perishable inventory system (Nahmias, 2011), the special features of the reserve, with a long shelf life and a minimum stock level, enable us to characterise the optimal policy structure.

**References**


