Multi-stage onboard inventory management policies for food and beverage items in cruise liner operations

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Abstract

We examine optimal policies for multi-stage replenishment of an onboard food and beverage (F&B) item for a cruise liner. Typically, in cruise liner operations, F&B items are ordered from suppliers before the final number of bookings is realized so as to take advantage of price discounts due to advanced contracting. Later, based on the realized headcount, F&B consumption distribution is updated, and subsequently, additional purchases can be made from local spot markets at the origin just prior to the departure and/or at an intermediate stop during the voyage. We investigate and identify optimal contracting and inventory replenishment policies that incorporate contracted and expedited purchasing schemes. We show that while optimal stock market replenishments follow base stock policies, optimal contracting decision can be derived from a piecewise cost function. We discuss insights from our results and propose future research opportunities for similar settings with multiple replenishment instants.
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1. Introduction

In this paper, we consider management of inventory for perishable food and beverage items in the cruise industry where the supply of food is an essential part of the services offered to customers. The motivation of this study originates from our involvement with a major cruise line headquartered in the South Eastern part of the United States. The cruise line under study manages its procurement process by establishing contracts with distributors/vendors in the designated home port and/or purchasing products through expedited replenishment orders from spot markets. Minimizing the likelihood of stock-outs, being protected against fluctu-

ations in the market, and price discounts are basic incentives for cruise lines to sign contracts with various distributors. However, such contracts need to be signed in advance to assure timely delivery of the products with lower cost.

Oftentimes, the supply contract for an F&B product is signed before an accurate number of customers (bookings) for the cruise is known. As the cruise ship nears its departure time, the demand information becomes more accurate. If there is a need to increase inventory, additional procurements are made through expedited orders from local spot markets. It is our observation that expedited replenishments from spot markets, although more costly, play a critical role in the provisioning of food and beverage items in the cruise line industry. While advance supply contracting provides cost efficient procurement opportunities, spot market purchases serve as a hedge against stock-outs due to variations across day-to-day demands. Therefore, an efficient inventory control

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Nomenclature

y_j	purchase amount at stage j; $j = 0,1,2$	D^t	onboard demand for the F&B item during time t
c_j	unit purchase price of the F&B item at stage j		
p	per-unit stock out cost	$f(D/B)$	probabilistic density function for demand over t given B
h	per-unit leftover cost at the end of the cruise trip	$F^t(D/B)$	cumulative distribution function for demand over t given B
t_i	time elapsed during the ith leg of the cruise trip; $i = 1,2$	I	excess onboard inventory at the beginning of stage 2
B	number of bookings (home port demand) for the cruise trip	$S_j(x)$	expected total cost of leftovers and stock outs given inventory level, x, at the beginning of stage j
s	scenario index for the home port demand ($s = L, H$)		
q_s	probability for scenario s	G_j	expected total cost at stage j
B_s	number of bookings under scenario s	K_j	order-up-to level for stage j

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mechanism must take in consideration the trade-offs between both replenishment approaches.

In this study, we propose a stochastic dynamic programming model to optimize onboard inventories of food and beverage items for a cruise liner. The proposed model incorporates multiple replenishment stages comprised of both contracted and expedited purchases. In service sectors such as the cruise line industry, the availability of products is an essential part of the quality of services provided to the customers. Therefore, purchasing and inventory decisions play a central role in planning of the operations. In a recent survey, Stanley and Wisner (2001) established a strong relationship between purchasing operations and service quality to external customers. Researchers such as Iyer and Bergen (1997), Kouvelis and Gutierrez (1997) and Gurnani and Tang (1999) consider multiple replenishment instants as part of a newsvendor setting where the purchases are carried out in two stages to utilize price discounts and forecast updates similar to our case. However, our model differs from these papers in two aspects. First, in the aforementioned work, the objective is to maximize profits, while we focus on cost minimization. Newsvendor settings primarily focus on direct sales and thus the main motivation is to increase revenues from sales. On the other hand, on a cruise liner the main goal of carrying food inventory is to achieve higher customer satisfaction through availability of products while being cost efficient. Second, in those models, all sales take place after purchases from suppliers are finalized (single period setting) whereas we consider option of replenishment while the good is already being consumed (multi-period setting).

In parallel to the increasing trend in operations research literature towards analyzing service sector related problems, food logistics emerges as one of the most appealing research topics in this area in recent years. The focus spans production planning and logistics in food processing industries (van Donk, 2001), efficient distribution of foods (Lijima, Komatsu, & Katoh, 1996; Tarantilis & Kiranoudis, 2001) and food supply chains (Henson, Loader, & Traill, 1995; van der Vorst, Beulens, & van Beek, 2000). The work by Evangelos, Hill, Saraf, and Miller (1998) is the only one that we are aware of focusing on food logistics under the context of maritime operations. In their paper, authors present a software tool that ''optimizes'' Navy menus based on food cost, labor hours and storage requirements. We believe that our research contributes to the related literature by opening up a new venue that deals with multistage inventory management of perishables in food logistics and maritime operations.

The rest of the paper is organized as follows: in Section 2 we present the description of our model. Optimal replenishment policies are derived in Section 3. Section 4 presents numerical examples. We provide insights and discuss various extensions to the model in Section 5 and conclude the paper in Section 6.

2. Model description

In this section, we will first discuss the main components and the nature of the model under study and then present the underlying assumptions. Our study focuses on cost efficient inventory management policies for perishable food and beverage items for a cruise line that offers vocational services to its customers with day-to-day stochastic consumption rates. Without any doubt, services of food and beverage (F&B) items during the voyage of a cruise liner constitute a crucial part of this business. The main components of the consumer service in food supply chains are availability, quality and pricing, (van der Vorst et al., 2000). Since the pricing part is already accounted for, during the sales of the vacation packages, the main concentration in cruise line food and