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Allocation of flexible and indivisible resources with decision postponement and demand learning ☆

Ebru K. Bish [a,*], Kyle Y. Lin [b,1], Seong-Jong Hong [a,2]

[a] *Grado Department of Industrial and Systems Engineering (0118), 250 Durham Hall, Virginia Tech, Blacksburg, VA 24061, USA*
[b] *Operations Research Department, 1411 Cunningham Road, Naval Postgraduate School, Monterey, CA 93943, USA*

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Abstract

We consider a firm that uses two perishable resources to satisfy two demand types. Resources are *flexible* such that each resource can be used to satisfy either demand type. Resources are also *indivisible* such that the entire resource must be allocated to the same demand type. This type of resource flexibility can be found in different applications such as movie theater complexes, cruise lines, and airlines. In our model, customers arrive according to independent Poisson processes, but the arrival rates are uncertain. Thus, the manager can learn about customer arrival rates from earlier demand figures and potentially increase the sales by postponing the resource allocation decision. We consider two settings, and derive the optimal resource allocation policy for one setting and develop a heuristic policy for the other. Our analysis provides managerial insights into the effectiveness of different resource allocation mechanisms for flexible and indivisible resources.

Keywords: Retailing; Resource flexibility; Demand forecast; Capacity allocation; Perishable inventory

1. Introduction

In this paper, we study the optimal capacity allocation[3] decision and the value of postponement for *flexible* and *indivisible* resources in the presence of *forecast uncertainty*. Although indivisible and flexible resources are utilized in various service industries, issues dealing with the management of such resources have not received much attention in the operations management literature. Our objective is to provide managerial implications and guidelines on how to manage this type of resources.

Specifically, we consider a service system that utilizes two capacitated and perishable resources to satisfy two types of consumers (demand streams) arriving stochastically and dynamically over a selling season. Each consumer type requires a different type of service, to be provided at the end of the

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* Corresponding author. Tel.: +1 540 231 7099; fax: +1 540 231 3322.
E-mail addresses: ebru@vt.edu (E.K. Bish), kylin@nps.edu (K.Y. Lin), sehong1@vt.edu (S.-J. Hong).
[1] Tel.: +1 831 656 2648; fax: +1 831 656 2595.
[2] Fax: +1 540 231 3322.
[3] We use the terms "capacity allocation" and "resource allocation" interchangeably throughout the paper.

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selling season. Resources are (i) *flexible* because each resource can provide either type of service, (ii) *indivisible* because each resource can only provide one type of service in its entirety, and (iii) *perishable* because resource capacity cannot be stored in the form of inventory. We assume resources are identical except for their capacities. In order to maximize the expected revenue at the end of the selling season, the revenue manager faces two operational-level questions: (i) whether or not to grant the service request of each arriving consumer, and (ii) how to allocate the resources to the demand streams. Obviously, these two questions are closely related: Once the capacity allocation decision is given, the manager knows exactly up to how many consumers of each type he can admit into the system. What complicates this decision problem is the fact that in most real-world applications, arrival rates of the demand streams are not known, and can only be estimated with uncertainty at the beginning of the selling season.

To simplify the analysis, we assume there are no cancelations (hence, no overbooking); that is, every accepted consumer will show up at the time of service and be granted service. In addition, we assume that there is no consumer-driven substitution; that is, a consumer will not switch to a different service type if what she desires is unavailable. We will discuss the implications of these assumptions in detail in Section 6.

One commonly used strategy is to allocate resources to the demand streams at the beginning of the selling season in a way that maximizes the expected total revenue; we refer to this strategy as the *no postponement* strategy. Although this strategy is convenient and easy to implement, it is often difficult to make the ‘‘right’’ allocation that early, especially when the demand forecast is subject to errors. By postponing the allocation decision, it is possible for the manager to learn about the demand pattern from early sales figures to make a better allocation decision at a later time. In this paper, we study this capacity allocation problem and devise two postponement strategies. Our objective is to analyze the effectiveness of each postponement strategy, and the value of postponement in general, for managing flexible and indivisible resources.

The capacity allocation problem of flexible and indivisible resources arises in many real-world situations. For example, consider a multiplex movie theater that has several screens of different seating capacities. The manager starts selling movie tickets on the Internet and over the phone well in advance.[4] By scheduling different movies around the same time, it is possible for the manager not to assign movies to screens until close to the show time. The screens in this example are the flexible, divisible, and perishable resources. Because screens have different seating capacities, the manager would like to allocate a screen of a larger seating capacity to a more ‘‘popular’’ movie in order to increase sales. However, before the ticket sale begins, the manager need not have a good idea about each movie’s popularity. For another example, a transportation service provider (a cruise company, a shuttle service provider, or an airline) usually has vehicles of different sizes that need to be assigned to different services around the same time. Still another example can be found in the manufacturing industry, where a production facility has different production lines that can be set up to produce one of many different products.

As discussed above, resource flexibility allows the manager to postpone the resource allocation decision to exploit benefits of learning through early demand figures and hedge against demand and capacity imbalances, thus providing a *risk pooling* effect. While several strategies for risk pooling – such as centralization of inventory, delayed product differentiation, component commonality, and lateral transshipments – have been analyzed extensively in the literature (see de Kok and Graves, 2003; Tayur et al., 1999, and the references therein), only recently have flexible resource management issues been incorporated into operations management models; see Van Mieghem (2003) for an excellent review of research in this area. However, most research concerning capacity allocation mechanisms for flexible resources supposes that the capacity of a flexible resource can be shared between multiple products; that is, flexible resources are divisible. This type of (divisible) resource flexibility – also referred to as ‘‘process flexibility’’ or ‘‘product mix flexibility’’ (Sethi and Sethi, 1990) – is commonly encountered in flexible plants/assembly lines that can produce multiple products at the same time (see, for instance, Bish and Wang, 2004; Chod and Rudi, 2005; Fine and Freund, 1990; Van Mieghem, 1998) as well as in environments where a higher

[4] An example in the United States is www.fandango.com, which sells movie tickets online.