**International Journal of Management and Marketing Research**
Vol. 7, No. 2, 2014, pp. 15-27
ISSN: 1933-3153 (print)
ISSN: 2157-0205 (online)

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www.theIBFR.com

# SERVICE CHAIN COORDINATION USING SALVAGE MANIPULATION

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**ABSTRACT**

*This paper introduces a new coordinating mechanism for a two-echelon service chain with a single service retailer and multiple suppliers. The retailer sells a bundled product with perishable demand to the end customer. Prior to the selling season, suppliers must make components available to the retailer, and the retailer must acquire capacity. The bundled components consist of service capacity at the retailer and products from the suppliers. We demonstrate our salvage manipulation mechanism using an example of a travel agency that provides vacation packages using components provided by suppliers in a service chain. Our mechanism is simple to calculate and does not require the use of burdensome revenue-sharing contracts.*

**JEL:** C61, D21, L11, L81

**KEYWORDS:** Service Chain, Coordination, Newsvendor, Exogenous Pricing

## INTRODUCTION

Retailers in the service industry may sell a combination of tangible and intangible items. For example, in a restaurant, the intangible capacities of the server and the chef are combined with the tangible components of a steak and a glass of wine. In a service chain, when all these elements need to exist in concert to provide a complete customer experience, the quantities of each need to be coordinated. If the package or bundle to be provided by the retailer consists of an item that has a short life cycle, this problem can be modeled as a single-period newsvendor problem. Tangible items may be sold at a reduced price after the selling season ends (or may require a disposal fee). However, if the components are intangible/perishable (e.g., unused seats on an airplane), then salvage value may be zero. Each firm in the service chain will want to balance its own costs of having too much capacity or goods on hand with the amount of lost profit due to having too little capacity or goods on hand. If the retailer and all component suppliers were owned by a single firm, that firm would choose the stocking quantity (capacity and components) to maximize the expected profit of the entire service chain. However, with different owners, each company is likely to optimize locally, potentially resulting in a lower expected profit for the entire service chain.

The rest of this paper is organized as follows. In the next section, we review the literature on coordinating manufacturing supply chains and service chains. After that, we discuss the model and the notation for the service chain examined in this paper. Then, we analyze centralized versus decentralized service chain operation and discuss the use of salvage manipulation to coordinate the decentralized service chain. Finally, we discuss the results and present conclusions.

## LITERATURE REVIEW

Due to the presence of many stakeholders, each with its own localized objectives, service chains are difficult to manage. Fugate, Sahin, and Mentzer (2006) noted that often in business, each participant attempts to optimize locally without considering the entire service chain. A centralized decision maker could optimize the profits for the service chain, but many participants would be unwilling to give up control. As a result, many of these service chains operate in a decentralized manner, which results in a significant loss in overall efficiency, even with full information available to all participants. To overcome this inefficiency, it is necessary to identify mechanisms that give the participants control over their local entities and, simultaneously, enable them to make decisions that achieve the centralized efficiency. As noted in Lau, Lau, and Wang (2007), a manufacturer/retailer channel has difficulties in fully realizing the profit potential of the market.

Spengler (1950) referred to this inefficiency as double marginalization. To eliminate double marginalization, Pasternack (1985) proposed a coordination mechanism that provides partial credit to the retailer for unsold goods. Since then, a number of authors have identified other contracts to achieve coordination in supply chains. Examples include buy-back contracts (He, Chin, & Zhu, 2006), revenue-sharing contracts (Cachon & Lariviere, 2005; Dana & Spier, 2001), and mid-term returns (Taylor, 2001). All of these contracts were developed assuming a two-stage serial system (similar to the one described in Bollapragada, Rao, & Zhang, 2004) as the basic service chain setting.

There is a dearth of literature related to service industry coordination, although supply chain literature can be modified by adding assumptions for perishable service capacity instead of inventory on hand. The extant Assemble-To-Order (ATO) coordination literature was used for our service coordination model. Gerchak and Wang (2004) argued that a revenue-sharing contract alone does not coordinate an ATO service chain. They proposed a subsidy mechanism by which the retailer helps the two suppliers with excess inventory at their locations by partially paying suppliers for unsold delivered components. In their system, the retailer does not face any uncertainty and is a market price taker, while the suppliers set the prices of their components. Bernstein and DeCroix (2006) analyzed a three-player ATO supply chain in a multi-period setting and established the effectiveness of a mechanism in which subsidies flow from the retailer to the suppliers, and transfer payments flow from the suppliers to the retailer.

Our paper extends the existing literature on coordination contracts from ATO supply chains to the service industry where all prices are exogenous and revenue sharing is not necessary by design. All of the participants make their decisions simultaneously before the selling season. We model a service chain for which the retailer faces uncertainty and must make a capacity acquisition decision at the same time that the suppliers must make their component quantity availability decisions. If the retailer has sufficient bundling capacity, there is an insignificant lead-time to create the final vacation packages upon demand realization (similar to the assumption in Wang and Gerchak, 2003)—their mechanism coordinates with a non-zero revenue-sharing arrangement and a subsidy. Given the high administrative burden of a revenue-sharing contract (Cachon & Lariviere, 2005) and the ability of retailers to "cheat" (Wang, Jiang, & Shen, 2004), we provide a method that does not require revenue sharing to coordinate the service chain.

For this type of service chain to achieve coordination, we propose using salvage manipulation that requires the higher ratio service chain participants (as defined by cost of underage divided by cost of overage) to support the lower ratio participants by promising additional salvage value for their leftover inventories (unutilized capacity in the case of a service provider). We provide a simple computational mechanism (by solving a set of simultaneous linear equations) to obtain the exact magnitudes of the salvage manipulation among participants in the service chain.

## MODEL AND NOTATION

We investigate a service chain with a single retailer (assembler) that provides a finished package upon realized customer demand. Participants in the service chain know only the demand distribution when making the quantity allocation decisions (at the suppliers) and the capacity acquisition decision (at the retailer) prior to the selling season. The actual value of demand is unknown until it occurs. The components (without loss of generality equal to one each) from $n$ suppliers comprise the package sold by the retailer (possibly including material and labor from the retailer). The components in the service chain have a single selling period and must be salvaged (potentially at zero value) at the end of the season. Although at first the single period assumption appears to be very restrictive, it is valid for many products that have a well-defined selling season, such as vacation travel packages and holiday spa packages. We assume that the retailer sells a single package to consumers at a fixed market price (exogenously specified) for a single selling season.

### Sequence of Events

In our model, the sequence of events for the service chain participants is as follows:

Before the selling season:

1. All participants view the forecasted demand distribution.
2. The retailer decides how much capacity to provide, i.e., the number of packages to bundle, and then acquires that amount of capacity.
3. Each supplier determines its component quantity allocation for the retailer and makes those components available to the retailer.

During the selling season:

4. Actual end customer demand $x$ occurs at the retailer, i.e., the retailer sells finished good packages to customers.
5. If there are any salvage values, the suppliers and the retailer recoup those.

### Model Assumptions

We assume that the production costs, selling prices, and salvage values for all of the components and the final package are exogenous and known to all participants in the service chain. Similarly, prior to the selling season, all participants in the service chain know the parameters of customer demand distribution. This is similar to Moon and Silver (2000), where they solved a multi-item newsvendor problem assuming known end item demand. However, they imposed a total acquisition budget, whereas we assume consigned inventory. We further assume that for each of the suppliers, the selling price per unit that a supplier charges the retailer must be greater than the supplier's unit cost to ensure a positive profit margin for the supplier. In addition, all participants know the costs of each other. Complete information regarding supplier costs is not unheard of in world-class firms. Anecdotally, the Vice President of Supply Chain, Direct Supply, Inc. notes, "[Our personnel] track most/all relevant raw materials and have experts on staff who have a good handle on what goes into a supplier's product cost" (Email from Brian Rouse, personal communication, April 3, 2012).

Further, we assume that the suppliers of the package components participate in vendor-managed inventory (VMI). Because the suppliers manage the stock levels in the case of any tangible components, the suppliers will know the amount used by the retailer, thereby eliminating the opportunity for the retailer to report a lower number artificially.

Model Notation

The following notation is used in the model:

- $i$ Index, for the suppliers ($i$ = 1, …, $n$), for the retailer ($i$ = 0).
- $x$ Random variable for final product (vacation package) demand from end customers.
- $\mu$ Mean of demand $x$.
- $q_i$ The quantity of the component that supplier $i$ ($i$ = 1, ..., $n$) makes available, and the number of packages bundled by the retailer ($i$ = 0).
- $m$ The minimum quantity available from all suppliers and the retailer, i.e., the minimum of $q_i$, $i$ = 0, ..., $n$.
- $p$ The selling price per unit (vacation package) to the end customer.
- $c_i$ The cost of one unit at supplier $i$ ($i$ = 1, ..., $n$), and the cost of assembling and selling one package at the retailer ($i$ = 0).
- $w_i$ The selling price of one component from supplier $i$ to the retailer.
- $s_i$ The salvage value of one unsold unit at supplier $i$ ($i$ = 1, …, $n$), and the salvage value of one unsold unit at the retailer ($i$ = 0). This term is included for completeness only; salvage value is zero in many service environments.
- $\delta_i$ The salvage manipulation per unit between the retailer and each supplier $i$ (i = 1, ..., $n$).

Based on our discussion above, all of the costs must be non-negative and must satisfy the following conditions to make sense in a business context:

$$p > w_i > c_i > 0 \tag{1}$$

The retailer must stand to make a profit above its capacity acquisition cost plus the supplier components' costs to remain in business.

$$p > \left[ c_0 + \sum_{i=1}^{n} w_i \right] \tag{2}$$

## CENTRALIZED VS. DECENTRALIZED SERVICE CHAIN OPERATION

In this section, we determine the optimal inventory control policies when this service chain operates under both centralized control and decentralized control. First, we explain the centralized control operation scenario.

Centralized Control Operation

Solving the centralized setting enables us to determine the maximum expected service chain profit, which we use as a baseline for evaluating the performance of the decentralized service chain. The retailer decides on the quantity of each component and the equivalent bundling capacity to create a set number of finished units the customer may buy.

Proposition 1: The total service chain maximizes profit only when all participants select the same quantity. Proof: By contradiction, assume that $\{q_0, q_1, \ldots, q_n\}$ with $q_i \neq q_j$, for some pair $i, j$ is an optimal solution. Let $m$ be the minimum of $\{q_0, q_1, \ldots, q_n\}$. Consider an alternate solution where every participant in the service chain acquired only $m$ units. The revenues associated with this new solution would equal the revenues associated with the original solution. However, the costs associated with the new solution would be lower than those in the original solution would be. Thus, either (i) the solution in which every participant orders *m* units is an alternate optimal solution; or (ii) the original solution was not optimal, implying a contradiction.

The total expected profit of the centralized service chain $E[\Pi_C]$ is computed as:

$$E[\Pi_C] = -q_c \sum_{i=0}^{n} c_i + \int_{-\infty}^{q_c} \left( \sum_{i=0}^{n} s_i (q_c - x) + px \right) f(x)dx + pq_c \int_{q_c}^{\infty} f(x)dx \tag{3}$$

The first term in (3) represents the component costs and the capacity acquisition cost at the retailer. In the second term in (3) within the parentheses, the brackets house the capacity and component salvage value, and the last term within the parentheses is the retailer's revenue when demand is less than $q_c$. The final term in (3) represents the retailer's revenue when demand is greater than or equal to $q_c$. We take the first derivative of (3) with respect to $q_c$ and set it to zero to give the critical fractile shown below, where $q_c^*$ is the optimal order quantity for the centralized system and $F(q_c^*)$ is its corresponding cumulative distribution function (CDF) of demand.

$$F(q_c^*) = \frac{p - \sum_{i=0}^{n} c_i}{p - \sum_{i=0}^{n} s_i} \tag{4}$$

The ratio in (4) is always less than 1.0 given the conditions in (1). The second derivative of (4) is negative, indicating a concave profit function.

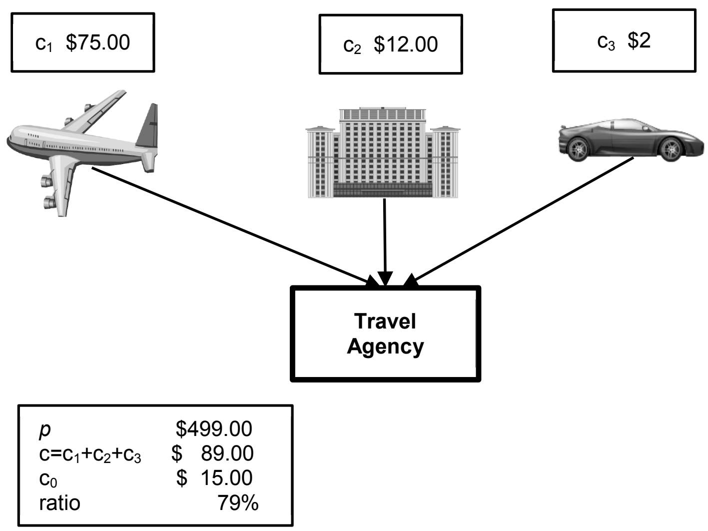
As an illustration of a service chain, in Figure 1 we model a travel agency (a retailer that bundles vacation packages) by working with three component suppliers that it <u>owns</u>—an airline, a hotel chain, and a rental car company. This travel agency must acquire capacity to bundle and sell vacation packages prior to actual demand realization. The three suppliers provide perishable components for the vacation packages. Because the airline cannot sell an unused airline seat on a flight the next day, we set salvage values for components and unutilized retailer capacity to zero in this example.

For this service chain, if demand were distributed uniformly between 0 and 100, using (4) would provide a critical fractile ratio of 0.80 and $q_c^*$ = 80 [(100 – 0) * 0.80]. Using (3), the total expected profit would be $15,592.72, given the values for $p$ and $c_i$ as shown in Figure 1. Similar results come from analyzing normal and exponential demand distributions, but we used a uniform distribution here because of its simplicity—this should enable other researchers to replicate our results quickly.

In the expected profit function in (3), we used the subscript *C* to denote centralized control. Later in the paper, we use the subscripts *D* to denote decentralized control and *M* to denote the use of decentralized control combined with salvage manipulation. It is interesting to note that, as shown in Benzion, Cohen, and Shavit (2010), knowing the demand distribution does not lead participants necessarily to make decisions that improve profits. It might be that knowledge of the exact shape of the customer demand distribution is less important than prior research suggests.

We now look at the case where all component suppliers and the retailer act independently to maximize their local profits without implicit or explicit agreements between them. We assume the same service chain as in the centralized control case, but now the travel agency does not own or control the suppliers, i.e., we assume a small travel agency that wants to provide vacation packages to its customers using components from Delta Airlines, Marriott Hotels, and Hertz rental cars. The retailer's objective is to maximize its profit by selecting the capacity to acquire ($q_0$), with known values for all other variables except the amount of demand.

Figure 1: Service Chain – Centralized Control




*At the top of this figure are each supplier's cost per unit. At the bottom of this figure are the selling price per unit to the end customer, the combined cost per unit for supplier components, the cost of assembling and selling one unit at the retailer, and the calculated critical fractile ratio for the retailer.*

The expected profit for the retailer is:

$$E[\Pi_0] = -q_0 c_0 + \left(p - \sum_{i=1}^{n} w_i\right)\int_{-\infty}^{q_0} x f(x)dx + \left(p - \sum_{i=1}^{n} w_i\right) q_0 \int_{q_0}^{\infty} f(x)dx + s_0 \int_{-\infty}^{q_0} (q_0 - x) f(x)dx \tag{5}$$

Taking the first derivative of the profit function above with respect to $q_0$ and setting the result to zero allows us to solve for the retailer's critical fractile; hence, the optimal capacity $q_0^*$ to maximize the retailer's expected profit equals:

$$F(q_0^*) = \frac{p - \sum_{i=1}^{n} w_i - c_0}{p - \sum_{i=1}^{n} w_i - s_0} \tag{6}$$

Because $w_i > c_i > s_i$, from the assumptions in (1) and (2), the ratio in (6) may be more or less than the ratio in (4). That is, depending on the values of the parameters, the retailer may have a higher or a lower ratio under decentralized control than under centralized control.

In addition, the suppliers need to determine their allocation quantities prior to the retailer's selling season. However, the retailer will pay for the units it needs only <u>after</u> the demand for customer vacation packages, i.e., supplier components are consigned. A supplier may receive a salvage value $\left(s_i < c_i\right)$ for each unsold unit at the end of the selling season (e.g., in addition to a hotel room, if a welcome fruit basket is part of the package and the fruit can be sold after the selling season at a reduced price). Assuming that the retailer has sufficient capacity to use any quantity that each supplier makes available, supplier $i$'s expected profit is:

$$E[\Pi_i] = -q_i c_i + w_i \int_{-\infty}^{q_i} x f(x)dx + s_i \int_{-\infty}^{q_i} (q_i - x) f(x)dx + w_i q_i \int_{q_i}^{\infty} f(x)dx \tag{7}$$

Taking the first derivative of (7) with respect to $q_i$ and setting the result equal to zero allows us to solve for the supplier's critical fractile; hence, the optimal production quantity $q_i^*$ for each supplier in the decentralized situation is calculated as:

$$F(q_i^*) = \frac{w_i - c_i}{w_i - s_i} \tag{8}$$

Providing that the retailer makes its quantity decision $q_0^*$ based on (6) and that each supplier makes its quantity decision $q_i^*$ based on (8), the quantity of complete packages that the retailer can bundle and sell will be the minimum of those two values, denoted as $m$. The total expected profit for the decentralized service chain is:

$$E[\Pi_D] = -\sum_{i=0}^{n} mc_i + p\int_{-\infty}^{m} x f(x)dx + pm\int_{m}^{\infty} f(x)dx + \sum_{i=0}^{n} s_i \left( \int_{-\infty}^{\infty} (m - x) f(x)dx + \int_{m}^{\infty} (x - m) f(x)dx \right) \tag{9}$$

Decentralized Control Operation

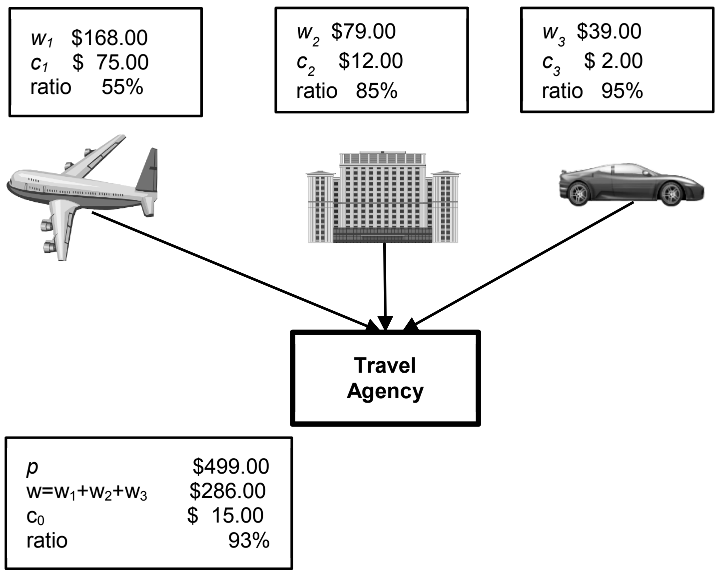
Figure 2 shows the same service chain as in Figure 1, but under decentralized control. The retailer has a ratio of 93% (determined using (6)), which is higher than the ratios of all of the suppliers. The suppliers' ratios are determined using (8). The retailer's quantity, given a $U$ [0, 100] demand distribution, equals 93. The quantities for the suppliers equal 55, 85, and 95, respectively. Therefore, this travel agency would like to acquire capacity to bundle and sell more packages than is optimal (79). Notice that the airline supplier has a localized ratio of 55%; thus, it is the limiting factor in this service chain. The other suppliers need not make extra components available beyond the number of seats made available by the airline (55).

Given uniform demand [0,100], total service chain profit calculated with (9) = $E[\Pi]$ = \$14,116.50. This expected profit assumes that each participant is rational and will maximize its expected profit with full knowledge of the other participants' costs (as done in Cachon and Lariviere, 2001). If each participant makes available a quantity corresponding to its ratio rather than on a $q$ based on the lowest ratio of all participants, expected profit is lower because there will be unmatched components/capacity—this would increase cost, but not potential sales of packages. By assuming common knowledge of cost parameters, we estimate a lower bound on the performance of the salvage manipulation mechanism (explained below).

Proposition 2: The expected profit under decentralized control will be lower than the expected profit under centralized control if the localized participant ratios are not equivalent.

Proof: It is well understood that either (i) all of the localized critical fractiles (ratios) are equal to the centralized critical fractile; or (ii) one or more of the localized critical fractiles is lower than the centralized critical fractile. This leads to the observation that $m$ must be lower than $q_0$. Because the expected profit function is concave and its maximum occurs at $q_0$, the decentralized service chain must have lower profits than the centralized service chain when $m < q_0$.

Figure 2: Service Chain – Decentralized Control




*At the top of this figure are each supplier's selling price per unit to the retailer, cost per unit, and critical fractile ratio. At the bottom of this figure are the selling price per unit to the end customer, the combined selling price per unit to the retailer, the cost of assembling and selling one unit at the retailer, and the calculated critical fractile ratio for the retailer.*

<u>Decentralized Control Operation Coordinated Using Salvage Manipulation</u>

It is not realistic to assume that complete vertical integration is possible or even desirable in all service chains. If a single entity owned and controlled the complete service chain, coordination would not be necessary. More commonly, all participants would remain decentralized decision makers, each with its local profit function. However, as shown above, the expected profit under decentralized control always will be lower than the expected profit under centralized control. It would be desirable to have a mechanism that enables all of the decision makers to optimize their local expected profit functions, yet make decisions that lead to increased service chain profits. This is the concept of service chain coordination, and we achieve that here with a method we call salvage manipulation.

Prior research has used a combination of subsidies and revenue sharing to motivate individual decentralized participants to select the same quantity (required for optimal profit per Proposition 1). To overcome the deficiency of revenue sharing, researchers such as Gerchak and Wang (2004) added a subsidy. However, using revenue sharing and a subsidy as two dependent levers is more complex than using a single mechanism only. Additionally, revenue sharing has the previously noted issues of cheating and high administrative burden. We propose a salvage manipulation mechanism (i.e., a salvage manipulator) as a form of subsidy between each retailer/supplier pair such that each participant will set its quantity to the optimal quantity of the centralized service chain, thus always obtaining the optimal expected service chain profit. Our method is simple to understand and use. We believe it is practical because it uses a single parameter (i.e., a salvage manipulator) and avoids using revenue sharing.

In effect, service chain participants desiring higher inventory and capacity available for potential customer sales would promise salvage manipulation to those participants desiring lower quantities. By doing so, all participants in the decentralized setting may improve their expected profit. Let us denote by $\delta_i$ the additional salvage value that the retailer promises to supplier $i$ for the leftover inventory at its location. Notice that $\delta_i$

can be either positive or negative. If it were negative, the retailer would want to select a capacity quantity higher than the corresponding amount of components that supplier *i* would want to provide; and if it were positive, the converse would be true.

Under decentralized control coordinated with salvage manipulation, the expected profit for supplier *i* is:

$$E[\Pi_i] = -q_i c_i + w_i \int_{-\infty}^{q_i} x f(x)dx + (s_i + \delta_i) \int_{-\infty}^{q_i} (q_i - x) f(x)dx + w_i q_i \int_{q_i}^{\infty} f(x)dx \tag{10}$$

To determine the maximum profit, we take the first derivative of (10) with respect to $q_i$ and set it equal to zero:

$$\frac{\partial E[\Pi_i]}{\partial q_i} = -c_i + (s_i + \delta_i)F(q_i) + w_i(1 - F(q_i)) = 0 \tag{11}$$

This gives us the critical fractile on the left hand side of the equation below, which we set equal to the critical fractile that was calculated as optimal in (4) for the centralized scenario.

$$\frac{w_i - c_i}{w_i - s_i - \delta_i} = \frac{p - \sum_{i=0}^{n} c_i}{p - \sum_{i=0}^{n} s_i} \tag{12}$$

Then, we re-arrange (12) to solve for the salvage manipulator ($\delta_i$) for each retailer/supplier contract as shown below:

$$\delta_i = \frac{-c_i p - s_i \sum_{i=0}^{n} c_i + p s_i + c_i \sum_{i=0}^{n} s_i + w_i \sum_{i=0}^{n} c_i - w_i \sum_{i=0}^{n} s_i}{\sum_{i=0}^{n} c_i - p} \tag{13}$$

Note that in our assumptions, the retailer's selling price ($p$) has to be greater than the capacity acquisition cost plus the sum of supplier wholesale prices so that the retailer makes a profit on each unit sold. Because the component price is greater than the cost per unit for each supplier, the denominator of the above equation must be greater than zero. Therefore, the salvage manipulator always would be defined.

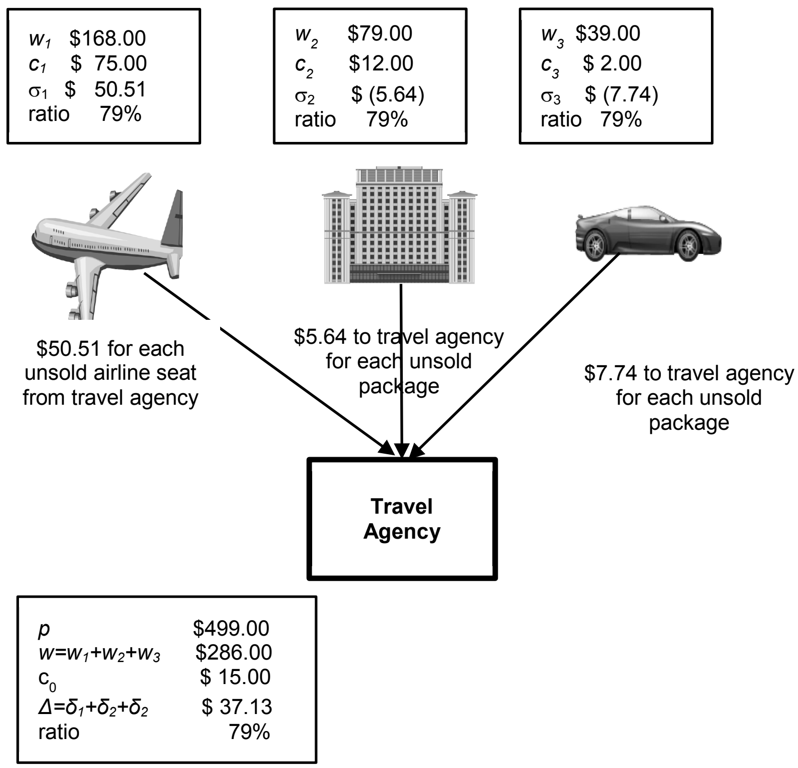
The expected profit for the retailer, where *m* is the chosen quantity, is:

$$E[\Pi_0] = -mc_0 + \left(p - \sum_{i=1}^{n} w_i\right) \int_{-\infty}^{m} x f(x)dx + \left(s_0 - \sum_{i=1}^{n} \delta_i\right) \int_{-\infty}^{m} (m - x) f(x)dx + \left(p - \sum_{i=1}^{n} w_i\right) m \int_{m}^{\infty} f(x)dx \tag{14}$$

Proposition 3: $E[\Pi_M] = E[\Pi_C]$. The proposed salvage manipulation mechanism coordinates the decentralized service chain.

Proof: The *n* salvage manipulators are designed to produce the same critical fractile (ratio) at each supplier and the retailer as found in the centralized control case. Therefore, if salvage manipulation is used, the quantities selected by all participants equal $q_C$ from the centralized case and ensure that the service chain expected profit is equal to the service chain expected profit under centralized control.

Figure 3: Service Chain Coordinated Using Salvage Manipulation




*At the top of this figure are each supplier's selling price per unit to the retailer, cost per unit, salvage manipulation per unit, and critical fractile ratio. At the bottom of this figure are the selling price per unit to the end customer, the combined selling price per unit to the retailer, the cost of assembling and selling one unit at the retailer, the net effect of salvage manipulation per unit promised by the retailer, and the critical fractile ratio for the retailer.*

Given uniform demand [0, 100], total service chain expected profit = $E[\Pi]$ = $15,592.72 using salvage manipulation, and the optimal number of packages to sell equals 79. The expected profit using salvage manipulation is identical to the profit under centralized control. The salvage manipulation would work as follows:

Those service chain participants below the optimal ratio of 79% of the cumulative expected demand will receive a promise of salvage manipulation from those participants above the optimal ratio. Recall that in Figure 2 the retailer had a ratio of 93%, and the suppliers had ratios of 55%, 85% and 95%, respectively. Because the retailer wants more airline seats to be made available (79) than the airline normally would choose to make available (55), it offers the airline a promise of additional salvage for any unsold units (seats) at the end of the selling season. For example, the retailer would offer a promise, in the form of salvage manipulation, of $50.51 per unit to supplier 1 (airline) for each unsold airline seat, which would induce that supplier to make available a quantity that is 24 units more than it would otherwise (79 – 55). On the other hand, the ratios for the hotel chain supplier and the car rental company are above the optimal ratio. The hotel chain supplier would offer the retailer a promise of $5.64 per unit for unsold packages, which, in turn, then would flow to the airline if the cumulative expected demand were below 79 packages. The car rental company would offer the retailer a promise of $7.74 per unit for unsold packages, which, in turn, then would flow to the airline if the cumulative expected demand were less than 79 packages. In this manner, the travel agency coordinates the flow of salvage manipulation funds among all participants in the service chain. The net effect to the retailer would equal $50.51 - $5.64 - $7.74 = $37.13 promised per unsold vacation package to the airline.

This salvage manipulation promise allows each decentralized participant to achieve the same quantity locally (under decentralized decision-making) that would have been selected globally (under centralized decision-making) if a single firm owned all participants. Any firm that has a locally higher ratio than the optimal centralized ratio promises salvage manipulation to those firms with ratios lower than the optimal centralized ratio. This salvage manipulation flows through the retailer as the touch point. Table 1 demonstrates how our coordination mechanism optimizes the decentralized control service chain with the three suppliers.

Table 1: Centralized, Decentralized, and Decentralized Coordinated with Salvage Manipulation Profits

| | **Centralized Control** | | **Decentralized Control with No Coordination** | | **Decentralized Control Coordinated Using Salvage Manipulation** | | **Transfer Payment** | |
|---|---|---|---|---|---|---|---|---|
| | **Ratio** | **Profit** | **Profit** | **%** | **Profit** | **%** | **Amount** | **Profit** |
| **Retailer** | 79% | $15,592.72 | $ 7,642.28 | 54% | $ 7,816.10 | 50% | $625.37 | $ 8,441.47 |
| **Airline** | | | $ 2,553.42 | 18% | $ 3,671.20 | 24% | $(850.76) | $ 2,820.44 |
| **Hotel** | | | $ 2,480.45 | 18% | $ 2,644.84 | 17% | $ 95.00 | $ 2,739.84 |
| **Rental Car** | | | $ 1,440.35 | 10% | $ 1,460.58 | 9% | $ 130.39 | $ 1,590.97 |
| **Total** | | **$15,592.72** | **$14,116.50** | **100%** | **$15,592.72** | **100%** | | **$15,592.72** |

*This table shows the optimal ratio and the expected profit for the service chain in the Centralized Control columns. The Decentralized Control with No Coordination columns show the expected profit for each participant, the total expected profit for the service chain, and the percent of total expected profit for each participant. The Decentralized Control Coordinated Using Salvage Manipulation columns show the expected profit for each participant, the total expected profit for the service chain, and the percent of total expected profit for each participant. The Transfer Payment columns show the amount of expected profit to be transferred to or from each participant such that each participant maintains its percent of total expected profit that it would have received under Decentralized Control with No Coordination along with each participant's post-transfer expected profit.*

In theory, there are $\delta_i$ such that the solution is not Pareto optimal. In the instance where the expected profit under Decentralized Control with No Coordination for any participant is higher than its expected profit under Decentralized Control Coordinated Using Salvage Manipulation, that participant may choose not to enter a contract requiring salvage manipulation with the retailer. Similarly, a participant whose percent of total expected profit for the service chain would decrease under a salvage manipulation contract might agree to the salvage manipulation contract with the retailer, but then might demand a post-transfer payment from other participants to maintain its percent of total expected profit. Moreover, all participants in the service chain might deem it equitable to achieve their pre-coordination share of the total expected service chain profit. For example, Table 1 shows that the retailer expects to receive 54% of the total expected profit if it maximized its profits under Decentralized Control with No Coordination. However, after coordination using salvage manipulation, it expects to receive only 50% of the total profit. The transfer payment arrangement would stipulate post-profit realization splitting of achieved profit per the percent under Decentralized Control with No Coordination (i.e., 54% of realized profit would go to the retailer).

Because the salvage manipulator value is a subsidy (positive or negative) allowing each participant to achieve the centralized ratio, the net effect is that subsidies flow from participants that otherwise would select higher quantities locally (due to the cost ratio of underage to overage) to participants that otherwise would normally select smaller quantities. In other words, the retailer allows the flow of promised subsidies among all participants indirectly.

## DISCUSSION AND CONCLUSIONS

Centralized control results in the highest expected profit for the *n*-supplier, one-retailer service chain. However, it typically is not desirable or feasible to have a single company that owns or controls the entire service chain. Often in the service industry, the retailer does not own all of the suppliers of the required components (e.g., hotel room, rental car, and airline seat) to bundle complete packages for the customer. Therefore, a decentralized service chain is the business setting within which the retailer and suppliers of components have to operate. With each participant acting independently, we have shown that the expected profits of the total service chain may decrease due to asymmetries in the critical ratios among the participants, even with perfect information availability.

We have introduced a new coordinating mechanism called salvage manipulation, which allows the service chain to obtain the same expected profit as under centralized control. Our contribution comes from eliminating the need to use revenue sharing combined with subsidies to coordinate a service chain. Revenue sharing alone cannot coordinate all service chains, and the administrative burden and ability to cheat make it unappealing. It is possible that a full application of salvage manipulation makes one or more participants worse off than under decentralized control. If this is the case, participants may choose to stay with decentralized quantities or to select a contract that also involves salvage manipulation combined with transfer payments to ensure that no participant's percent of total expected profit is worse off after coordination with salvage manipulation. Our model accommodates cases when prices at both echelons are exogenous. Prior research required suppliers to be able to set prices (i.e., ignore market prices for their goods) while requiring the retailer to adhere to market prices. An interesting future research extension could be looking at performance of our mechanism when the demand distribution is unknown, as done in Benzion, Cohen, and Shavit (2010). Eliminating the demand distribution shape as a required input would enhance the appeal of any coordination mechanism for implementation.

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