# 行政院國家科學委員會專題研究計畫 成果報告

## 在有供應中斷風險之下的雙重供應商策略分析：非腐蝕性與腐蝕性商品評估
## 研究成果報告(精簡版)

計 畫 類 別 ：個別型
計 畫 編 號 ：NSC 99-2410-H-004-003-
執 行 期 間 ：99 年 01 月 01 日至 99 年 12 月 31 日
執 行 單 位 ：國立政治大學企業管理學系

計 畫 主 持 人 ：陳立民

報 告 附 件 ：出席國際會議研究心得報告及發表論文

處 理 方 式 ：本計畫可公開查詢

中 華 民 國 100 年 02 月 27 日

# 1. INTRODUCTION AND RESEARCH PURPOSE

The work in this year focuses on the replenishment and pricing decision from the retailers' perspective. The first work explores the dual sourcing inventory model for nonperishable products. This dual sourcing strategy is suitably adopted to mitigate the potential damage from the supply disruptions. Disruptions become a serious business concern when the globalized marketplace drives the stages of supply chain distributing worldwide. Damage to any stage could cause enormous loss in profit and customers. To help a store manager practically make better operational decisions under the risk of disruptions in supply, this talk proposes the dual sourcing strategy and provides managerial insight on the joint price and replenishment decisions. The model is based on a periodic review, finite horizon model. This study identifies the optimal price and replenishment policy for different recovery lengths and then proposes a contract that allows a retailer to choose the arrival of delayed items or wait until the regular supplier recovers from disruptions. Experimental results illustrate the performance of the proposed approach in terms of profit and the variations on joint order and price decisions. This study explores if a retailer takes advantage of demand management and if so, to what extent. This study then analyzes the magnitude of profit advantage in the presence of dual sourcing and dynamic pricing strategy respectively under the effect of recovery length. In the discussion of the contract agreement between a retailer and regular supplier, this study evaluates how it affects profit from both sides by examining a wide range of parameter settings.

The second work develops the perishable product inventory model and optimizes these two decisions based on different observed consumption behavior settings. The following is the brief introduction. FIFO is an ideal inventory system for a physical store selling perishables since it diminishes disposal units. In general, customers would involve the order of inventory consumption when items are freely placed on the shelf. In this paper, we discuss different retail inventory models based on the periodic review with a finite horizon. Each model adheres to a particular type of consumption behavior which relates to the accessibility of items with different ages among customer segments. The total profit is maximized by optimizing the price and order quantity at the beginning of each period. This study identifies the optimal price or replenishment policy under some inventory models. We further analyze the effect of demand management during the experiments based on two scenarios: heterogeneous demand and capacity constraint. For a wide range of system parameters, we find that demand management provides more benefits for consumption behaviors from which customers who prefer discounted items leave a grocer when old items are unavailable. Results also indicate that inventory systems with small price-differentiation take advantage of demand management.

# 2. LITERATURE REVIEW

This literature review begins by exploring two main streams of articles on dual sourcing. The first stream emphasizes the procurement strategy of a buyer by splitting orders from dual or multiple sourcing. Many authors, including Seshadri et al. (1991), Klotz and Chatterjee (1995a), Klotz and Chatterjee (1995b), and Anton and Yao (1989), have adopted auction or game theory models. This stream of research regards the competition among suppliers and buy-and-sell relationship as a key factor. The second stream studies the inventory control of a retailer with dual or multiple sourcing and generally includes three categories. The first category examines the relationship between safety stock and dual sourcing (Sculli and Wu, 1981; Sculli and Shum, 1990; Kelle and Silver, 1990; Pan et al., 1991; Chiang and Benton, 1994; Ramasesh et al., 1993). In the second category, Zhao and Lau (1992), Lau and Zhao (1993), Lau and Zhao (1994), and Lau and Lau (1994) quantitatively analyzed the cycle inventory under dual or multiple sourcing. Finally, the third category explores dual souring with different leadtimes. The studies include Whittemore and Saunders (1977), Tagaras and Vlachos (2001), Groenevelt and Rudi (2003), Sheopuri et al. (2010), and Plambeck and Ward (2007). Veeraraghavan and Scheller-Wolf (2006) further took the capacity into consideration. Mishra and Tadikamalla (2006) showed benefits of the dual sourcing inventory model due to the order splitting rather than two suppliers.

The following discussion consider the literature positions on supply chain disruptions. Sheffi et al. (2003) illustrated various types of disruptions. Billington and Johnson (2006) studied how Hewlett-Packard created a local supply sourcing in Vancouver to prepare the North American market for disruptions. As for replenishment decision, Parlar and Daphne (1991) and Berk and Arreola-Risa (1994) considered EOQ-based models with stochastic disruptions. Moinzadeh and Aggarwal (1973) discussed a continuous-review $(s,S)$ model. Arreola-Risa and DeCroix (1998) presented a periodic-review $(s,S)$ model. These papers primarily examine the ordering policies of existing inventory systems in response to supply disruptions. Recent research proposes practical supply chain designs and strategies to cope with disruptions (Tomlin, 2006, 2009b,a). Since supply disruptions is defined as a random variable in the model development later which is similar to papers mentioning the yield rate, this study also refers to Yano and Lee (1973) for a review of random yield.

Existing literature on the inventory control of perishable products can be classified into two categories depending on how the perishability of a product is modeled. Papers in the first category seek to model products with random lifetimes such as meat and vegetable produce. On the other hand, papers in the second category consider products whose lifetime is fixed and completely known. Once the product reaches the end of its usable lifetime, it becomes unfit for consumption and must be discarded (perhaps for a cost) or salvaged. This approach is motivated by items whose lifetime is predictable, such as packaged and processed food products. Among the papers in the first category, one popular way to model random lifetimes is by assuming that the lifetime of each unit is an exponentially distributed random variable. (This leads to the model being called an exponential decay model.) Given this approach, numerous models have been developed using an EOQ-model type methodology; see Dave (1991), Goyal and Giri (2001), and Raafat (1991) for a review of such models.

On the other hand, most of the papers that adopt the second approach utilize periodic review models with random demand. The optimal replenishment policy depends on the relative order of inventory arrival and consumption. Assuming that inventory is consumed in the order of FIFO, Fries (1975) and Nahmias (1975) characterized the form of the optimal policy for the lost-sales and backlogging cases, respectively, with general lifetime. Using the special characteristics of the optimal solution, many papers have developed myopic or near-myopic policies that ignore the age-distribution of on-hand inventory (e.g. Nahmias (1976)); see review papers by Nahmias (1982) and Karaesmen et al. (2009) for a summary of these papers. Since the analysis of the optimal inventory policy for the LIFO rule is difficult using standard techniques, research on this topic is limited. As an example of research in this area, Cohen and Pekelman (1978) developed age-distributions in a periodic review inventory system with lost-sales to determine the optimal order policy. Once again, Nahmias (1982) and Karaesmen et al. (2009) summarized many of these papers. Our work extends the discussion of such the relative order of inventory arrivals and consumption. To simplify the exploration, we assume a perishable product with fixed (two-period) lifetime.

# 3. MATHEMATICAL MODELS

## 3.1 Inventory Model of a Non-perishable Product under Dual Sourcing

Consider a finite-horizon, periodic-review model for a nonperishable product. At the beginning of period $t$, a retailer inspects the net inventory $x^t$, and places an order for quantity $q_1^t$ from a regular but unreliable supplier with unit cost $c_1$. Here, unreliability implies that a risk of disruption exists. A random variable $\gamma$, which is identically and independently distributed in each period between $[0,1]$ with pdf $q(\gamma)$ and CDF $Q(\gamma)$, represents the fulfillment rate of items due to disruptions. A larger value of $\gamma$ means the effect of disruptions is relatively minor and vice versa. For a realized $\Gamma$, the regular supplier charges $c_1$ per unit and transports $\Gamma q_1^t$ items to the retailer. The recovery length is assumed to be one period. Therefore, partial quantities $(1-\Gamma)q_1^t$, which are delayed, will come into stock at the beginning of period $t+1$. To mitigate disruption risks, a retailer also orders $q_2^t$ units from an emergency supplier with unit cost $c_2$. This reliable sourcing guarantees that all units ordered will be delivered immediately without any delivery delay. For the simplicity of analysis, assume that the supply from both sources has no leadtime. In general, the unit cost from the emergency supplier is higher than that from an unsecured supplier ($c_2 > c_1$). The retailer combines the replenishment decisions with retail price (Chen and Simchi-Levi (2004), Federgruen and Heching (1999), and Chen et al. (2006)). Let $p^t$ be the price in period $t$ and $d^t(p^t)$ is the expected demand corresponding to $p^t$. Assume that the expected revenue $p^t \cdot d^t(p^t)$ is strictly concave in $p^t$. This assumption is standard in the literature on joint inventory-price decisions. One example of $d^t(p^t)$ for which the expected revenue is strictly concave is $d^t(p^t) = a_0 - b_0 p^t$, where $a_0, b_0 > 0$. Another example of such a function is $d^t(p^t) = a_0 \exp(-b_0 p^t)$, where $a_0, b_0 > 0$, for $p^t \in [0, 2/b_0]$. Once the order is delivered, it meets customer demand for the rest of the period. Due to the one-to-one correspondence between $p^t$ and $d^t$, they are interchangeable in the following analysis and $d^t$ is the form used for modeling. Let $\mathcal{D}$ be the set of all feasible values of expected demand in a period. Further, assume that $\mathcal{D}$ is convex, which implies that the set is an interval. Given the expected demand $d^t$, the realized demand in period $t$ is equal to $D^t = d^t + \xi^t$, where $\xi^t$ is a random variable with support $[-a, \infty)$, distribution $f(\xi)$, and CDF $F(\xi)$, where $a > 0$, such that $E(\xi^t) = 0$. Bounding the support of $\xi^t$ at $-a$ ensures that demand $D^t$ remains non-negative. Assume that $\xi^t$ is independently and identically distributed over time. Previous studies call this the *additive* demand model in the existing literature. The word "additive" arises from the additive nature of randomness ($\xi^t$). The *multiplicative* model is a more general model, and has the following form: $D^t = d^t\xi_1^t + \xi_2^t$ such that $E[\xi_1^t] = 1$ and $E[\xi_2^t] = 0$. Thus, randomness is present in both additive and multiplicative forms. The models and numerical experiments in this study adopt the additive demand form. Two requirements for any $d^t$ to be contained in $\mathcal{D}$ are that (a) the realized demand $D^t$ must remain non-negative for all $\xi^t \in [-a, \infty)$ (b) the corresponding price must be non-negative.

Given values of $x^t, q_1^t$, $q_2^t$, and $d^t$, the one-period expected profit is

$$L(x^t, q_1^t, q_2^t, d^t) = R(d^t) - c_1 q_1^t - c_2 q_2^t - hE[x^t + \Gamma q_1^t + q_2^t - D^t]^+ - \pi E[D^t - x^t - \Gamma q_1^t - q_2^t]^+,$$

where $[\cdot]^+$ stands for $\max(\cdot, 0)$ and $R(d^t) = d^t D^{-1}(d^t)$. The number of items on-hand(or shortage) at the end of the period depends on whether net inventory, $(x^t + \Gamma q_1^t + q_2^t - D^t)$, is positive(or negative). Items delayed by disruptions also arrive and increase net inventory to the amount $(x^t + q_1^t + q_2^t - D^t)$. For simplicity, omit the superscript $t$ from all the variables through the rest of this paper unless necessary for exposition, and denote regular and emergency suppliers as $R$ and $E$, respectively. The dynamic equation of the optimal profit from period $t$ to the end of horizon is

$$v_t(x) = \max_{d \in D, q_1 \geq 0, q_2 \geq 0} L(x, q_1, q_2, d) + \beta E[v_{t+1}(x + q_1 + q_2 - D)], \tag{1}$$

where $\beta$ is the discount factor. Set the profit function at the end of horizon $v_{T+1}(x)$ equal to

$sx^+ + c_1x^-$, where $s$ is the salvage value and $x^- = \min[0,x]$ . Then, define

$$G_t(x,q_1,q_2,d) = L(x,q_1,q_2,d) + \beta E[v_{t+1}(x+q_1+q_2-D)], \tag{2}$$

so that $v_t(x) = \max_{d \in D, q_1 \geq 0, q_2 \geq 0} G_t(x,q_1,q_2,d)$.

This work also extends the model to two cases: one for recovery length Equal to Two periods and another for actions on delayed items (The detail of these actions is omitted.).

## 3.2 Inventory Models of a Perishable Product with Various Consumption Behaviors

We consider a finite-horizon, periodic-review model for a perishable product with a fixed lifetime equal to two periods at a single retailer. At the beginning of each period, the retailer inspects his net inventory, $x_t$, which is one-period old, and places an order for quantity, $q_t$. For simplicity, we assume that the lead-time is equal to zero. The assumption of zero lead-times is a standard convention in both perishable inventory theory as well as in the literature on joint replenishment and pricing decisions.

At the same time, the retailer determines price(s) for that period. Let $p_t$ be the price in period $t$ and $d_t(p_t)$ be the expected demand corresponding to $p_t$. We assume that the function $d_t(\cdot)$ is strictly decreasing. As a result, there is a one-to-one correspondence between price and expected demand. This also means that we can use price and expected demand interchangeably in analysis. In fact, the exposition is considerably simplified when expected demand is used as a variable instead of price. Accordingly, throughout the paper we use expected demand as a variable to present results. In doing so, we omit the argument $p_t$ for simplicity and use only $d_t$ to denote the expected demand.

We assume that the expected revenue $p_t \cdot d_t(p_t)$ is strictly concave in $p_t$. This assumption is standard in the literature on joint inventory-price decisions. One example of $d_t(p_t)$ for which the expected revenue is strictly concave is $d_t(p_t) = a_0 - b_0 p_t$, where $a_0, b_0 > 0$. Another example of such a function is $d_t(p_t) = a_0 \exp(-b_0 p_t)$, where $a_0, b_0 > 0$, for $p_t \in [0, 2/b_0]$.

Once the order is delivered, customer demand arrives through the rest of the period. Let $\mathcal{D}$

to be the set of all feasible values of expected demand in a period. Further, we assume $\mathcal{D}$ to be convex, which implies that the set is an interval. Given expected demand $d_t$, the realized demand in period $t$ is equal to $D_t = d_t + \xi_t$, where $\xi_t$ is a random variable with support $[-a, \infty)$, where $a > 0$, such that $E(\xi_t) = 0$. Bounding the support of $\xi_t$ at $-a$ is necessary to ensure that demand $D_t$ remains non-negative. We assume that $\xi_t$ is independently and identically distributed over time. This demand model is referred to as the *additive* demand model in the existing literature. The word "additive" arises from the additive nature of the randomness ($\xi_t$). A more general model belongs to the *multiplicative* model, which has the following form: $D_t = d_t\xi_t^1 + \xi_t^2$. Thus, the randomness is present in both additive and multiplicative forms. We will develop our following models and computational experiments based on the multiplicative demand form. Two requirements for any $d$ to be contained in $\mathcal{D}$ are that (a) the realized demand $D_t$ remains non-negative for all $\xi_t^1 \in [-a, \infty)$ and $\xi_t^2 \in (0, b]$ (b) the corresponding price be non-negative. Since $\xi_t^1 \geq -a$ and $\xi_t^2 \leq b$, requirement (a) ensures that any $d$ in $\mathcal{D}$ is greater than or equal to $\frac{b}{a}$.

The discussion of consumption behaviors is separated into two stages. The first stage is to classified customers according to their preference. According to manners of selecting items, they are categorized into two groups. The first group prefers to pick fresh items from shelves and people from the second group randomly choose items without paying too much attention for the freshness. By observing this fact, we include a parameter $\beta$ such that partial demand $\beta D_t$ is fulfilled by fresh items we just ordered. The rest of demand $(1-\beta)D_t$ which represents demand from the second group is satisfied by items with age equal to one.

At the end of the period, once all the demand is realized, holding cost is charged on any remaining inventory at rate $h$ per unit. On the other hand, if demand exceeds inventory, the excess demand is lost, and lost-sales cost is charged at $\pi$ per unit. We let $\theta$ (possibly negative) be the unit cost of discarding old inventory. The parameter $\theta$ can be both positive or negative depending upon whether old inventory incurs a cost while being discarded or it is salvaged.

Standing from a store manager's point of view, First-in, First out issuing policy would be ideal to achieve the maximum utilization of a product. Hence, we assume that store staff re-arrange the shelf frequently from which items with older age will be placed in the front of the shelf. As a result, customers who randomly pick items actually acquire these old units following such an operational decision. In the later, we refer the customers' random selection as the acquisition of old items.

The second stage of consumption behaviors begins if the preference disappears in either segments. Based on our setting of items with age equal to two periods, we conduct four different types of inventory system to reflect such a two-stage consumption behaviors: All Units Accessible between Consumer Segmentations, Fresh Items Accessible to Customers who Randomly Pick Items, Non-interchangeable Demand between Customer Segmentations, and Old Items Accessible to Picky Customers. We start the first type model formulation and analysis as follows.

The first consumption behavior discusses the interchangeability of items between customer segments. That is, excess items (after stage one) which are preferred by a specific segment are available to another segment where desired demand are not completed fulfilled. For stores with well-established credibility would be good examples to represent this interchangeable relation among age-different inventory. Since the business strategy focuses on providing reliable products in these stores, the quality of freshness is assured. Due to the diminution of cognitive difference related to age, old items become acceptable for picky customers if their preferred items are depleted.

Now, we start to develop the profit function in a period. For simplicity, we omit the subscript $t$ from all the variables and let $D$ as a realized demand through the rest of this paper unless necessary for exposition. Given values of $x, q$ and $d$, the revenue, holding, and shortage costs incurred in a period are equal to

$$L^1(x,q,d) = R(d) - hE[q+x-D]^+ - \pi E[D-q-x]^+,$$

where $R(d)$ is the expected revenue, which is equal to the product of expected demand and the corresponding price, and $[\cdot]^+$ stands for $\max(\cdot, 0)$. Due to the interchangeable characteristic of age-differentiated items, the holding and shortage costs are exactly the same as these following FIFO and LIFO issuing rules.

Since inventory that is two periods old will spoil, the total amount of inventory discarded at the end of a period equals $[x-(1-\beta)D-(\beta D-q)^+]^+$. The dynamic programming equation of the optimal profit from period $t$ through the end of horizon $v_t$ is formulated as

$$\begin{aligned} v_t^1(x) &= \max_{d \in \mathcal{D}, q \geq 0} L^1(x,q,d) - cq - \theta E[x - (1-\beta)D - (\beta D - q)^+]^+ \\ &\quad + \alpha E v_{t+1}^1 [q - \beta D - ((1-\beta)D - x)^+]^+, \end{aligned} \tag{3}$$

where $\alpha$ is the discount factor. For simplicity, we drop the effect of $\alpha$ (set $\alpha = 1$) through the rest of discussion. It is a reasonable neglect since the arbitrary duration of a period should be short for perishables we specialize. We take the end of horizon profit $v_{T+1}^1(x)$ to be equal to $sx$, where $s$ is the salvage value. Observe that the argument of $v_{t+1}^1$, $[q - \beta D - ((1-\beta)D - x)^+]^+$, is the amount of inventory that is one-period old at the beginning of period $t+1$. (Other models based different consumption behaviors are omitted.)

# 4. CONCLUSIONS AND FUTURE RESEARCH

## 4.1 Inventory Management of a Non-perishable Product under the Dual Sourcing Strategy

This study identifies the joint pricing and ordering decisions for a retailer that adopts dual sourcing to mitigate disruptions in supply. When a regular supplier can recover in one period, the analysis indicates that a store manager should follow the base-stock, list-price policy. This policy is to order a fixed amount of units from the regular supplier and place another order from the emergency supplier up to a fixed inventory level. If the initial net inventory exceeds this fixed level, an order should only be placed with the regular supplier and the manager should consider price markdowns. For recovery of two periods, the bases-stock, list-price policy no longer exists. This study also proposes a contract agreement that motivates a retailer to acquire reimbursement from the regular supplier if this retailer opts not to wait for delayed items during recovery.

The experiments explore a wide range of parameter settings in the order quantity and list price. Besides, this study computationally illustrates the benefit of dual sourcing and demand management. Results reveal that demand management improves profit more when the regular supplier possesses a faster recovery ability. For profit improvement when adding an emergency supplier, a longer recovery length is beneficial. Finally, this work examines how a contract affects the retailer's profit, regular supplier's profit, and their mutual profit.

This study discusses the dual sourcing strategy for the inventory management particularly of a non-perishable product. Future research should explore dual sourcing for perishable products, and especially food. This extension is important for several reasons. Due to the specific characteristic of limited lifetime, disruptions in food supply create even more challenging inventory management problem for store managers. For example, the devastation of an area in which a particular crop is grown can create a supply shortage. Hence, people's anxiety can increase the demand for this product, and its price will likely soar in a short time. Another difficulty is that managers cannot store food too early due to spoilage, even though its holding cost may be very low. The extension of dual sourcing to this problem should also cover orders leadtime in both sources and a fixed cost per order.

## 4.2 Inventory Management of a Perishable Product under Various Consumption Behaviors

This study develops a periodic review model for perishable products with a fixed lifetime of two periods. Customers are classified according to their purchasing preference: they either select a fresh item or pick one from the shelf randomly. Following retailers' FIFO arrangement of items on the shelf, this study explores four different consumption behaviors. Results show that profit depends on on the demand interchangeability of various customer segments.

When picky customers are unwilling to take old items, but customers who take advantage of price will choose new one, the optimal price depends on the value of theinitial inventory. The inflexibility of interchangeability among items, which appears in the third type of customer behavior, creates structure in which both the optimal price and order quantity depend on inventory. Due to the lack of concavity in the first and fourth inventory systems, the optimal price and order quantity fluctuate randomly. With the increasing availability of products among customers, a retailer generates more profit. Accordingly, the first type of consumption behavior performs better than the other behaviors. Computational experiments reveal the effect of demand management based on two scenarios: heterogeneous demand and capacity constraint. Results indicate that the profit advantage of behaviors where random customers do not pick fresh items is better than that of behaviors where customers who randomly select items are willing to take fresh items in the presence of demand management.

## 5. Future Research

Some expectation is not completed in these efforts. The inventory control under the dual sourcing strategy will be developed for perishable products in the future. Besides, the promotion effort and green idea become interesting factors to affect consumption willingness. Thus, the inclusion of these two factors will be considered when a retailer controls his inventory

## References


Anton, J. J. and Yao, D. A. (1989). Split awards, procurement, and innovation. *The Rand Journal of Economics*, 20(4):538–552.

Arreola-Risa, A. and DeCroix, G. A. (1998). Inventory management under random supply disruptions and partial backorders. *Naval Research Logistics*, 45(7):687–703.

Berk, E. and Arreola-Risa, A. (1994). Note on "future supply uncertainty in eoq models". *Naval Research Logistics*, 41(1):129–132.

Billington, C. and Johnson, B. (2006). Creating and leveraging options in the high technology supply chain. *Journal of Applied Corporation Finance*, 15(2):32–43.

Chen, X. and Simchi-Levi, D. (2004). Coordinating inventory control and pricing strategies with random demand and fixed order cost: The finite horizon case. *Operations Research*, 52(6):887–896.

Chen, Y. F., Ray, S., and Song, Y. (2006). Optimal pricing and inventory control policy in periodic-review systems with fixed ordering cost and lost sales. *Naval Research Logistics*, 53(2):117–136.

Chiang, C. and Benton, W. C. (1994). Sole sourcing versus dual sourcing under stochastic demand and lead times. *Naval Research Logistics*, 41(5):609–624.

Cohen, M. A. and Pekelman, D. (1978). Lifo inventory systems. *Management Science*, 24(11):1150–1162.

Dave, U. (1991). Survey of literature on continuously deteriorating inventory models - a rejoinder. *The Journal of Operational Research Society*, 42(8):725.

Federgruen, A. and Heching, A. (1999). Combined pricing and inventory control under uncertainty. *Operations Research*, 47(3):454–475.

Fries, B. E. (1975). Optimal ordering policy for a perishable commodity with fixed lifetime. *Operations Research*, 23(1):46–61.

Goyal, S. K. and Giri, B. C. (2001). Recent trends in modeling of deteriorating inventory. *European Journal of Operational Research*, 134(1):1–16.

Groenevelt, H. and Rudi, N. (2003). A base stock inventory model with possibility of rushing part of order. Technical report, Simon Graduate School of Business, University of Rochester. Working Paper.

Karaesmen, I. Z., Scheller-Wolf, A., and Deniz, B. (To Appear, 2009). Managing perishable and aging inventories: Review and future directions. Handbooks of Production Planning. Kluwer Internation Series in Operations Research and Management Science.

Kelle, P. and Silver, E. A. (1990). Safety stock reduction by order splitting. *Naval Research Logistics*, 37(5):725–743.

Klotz, D. E. and Chatterjee, K. (1995a). Dual sourcing in repeated procurement competitions. *Management Science*, 41(8):1317–1327.

Klotz, D. E. and Chatterjee, K. (1995b). Variable split awards in a single-stage procurement model. *Group Decision and Negotiation*, 4:295–310.

Lau, H.-S. and Lau, A. H.-L. (1994). Coordinating two suppliers with offsetting lead time and price performance. *Journal of Operations Management*, 11(4):327–337.

Lau, H.-S. and Zhao, L.-G. (1993). Optimal ordering policies with two suppliers when lead times and demands are all stochastic. *European Journal of Operational Research*, 68(1):120–133.

Lau, H.-S. and Zhao, L.-G. (1994). Dual sourcing cost-optimization with unrestricted lead-time distributions and order-split proportions. *IIE Transactions*, 26(5):66–75.

Mishra, A. K. and Tadikamalla, P. R. (2006). Order splitting in single sourcing with scheduled-release orders. *The Journal of the Operations Research Society*, 57(2):177–189.

Moinzadeh, K. and Aggarwal, P. (1973). Analysis of a production/inventory system subject to random disruptions. *Management Science*, 43(11):1577–1588.

Nahmias, S. (1975). Optimal ordering policies for perishable inventory - ii. *Operations Research*, 23(4):735–749.

Nahmias, S. (1976). Myopic approximations for the perishable inventory problem. *Management Science*, 22:1002–1008.

Nahmias, S. (1982). Perishable inventory theory: A review. *Operations Research*, 30(4):680–708.

Pan, A. C., Ramasesh, R. V., Hayya, J. C., and Ord, J. K. (1991). Multiple sourcing: The determination of lead times. *Operations Research Letters*, 10(1):1–7.

Parlar, M. and Daphne, B. (1991). Future supply uncertainty in eoq models. *Naval Research Logistics*, 38(1):107–121.

Plambeck, E. L. and Ward, A. R. (2007). Note: A separation principle for a class of assemble-to-order system with expediting. *Operations Research*, 55(3):603–609.

Raafat, F. (1991). Survey of literature on continuously deteriorating inventory models. *The Journal of Operational Research Society*, 42(1):27–37.

Ramasesh, R. V., Ord, J. K., and Hayya, J. C. (1993). Note: Dual sourcing and nonidentical supplier. *Naval Research Logistics*, 40(2):279–288.

Sculli, D. and Shum, Y. W. (1990). Analysis of a continuous review stock-control model with multiple suppliers. *The Journal of the Operational Research Society*, 41(9):873–877.

Sculli, D. and Wu, S. Y. (1981). Stock control with two suppliers and normal lead times. *The Journal of the Operational Research Society*, 32(11):1003–1009.

Seshadri, S., Chatterjee, K., and Lilien, G. L. (1991). Multiple source procurement competitions. *Marketing Science*, 10(3):246–263.

Sheffi, Y., Rice, J. B., Fleck, J. M., and Caniato, F. (2003). Supply chain response to global terrorism. Technical report, Center for Transportation and Logistics, MIT, Boston, USA.

Sheopuri, A., Janakiraman, G., and Seshadri, S. (2010). New policies for the stochastic inventory control problem wth two supply sources. *Operations research*, 58(3):734–745.

Tagaras, G. and Vlachos, D. (2001). A periodic review inventory system with emergency replenishments. *Managemenet Science*, 47(3):415–429.

Tomlin, B. T. (2006). On the value of mitigation and contingency strategies for managing supply chain disruption risks. *Management Science*, 52(5):639–657.

Tomlin, B. T. (2009a). Disruption-management strategies for short life-cycle products. *Naval Research Logistics*, 56(4):318–347.

Tomlin, B. T. (2009b). Impact of supply learning when suppliers are unreliable. *Manufacturing and Service Operations Management*, 11(2):192–209.

Veeraraghavan, S. and Scheller-Wolf, A. (2006). Now or later: A simple policy for effective dual sourcing in capacitated systems. *Operations Research*, 56(4):850–864.

Whittemore, A. S. and Saunders, S. C. (1977). Optimal inventory under stochastic demand with two supply options. *SIAM Journal of Applied Mathematics*, 32(2):293–305.

Yano, C. A. and Lee, H. A. (1973). Lot sizing with random yield: A review. *Operations Research*, 43(2):311–334.

Zhao, L.-G. and Lau, H.-S. (1992). Reducing inventory costs and choosing suppliers with order splitting. *The Journal of the Operational Research Society*, 43(10):1003–1008.

The 41st annual meeting of Decision Sciences institute was hold in San Diego and emphasized on the topic "*Challenging the status quo-Breakthrough Innovations that Rejuvenate Organizations*". I was proud to be part of this activity and had a talk "*Pricing and Replenishment Decisions of a Retailer with Dual Sourcing under the Risk of Supply Chain Disruptions*"

Disruptions become a serious business concern when the globalized marketplace drives the stages of supply chain distributing worldwide. Damage to any stage could cause enormous loss in profit and customers. To help a store manager practically make better operational decisions under the risk of disruptions in supply, this talk proposes the dual sourcing strategy and provides managerial insight on the joint price and replenishment decisions. The model is based on a periodic review, finite horizon model. This study identifies the optimal price and replenishment policy for different recovery lengths and then proposes a contract that allows a retailer to choose the arrival of delayed items or wait until the regular supplier recovers from disruptions. Experimental results illustrate the performance of the proposed approach in terms of profit and the variations on joint order and price decisions. This study explores if a retailer takes advantage of demand management and if so, to what extent. This study then analyzes the magnitude of profit advantage in the presence of dual sourcing and dynamic pricing strategy respectively under the effect of recovery length. In the discussion of the contract agreement between a retailer and regular supplier, this study evaluates how it affects profit from both sides by examining a wide range of parameter settings.

Beside the session I was arranged, I also attend others which particularly focus on Supply Chain issues. One topic I am desperately searching for is the reversed and green idea in the supply chain (Session 192-LD in this conference). Many contexts give me good ideas and knowledge for my future research. For example, how the return policy affects the selling price in the e-marketplace supply chain? In additions, how the effect of Green supply chain helps a company earn customers perception is talked. In the future, I definitely combined this and make the price and replenishment decisions for products from firms which devote Green effort.

# 國科會補助計畫衍生研發成果推廣資料表

日期:2011/02/27

<table>
<tr><td rowspan="3">國科會補助計畫</td><td>計畫名稱: 在有供應中斷風險之下的雙重供應商策略分析: 非腐蝕性與腐蝕性商品評估</td></tr>
<tr><td>計畫主持人: 陳立民</td></tr>
<tr><td>計畫編號: 99-2410-H-004-003- 學門領域: 生產及作業管理</td></tr>
<tr><td colspan="2">無研發成果推廣資料</td></tr>
</table>

# 99 年度專題研究計畫研究成果彙整表

| 計畫主持人：陳立民 | 計畫編號：99-2410-H-004-003- |
|---|---|
| 計畫名稱：在有供應中斷風險之下的雙重供應商策略分析：非腐蝕性與腐蝕性商品評估 | |

| 成果項目 | | | 量化 | | | 單位 | 備註（質化說明：如數個計畫共同成果、成果列為該期刊之封面故事...等） |
|---|---|---|---|---|---|---|---|
| | | | 實際已達成數（被接受或已發表） | 預期總達成數(含實際已達成數) | 本計畫實際貢獻百分比 | | |
| 國內 | 論文著作 | 期刊論文 | 0 | 0 | 100% | 篇 | |
| | | 研究報告/技術報告 | 0 | 0 | 100% | | |
| | | 研討會論文 | 0 | 0 | 100% | | |
| | | 專書 | 0 | 0 | 100% | | |
| | 專利 | 申請中件數 | 0 | 0 | 100% | 件 | |
| | | 已獲得件數 | 0 | 0 | 100% | | |
| | 技術移轉 | 件數 | 0 | 0 | 100% | 件 | |
| | | 權利金 | 0 | 0 | 100% | 千元 | |
| | 參與計畫人力（本國籍） | 碩士生 | 1 | 1 | 100% | 人次 | |
| | | 博士生 | 0 | 0 | 100% | | |
| | | 博士後研究員 | 0 | 0 | 100% | | |
| | | 專任助理 | 0 | 0 | 100% | | |
| 國外 | 論文著作 | 期刊論文 | 0 | 2 | 100% | 篇 | |
| | | 研究報告/技術報告 | 0 | 0 | 100% | | |
| | | 研討會論文 | 2 | 2 | 100% | | |
| | | 專書 | 0 | 0 | 100% | 章/本 | |
| | 專利 | 申請中件數 | 0 | 0 | 100% | 件 | |
| | | 已獲得件數 | 0 | 0 | 100% | | |
| | 技術移轉 | 件數 | 0 | 0 | 100% | 件 | |
| | | 權利金 | 0 | 0 | 100% | 千元 | |
| | 參與計畫人力（外國籍） | 碩士生 | 1 | 1 | 100% | 人次 | |
| | | 博士生 | 0 | 0 | 100% | | |
| | | 博士後研究員 | 0 | 0 | 100% | | |
| | | 專任助理 | 0 | 0 | 100% | | |

| | |
|---|---|
| 其他成果<br>(無法以量化表達之成果如辦理學術活動、獲得獎項、重要國際合作、研究成果國際影響力及其他協助產業技術發展之具體效益事項等，請以文字敘述填列。) | 無 |

| | 成果項目 | 量化 | 名稱或內容性質簡述 |
|---|---|---|---|
| 科教處計畫加填項目 | 測驗工具(含質性與量性) | 0 | |
| | 課程/模組 | 0 | |
| | 電腦及網路系統或工具 | 0 | |
| | 教材 | 0 | |
| | 舉辦之活動/競賽 | 0 | |
| | 研討會/工作坊 | 0 | |
| | 電子報、網站 | 0 | |
| | 計畫成果推廣之參與（閱聽）人數 | 0 | |

# 國科會補助專題研究計畫成果報告自評表

請就研究內容與原計畫相符程度、達成預期目標情況、研究成果之學術或應用價值（簡要敘述成果所代表之意義、價值、影響或進一步發展之可能性）、是否適合在學術期刊發表或申請專利、主要發現或其他有關價值等，作一綜合評估。

1. 請就研究內容與原計畫相符程度、達成預期目標情況作一綜合評估

   ■達成目標

   □未達成目標（請說明，以 100 字為限）

   　　□實驗失敗

   　　□因故實驗中斷

   　　□其他原因

   說明：

2. 研究成果在學術期刊發表或申請專利等情形：

   論文：□已發表 ■未發表之文稿 □撰寫中 □無

   專利：□已獲得 □申請中 ■無

   技轉：□已技轉 □洽談中 ■無

   其他：（以 100 字為限）

   The paper has got the feedback from the Decision Sciences Journal. Some work needs to be modified this year.

3. 請依學術成就、技術創新、社會影響等方面，評估研究成果之學術或應用價值（簡要敘述成果所代表之意義、價值、影響或進一步發展之可能性）（以 500 字為限）

   After 911 attack, many research exploring the crisis management is derived exponentially. In this work, the dual sourcing strategy is adopted for supply disruptions and the replenishment in each sourcing and pricing decisions are optimized. Besides, the buyback contract from the supplier is proposed to examine how much the profit is improved. In the future, Green Effort and Promotion efforts in the supply chain system will be included into the model development.