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Modeling pooled purchasing strategy in purchasing consortium to optimize total purchasing cost

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Abstract

Purchasing consortium (PC) is horizontal collaboration amongst companies to jointly perform their purchasing activities. PC offers companies with better pricing in obtaining goods. One of the critical factors companies to join in the PC is the amount of benefits that would be achieved when they join in the PC compared to when they purchase individually, this factor also called nature of benefits. Strategies to maximize the nature of benefit of PC include two aspects, namely minimizing the total cost of purchasing and maximizing the allocation of saving/gain to each member. This research will be focused on the first aspect of those strategies which is modelling strategy to minimize the total purchase cost. The total purchase cost involves the purchase costs, ordering costs, shipping costs, inventory costs, fix operational cost and penalty cost. Mixed integer programming was developed to model procurement strategy to minimize the total cost of the purchasing system. Sensitivity analysis was also performed to evaluate how different values of parameters affect the total cost. Numerical experiments showed that the total cost of purchasing very sensitive to changes in number of demand from each member of PC. Potential contributions of this research is to provide an overview of the purchasing strategy in the PC by a quantitative approach and determine the condition when a PC needs to make changes on its procurement strategy to maintain and/or improve its nature of benefits during different system's condition.

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1. Introduction

Purchasing consortium (PC) is a strategy to enhance company competitiveness through procurement practices. Based on Essig [1] concepts and forms of cooperation in the purchasing discussed for the first time in 1927 by Mitchell, but the term used to describe a form of cooperation is very diverse, including cooperative purchasing, purchasing consortium, group purchasing, buying office, etc. Purchasing consortium has gained increasing attention in academic now days, as it offers companies to lower their sourcing costs by joining in group purchasing. Number of papers published and developed both concept and implementation of purchasing consortia. Majority of researchs in PC (e.g [2], [3], [4], [5]) mainly focuse on the organizational aspecs of the PC. Quantitative analysis that discusses aspects of purchasing strategies that take into account the operational aspects of the PC has been very limited (e.g [6]). How to manage operational activities in PC including ordering policy remain unclear.

Therefore, this paper focuses on modeling strategies to maximize the benefits in PC by minimizing the total purchasing cost. Modeling strategy is started by identifying the operational activities of purchasing and PC that can trigger the costs. The cost components that are modeled in this research are purchase costs, ordering costs, shipping costs, and storage costs wich are commonly used in inventory model like in Sarmah et al [7] and Munshon and Hu [8]. Beside that, operational cost of PC that used in Muhammad [6], backorder cost, and penalti cost also considered in this model. The dynamic conditions that often happen in a PC like changes in the number of members, changes in demand and changes in the member dispersion that mentioned in Nollet and Beaulieu [2] also have taken in to account in this model.

The strategies that modeled in this paper called Pooled Pricing Strategy which is consolidation among the members of the PC in price negotiation with suppliers and determining ordering period. The dynamic condition of PC applied in model by doing sensitivity analysist to the model. The system that modeled in this paper consist of one supplier, one PC agent, and several buyer that join their purchase in PC.

This paper is organized as follows: Section 2 presents a literature review, Section 3 describe a mathematical model of strategy. In Section 4, Numerical experiment are presented to illustrate the strategy model. A sensitivity analysis also performed to illustrate the effects of parameter changes on the objective function. Section 5 presents a summary and conclussion.

2. Literature Review

2.1 Purchasing Consortium

In PC system some independent company at the same level of a supply chain gathering their demand [1] to purchase to one or more suppliers. With combining volume of product need and doing purchase together so the PC member will have a higher bargaining power to the suppliers. In addition, member of PC can get a lower price due to higher volume of purchasing. On the other side, the PC also have some weakness, such as increase complexity of the purchasing process, the member will lost the purchasing control capability and flexibility, rise up the coordination cost and other thing, that maybe will impact the PC profitability not always maximum. Strategies to maximize the nature of benefit of PC include two aspects, namely minimizing the total cost of purchasing and maximizing the allocation of saving/gain to each member. The strategies to maximize the nature of benefit from PC includes two aspects, that are minimizing the total cost of a purchase via PC and maximize the allocation saving or distribution mechanism results of the purchase cost savings from each member. Resently research that related with PC strategy more focused on the second aspect, as has been done by Heijboer [9], Schotanus [10], Nagarajan et al [11], and Schotanus et al [12]. The first aspect of the strategy to minimize the total purchasing cost of the PC had been conceptualy discussed by Essig [1] and Nollet and Beaulieu [2]. Essig [1] states that the concept of cooperation in purchasing activity must change towards a strategic perspective like sourcing consortium (cooperative procurement). On the other side, Nollet and Beaulieu [2] conducted a survey to the member of the PC, to determine the form of strategy adjustments by the PC to maintain and improve the nature of the benefits. Both of Essig [1] and Nollet and Beaulieu [2] used a qualitative approach to explain the purchasing strategy in the PC.

Based on Nollet and Beaulieu [2], as the PC grow from the forming phase (birth) to concentration phase

(concentration) and the demands of a competitive business environment, nature of benefits to be achieved by members of the PC are also evolve from a decrease the purchase price to decrease operational costs . This aspect finally responded by PC management organization in the form of adjustments components, such as:

1) Purchasing strategy that includes adjustments to the types and quantities of commodities, number of members, and the diversification of services offered
2) How to establish relationships with suppliers that can be done through bidding, partnership, and direct negotiation with suppliers
3) Organizational management structure which consists of a change of confederation structure, autonomous structure, or a third party
4) The size and location distribution of each member
5) The type of relationships between members, and
6) Purchasing staff ability.

These six components above also will be the critical factor that affecting the success and sustainability of a PC. From the six components that have been mentioned, 3rd and 5th component are developed by some researchers with build a framework to map and select the type of interaction and organization form of PC management. Research related with organization model selection is done with a qualitative approach, through direct surveys to the perpetrators of the PC to determine the form of management and organization that is used to build a framework for classifying the forms of interaction within the organization PC based theories on previous research. Research related to the interaction structure between members of the PC can be reviewed further in Schotanus and Telgen [13], Waltmans et al [14], Bakker et al [5], Schotanus and Telgen [4] and Bakker et al [5]. Although purchasing strategy in purchasing consortium has been mentioned in two previous researchers [1] and [2], but research using quantitative approach to model purchasing strategy in PC has never been done before.

Other research in PC that used quantitative method are done by Keskinocak and Saneril [15] and Zhou and Xie [16]. Keskinocak and Saneril [15] using game theory method in modeled the economical factors (profitability) that underlie purchase collaboration among buyers and the relationship with suppliers. On the other side Zhou and Xie [16] used dynamic game method to see the effects of discounts policy implementation for each entities of group purchase.

3.2. Previous research in purchasing and inventory model

Purchasing coordination are modeled by Sarmaha et al [7] and Munson and Hu [8]. Sarmaha et al [7] modeled coordination between one company with some purchaser involves the credit payment with two scenarios, ex-site delivery-common replenishment time-common carrier and ex-factory delivery-common replenishment time. In their model transportation costs are con-sidered equal and uniform for each buyer. Cost that considered in their model are Purchase Cost, Ordering Cost, Shipping Cost, and Inventory Cost. Munson and Hu [8] modeled coordination between buyers in a centralized purchasing. Their model involved both incremental and all units discounts with four scenarios called decentralization, centralization price, centralized purchasing time, and centralized inventory. They also used two type of discount in their model which are all unit discount and incremental discount. Cost component that are modelled are Purchase Cost, Ordering Cost, Shipping Cost, and Inventory Cost.

Other purchasing model that incorporated inventory cost are modeled by Krichen et. Al [17]. Krichen et. Al [17] used game theory to find coalitions forms in purchase cooperation between many retailers with one supllier with price levels that involve discounts and payment delays. Scenario determined based on the payments delay mechanism. All unit discount used in their research used to determine discount scheme in this research. The most resent research in PC (e.g Muhammad [6]) used Common Replenishment Epoch (CRE) scenario determine the optimum procurement time for PC agent and the PC member. This research also determine the allocation of the savings gained for each member. Although Muham-mad [6] already considering Purchase Cost, Ordering Cost, Inventory Cost, and Operational Cost in his model, he did not considering the cost of transportation and dynamic condition of PC.

Therefore, this paper is aimed to build a model of purchaing strategy in a PC that consider operational cost of PC‘s agents and also fix and variable cost of sipping, as well as delay penalty fee due to the different replenishment periods

between PC and members.

3. The model

Operational activities in the purchase consists of the activity of negotiation with suppliers, ordering, shipping, and storage. An agent of the PC will combine the number of demand from PC members and doing purchasing activities for its member as an entity to achieve economics of scale that required in getting better price from suppliers. Purchasing activities between members and supplier are suppose to be done by agent PC (one gate system). In this system the total purchasing cost of the system that consists of the purchasing cost in each member and at the PC is expected to be minimized. In order to minimize the total purchasing cost, it's necessary to choose proper cooperation strategy to manage purchasing activity in the PC. Kind of cooperation strategy that may occur in the PC depicts the diversification of services provided by the agent PC to its members. In pooled purchasing strategy, agent PC provided services not only in price negotiations and transactions with suppliers, but also to determine the optimum order time of PC to the supplier based on aggregation of their demand. In this strategy all members are agreed upon the price and the time reservations set by of the PC, while the shipping and storage activities performed separately by each member of the PC.

To establish the mathematical model, the following notation and assumptions are used.

o	Supplier index
i,j	PC member index, where i = 1,2,3....I; j = 1,2,3....I; i≠j
n	The number of PC members
R_i	Average demand of ith member of PC per year
μ	Average demand per unit time
σ_i	Standard deviation of demand per unit time for ith member of PC
R	Total demand of PC per year ($R = \sum_{i=1}^{n} R_i$)
σ	Standard deviation of demand per unit time for PC ($\sigma = \sqrt{\sum_{i=1}^{n} \sigma_i{}^2}$)
Po	Basic Price per unit product
P_{min}	Minimum price per unit product
p	Discount rate that assigned by supplier
P	Price per unit product
C_o	Order-preparation cost that assigned by supplier
C_p	Order-preparation cost that assigned by PC
c	Operating cost for PC agent
H_b	Storage cost per unit per year on the warehouse member
Q_i	Quantity optimum order for ith member
Q	Quantity order of PC
S	Fixed cost for each shipping
s	Shipping rate per mile
d_{oi}	Distance between supplier and ith member
d	Mileage delivery ($d = \sum_{i=1}^{n} d_{oi}$)
Lo	Lead time processing per order at supplier
Li	Lead time processing per order at PC
B	Backorder cost per unit
$E(X-r)^+$	Expected number of shortages per cycle
l	Penalty cost rate if for different the replenishment time between member and PC
$1-\beta$	Service level of ith member
$1-\beta_P$	Service level of PC

Assumptions:

1. There is one supplier that supplies a type of product to some buyers who incorporated in a PC

2. All order to the supplier conducted through PC Agent, so order processing lead time (L) is total order processing time at the PC and at the supplier
3. The amount purchaisng cost is assumed to be depended on the order quantity and discount rates offered by suppliers. In this model discount system followed the discount concept of Fazel et.al (1998) in Krichen et.al[17]. Based on their concept price per unit can be deterimined as:
$$P = \begin{Bmatrix} P_0 & Q_i = 0 \\ P_0 - p \times Q_i & 0 < Q_i \leq Q_{max} \\ P_{min} & Q_i > Q_{max} \end{Bmatrix} \text{ where } Q_{max} = (P_0 - P_{min})/p.$$
4. Demand during lead time (X) is assumed to be normally distributed with an average demand (μL) and standard deviation ($\sigma\sqrt{L}$), where σ is the standard deviation of demand per unit of time
5. PC Agent places the order quantity Q to the supplier when the inventory position reach reorder point level. The reorder point r = expected demand during lead time (μL) + safety stock (ss). In Simchi Levi [18], safety stock (ss) = $k \cdot \sigma\sqrt{L}$, with k as a safety factor that meets the probability P (X > r) = 1 - β , where 1 - β is the allowable stock out probability during lead time ([19], [20], [21])
6. Demand that can't be fulfilled in a given period will be met in the next period (backordered) with a compensation fee of B.
7. Purchasing adhere free on board (FOB) system, which means that the entire cost of transportation from the supplier warehouse to the member of PC warehouse is imposed to the member of PC.
8. Deliveries are done from suppliers direct to each member of PC. Assumption 1 to 8 also used in Dewi [22].
9. The different replenishment period at the first time the buyer just joint the PC accommodated by a penalty cost (BL). Penalty cost arise when replenishment period of PC (T_{PC}) is greater than optimum replenishment period of member without PC.

The objective function of this model is to minimize the total cost of purchasing (TC) of the system, which consists of seven cost components. Cost component that involved in the purchasing activities of PC can be identified into Purchase Costs (BB), Ordering Cost (BP), Shipping Cost (BD), Storage Cost (BS), Backorder Cost (BK), Penalty Cost of different replenishment time (BL) and Operating Costs of PC (BO). Total Purchasing cost of PC system when appliying Pooled Purchasing Strategy can be describe as:

$$TC = BB + BO + BP + BD + BS + BK + BL$$

For $0 < Q \leq Q_{max}$

$$TC = (P_0 - pQ)R + c + \frac{R}{Q}\left(C_o + nC_p\right) + \frac{R}{Q}\left(n.S + s.2\sum_i^n d_{0i}\right) + H_b\left(\frac{Q}{2} + k\sigma\sqrt{L_o + nL_i}\right)$$
$$+B\frac{R}{Q}\sigma Gu(k)\sqrt{L_o + nL_i} + \sum_i^n l(T_{PC} - T_i) \quad (1)$$

For $Q > Q_{max}$

$$TC = P_{min}R + c + \frac{R}{Q}\left(C_o + nC_p\right) + \frac{R}{Q}\left(n.S + s.2\sum_i^n d_{0i}\right) + H_b\left(\frac{Q}{2} + k\sigma\sqrt{L_o + nL_i}\right)$$
$$+B\frac{R}{Q}\sigma Gu(k)\sqrt{L_o + nL_i} + \sum_i^n l(T_{PC} - T_i) \quad (2)$$

Where $Gu(k) = \emptyset(k) - k\left(1 - \phi(k)\right)$ and $d_{oi} = \sqrt{(x_1 - x_0)^2 + (y_1 - y_0)^2}$. Decision variables that should be find to achieve the goal of this model is the optimum order quantity of PC (Q). The optimum order quantity can be calculated by performing partial derivatives TC to Q where $\frac{\partial TC}{\partial Q} = 0$.To simplify the calculation, we excluded the Penalty Cost of different replenishment time (BL) then put it back at the end of the calculation (see the numerical experiment). From the partial derivation we got:

For $0 < Q \leq Q_{max}$

$$Q = \sqrt[2]{\frac{2R\left(\left(C_o + nC_p\right) + \left(n.S + s.2\sum_i^n d_{0i}\right) + \left(B\sigma Gu(k)\sqrt{L_o + nL_i}\right)\right)}{(H_b - 2pR)}} \quad (3)$$

For $Q > Q_{max}$

$$Q = \sqrt[2]{\frac{2R\left(\left(C_o + nC_p\right) + \left(n.S + s.2\sum_i^n d_{0i}\right) + \left(B\sigma Gu(k)\sqrt{L_o + nL_i}\right)\right)}{H_b}} \quad (4)$$

4. Numerical Experiment

The value of parameters used in numerical experiment as follows:

Table 1 PC member data

Members	(i)	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Demand	Ri	489	381	1.139	1.602	1.560	747	184	1.235	980	913	482	1.265	1.064	1.634
	σi	15	9	9	7	4	12	13	13	13	5	8	14	9	15
Position	x	3	44	16	3	0	16	13	24	11	5	10	13	22	7
	y	6	4	41	9	14	23	27	23	29	26	32	9	45	11
$1-\beta_p$		88%	75%	80%	75%	77%	65%	90%	88%	85%	79%	94%	73%	94%	95%
Qi		234	248	412	522	389	506	121	386	374	287	140	638	233	331

Table 2 model parameter data

Parameter	P_o	P_{min}	p	C_o	C_p	c	B	S	s	n	L_o	L_i	H_b	$1-\beta_p$	l
Value	17	12	0,0005	3	2	1.500	125	30	0,1	14	3	1	5,1	97%	5.500

Table 1 shows parameter related to PC's member which are the number of member (e.g n=14) and that each member have different demand (Ri, σi), location (x, y), service level ($1-\beta_p$), and order quantity optimum (Qi). And for Table 2 consist of other parameters related with the model such as price, discount rate, unit cost for order, shipping, backordering, and holding, lead time, service level, and penalty cost per unit time.
Calculation step to determine the minimum Total Cost of PC system is shown in Fig. 1. Calculation result of Total Cost of PC using calculation scheme in Fig. 1 described in Table 3.

Table 3 Calculation results total cost of purchase in strategy 2

R	σ	*ni*	*L*	*1-Beta*	*Q**	T_o	
						Year	*day*
13675	41.158	14	17	0.97	10000	0.731	267
TC							
BB	*BO*	*BP*	*BD*	*BS*	*BK*	*BL*	**Total**
164100	1500	42	1061	27132	337	25385	219.558,23

Table 3 shows that aggregate demand of PC's member in those numerical experiment was 13,675 unit with deviation about 41.158. Quantity order optimum for PC was 10,000 using 97% service level wich is higher than Qi. Order placed for each 267 day which is relatively longer and generated penalty cost (BL) as much as 25,385. And finaly, the total purchasing cost that consist of Purchase Costs (*BB*), Ordering Cost (*BP*), Shipping Cost (*BD*), Storage Cost (*BS*), Backorder Cost (*BK*), Penalty Cost was 219,558.23.

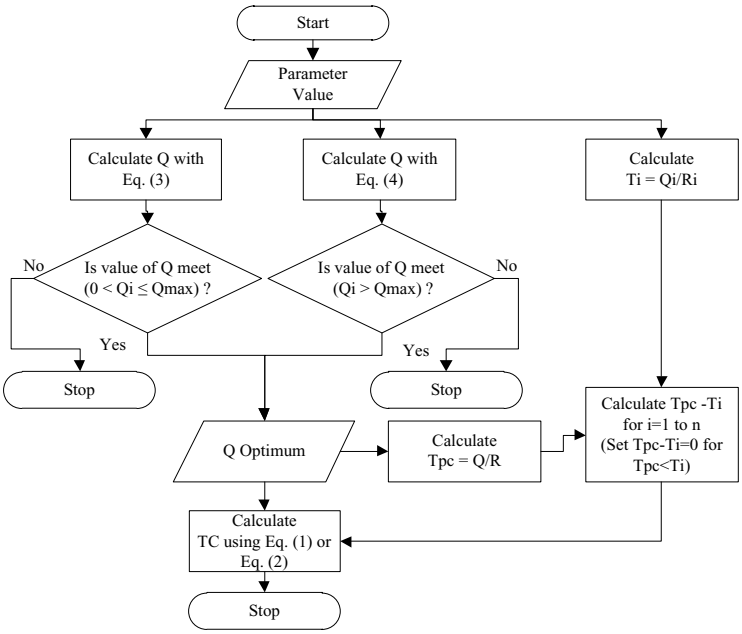

Fig. 1 TC Calculation scheme

Sensitivity analysis was done by varying one parameter (one way sensitivity analysis) or two parameter (two way sensitivity analysis) while other parameters remain the same. The goal was to see the influence of those parameters to the outputs of the model. Some parameter that used for this sensitivity analysis was the demand of members, number of members, and the shipping distance. Initial parameter in Table 1 and Table 2 was used as the basis values. Varying of those initial value was done by multiplying them by 50% to 150%. Sensitivity results are shown in Fig. 2 and Fig. 3.

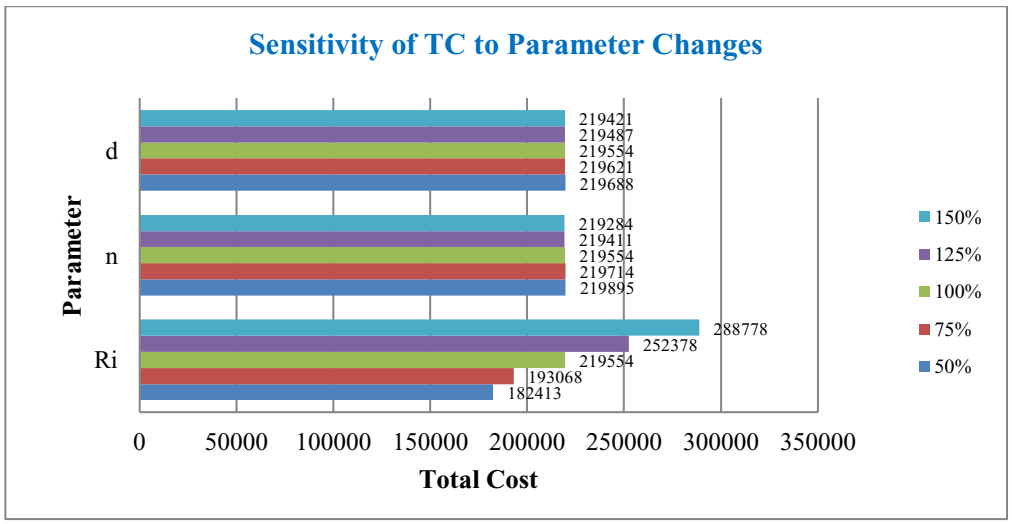

Fig. 2 One way sensitivity analysis result

One way sensitivity analysist present above shows that variying value of demands (Ri), member (n), and distances

(d), to 50%, 75%, 100%, 125%, and 150% from initial value make changes in Total Cost. Change in demands gave significant influence to Total Cost. On the other hand, two way sensitivity analysis was conducted to see wether a combination of two parameter value could give influence to Total Cost. The two way sensitivity analysis result as follows:

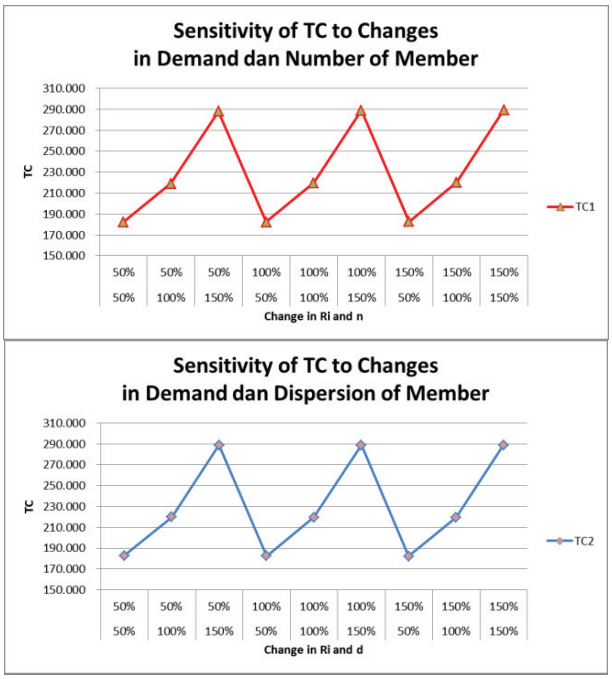

Fig. 3 Two way sensitivity analysis result

Fig. 3 shows that Total Cost changed according to the change of demand. Any combination of parameter (e.g Ri and n or Ri and d) didn't make significant change in Total Cost.

5. Conclussion

Numerical examples showed that model has been able to represent the conditions in a purchasing consortium (PC). PC conditions included in this model are: the existence of the number of members of the consortium purchasing more than one (n) with different location and dispersion (d) and also the number of demand (Ri) which vary from each member. Besides the additional costs in the form of variable cost (Cp) is charged to each member for every order and fixed costs (c) also consider as operational cost of the PC per year. In addition the model has also been prepared to consider additional lead time for processing order through PC (Li) other than the prosessing time set by the supplier (Lo). This model also still can give optimum result even the condition of PC has changed.

The PC strategy proposed in this study is a strategy that includes the consolidation to get discounts from supplier and also ordering time. The process of consolidation that occurred in this strategy was made during the negotiation process with major suppliers. Accumulated demand members joined in the PC increases the economic scale in the purchase of a PC so that members can buy in a large suppliers with lower prices due to the fraction of the discount given by the major suppliers. By ordering at the same time, the booking fee can be reduced and also by aggregating demand then discounted prices obtained is also greater.

Furthermore, by making some changes in the condition of the PC, in this case varying the quantity of demand, dispersion of members, and number of member we can conclude that the total cost in PC system that applying this kind of strategy is very sentitive to demand quantity of the member. So, to maintain its benefits PC should also

maintain the number of demand.

Our model can be extended by adding more level of consolidation like consolidation in shiping and warehousing between member that support by PC. Also, one can also extend this model for multi-echelon supply chain when there are multi items of goods. The model can be further extended to some more practical situations, such as adding some variable components to operational cost for maintainging PC. Because the the growing number of members lead more complex operational activities to be carried out. This of course can lead to additional costs such as the addition worker to place in PC agent which will directly increase the total cost of purchasing the system.

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