An Integrated Framework For Commodity Supply Chain In Higher Educational Institutes (HEIs)

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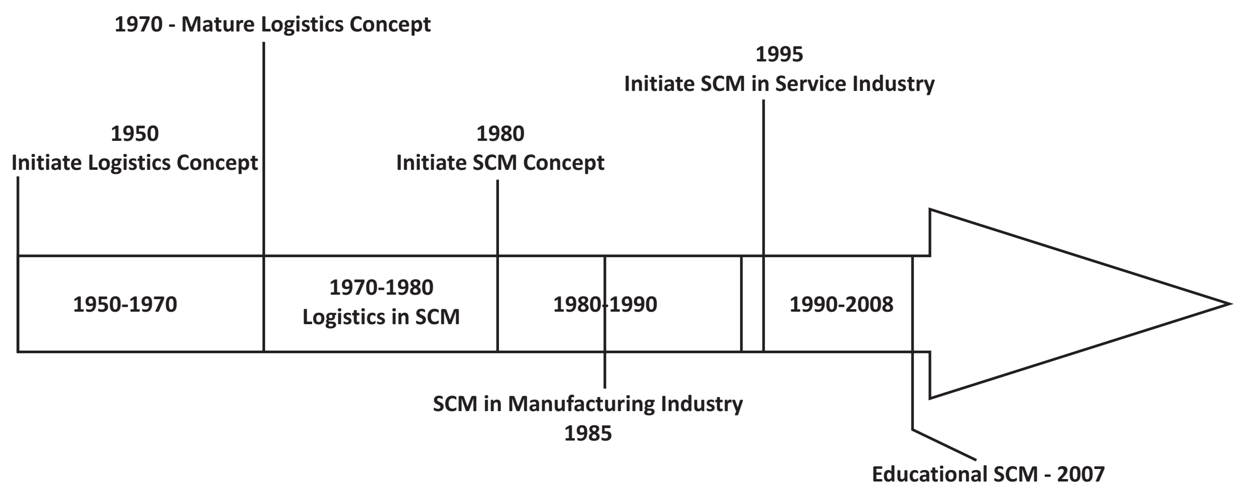
INTRODUCTION

The Institute for Supply Management (ISM) defines Supply Chain Management (SCM) as, *"design and management of seamless, value-added processes across organizational boundaries to meet the real needs of the end customer."*. B. S. Sahay et al. (2003) have characterized fulfilling customers' needs and creating trust among trading partners in the value chain imperative in organizations. The study also emphasized upon the alignment of supply chain strategy with organizational goals. However, O'Brien and Deans (1996) put forward that traditional SCM has been associated with the flow of orders and materials through the chain for adding value, i.e. predominantly, it is a logistics view. The study emphasized that the concept of adding value at every stage can be applied to the educational scenario, with higher-education institutions (HEIs) offering industrial placements and exchange facilities with overseas institutions as additional features of their programmes. The evolutionary time line of SCM has been shown in Figure 1 (Md. Mamun Habib and Chamnong Jungthirapanich, 2008).

Figure 1: Evolutionary Time Line of SCM



Lau (2007) stated that during the last decade, research on SCM has extensively appeared in different types of management areas like - strategic management, operations management, information management and knowledge management. Discerningly, these papers discuss the supply-chain issues in profit organizations for adding value, or reducing cost. O'Brein and Deans (1996) and Lau (2007) furthermore, summarized that only few papers are available, which discuss about educational supply chain. Later, the concept of adapting industry supply chain models to HEIs through collaboration was examined and yielded positive results in the study conducted by O'Brein and Deans,

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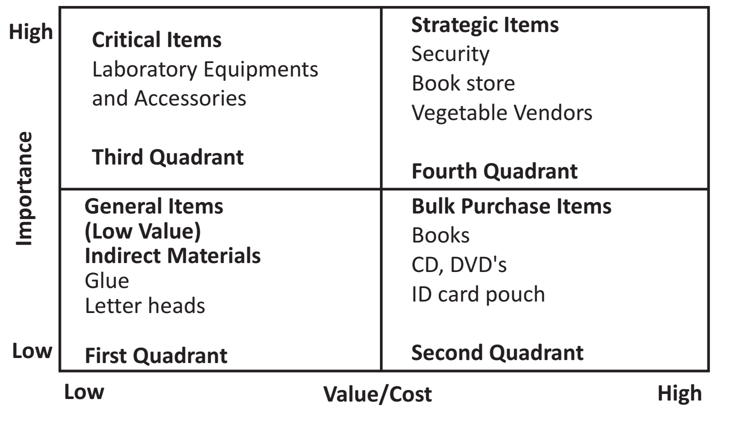
(1996). Lau (2007), in perpetuation, identified three types of educational supply chains, which have been considered as commodity supply chain, special requested supply chain and outsourcing supply chain. The study used Yin's case study approach, which has been considered to be subjective in nature. Hence, an objective method of obtaining the supply-chain performance in educational supply chain scenario becomes necessary for modeling supply chain quantitatively. In principle, this approach connects education management and general business management (Lau, 2007). Ramos (2004) then describes that the linking of supply-chain management and management accounting is not a well researched area, with only a handful of studies available on the same topic . Therefore, modeling supply chain quantitatively has been warranted to minimize the procurement cost optimally as HEIs procure multi-commodities in their value chain. Liao and Hong (2007) parallelly addressed critical issues to establish an effective supply network in a global supply chain network. In the study, supplier portfolio model had been used to cluster around the supplier, based on-key factors, labor ratio and cost ratio. Smith (2003) portrayed that an additional use of integrated spreadsheets allowed analysis of logistics and supply chain issues from different perspectives effectively. Chopra and Meindl (2008), in their book, report modeling supply chain quantitatively under different phases of the supply chain, along with the usage of spreadsheets. Shapiro (2002) eventually stated that data driven mathematical models play a crucial role for managers in effective decision making. Commodity supply chain, which processes multi-commodity purchases, targeting cost through reduction in administrative and processing cost, has been considered as an opening for the study. The main objective of the commodity supply chain has been to attain a value for money and accountability (Lau, 2007). Value for money has been considered to ensure use of funds productively. Accountability has been considered to promote cost-effectiveness in administrative and research areas, thereby, creating a rationale for modeling commodity supply chains in HEIs.

Significance of educational SCM improves the well-being of end customers, and this exploratory study addresses modeling commodity educational supply chain. The proposed conceptual model for the HEIs as scope, provides a novel approach for decision makers. From a managerial perspective, the study provides an approach to develop and assess SCM application in academia. In principle, an attempt has been made to model commodity supply chain, which will add value to HEIs. The main objective of mathematical formulation has been to optimize the supply-chain cost during multi-commodity purchase. This paper examines the possibility of handling multi-commodity in HEIs with an integrated framework by optimizing the cost. The spreadsheets help to reduce the calculation time of procurement managers, and divert resourceful time for value addition activity. Overall, an attempt to manage multi-commodities objectively has been made, which can add value to the organization.

RESEARCH METHODOLOGY

The main aim of the research has been to model commodity supply chain for HEIs using strategic and tactical planning. Firstly, the scope of the case has been clearly defined, wherein, data relevant to supply-chain management has been collected. The procurement personnel were requested to explain the current process followed in the chosen HEIs. Secondly, categorization of different commodities was carried out using product categorization matrix, which had been used as the primary tool to differentiate, based on its usage, in terms of value and importance. The matrix was used to segregate commodities as general, bulk purchases, critical and strategic commodities. Low value items or indirect materials such as glue, letter heads were considered as general commodities. Commodities like books, compact discs, which had been procured on bulk, were considered as bulk purchase commodities. Laboratory equipments were considered as critical commodities and security, book store were considered as strategic commodities. Thirdly, modeling commodity supply chain for different types of commodity categorizations was carried out. Demand was assumed to be stable for general and bulk purchase modeling. Similarly, continuous replenishment and fixed lead time was assumed for modeling critical and strategic commodity. Mathematical modeling of these items was formulated using economies of scale, uncertainty and product availability. General commodities were formulated by aggregating the products in the form of lot sizing. Bulk purchase commodities were formulated considering different buying situations. Critical commodities were evaluated in terms of demand pattern. Fourthly, strategic commodities were evaluated in terms of Cycle Service Level (CSL) and fill rate (fr). Spreadsheet frameworks for supply chain, with respect to different category commodities were developed to ease the calculation procedure. Finally, the viability of the framework was ascertained by implementing the supply chain model to MSRSAS operation, and by conducting a pilot run of the developed model.

Figure 2: Commodity Categorization in HEIs



SOLUTION PROCEDURE

Categorization matrix plays a pivotal role in the study to segregate multi-commodities based on their value and importance. Figure 2 shows the commodity categorization matrix by value and importance. The matrix shows general commodities as lower value and importance as shown in the first quadrant. Bulk purchase commodities have been considered as high value for money and less important as shown in the second quadrant. Critical commodities have been considered as low value for money and high importance as shown in the third quadrant. Similarly, strategic items have been considered to have higher value and higher importance as shown in the fourth quadrant.

GENERAL COMMODITY FRAMEWORK (QUADRANT 1)

The formulation has been carried out to maximise the profit or minimise the supply-chain cost. The supply-chain cost can be obtained as the sum of material cost, ordering cost and holding cost. Demand (D) has been assumed as stable and for a single commodity, lot sizing the supply-chain, the total cost (TC) has been shown in expression (1). Optimum order quantity (Q*) has been considered as optimal lot size as shown in expression (2). At this point, the ordering cost (S) is equal to the holding cost (hC). Holding cost has been assumed as 20% of the material cost. Optimal order frequency (n*) has been shown in expression (3).

$$TC = CD + ((D/Q) * S) + ((Q/2) * hC) \quad \ldots (1)$$

$$Q^* = \sqrt{\left(\frac{2DS}{hC}\right)} \quad \ldots (2)$$

$$n^* = D/Q^* \quad \ldots (3)$$

With this background, complete aggregation of multi-commodities in a single order was carried out to assess the impact of supply chain cost savings. Demand (D_i) has been considered for commodity, i and si had been considered as an additional order cost if product i had been included in the order along with fixed order cost (S). Therefore, the combined order fixed cost has been shown in expression (4). The total supply chain cost has been shown in expression (5).

$$S^* = S + \sum s_i \quad \ldots (4)$$

$$TC = \Sigma\left(\frac{D_i h C_i}{2n^*}\right) + \left(S^* * n^*\right) + \Sigma C_i D_i \quad \ldots (5)$$

Similarly, tailored aggregation of multi-commodities had been carried out to know the impact of supply chain cost savings. Frequency (m) where commodity i has been ordered for m_i deliveries plays a crucial role for multi-commodity lot sizing. Firstly, the most frequently ordered product, when procured independently, has been calculated using expression (6). Highest order frequency ($\bar{n}$) infers that commodity i has to be included in every order.

$$\bar{n}_i = \sqrt{\frac{D_i h C_i}{2(S + s_i)}} \quad \ldots (6)$$

Secondly, frequency ($\bar{n}$) for the remaining commodity has been calculated using expression (7).

$$\bar{n}_i = \sqrt{\frac{D_i h C_i}{2 s_i}} \quad \text{...(7)}$$

Thirdly, evaluation of the ordering frequency for remaining commodity i has been carried out using expression (8). Rounding off the obtained value, the order frequency (m_i) of multi-commodity has been determined.

$$\bar{\bar{m}}_i = \frac{\bar{\bar{n}}}{\bar{n}_i} \quad \text{...(8)}$$

Lastly, re-calculating the ordering frequency of the most frequently ordered commodity (n) using expression (9), the total supply chain cost has been derived.

$$n = \sqrt{\frac{\sum DihCimi}{2\left(S + \left(\sum \frac{si}{mi}\right)\right)}} \quad \text{...(9)}$$

BULK PURCHASE COMMODITY FRAMEWORK (QUADRANT 2)

Comprehensively, all unit quantity discounts have been considered as the buying situations. Here also, the main objective of this framework has been to maximize profit or minimize supply chain cost. In all unit quantity discounts, the pricing schedule has a specified range in the form of q_0, q_1, q_2, ……q_n. and the subsequent cost (C_i) decreases as the quantity increases. For each value of i, the following three cases have been considered for Q_i :

- $q_i \le Q_i < q_{i+1}$
- $Q_i < q_i$
- $Q_i \ge q_{i+1}$

The third case has been ignored as it becomes equivalent to the first case in the next iteration. Furthermore, the total cost (TC) can be calculated using appropriate Q_i or q_i procurement situation.

CRITICAL COMMODITY FRAMEWORK (QUADRANT 3)

The formulation has been carried out assuming continuous replenishment policy with only demand as uncertain. The main objective of this framework has been to counter act demand uncertainty. Mathematical formulation to know cycle service level (CSL) and fill rate (fr) had been calculated to make appropriate trade-off based on the demand pattern. Uncertainty in demand had been considered as normal distribution, with mean as average demand (D), standard deviation of demand (σ_D), with lead time (L). Average inventory left when the replenishment lot arrives has been known as safety inventory (SS). Enumerating the appropriate re-order point (ROP) has been considered critical in this framework. Expression (10) shows the formula to calculate safety inventory. (SS).

$$SS = ROP - DL \quad \text{...(10)}$$

With this setting, expected demand during lead time (D_L) and standard deviation during lead time (σ_L) have been written mathematically as shown in expressions (11) and (12) respectively.

$$D_L = D * L \quad \text{...(11)}$$

$$\sigma_L = \sqrt{L} * \sigma_D \quad \text{..(12)}$$

Cycle Service Level (CSL) for a replenishment policy had been evaluated by considering as the probability of not stocking out during the replenishment cycle. Scientifically, CSL has been calculated using expression (13).

$$CSL = F\,(ROP, D_L, \sigma_L) \quad \text{..(13)}$$

Similarly, fill rate (fr) estimates the portion of demand satisfied when Q units have been ordered, when the quantity on hand drops to ROP. The process of stock out (ESC) has to be understood to evaluate fr. A book from Chopra and Meindl (2008) shows mathematical interpretation of ESC (Expression 14). For a lot size of Q, expected portion of demand lost has been given by expression (15) and the commodity fill rate has been obtained as shown in expression (16).

$$ESC = -SS\left[1 - F_s\left(\frac{SS}{\sigma_L}\right)\right] + \sigma_L f_s\left(\frac{SS}{\sigma_L}\right) \quad \text{.......(14)}$$

Portion of demand lost = ESC / Q ....(15)

Commodity fill rate, fr = 1 - (ESC/Q) .... (16)

STRATEGIC COMMODITY FRAMEWORK (QUADRANT 4)

The formulation has been carried out assuming continuous replenishment policy. The main objective of this framework has been to maintain optimum commodity or product availability. Business settings have the desired level of product availability and design replenishment policy to achieve that level. The desired level of product availability had been determined by trading off holding cost and stock out cost. The formulation has been carried out to arrive at appropriate inventories for individual commodities from the desired level of product availability. Firstly, estimation of appropriate inventory level for different commodities had been carried out with respect to the desired CSL. Expression (10) and (13) shows the mathematical formulation of safety stock (SS) and Cycle Service Level (CSL) respectively. Expression (13) has been further interpreted as shown in expression (17).

$CSL = F(D_L + SS, D_L, \sigma_L)$ ....(17)

Expression (16) has been re-arranged to get the mathematical relation for safety stock (SS) as shown in expression (18).

$SS = F_S^{-1}(CSL) * \sigma_L$ ....(18)

Secondly, estimation of appropriate inventory level for different commodities had been carried out with respect to desired fr. Expression (14) and (16) show the mathematical formulation of ESC and fr. After calculating ESC, the appropriate inventory level for different commodities had been calculated.

In order to ease procurement manager's calculation efforts in mathematically formulating different commodities based on their value and importance, spreadsheets have been constructed for different frameworks accordingly. In these spreadsheets, the procurement manager has to key in only variable information of the commodities. This makes the proposed model simple towards promoting cost-effectiveness in HEIs. This means, keeping academic quality in mind, the HEIs shall manage the multi-commodity supply chain effectively, with cost being an important factor.

VALIDATION STUDIES

The proposed model has been assimilated for viability by considering pilot data from MSRSAS HEI from April 2008 to March 2009. General and Bulk purchase frameworks had been evaluated based on supply chain cost, which includes material, order and holding cost. In the same way, critical and strategic commodities have been evaluated based on CSL and fr. Overall, a holistic approach to manage commodity supply chain optimally for HEIs has been made.

Figure 3: Order Size Comparison Of Legacy And Proposed Model

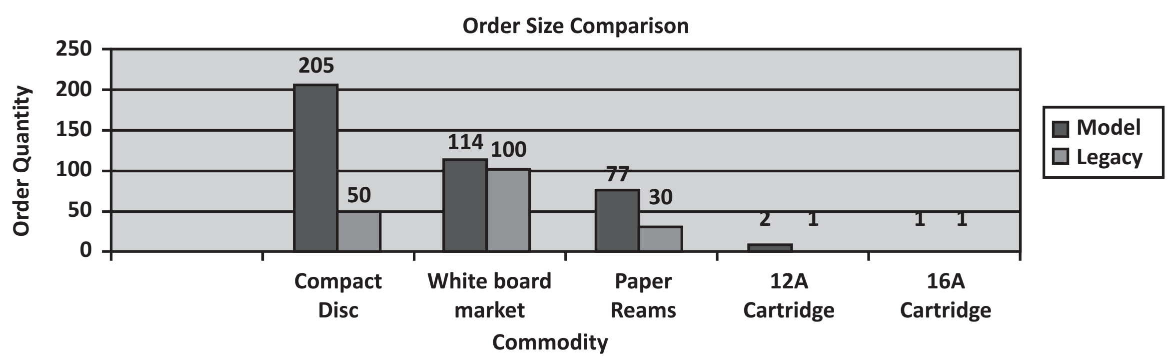


Figure 4: Order Frequency - Comparison of Legacy and Proposed Model

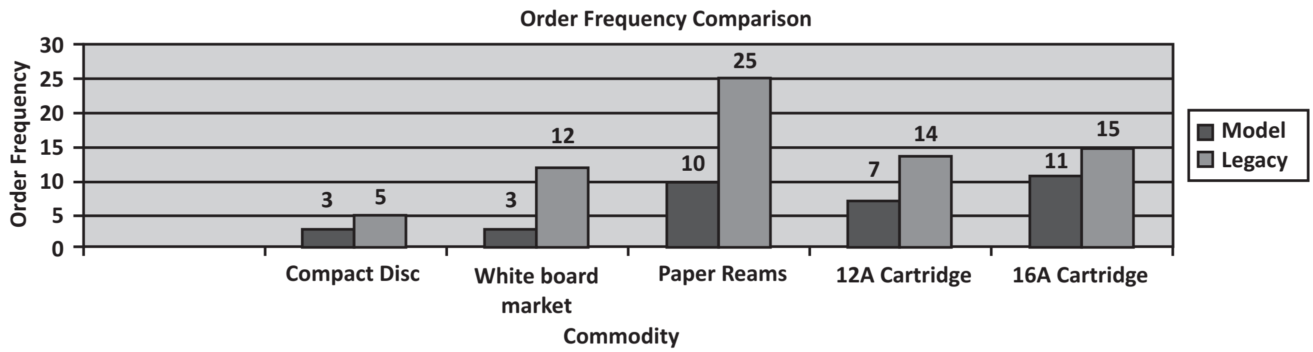


Table 1: Comparison Between Legacy And Lot Sizing Single Commodity			
Sl. No.	General	Order Size	Cost
	Commodity	Comparison	Savings
1	Compact Disc	75%	40%
2	White board marker	12%	75%
3	Paper Reams	60%	60%
4	12A Cartridge	50%	50%
5	16A Cartridge	NIL	27%

RESULTS AND DISCUSSIONS

☸ **General and Bulk Purchase Framework :** By implementing the proposed model for HEIs, a scientific approach towards procurement activities has been carried out based on value and importance of the commodity. The proposed general and bulk purchase framework has been implemented as a pilot study by considering compact discs (CD's), white board markers, paper reams and printer cartridges as commodities. Information related to quantity purchased, average unit cost in rupees, and order frequency had been collected in order to understand the legacy system. Firstly, with this pre-hand information, single product lot sizing for the selected commodities had been carried out. Order size

Table 2: Multiple Lot Sizing For Commodities				
Sl. No.	Description	Compact Disc's	White board marker	Paper Reams
1	Demand per Year D	550	300	750
2	Order Frequency n*	7.85/year		
3	Optimal Order Size Q*	70	38	96
4	Cycle Inventory	35	19	48
5	Annual Holding Cost in ₹	92	88	1194
6	Annual Order Cost in ₹	1374		
7	Total Annual Cost in ₹	2748		

Table 3: Comparison Of Single Commodity And Multiple Commodity Lot Sizing				
Sl. No.	Supply Chain Cost	Single Commodity in ₹	Multiple Commodity in ₹	Percentage Cost Saved
1	Holding Cost	1500	1374	8.40%
2	Ordering Cost	1600	1374	14.12%
3	Annual Cost	3100	2748	11.35%

(Q) comparison of legacy and proposed model has been shown in Figure 3. The results suggested to increase the order size in order to achieve optimum order. The study suggested to reduce the order frequency (n) as shown in Figure 4.The comparison between order size and fixed cost saved by implementing single commodity lot sizing has been depicted in Table 1.

Table 4: Lot Sizing Using Tailored Aggregation

Sl. No.	Description	Compact Disc's	White Board Marker	Paper Reams
1	Demand per Year D	550	300	750
2	Order Frequency n*	4.5	4.5	9
3	Optimal Order Size Q*	122	67	83
4	Cycle Inventory	61	33	42
5	Annual holding Cost in ₹	160	154	1038
6	Annual Order Cost in ₹	1350		
7	Total Annual Cost in ₹	2702		

Secondly, impact of aggregation has been carried out by multiple commodity lot sizing. Commodities like CD's, white board markers, and paper reams were considered for the study. Based on the demand pattern, optimal order quantity (Q*), optimal order frequency (n*) and supply chain costs in the form of holding and ordering cost had been calculated as shown in Table 2. Material cost was not considered due to equal demand for commodities in single lot sizing and multiple lot sizing.

Figure 5: Cost Comparison Of Tailored Framework With Single And Multiple Commodity Model

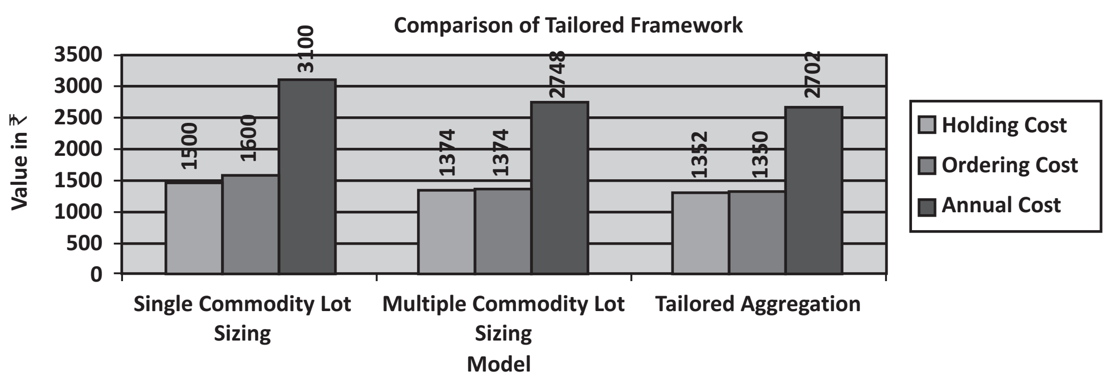


Table 3 shows cost comparison between the single commodity lot sizing and the multiple commodity lot sizing. Cost savings of up to 14.12% have been depicted due to aggregation. Thirdly, tailored aggregation was carried out for the same commodities as that of aggregating multiple commodities. Table 4 shows optimal order frequency (n*), optimal order quantity (Q*), total holding and ordering cost, which has been calculated using tailored aggregation. Figure 5 shows the cost comparison between tailored aggregation, and single and multiple commodity frameworks. The

Table 5: Comparison of the Proposed Frameworks

Sl. No.	Cost	Single vs. Multiple Lot Sizing Percentage Saved	Multiple Lot Sizing vs. Tailored Aggregation Percentage Saved
1	Holding Cost	8.40%	2%
2	Ordering Cost	14.12%	2%
3	Annual Cost	11.35%	2%

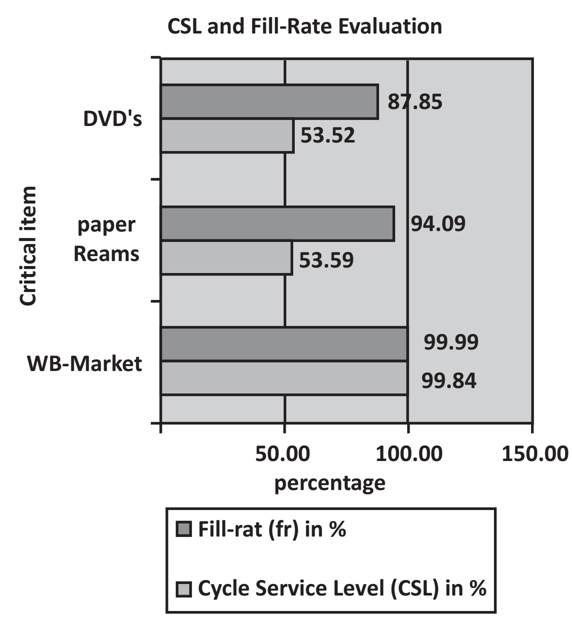
Figure 6: Bulk Purchase Framework

Quantity Discounts
All unit Quantity Discounts

Sl. No.	Product	Annual Demand in Units 'D'	Fixed cost in ₹ 'S'	Holding cost per year as fraction 'h'	Order quantity qi			Unit price in ₹,			For i=0, Q0	Remarks	For i=1, Q1	Remarks	Order Cost	Holding Cost	Material Cost	Total Cost TC1	For i=2, Q2	Remarks	Order Cost	Holding Cost	Material Cost	Total Cost TC2	Final Remarks
					q0	q1	q2	co	c1	c2															
1	Examination Answer Sheet	120000	100	0.2	0	5000	10000	3	2.96	2.92	6324.6	6324 >q1 = 5000	6367.1	5000 <6367 <10 000	1884.7	1884.7	355200	358969.4	6410.6	6410< 10000 Q=q2	1200	2920	350400	354520	Since lowest total cost is for i=2, the Manger should select this

Table 6: CSL and fr Evaluation for DVD's	
Description	**Values**
Average Demand Per Month	13.33
Fixed Cost	₹ 100
Holding Cost	₹ 4.24
Optimal Order Quantity Q*	100.21
Optimal Order Frequency n*	1.60
Cycle Inventory	50.105
Avg. Lead Time in Days	8.40
Re-order Point (ROP)	75
Std. Deviation σD	14.70
Safety Inventory	3.02
Std. Deviation during Lead Time σL	34.15
Demand during Lead Time D_L	71.98
Cycle Service Level (CSL)	**0.5352**
ss/σL	0.09
Expected Shortage per Cycle (ESC)	12.169079
Fill Rate (fr)	**0.87856**

Figure 7: Comparison of CSL and fr for Critical Commodities



comparison of cost savings in percentage between single, multiple aggregation and tailored multiple aggregation has been shown in Table 5.

Table 7: Inventory Levels at 90% CSL

Sl. No.	Criteria	WB-Marker	A4-Sheets	DVD's
1	Optimal Quantity Q*	90.49	62.5	100.21
2	CSL	0.9		
3	Lead Time	2.63	3.6	8.4
4	Demand Per Month	15	43.75	13.33
5	Std. Deviation of Lead time σL	7.02	10.39	34.15
6	**Safety Inventory Required**	**8.99**	**13.315**	**43.765**
7	Cycle Inventory	45.24	31.25	50.105
8	Avg. Inventory	54.24	44.56	93.86

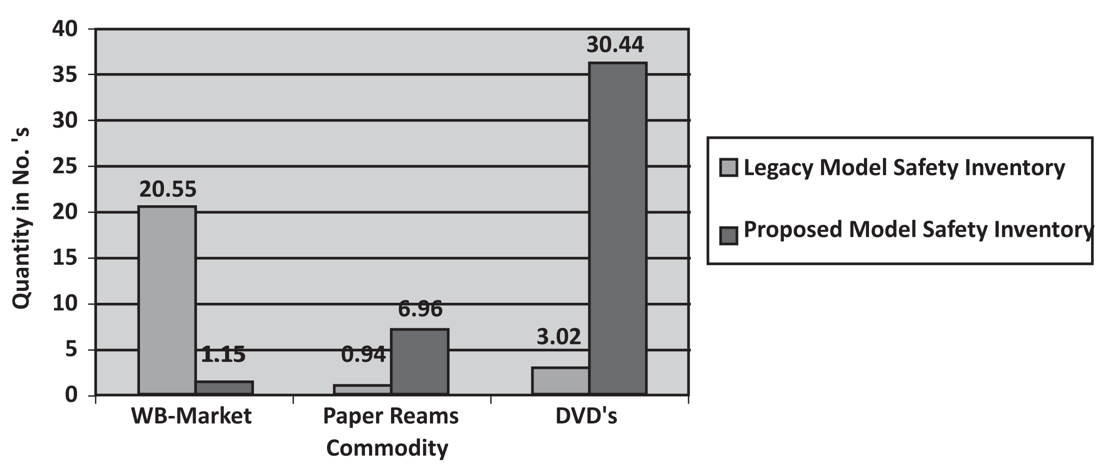
Bulk purchase framework has been applied, based on different criteria of the procurement situation - like quantity discounts. Significant savings have been depicted, and the spreadsheet framework has been developed in order to ease the calculation procedure for the procurement managers of HEIs. Figure 6 shows the spreadsheet framework for the bulk purchase framework.

CRITICAL COMMODITY FRAMEWORK

The framework has been applied to commodities like DVDs, white board markers and paper reams on a pilot run, which have been considered as critical. CSL and fr have been evaluated for DVDs, which helps the procurement manager to devise replenishment policy as shown in Table 6. Current level of CSL has been considered as 53.52% and fr has been considered as 87.85%. Based on the obtained values, procurement managers can take suitable action to improve CSL and fr. Parallely, CSL and fr have been evaluated for other considered commodities and their CSL and fr evaluation comparison has been shown in the Figure 7.

Results suggested that CSL for critical commodities has to be increased. However, fr maintained at the present level has been considered appropriate. These results help the procurement manager to arrive at appropriate replenishment policy for different critical commodities, which have high importance and low value in the commodity categorization matrix.

Figure 8: Inventory Level Comparison at 95% fr



STRATEGIC COMMODITY FRAMEWORK

Commodities with high importance and high value in commodity categorization matrix come under this framework. HEIs need to collaborate with book store vendors, security agencies etc. as a strategic activity in their commodity supply chain. Normally, these collaborations have been defined in terms of service level agreements in management contracts. This framework quantifies the appropriate service level into appropriate inventory levels by evaluating CSL and fr. For the pilot study, 90% CSL and 95% fr has been considered for DVDs, white board markers and paper ream commodities, with respect to book store vendors. The inventory levels at 90% CSL for these commodities have been shown in the Table 7.

Similarly, fr at 95% has been evaluated for the same commodities. The safety inventory level comparison of legacy and proposed model has been shown in Figure 8. The result suggests to decrease the order quantity for white board markers and increase the order size for paper reams and DVDs.

CONCLUSION

The integrated framework helped to rationalize procurement efforts in the multi-commodity situation in HEIs. Product categorization matrix has been useful in-order to segregate commodities based on value and their importance. Cost savings up to 50 % from the selected commodity lot have been depicted using an aggregate approach for multiple products for general and bulk purchase commodities. CSL and Fill-rate has been successfully used for critical and strategic commodities to convert subjective information to objective information. In principle, the study helps the procurement manager of HEIs to manage multi-commodities scientifically and optimally. Spreadsheet frameworks have been constructed in order to cut-down the calculation time for the procurement managers. The present study makes an effort to bring industry oriented supply chain concepts to an academic scenario.

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