

Seafood Supply Chain Coordination Model

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ABSTRACT

Most of the countries are surrounded by ocean. In ocean, various sea foods are available. Sea foods are very useful for human body. It is necessary to supply sea foods to each and every person from sea area to the various destination in the country. In this article, supply chain coordination model for seafood was developed and sales revenue, material cost, holding cost, profit for the supply chain with an illustrative real-life example.

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1. Introduction:

In the world, different people live in their respective countries. The choice of food is also different depending on their culture. Fish is one of the most traded commodities globally, and India is one of the largest producers and exporters of fish. Its global contribution to production in 2018-2019 was 7.58 percent. Fish also contributes 1.24 percent to India's Gross Value Added (GVA) and 7.28 percent (2018-19) to the agricultural GVA. Fisheries also contribute significantly to food and nutritional security, as well as livelihood and employment generation. Aquaculture also happens to be one of the fastest growing food production systems in the country. The average annual growth rate of fisheries sector over 2014-15 to 2018-19 has been 10.88 percent. The exports stood at 13.93 lakh metric tonnes bringing in Rs. 46589 crore in 2018-19. As per the research most of the people like sea food, which is very useful for human body. Particularly, in India, most of the states are spread around the ocean.

Western side of Maharashtra surrounded by ocean. The main business of these peoples are to sale the sea food. These peoples collect the sea food from the sea and sale to the various areas of the states as well as country. Koli Peoples collect the sea food from the various places of sea and send this food to the warehouse. Warehouse collect the sea food up to time T , there will be accumulation from the KOLI people. All the sea foods are perishable items. So, it is necessary to use refrigerator facility during transportation as well as in the warehouse. It should be sold out before it deteriorates.

Supply chain is the process of shifting finished or semi-finished products from the origin to the destination. In this process, there are number of components are included. Depends upon the components or depends upon the behaviour of components there are two types of supply

chain viz, centralised supply chain and decentralised supply chain. If all the entities in the supply chains are independent and they are taking own decision then that supply chain is called as decentralised supply chain and if all the entities follow the decision given by higher authority and cooperate to each other then that supply chain is called as centralised supply chain. The process of shifting the products from the source to the destination is nothing but forward supply chain and shifting the product from the customer to the manufacturer is reverse supply chain. Addition of forward and backward supply chain is called as closed loop supply chain.

A sea food supply chain can be described as a set of independent fishers, agents, processors, distributors, and wholesalers/retailers/food services who work together to supply a fish or derived product to the consumer. No individual organization or entity within the fish supply chain is independent. They are interlinked because actions taken by one member of the supply chain can affect, improve or disturb the complete chain and also the livelihoods of fishermen who have fishing as their primary source of income. Fish supply chains have high variation based on factors like fish species and products, harvesting techniques, end users apart from differences in socio economic, environmental and cultural differences among different countries and regions.

The main source of Koli peoples is to collect the fish from the sea and sale to the customer near by the sea as well as all the region of the country. They collect the fish and sale as early as possible as before it deteriorate. Fish and fish products are the perishable items. Here, Koli people collects the fish products and sales to the customer. Therefore, it is called as single stage supply chain coordination model.

1.1. Sea Food Supply Chain:

The seafood industry comprises activities including

catching or harvesting, preserving, processing, selling or marketing of fish or fish products. 85 percent of the global seafood produced are mainly used for human consumption while the remaining is converted to fish. Harvesting involves the activity of collecting seafood species through commercial fishing or aquaculture meal or fish oil to feed the livestock. Preserving includes preserving the seafood species harvested by icing, cold storing, and so on or it may lose its quality because of its perishable nature. Processing includes cleaning, sorting, filleting, packing, and so on. Processing also involves converting the seafood to ready-made meals. Distribution is the process of marketing the processed or live seafood to the consumers. The seafood demand is increasing continuously. India, being the second largest populated country is the key demand driver for the seafood industry. Seafood demand will exceed the production level in the future mainly due to the increased human consumption.

1.2. Key Players in the sea food supply chain:

The key players in the seafood supply chain includes the fishermen, intermediaries like auctioneers, commission agents, transporters, retailers, wholesalers, and so on, exporting companies and the end consumer.

1. Fishermen: Fishermen are the producers of the seafood supply chain. They hunt, capture or harvest the seafood from the sea through commercial fishing methods.
2. Intermediaries: Intermediaries include the auctioneers, commission agents, transporters, retailers, wholesalers, vendors, and so on.
3. Auctioneer: The fish auctioneer acts as an intermediary between the supplier and the buyer. The fish auction makes an opportunity where fish is graded, stored and unloaded in the display area. Every auction has a bidding room with an auction clock. The auctioneer is the first intermediary in seafood supply chain. The fishermen bring their catch to auctioneer, who auctions the fish to various agents at landing centre.
4. Commission Agent: Commission agents are the intermediary who acts as middlemen between the fishermen and the exporting companies.
5. Transporters: The transporter has trucks to transport products to his facility where they are cleaned and graded in three to four grades based on size, quality and defects. Transporters are the intermediary who provide logistics facility or who transports the seafood from one place to another.
6. Retailers: The retailers sell fish directly to consumers. They have the estimation of local demand and disadvantage of their buying power. Maximum value addition to fish occurs with the retailer. The retailer arranges, cleans, ices, packs, displays and dresses fish for the customers. Retailers mostly purchase fish from the wholesalers, but in quite a few cases, group of retailers have been found take part in the auction process for buying fish straight from the auctioneer.

7. Wholesalers: The wholesalers buy fish in bulk from auctioneers and transports to exporting companies. Accurate guidance on the marketing margin of wholesalers is not obtainable but it has been found that cost configuration is highly profit intensive. They usually know the demand of species outside markets and are conscious of average trend of daily fish catches at landing centres.

8. Vendors: Vendors being movable, sell fish directly at the customer's door step. Most of the fish vendors are usually women. They take dynamic part in auctioning directly. They are enforced to sell all the produce on a given day, as they don't have the ability to hold or stock up the fish.

2. Mathematical Model

In this section, KOLI people collect the fish from the sea and sale fish to the customer. Fish are the perishable products. So, it is necessary to sale the sea product before it deteriorate. While transporting, it is necessary to use cold storage facility. Fresh sea foods are transported from the various area of the sea to the warehouse $[0, T]$. Let δ_1 be the number of deteriorated sea products in the time $[0, T]$. Deterioration of sea food is the natural occurrence for production inventory which occurs for production inventory which occurs due to environmental change or damage or spoilage. It reduces the quality of sea food products.

In this article, KOLI peoples are collecting the fish from the various areas of the sea and collect at the warehouse. Up to time T all the fishes are accumulated and after time T all the fishes are sold to the customers. Here, we are considering one stage supply chain coordination model or this is also called as newsboy vendor model. Fish and fish products depends upon the time. As time passes then the demand decreases rapidly because fish and sea products are the perishable therefore it is necessary to sale before deteriorate. If time t is very high then peak demand will becomes zero. Hence, fresh fish has the age dependent demand. The perishability of fish is purely depends upon the time. In this situation vendor purchase the fresh fish early in the morning from the sea and sold out to the customer within the short period. This is the single cycle process which is called as newsboy vendor problem. Therefore we are defining the age dependent demand function, which is given below,

Demand rate function is:

$$D(t) = D(1 - \frac{t}{\tau}) \quad , \quad 0 \leq t \leq \tau$$

For simplification, we are assuming that customers are uniformly distributed with their threshold on $(0, \tau)$, where τ is life length of product. Thus, on a day t in the cycle and which is in $(0, \tau)$, $D(1 - \frac{t}{\tau})$ customer will buy. For simplification, we are assuming that both time and demand continuous. The proposed model is solved by using Newton-Raphson method for the supply chain of fresh fish vendor with age dependent demand rate.

3. Problem Description

Supply chain is the process of supplying the finished or semi-finished products from the manufacturer to the customer. The main objective of the supply chain is to satisfy the customer demand, maximize the supply chain profit, minimize the cost, and optimize the economic order quantity. The supply chain includes not only flow of material from the supplier to the customer but also the exchange of funds and information. The efficiency of supply chain depends upon proper management of goods and services in all the stages. In supply chain, inventory technique plays an important role to increase the profit, service level, optimize order quantity etc. Manufacturer produces multiple products and supply to the customers. To increase the profit of supply chain manufacturer applies different policies such as price discount, quantity discount, cashback, reward, gift vouchers etc. In this article, we developed inventory model for fresh fish vendor with age dependent demand rate. The demands for all products are assumed to be linear which is defined in equation (3.1). The objective of this research is to analyze the effect of EOQ for fresh fish with age dependent demand rate.

4. Mathematical Model:

4.1. Assumptions:

1. Demand rate is constant.
2. KOLI peoples collect the fish and bring to the warehouse.

3. Distribution of items follows uniform distribution.
4. Inventory policy is a continuous review policy of EOQ type.

4.2. Notations:

Following notations are used for construction of model:

- Q : Economic Order Quantity
- D : Demand
- T : Total cycle time
- τ : Life length of product
- t : time period
- S : Selling price per unit are known and constant
- C : Purchase cost of the item is known and constant
- h : Holding cost is known and constant
- OC : Order cost is known and constant
- $I(t)$: Inventory level at time t
- $\theta(t)$ =Deterioration rate at time t

Here, we are assuming deterioration rate is constant θ

4.3. Model

The main objective of the model is to obtain optimum order quantity Q for perishable items having age dependent demand with peak demand is D and constant deterioration rate θ . The differential equation representing inventory level at time t can be written as

$$\frac{dI(t)}{dt} + \theta I(t) = -D\theta e^{-\theta t}, \quad 0 \leq t \leq \tau \quad (4)$$

The solution of equation (2) with boundary condition $I(\tau) = 0$ is

$$e^{\int \theta dt} \frac{dI(t)}{dt} + e^{\int \theta dt} \theta I(t) = -D\theta e^{-\theta t} e^{\int \theta dt}$$

$$\frac{d}{dt} [e^{\int \theta dt} I(t)] = -D \int_t^\tau \theta e^{-\theta \tau} e^{\theta t}$$

Integrating on both sides of above equation, we get

$$[e^{\int \theta dx} I(x)] = -D \int_t^\tau \theta e^{-\theta \tau} e^{\theta t} dx$$

By using boundary condition $I(\tau) = 0$, we get

$$I(t) = D e^{-\theta t} (1 - e^{-\theta(\tau-t)}) \quad 0 \leq t \leq \tau \quad (5)$$

Various costs which are related to inventory are given below.

Sales Revenue Per Cycle

$$SR = S \int_0^\tau I(t) dt$$

$$SR = DS \left(-\frac{e^{-\theta t} - 1}{\theta} - t e^{-\theta t} \right) \quad (6)$$

Material Cost is given by

$$MC = c I(t)$$

$$MC = c \int_t^\tau I(t) dt$$

$$MC = c \int_t^\tau D e^{-\theta t} (1 - e^{\theta(t-\tau)}) dt$$

$$MC = cD \left(-\frac{e^{-\tau\theta} - e^{-t\theta}}{\theta} - \tau e^{-\theta t} + t e^{-\theta t} \right) \tag{7}$$

Holding Cost-

$$HC = h \int_0^\tau I(t) dt$$

$$HC = hD \int_0^\tau e^{-\theta t} (1 - e^{\theta(t-\tau)}) dt$$

$$HC = hD \left(-\frac{e^{-\tau\theta} - e^{-t\theta}}{\theta} - t e^{-\theta t} \right) \tag{8}$$

Total Profit per unit is

$$P(\tau) = \frac{1}{\tau} [SR - OC - HC - MC]$$

$$P(\tau) = \frac{1}{\tau} \left[DS \left(-\frac{e^{-\theta\tau} - 1}{\theta} - t e^{-\theta t} \right) - OC - hD \left(-\frac{e^{-\theta\tau} - e^{-t\theta}}{\theta} - t e^{-\theta t} \right) - cD \left(-\frac{e^{-\theta\tau} - e^{-t\theta}}{\theta} - \tau e^{-\theta t} + t e^{-\theta t} \right) \right]$$

The necessary condition for maximum profit per unit time is

$$\frac{d}{d\tau} P(\tau) = \frac{D}{\tau} e^{-\theta t} [S\theta - h\theta t - c] = 0 \tag{9}$$

$$\tau = D e^{-\theta t [S\theta - h\theta t - c]} \tag{10}$$

From equation (10) the optimum value of τ can be obtained by using Newton -Raphson method and equation (5) gives the optimum order quantity.

$$\frac{d^2}{d\tau^2} = -\frac{D}{\tau} \left\{ e^{-\theta t} (-h\theta) - (S\theta - h\theta t - c) \frac{e^{-\theta t}}{\theta} \right\} \tag{11}$$

In equation (11), term is negative, therefore, second derivative is negative. Therefore,

$$\frac{d^2}{d\tau^2} \leq 0 \tag{12}$$

Equation (12) showed that convexity condition satisfies. Thus, profit maximizes.

Table 1: Effect of deterioration rate on profit, and Economic Order Quantity

θ		$D = 100$	$D = 110$	$D = 120$	$D = 130$	$D = 140$	$D = 150$
0.05	τ	0.949408	0.905721	0.867578	0.833894	0.803863	0.776869
	Profit	645.2932	715.2129	785.3588	855.7031	926.2232	996.9007
	Q	48.23052	50.57523	52.81558	54.96436	57.03197	59.02696
0.06	τ	0.876883	0.836583	0.801392	0.770313	0.742603	0.717692
	Profit	636.7057	706.2123	775.9635	845.9292	916.0851	986.4111
	Q	44.62327	46.79167	48.86355	50.85076	52.76289	54.60787
0.07	τ	0.818609	0.781103	0.748211	0.719224	0.693377	0.67014
	Profit	628.7116	697.8341	767.2182	836.8319	906.6491	976.6482
	Q	41.7236	43.75029	45.68677	47.5441	49.33127	51.05567
0.09	τ	0.729806	0.69637	0.667165	0.641365	0.618357	0.597669
	Profit	614.0949	82.5161	751.2302	820.2011	889.3998	958.8023
	Q	37.30253	39.11318	40.84324	42.50258	44.09925	45.63983
0.1	τ	0.694887	0.663079	0.635294	0.610748	0.588856	0.56917

	Profit	607.333	675.4302	743.8347	812.5087	881.4217	950.5485
	Q	35.5633	37.28897	38.93783	40.5193	42.04102	43.5093
0.2	τ	0.498128	0.47549	0.455702	0.43821	0.422603	0.408562
	Profit	551.7236	617.1667	683.0354	749.2772	815.85	882.7187
	Q	25.75453	27.00102	28.19203	29.33436	30.43353	31.4941

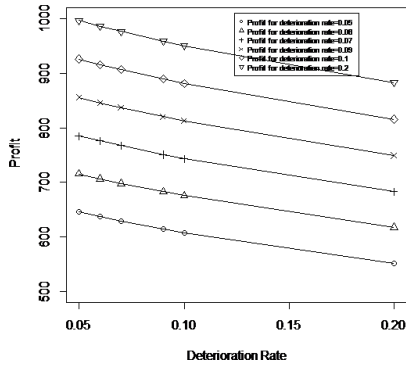


Figure 1: The effect of deterioration rate on Profit

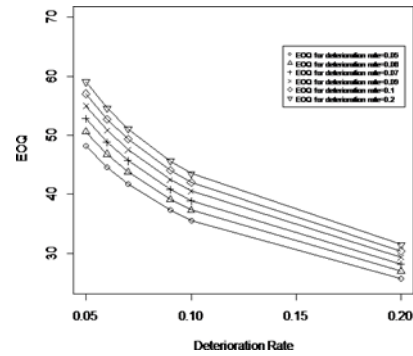


Figure 2: The effect of deterioration rate on EOQ

5. Numerical Analysis and Discussion

For numerical analysis, we set the parameters $D = Rs.100$, $OC = Rs.50$, $h = Rs.3$, $c = Rs.55$, $S = Rs.70$. Deterioration rate varies from $\theta = 0.05$ to $\theta = 0.2$ and demand varies from $D = 100$ to $D = 150$. Table No.1 shows that as deterioration rate increases from $\theta = 0.05$ to $\theta = 0.2$ then profit decreases for all the peak demands and peak demand varies from 100 to 150. As demand increases then profit rapidly increases from Rs.645.2932 to Rs.996.9007 for the deterioration rate $\theta = 0.05$. Similarly, same situation happens in the other deterioration rates but order quantity increases from 48.23052 to 59.62696 for the deterioration rate $\theta = 0.05$. And for all other deterioration rates EOQ increases and profit decreases. Figure No.1 shows that as deterioration rate increases from $\theta = 0.05$ to $\theta = 0.2$ then profit decreases for all the peak demands $D = 100$ to $D = 150$. Also, for all deterioration rates, time τ decreases. Figure No.2 shows that as deterioration rate increases then EOQ decreases for all the deterioration rates. It shows that if demand is maximum then EOQ also maximum.

6. Conclusion

In this research paper, more realistic parameters such as peak demand, selling price, purchase cost holding cost, deterioration rate are collected from Kokan area, India. We consider the age dependent rate is constant. As time passes then profit decreases and as deterioration rate increases then profit decreases for all the demand.

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