Journal of Supply Chain Management Systems
12 (1) 2023, 28-37
http://publishingindia.com/jscms/

Inventory Optimization through an Integrated Model: A Case Study

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Abstract

In order to reduce operating costs and accelerate deliveries, smarter practices like the 'Hub and Spoke Distribution Model' have been adopted by supply chain enterprises. However, it's high time for strategic decision-makers in logistics to evaluate whether it would be an ideal match for the supply chain. For taking a holistic decision, two factors play an important role – the nature of the business and the size of operations. Accordingly, the purpose of this study is to understand the numerous benefits of the Hub and Spoke model as compared to earlier practices and how does it work in the supply chain model of the select industry. The Hub and Spoke model is used when there is a multiple location sourcing, with central locations called the "Hub" or single source of sourcing and multiple points of distribution. For this study, as select industry, we have identified CESC, India's first fully integrated electrical utility company, which has a large distribution network comprising the twin cities of Kolkata, Howrah and part of Hooghly District. The analysis shows that the application of the Hub and Spoke Model in Supply Chain of CESC reduces power tariff; Operation and maintenance expenses; Cost of capital equipment for the distribution network; Cost of maintenance of distribution network; furthermore, maintains low inventory. Yet, it is worthwhile to mention that application of this integrated model has some limitations - if just one spoke were to get out of place, however, the entire model can start to experience problems. However, to overcome these problems, proactive organizations need to implement a multiple hub system.

Keywords: Inventory Optimization, Integrated Model, Inventory Management, Supply Chain, Transportation and Distribution Industry, CESC

Introduction

'Inventory optimization' is a subset of inventory management that refers more specifically to profit margins and minimizing loss. Carrying surplus inventory causes loss and waste. It takes up space, becomes obsolete, and often doesn't sell or must be sold at reduced prices. On the other hand, as we saw during the pandemic, due to shortages and unexpected demand, the costs come in the form of loss of Possible profit and damage to the brand. Therefore, the goal of inventory optimization is to best forecast demand and maximize the financial output of the inventory for the company (Manatkar et al., 2016).

From the consumer's point of view, inventory primarily consists of finished goods. But for a business, inventory is anything they have to keep in stock, maintain, and replenish. Looking at inventory management in this more holistic way gives a greater appreciation of its complexity.

Historically, the benefits of even small improvements to strategic inventory optimization could be realized in lowered costs and better profit margins. With the application of integrated business processes and inventory management software, these benefits become more robust and measurable and only improve over time as the software learns and adapts. According to Kos,

and Duhovnik (2002), Guo and Liu (2018), Golari et al. (2017), Yang et al. (2021), and Boone et al. (2013), some of the remarkable benefits of inventory optimization are as follows:

- *Greater Business-Wide Visibility:* The enhanced transparency enabled by inventory optimization software extends from sales, marketing, and accounting to raw materials suppliers and even global partners, assets, and expenses. Cloud connectivity enables all teams involved in the supply chain to work together in real-time.
- *Improved Demand Forecasting and Predictive Abilities:* Smart technologies can process complex data from sources inside and outside the business – and deliver accurate predictions and insights. When supply chain technologies are powered by artificial intelligence and machine learning, predictive analytics and demand forecasting become more accurate and insightful.
- *More Sophisticated Optimization Outcomes:* With smart systems that can analyse complex and diverse data sets, inventory managers can see not only which products are the most profitable but things like which locations are best for which Stock-keeping Units (SKU) and which combinations of products sell best at different times of the year.
- *Scalability:* Companies must scale up quickly for lots of reasons, including success and general growth, unexpected events, or seasonality. Smart software and modern databases are infinitely scalable and can ramp up and optimize operations on a global scale.

There are five sections in this paper. The second section provides a brief overview of inventory optimization and the application of the Integrated Model. It also makes comparative evaluation between Integrated Model and Earlier Practices. Further, it presents the benefits of the Model. Section 3 describes the application of such a model in CESC, India's first fully integrated electrical utility company. Section 4 draws the implication of such a model in theory and practice, including its limitations. Conclusions drawn from the study and strategic implications are discussed in the final section (Section 5).

Literature Review

A number of studies have been undertaken by eminent researchers who have put stress on benefits of inventory optimization in the supply chain (Aggarwal, 1974; Barnes, 2014; Boone et al., 2013; Kos & Duhovnik, 2002). Even some studies (Benjamin, 1989) focussed on the cost associated with inventory optimization in the supply chain. Bryan and O'Kelly (1999), Golari et al. (2017), Guo and Liu (2018), Manatkat et al. (2016), O'Kelly (2002), Wieland et al. (2012), Xu et al. (2020), Yang et al. (2021) in more detail, mentioned about the specific integrated model for the application of such optimization in the supply chain. Accordingly, based on various literatures, the following section describes the detail of the inventory optimization model, which also includes its benefits and limitations.

Inventory Optimization and Integrated Model

In order to reduce operating costs and accelerate deliveries, smarter practices like the 'Hub and Spoke Distribution Model' have been adopted by supply chain enterprises. However, it's the high time for strategic decision-makers in logistics to evaluate whether it would be an ideal match for the supply chain. For taking holistic decision, two factors play an important role – the nature of the business and the size of operations.

Hence the purpose of this study is to understand the numerous benefits of the Hub and Spoke model as compared to earlier practices and how does it works in the supply chain model of the select industry.

In the past, the Indian transportation and distribution industry was guided by the principles of point-to-point or direct-route operations (Aggarwal, 1974). Transportation networks were disorganized, and shipping, aviation, and transit companies were losing money (Benjamin, 1989). As technology has developed, the logistics sector has found faster and more cost-effective ways of shipping freight. The hub-and-spoke model is born from industry's and government's efforts to develop more efficient networks. In recent years, shipping companies in other developed countries such as the US, UK, Singapore, and Australia have adopted the hub-and-spoke warehousing model to speed up deliveries and reduce costs (Barnes, 2014; Wieland et al., 2012).

A hub and spoke model is a centralised warehousing and shipment system that looks like the structure of a bicycle wheel. The centre of the wheel is the hub or a distribution centre, whereas each spoke signifies a route of delivery (Fig. 1). Using this model, transports collect cargo from its point of origin (the tips of the spokes) and transport it back to a central processing facility (the-hub).

The shipment is then either warehoused or distributed directly from the heart of the network. Larger-scale companies operate several hub-and-spoke system (Bryan & O'Kelly, 1999). Hub and Spoke model offers a method of finding the optimal schedule quantity that minimises total costs by finding a balance between ordering cost and inventory carrying cost. While an enterprise chooses a 'Hub and Spoke' model to implement the inventory optimiation process, it ensures seamless integration of business process. This model also lessens the number of distribution centres, which ultimately lowers the inventory management cost.

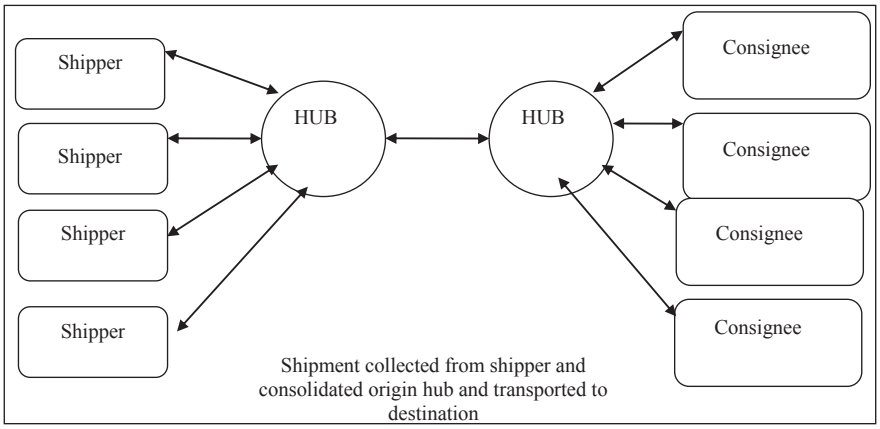

Fig. 1: Schematic Diagram of Hub and Spoke Transport Model

Comparative Evaluation between Integrated Model and Earlier Practices

Fig. 2 represents the comparative advantages of the hub and spoke model against earlier practices, i.e. the point-to-point model. The exact opposite of the hub and spoke model, the point-to-point model has goods and services go directly from Point A to Point B without going to a centralized distribution hub.

It is observed that transportation costs in the point-to-point model can actually be higher than in a hub and spoke model. The reason is that in a point-to-point model, more routes are created, on the contrary; in a hub and spoke model, products can be grouped and efficiently shipped following set routes.

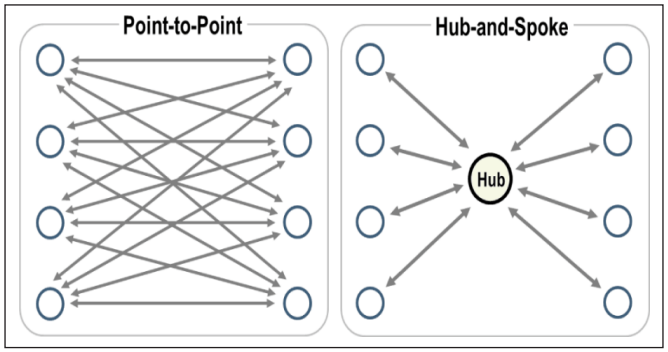

Fig. 2: Point-to-Point Model Vs. Hub and Spoke Model

Benefits of Integrated Model

According to O'Kelly and Bryan (2002), the hub-and-spoke model creates numerous benefits, which are as follows:

- *Continuous Movement for Loads:* Freight traffic moves along spokes connected to a central hub. This efficiently moves products out of strategically located distribution centres and shortens travel time. The design of a hub and spoke model allows a company to afford a smaller staff which concentrates on management from a central location. All packages can be sorted at the hub rather than sorted in multiple locations. This makes the freight company much more efficient and reduces the risk of error.
- *Simplified and Streamlined Shipment Processes:* With all shipments picked from a single hub, managing last mile delivery processes and scheduling dispatch becomes easier. Logistics and Supply chain managers can allot duties and monitor them all methodically and effortlessly. Loading shipments from a single distribution center is also easy. This type of model also makes it effortless to maintain the right inventory.
- *Consistent On-Time Performance:* It augments service levels, and guarantees products arrive in the right place at the right time.

- *Consistent Pricing:* Consistent/steady pricing lessens the risk of third-party carrier price fluctuations.
- *Automated Route Planning:* Hub and spoke model enables optimal planning of delivery routes. Logistics and supply chain managers who are using last-mile delivery software and following this type of model can get digitized route planning and optimization. The software considers a few parameters, viz., real-time traffic conditions, customers' delivery preferences, delivery location, and other restrictions, to generate the most efficient delivery routes.
- *Enhancement of Productivity through Improved Driver Rotational Duties:* Logistic and supply chain managers face the hassle of deciding which order to deliver first or which customer's place to visit first, whereas auto-generated delivery routes relieve drivers from this confusion. This accelerates the delivery process, offers on-time delivery and ultimately brings customer satisfaction.
- *Reduced Logistics Costs:* As in Hub and spoke model, everything is managed from one place, which makes it the most cost-effective solution. There is no need to hire huge professionals at different distribution centres. Furthermore, as the transportation of goods is held from a single place, therefore it saves fuel costs and time. It also reduces the cost of inventory management.
- *Lower Carbon Footprint:* Empty miles are a sustainability issue and a cost issue as well, whereas supply chain optimization through Hub and spoke model can reduce cost, and a few empty miles driven reduces wasted fuel and emissions.

Methods

The focus of this study is to understand how does Hub and Spoke model works in the supply chain model of select industries. In this study, we have highlighted a case study-based discussion on inventory optimization through an integrated model.

For any Power Distribution Utility, the operations of the company, including Supply Chain Support to internal stakeholders, should always be continuous and consistent. As such, there is no room for slowdown or shutdown under any circumstances. Sustainability in Supply Chain is maintained through the uninterrupted availability of all Stock Keeping Units (SKUs) required to operate, maintain and augment the electricity distribution network. Materials planning and budgeting, procurement, warehousing & inventory management should follow robust processes to ensure the highest practicable service level. At no point in time should there be stock-outs of any material. Such continuous availability of all materials can only confirm the establishment of Supply Chain Sustainability in a Power Distribution Utility.

The Hub and Spoke model is used when there is a multiple location sourcing, with central locations called the "Hub" or a single source of sourcing and multiple points of distribution.

For this study, as a select industry, we have identified CESC, India's first fully integrated electrical utility company, which has a large distribution network comprising the twin cities of Kolkata, Howrah and part of Hooghly District. In the case of CESC, there is a single sourcing point (Central Store) and multiple distribution points (Sub Store). The spoke is the delivery centre of materials which is distributed to various locations for consumption of capital and repair and maintenance purposes. The licensed area of CESC is as high as 567 square kilometres, containing 474 km circuit of transmission lines linking the company's generating & receiving stations with 105 distribution stations, 8,211 circuit km of HT lines further linking distribution stations with LT substations, large industrial consumers and 12,269 circuit km of LT lines connecting the LT substations to LT consumers (CESC Limited, Annual Report, 2021-22).

Discussions

Implications for Theory

CESC follows Hub & Spoke model due to following reasons:

- To reduce power tariff;
- Operation and maintenance expenses;
- Cost of capital equipment for distribution network;
- Cost of maintenance of distribution network;
- Maintain low inventory.

Inventory holding cost can be optimized by the following methods at CESC:

- Lesser storage area;
- Decentralization of storage;
- Scheduling the deliveries based on actual needs.

As businesses grow, inventory orders, shipping, storage, and selling becomes paramount decisions that have to be made. CESC inventory distribution model follows a decentralised distribution network to optimise inventory holding cost.

In order to understand the decentralised inventory system is best for a company, we need to discuss the differences between centralised and decentralised distribution systems based on their structure, goals, and management style.

Centralized Inventory has following features:

- Operations are carried out in a central location.
- High shipping costs especially in the long term and rush deliveries may be passed to the customer.
- Leads to competition for resources such as human resource.

Decentralized Inventory has following features:

- This is an inventory management system where products move from a central office to other locations that are close to the customer.
- Rush deliveries can be carried out at reasonably low costs.
- Customer trust in the brands and products can be enhanced due to usage of local branding options on product packaging and shipping labels.

Implications for Practice

CESC Limited, a power utility, has a sustainable supply chain which covers the following functions:

- Procurement
- Warehousing
- Inventory Management
- Quality Assurance
- IT Applications
- Disposal of scrap

The average annual spend base of CESC Limited is in the range of Rs. 600 to 700 Crores which includes all materials required for operation / maintenance / overhauling of the following:

- Coal-fired thermal power stations
- Transmission Lines
- Distribution network – both overhead and underground
- Receiving Stations
- Sub Stations

The procurement activities are carried out centrally by the Central Purchase Department. All transactions are fully computerized, including e-Tenders, e-Purchase Orders, e-Goods Receipt Notes, and e-Rejection Notes. The payments to vendors are also made electronically through RTGS. The warehousing of materials required for the Transmission / Distribution network as well as Receiving Stations & Sub-stations, are made centrally, followed by a Hub-and-Spoke Model of supply to seven Sub-stores spread over the licensed area.

The inventory is managed by adopting various modern tools and techniques, including a number of home-grown software. The optimization of inventory is carried out by:

- Providing 3 month rolling "Need-By" dates
- VMI (Vendor Managed Inventory)
- Cross – Docking
- Hot Transfer

The materials required for operation and maintenance of thermal power stations are stored inside the Stores located inside the respective power stations.

CESC focusses principally on 24x7 uninterrupted supply of electricity to all its consumers, including Domestic, Commercial as well as Industrial Consumers. For this purpose, it is absolutely essential that all materials should be available on time and in right quantities.

Based on operating profile and strategic plans, CESC Supply chain members accurately determine the appropriate level of inventory to hold and offers significant value in terms of financial performance and reliability of service.

However, it is more important that such materials should be available at the door steps of the Operations & Maintenance Team (O&M Team). This is a pre-requisite condition to run the *"Business as Usual"*. For utility companies, it is critical that field workers complete their job right, the first time. This means that field workers need to arrive with the right equipment, tools, and parts, so that they can be as flexible and responsive as the job demands. Utility companies need to have an inventory system that can keep track of their operations.

To confirm the door step availability of all materials, it is necessary for a Power Utility to decentralize the total inventory holding. By the process of decentralization, inventory can be kept scattered separately in different zones. The zonal requirement can be met from the local stock point, thereby strengthening the supply chain by the following strategies:

- Avoiding unnecessary high inventory holding at a central place.
- Easy access to the local inventory.
- Lesser space requirement to store localised inventory.
- Avoiding unnecessary logistics cost to bring inventory from centralised place for every job-wise requirement.
- Eliminating wastage of time to transport job-wise materials from long distance.
- Relieving the pressure at the central warehouse for the operating staff.

A utility's generation, transmission and distribution inventory can have a huge amount of valuable capital that could be used to meet its growing demand. Utility companies have relied on manual inventory tracking, but in today's fast-paced setting, that doesn't cut it. In order to keep up with the demands and the competition, they must optimize their inventory and system.

A "Sub-Store" can be defined as a localized satellite store which remains under the umbrella of a Centralized Warehouse (Main Store) and operates in tandem with the Centralized Main Store. Sub-Stores can be located zone-wise to cater to the zonal demands. The added advantage of a Sub-store system is that zone-specific unique materials (which have no demand at other zones) can be stored at specific local points. The Sub-Store System across the total operational area is fed with materials from the Centralized Warehouse (Main Store) at pre-defined intervals (e.g., on a weekly basis) based on inventory policy as well as logistics cost.

Sub-Store Structure in CESC

The total licensed area of CESC is 567 sq. km. and spreads across the twin cities of Kolkata and Howrah (CESC Annual Report, 2021-22). A portion of the Hooghly district is also within its licensed area. The entire licensed area of CESC is split into ten zones for operational convenience. These ten zones, named based on their geographical locations, are presented in Table 1.

Table 1: Distribution of Zones Served by CESC

Sr. No.	Zones
1	Southern
2	South
3	Central
4	North
5	Northern
6	Northern Suburban
7	South West
8	West Suburban
9	Howrah
10	Serampore

Seven Sub-Stores are located at different strategic points of the licensed area to cater to the requirement of materials for the above ten zones. All these seven Sub-Stores operate in tandem with *"Central Stores"*, which feeds the Sub-Stores with materials through weekly consignment.

The locations of Central Stores and Sub-Stores are presented in Table 2.

Table 2: Locations of Central Stores and Sub-Stores of CESC

Store Name	Store Location	Serves All 7 Sub-Stores
Central Stores [Central Hub]	Kustia	All 7 Sub-Stores
Bompass Sub-Stores	Southern Avenue	Southern South
Amherst Sub-Stores	Amherst Street	Central North
Cossipore Sub-Stores	Inside Cossipore Power House	Northern North Suburban
Taratalla Sub-Stores	Taralalla Crossing	South West
Maheshtala Sub-Stores	Maheshtala	West Suburban
Howrah Sub-Stores	Howrah Maidan	Howrah
Serampore Sub-Stores	Serampore	Serampore

Hub-and-Spoke Supply Chain in CESC

CESC Limited uses 650 to 700 types of various materials to operate, maintain and augment its large electricity distribution network. These materials are categorised as under:

- Underground network specific

- Overhead network specific
- Common to both

The different zones of CESC have different electricity distribution networks – either predominantly overhead or predominantly underground. The requirement of items by any zone depends on the type of network it has, while common items are required by all zones.

The Sub-Store, which takes care of the specific zone(s), maintains the inventory of the corresponding items only (i.e., underground or overhead), along with common items. Materials in bulk quantities are received from vendors at the Central Stores (Central Hub). An internal fleet of vehicles transports a truckload of weekly requirements to each Sub-Store, thereby reaching materials at the doorsteps of the O&M teams.

Total Area of Operation Served by Sub Stores: 567 sq. Km, 10 zones, 1 Central zone and 7 sub-stores.

Procurement of Material: Annual orders for 95% of 670 items were placed at the beginning of the financial year (April).

Delivery Scheduling: Monthly delivery schedules are given to 70 vendors through a software driven process. Delivery schedules for the future 3 months on a rolling basis are given.

Delivery on Central Store: Based on rolling schedules, vendors supply materials to central stores on a monthly basis. Subsequent to receiving the quantity, checks are done. If it's found ok, materials are taken into inventory.

Weekly Demand Forecast for Individual Sub Stores: Annalise 6 months' consumption data. Take care of seasonal variations. Calculate monthly and weekly requirements.

Weekly Replenishment: Weekly report is transferred from the central store to individual sub-stores.

Receipt on Sub Stores: Here no need to quality check; only quantity is checked and kept in inventory.

Return of Materials: Excess materials are returned to sub-stores. A return voucher usually includes item names and quantity of each item being returned, voucher date, operational entity name and inventory location name.

Logistics Plan

The process of planning specific days and times to move a product or service through a logistics workflow or pipeline is known as Logistics scheduling. It includes everything from scheduling certain parts to arrive for production or dropping the packaged product off at the customer's door at a scheduled time.

Efficient scheduling takes less time, which means logistic and supply chain managers will have a greater capacity to focus on logistics strategy and higher-level planning. Route planning and optimization assist in determining the most efficient and cost-effective methods. It also implies that operations become more structured and quantified, making it easier to track performance and complete projects.

Once drivers start their routes, the operational manager loses control over where or what they are doing. It means two things: The manager cannot measure and monitor driver performance and improvement.

They are always assigning new assignments, pick-ups, and drop-offs. Adopting a cloud-first strategy for delivery logistics is possible with route optimization software. This allows for real-time tracking of all drivers via phone tracking or vehicle telematics. Divers can access these channels through their phones' delivery apps. It means they will be able to observe any modifications to their route or itinerary right away. As orders come in, it allows them to assign supply pick-ups, deliveries, and service visits. The ability to deliver in real-time is what can aid in the development of an agile delivery operation.

In CESC, the vendor will supply monthly materials at the central store from the 1st to the 7th of the month. The inventory Cycle for sub-stores is the 8th to 7th of the month.

Quantity dispatched from hub to spoke based on the following conditions:

- Average weekly consumption of a sub-stores.
- Stock position, so that it does not exceed the max level of the sub-stores.
- Any extra / additional project requirements.

However, in case of an emergency, it will break all rules. In that case, vendors are advised to supply the required quantity directly to sub-stores on an urgent basis, as CESC believe in reaching out to their consumers in every possible way. Also, CESC has its own Optical Fibre Communication network, which has enabled all its establishment, substations to stay connected 24 x 7. The same is spread across the licensed area, facilitating seamless transportation of OT and IT data.

Hub and Spoke Model and Process Flow Chart for materials of CESC is presented in Fig. 3 and 4, respectively.

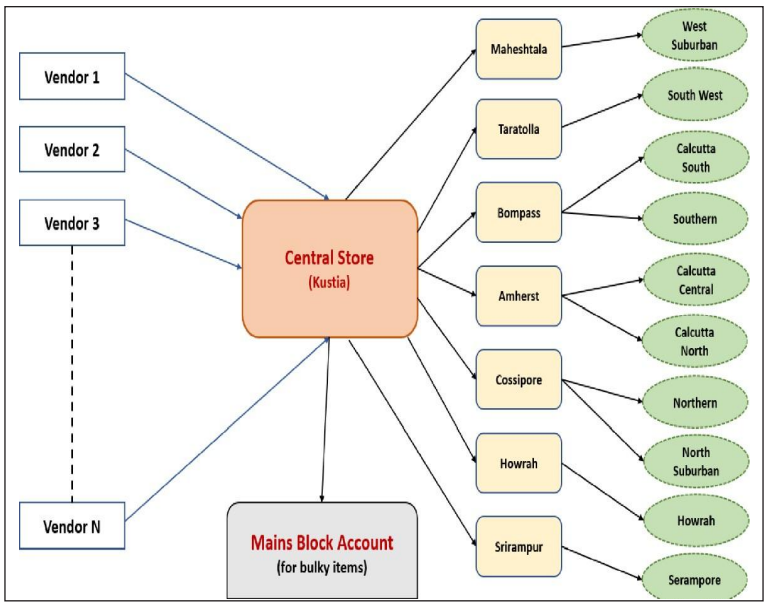

Fig. 3: Hub and Spoke Model Flow Chart of CESC

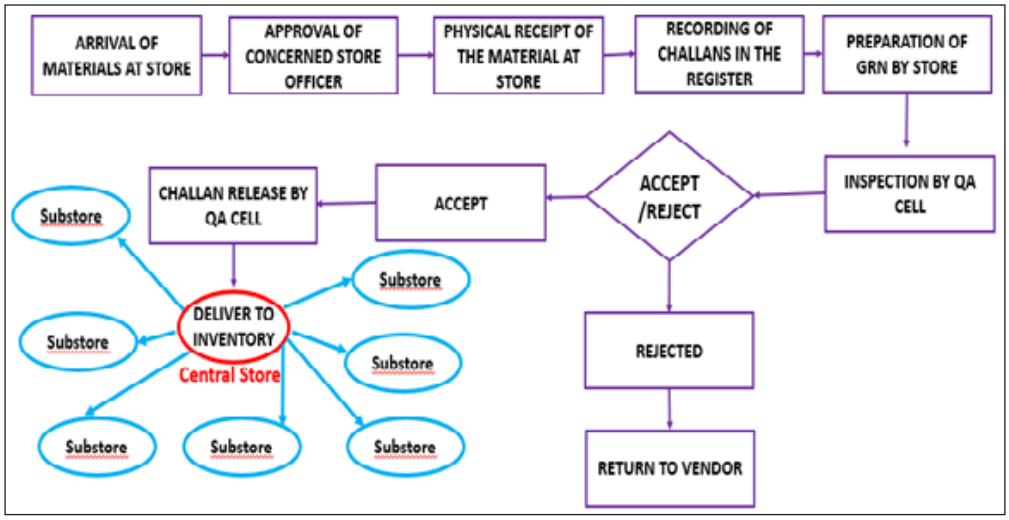

Fig. 4: Process Flowchart for Materials

Limitations of Study

The hub and spoke business model relies on perfection (Xu et al., 2020). When everything is working in harmony together, then the entire system is incredibly efficient. If just one spoke, by any chance, were to get out of place; however, the entire model can start to experience difficulties.

- Employees might not agree with a decision and not implement the centralised instruction, which would generate conflicts along the supply chain and ultimately jeopardise the business model.
- Unexpected elements that are introduced into the system, like traffic congestion due to an unexpected rally, can create delays or cancellations that affect the entire hub and spoke system.
- A sudden breakdown at the centralised hub could potentially create an instant collapse of the business since it supports the entire weight of the organization.

To avoid these problems, organizations need to implement a multiple-hub system. A central hub, a headquarters, would control the total system, but the lower-level hubs would have the authority to issue instructions within their region as necessary to keep the business operational.

Even when problems do strike the system, the hub and spoke business model is cheaper than most other models. Because everything is centralized, there is no need to pay for duplication throughout the entire organization. The costs of maintenance and repair are also much cheaper. Transporting needed repairs to a centralized location allows for constant training and oversight of skills. It is also a more cost-effective solution in the long term to send consistently skilled people out along a spoke than it is to put someone on the spoke and train them locally.

It is worthwhile to mention that for every organization, the hub and spoke business model is not applicable, but many do practice some components of it. Therefore, the motto here is to centralize, be consistent, and organize so that delays can be minimal. If that would benefit the organization, then this structure should be implemented today.

Conclusion and Recommendation

Inventory management is important for the utility business because of irregularity throughout the industry. Continuous changes and unpredictability make managing inventory difficult. Inventory cost consists of so many internal costs like inventory holding costs, stock out costs, ordering costs etc. In order to minimise the inventory cost and ensure a smooth operation of an organization, there should be optimal schedule quantity, which can be implemented through the 'Hub and Spoke Model'. The hub and spoke fulfilment model is a cost-efficient model. Taking the most efficient routes accelerates the delivery process but saves on fuel costs as well.

By application of the Hub-and-Spoke Model in CESC, it is envisaged that inventory reduction at Central Stores & Sub-Stores shall be in the range of more than 30%. This is because there shall be much less inventory accumulation at Central Stores since items shall be transferred at frequent intervals from Central Stores.

Also, since the transfer of materials from Hub (Central Stores) to Spokes (Sub-Stores) shall occur once every week, the Substores can maintain a very small inventory (Little more than one week's inventory). Also, since inventory is cleared from Central Stores every week (for transfer to 7 Sub-stores), so Central Stores inventory also will be reduced to a large extent. This model also lessens the number of distribution centres, which ultimately minimises inventory management costs.

Inventory optimisation is an agile practice that not only responds quickly to risk and opportunity but also has the capacity to predict and prepare for it. Optimising inventory through Hub and Spoke method can help us track SKU performance across your distribution network. This allows one strategically to allocate inventory to warehouse locations where there is the most demand, so you can ensure that a bulk of your orders can be shipped quickly and at a lower costs. Also, it enhances service levels and ensures products arrive in the right place at the right time.

Finally, it can be concluded that the "hub and spoke" sees the consumer choosing a core business management or Enterprise Resource Planning (ERP) system as the "hub" of their business. With ERP software, inventory managers can make real-time inventory optimisations decisions, confident that the data is backing them up. As with any business transformation, it's important to establish good communication across your inventory optimisation and supply chain team.

It is observed that the hub and spoke model is definitely a more flexible and lucrative distribution network, ensuring a smooth flow of goods compared to the old-school point-to-point model. It is a great decision for supply chain enterprises with ample shipments and delivery demands on a day-to-day basis.

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