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Review Article

Traditional Supply Chain VS. Cold Chain: Contribution in Global Carbon Emissions

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Abstract: Since last couple of decades, the discussion is going on traditional supply chain and cold supply chain. The key difference between both supply chains is the product or materials sensitivity. Usually, cold supply chain used for fragile items/products such as meat, milk, ice cream, tablets, medicine and medical instruments. Undeniably, cold supply chain carry a risk of product expiry due to unsuitable temperature. This research distinguish the difference between traditional supply chain and cold chain in detailed. Researchers used literature reviews method to sum-up the key findings and differences between these supply chains. In the cold supply chain, packaging part is also very costly in terms of delivery to avoid damage, protect from the temperature changes and special handling. As well special packaging increases the cost of storage and limits transportation capacity. On the other hand, modern material handling, the overall operational cost of cold chain warehouses is higher as compare to the normal/regular warehouses. And in the cold environments, electrical devices may lose their functionality. While reliability design in the cold temperatures; reduces the better life by 40 to 50%.

Keywords: Cold Chain, Global Carbon Emissions, Packaging, Traditional Supply Chain

1. Introduction

In the broader and modern supply chain; cold supply chain is a part of that's perspective due to their unique characteristics as well vibrant position in the world trades. Logistics' Glossary, definition of cold supply is "in order to keep goods in cold (specific) temperature to maintain quality, and cold chain required special logistics whole network" [1]. The Cold supply chain has different dynamics and requirements due to their special characteristics. Usually cold supply chain deals with perishable food items, vaccines and biological tissues. Because these all items and / or products should be in the cold place to safe their expiry and sustain quality. And to fulfil the requirement of cold supply chain; management required extra investment in terms of material, infrastructure, money and more energy to operate. These additions increase to the interaction of cold supply chain with environmental in terms of emissions. Management need to address these problems before going towards cold supply chain.

Many studies have been conducted over emissions from refrigerated trucks and transporters, packaging, cold warehouses and other supplies or parts. In the United States total refrigerated storage capacity is 3.96 billion cubic feet (bcf) exists [2]. The global market of refrigerated food was expected to reach almost $200 billion in the year of 2014. Nowadays, people's life style growing, consumers call for high service level from manufacturers so enterprises need to pay attention on cold supply chain to protect / shield the safety of food supply and for this purpose they need to make great development in terms of special logistics for cold supply chain [3]. Cold products has its own characteristics and requirements like specific temperature, short life / perishable and these all characteristics creates significant effects over distributions [4]. In the cold supply chain speed / velocity plays a vital role, usually cold supply chain use in the handling and marketing perishable / short life products [5].

The manufacturing of fruit in the Chinese market has been increased by 6% per year (48.3 Million MT in 2003 to 241.34 Million MT in the year of 2012) [6]. There are also major development in the perspective of quality, planting area and

variety. Usually 20 types of fruits including apples, bananas, grapes and oranges have the remarkable output. And they are almost 70% of the total production. In the Chinese market Vegetables are stable annually increase by 4% (564.5 Million MT in 2005 to 677 Million tons in 2011). Usually the origin areas are nearest from the consumers; which reduces / minimizes the needs of cold supply chain.

Cold supply chain has become more and more important within the changing global economy today due to the huge increasing demand on the products of temperature controlled industries, especially fresh agricultural products, manufactured food, chemicals, military services, and medical vaccines. Figure 1 shows the growth trend in supply chain industries and services. Cold chain logistics is considered as huge competition advantage as it cause a valuable extension to product shelf life which gives the suppliers the ability to access overseas markets and to meet the huge local demand caused by the population growth as well [7].

Due to the high increase demand on the items of temperature controlled sectors/ industries for example: perishable food products, chemicals, agricultural products and medical vaccines. Cold logistics considered big competitive benefit as it cause a valuable extension to product (shelf life) which gives ability to the supplier in access to overseas markets as well to meet the big local demand produced by the population growth [6-7]. Figure 1 shows the growth trend in the supply chain services and industries. The temperature monitoring and control are very essential mechanisms in the cold supply chain management, because off they are mandatory for maintaining quality and food safety [8].

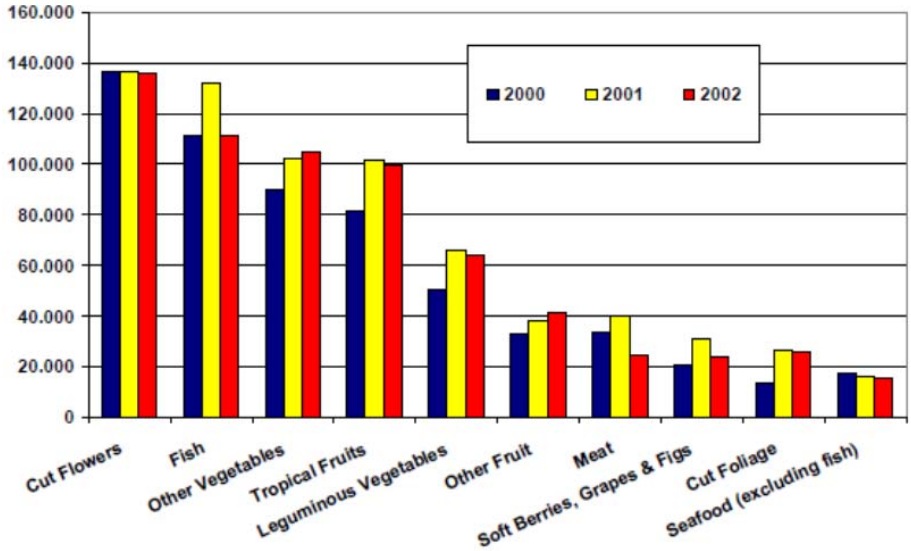

Figure 1. *Frozen/fragile products.*

In this research paper, we will survey the latest literature of cold supply chain from a carbon emissions viewpoint. This literature survey is not to be taken as an in-depth analysis but we will focus over the significant new developments in the cold supply chain.

2. Methodology

To discover latest and recent research work relevant to our article. We had searched scholarly databases by using different keywords to accumulate cold supply chain characteristics, for example: the keywords "cold", "cool", "cold chain", "cold supply", "perishable food chain" and for characteristics of emissions; We had used the following keywords: "carbon", "pollution", "CO_2", "warming and climate" we have repeated each search by changing different keywords and make different combinations of keywords, and also used an additional filter to limited and restricted the articles published in the journal during 2010 or later and then we studied each of these research works and the citations. Initially we face some degree of difficulty to restrict the boundary around the set of articles; to achieve the target of our research. Therefore, many research works could also be published in the field of economic, traffic, reverse logistics and material science. But surprisingly our keywords were effective. Particularly, the word of chain "as in supply chain" did not seem in research work related with other than supply chain. Likewise, the keyword "cold" was very useful in restricting a degree of focus over cold supply chain and usually these keywords were not presented in other than the field of supply chain.

3. Literature Review

In the supply chain and logistics, primarily these words of cold chains are used to transport and manage two kinds of items: one is medical stuff and second is foodstuff. If we more discuss to each kind so in the foodstuff; cold supply chain we use for raw vegetables & fruits, fresh meat and proteins, frozen foods, perishable food items. On the other side, cold supply chain we use in the medical stuff like drugs, blood, vaccines and tissues. These all are sensitive items which needs specific degree of temperature during sourcing, storage and transportations.

Cold chain that effect carbon emission and climate change.

An analysis of pineapple's lifecycle, which manufacture in Costa Rica to despatch in Florida's retailer [8]. As per his research result, 20% of the non-renewable energy consumption during the lifecycle's pineapple can be recognized to distribution and remaining 80% results due to the packing and farming. Likewise to other fruits, the cold supply chain aspect of fruits' carbon footprint calculation usually ignored / neglected in carrying out analysis.

The effects of environmental switching from traditional / normal supply chain to cold supply chain to minimize and reduce waste and at the same time increase local profitability [9]. As estimated, the incorporation of refrigeration increases carbon emissions by 2 to 3 times as compare the current levels. On the other hand, loss reduction & high food quality will be achieved. The researchers identify the use of a Solar Photovoltaic system to provide electricity to cultivate Paprika as well suggest that advances in items' quality will achieved with less increase in carbon emissions. Finally, they pointed that refrigerator one of the biggest contributor of emissions in the cold supply chain and currently it is not able to replace directly with less carbon intensive forms of generation. A number of inefficiencies (emissions) analysed in the Chinese market's cold chains from the perspective of transportation / logistics. Researchers detect the problems and lack of dedicated 3PL's cold supply chain providers as well many lacks in terms of different processes and stages integration of transport and manufacturing. To handle cold chain inefficiencies, they recommend to the development of 3PL or logistics providers. In the last they also point out the problems of coordination and information sharing between upstream and downstream level.

An analysis of consumer behaviour changes in order to minimize greenhouse gas emissions. Their work includes food choice, food eating behaviour and changes in the relationship of consumers with food. Ref. [9] research findings are the efforts with the big potential are those results which by the altering food consumption patterns in the individual level and almost 50% of the emissions (foods) occur "outside the gate" the farms manufacturing food. She also cites refrigeration as an emission creator in the whole process. Finally, garnett recommend to solve this problems by using more efficient refrigeration system as well sensible minimization of buying foods which needs refrigeration. She said, because refrigerated foods' demand are increasing including; meat, dairy products and microwave products because off the mass availability of refrigeration (domestically) in the developed world. She cautions even though a minimization in the emissions-intensive food buying would reduce demand for energy intensive cold supply chain services, and the dollars saved by these changes would; in terms of the cultural context explained, flow to another consumer services and goods with their own uncertain impact over environment.

Ref. [10] reviewed latest quantitative research works and addressed environmental food supply chain. They explain the major objectives which considered in the expansion of food traditional supply chain; explained both motives increasing food quality and profit, enhancing sustainability, minimize waste as well emerging a system for tracing food items in the whole systems. To explaining these tasks researcher classify them with a progression from traditional supply chain to food management and finally to environmental or sustainable food supply chain. Researchers review to the different modelling techniques to discuss challenges. Mainly, researcher highlight to the evolution in terms of practice and theory from a traditional, single-objective profit focus in the supply chain to cover and view the complete picture of the triple bottom line, for example: Planet, Profit and people. They conclude by noting industrial demands generally drive the progression with environmental / sustainable food supply chain. By the new technologies and techniques required to capture the challenges and complexities and unique characteristics of "multi-objective" food management systems.

There is not any doubt that's cold chain plays a vital role in the supply chain of vaccine's waste rate and improvement can result in the minimization and reduction of wastage rate. In the vaccination program and health sector; vaccine waste is a serious issue. Ref. [11] 39% is the wastage rate in the vaccination, finally this wastage not only creates problems in the efficiency of the vaccination program. Nevertheless major reason of increasing cost in two ways:

a. The purchasing (material & manufacturing) cost of the vaccines to replace those, which vaccines have been disposed.
b. Disposal cost of the vaccines.

The disposal cost of vaccines are high enough which need to be add and considered in the models of cost minimizations [11].

According to our best knowledge, no any comprehensive or particular analysis regarding environmental effects medical cold chain has been published. But few analysis' results are similar to those discussed before for focused-food systems, the cold supply chains of both medical goods and food items differ. In the medical goods (some vaccines and biological tissue) are very expensive than food items, that's why controlled over temperature stability in the whole logistics process are required greater than food items. Investigating the relationships between value able items and its emissions footprint will be a valuable contribution in the literature of cold supply chain.

4. Decision-Making of Cold VS. Traditional SC

In the supply chain, decision making has three main levels:

1. Long Term Decision – Strategic Level
2. Mid Term Decision – Tactical Level
3. Short Term Decision – Operational Level

4.1. Long Term Decision – Strategic Level

In the supply chain, strategic decisions usually called long term planning. And these types of decisions not take frequently, but these decisions create long term effect in terms of period 5 to 10 years, for example: facility location, heavy

equipment, building etc. Strategic level decisions need thorough planning and in-depth analysis and feasibility reports. In the cold chain, due to the high cost of facility design, instalment of equipment, freezers and special logistics, the importance of these decisions are significantly important.

4.1.1. Financial Dimension

In the cold supply chain, there are many factors, which influence over costs; but majority are given below.

1. Freezer/ Refrigerator for items as well warehouse space for regular items
2. Special types of dividers for loading docks (to reduce the temperature changes caused by shifting items)
3. Certificates / compliance regulations for cold products, like USDA6, FDA7, HACCP5 and USDC8

4.1.2. Environmental Dimension

Ref. [12] many cooling systems use produce GHG/other emissions. However, during the decisions should consider to the environmental side. Nevertheless, selecting the suitable technologies and investment in initial cost of construction could result in terms of huge savings in cost (operational) and emissions. For example, in the Canada newly opened Walmart cost $15 Million for 400,000 square feet, but saved almost 60% on energy cost (total cost of approximately $4.8 Million over 5 years). The facility's use hydrogen fuel cells for their 71 lift trucks has minimized the emission per year basis by 55%, or almost 530 Metric Tons annually ($1.3 Million savings) [12-13].

4.2. Tactical Level

In the tactical level, included allocation of demand / DCs, (distribution centres), inventory policies and maintenance schedules.

4.2.1. Financial Dimension

(i). Inventory

In the cold supply chain, holding cost of inventory is not only capital investment opportunity, but also the operational costs, usually which are not included for regular items like cost of electricity for containers (cold), wastage costs of expired products, inspection costs, etc. In the cold supply chain, the holding cost function is different from traditional / regular supply chains [5, 14].

Ref. [15] the perishable items, models of inventory need to consider the expiry date of the products within the normal inventory problem. The items near their expiration date are lower price, FIFO (first in first out) / "first expiring first out" both are same. Usually companies use this procedure for unloading, perishable inventory to minimize the expiry risk of products. Many times light and smell among the environmental features that need care in the cold chain, for example: dairy related products cannot be storage nearby seafood or meat. And these boundaries needs more additional cost to main the inventory and also make the complications in the process of inventory management.

Ref. [16-17] foods items manufactured in the facilities that also manufacture allergic items, like as wheat and peanuts, can encounter market share fall, as customers react to "negative" information on food tags. Ref. [18] in the end of 2015, allergenic foodstuffs is predicted to reach $5 Billion. And these items or products often needs separate holding capacity and/ or transportations.

(ii). Transportation and Allocation

Transportation allocation and scheduling are two other vital tactical decisions. While the core of allocation and louting problem is the same for traditional supply chain and cold supply chain, usually some features of cold supply distinguish the modelling approach for the two named supply chains. And these differences between traditional supply chain and cold supply chain may end up in some modification in the current models or develop new models for cold supply chain.

One major and important difference is capacity sharing of transportation. For example shares transportation capacity, like LTL (less than truckload). Usually LTL is frequently used in the traditional / normal supply chain's products. But LTL cannot be used for medical or foodstuff frequently as compare to regular products. And if it use, so many constraint apply in terms of following reasons.

1. The temperatures of different cold items are not same, which makes LTL difficult. Usually mostly vaccines are transported during the temperature of 2-8°C, as well fresh fruit truck that cannot share their capacity with a meat delivery truck, or an banana supplier cannot share capacity with an ice cream transporter.
2. Edible items cannot be despatched / transported with other kind of edible items because of the effects over the odour and taste. Such as, a shipment of dairy items may not be delivered in the same space and / or near a shipment of sea food.
3. Liquid products cannot share transportation and holding capacity. A tanker truck of orange juice and apple juice cannot supply both together.
4. Fresh items and those items which are near from the expiration both items' transportation route can be different, usually companies used short route and / or expensive mode for the nearing expiration products; as compare to those items, which expiration date is very far so companies try to use long route and cheap transportation mode to minimize the cost.

4.2.2. Environmental Dimension

In the traditional supply chain many environmental related components/ machineries are less important or do not exists as compare to cold supply chains coolant leakages, waste due to the expiry. Cold products have additional emission due to the refrigeration and cooling units. Ref. [19] results shows that's the emission of food transportation is higher for cold food items. Because LTL approach is unable to use frequently for cold products, and this will increase the number of transporters and freezers / refrigerators, in the result emission will be increase.

In the Figure 2, According to the CCTV (China), 26% contribution into global greenhouse gas (GHG) emissions are

due to the energy supply and heating, 19% contribution is industries and 13% contribution is due to the transportation. It means, due to the cold supply chain emissions are very high; because in the cold supply chain from producing till delivery, companies needs to use special refrigerated warehouses, transportation and packaging material. Finally, these all process of cold chain contributes a big portion of the Greenhouse gas (GHG) emissions in the global environment.

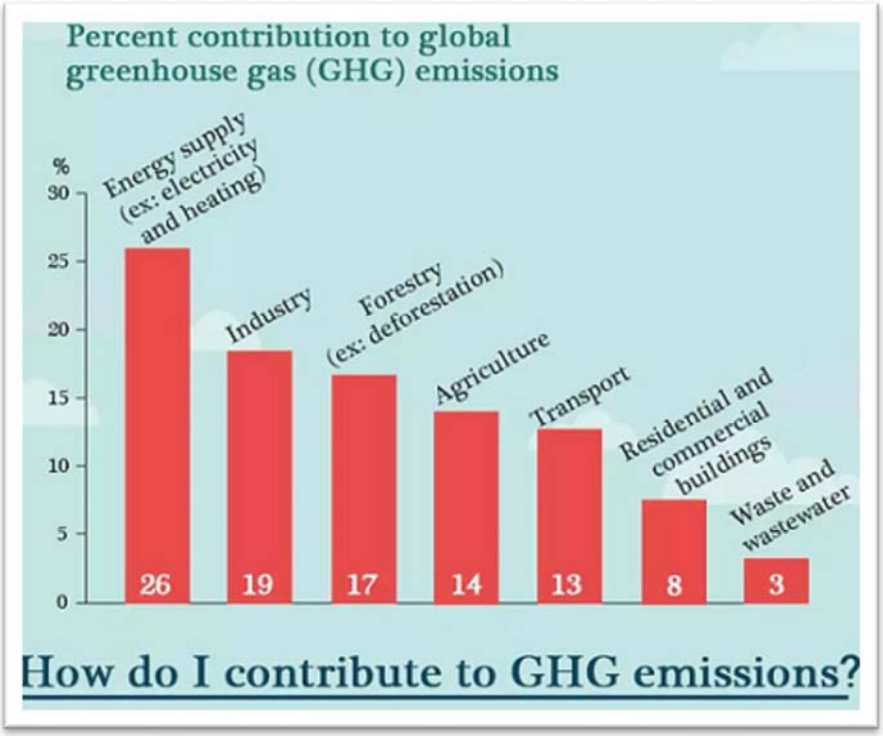

Figure 2. *Contribution to Global greenhouse gas (GHG) emissions.*

4.3. Operational Level

Operational decisions are related with the short term period. Generally these planning period are weekly or daily.

4.3.1. Financial Dimension

Products before despatch / sent to retailer are normally inspected for temperature, shape and deterioration, etc. Ref. [20, 21, 23] an inspection can produce a level lower, degrade for fruits, near expiration date, these are the reasons in the price reduction or implementing a policy to minimize risk / loss; usually these inspection as well loss of quality inspection is costly.

In the cold supply chain, packaging part is also very costly in terms of delivery to avoid damage, protect from the temperature changes and special handling. As well special packaging increases the cost of storage and limits transportation capacity [24].

As per the report of modern material handling, the overall operational cost of cold chain warehouses is higher as compare to the normal / regular warehouses. And in the cold environments, electrical devices may lose their functionality. While reliability design in the cold temperatures; reduces the better life by 40 to 50%.

4.3.2. Environmental Dimension

The handling of cold products has higher emission as compare to regular / non cold items. Includes the emission from defected items expired (waste), which needs special treatment, for example: expired medicines, vaccines having environmentally harmful materials.

5. Conclusions

Globalization increases the network of world trading/ import and export across vast distances. Many medical items and foodstuffs need very strict temperature controls throughout the process including; production, storage, transport and till retailer/ final sale. Cold supply chain cannot be ignored from their uniqueness and emissions perspective.

In the recent surveying literature of cold supply chain, we found that many papers totally focus over cold chains and on emissions from a broader perspective of supply chain. And some research paper deal with pollution, greenhouse gas. In addition, we noted a relative Scarcity of research in the systems engineering & industrial domain. Many research papers' titled are towards either economic policy or a material engineering concentration. We used in the starting point for our research survey was the most recent complete research paper addressing to the emissions and cold supply chains specifically. We have confidence that these convergent trends: greater attention to emissions-efficient and energy efficient refrigeration systems from an engineering side, and a focus over less emissions-intensive systems, greener from the side/ perspective of micro and macroeconomics policy as well

industrial organization, offers an ideal conditions for latest research on related topics. We proposed that subfield of cold supply chain management stands to benefit from the confluence (flowing together) of these trends. We show our idea / conception of this possible convergence in Figure 3.

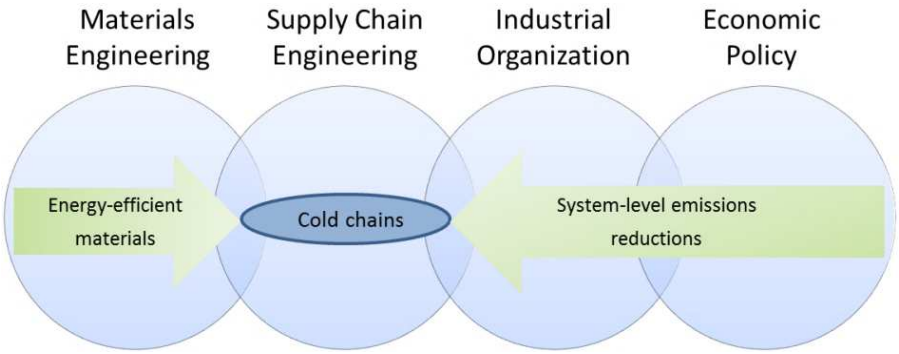

Figure 3. *Convergence of Complementary research streams (emissions-reduction) on the field of cold supply chain management within the field of Engineering Supply Chain.*

There has been little discussion of parallel problems relating towards vaccines, medicines, blood, and tissues transported through cold supply chain. We believe that the basic differences between the transporting of food goods and medical focused systems merit independent examination with the perspective of their energy consumption and their emissions. Such as, medical related items are more rigorous and strict regulations than food related products, thus requiring more care to avoid degradation and spoilage during transport allow for less and few extreme deviations from optimal temperatures and potentially demand more energy intensive and new cooling technologies. In addition, logistics networks of medical related items restricted to facilities those items, process and receive such goods will require cold chains having different /diverse network characteristics as well corresponding opportunities for reduction in emissions. We recommend a research analysis of the subfield of cold supply chain used to handle medical related goods may disclose behaviours and new results greatly different from those known. As in the global supply chain trade, commerce and emissions are increasing; academic research must expand to help/assist decision-making and engineers about environmental sustainability, economic cost control and green supply chain.

In the conclusion, simply more research works required over emissions and environmental impacts of cold chains. These elements of the world's logistical superstructure are basically distinct and different from their room temperature counterparts, and that study can expose real opportunities for impactful execution and change system design. These innovations needed more as emissions and world's trade grow, as well need to balance environmental and financial concerns becomes ever more important and critical.

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