Logistic Techniques to Reduce Losses in Fresh Food Supply Chain

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Abstract— This paper discusses various techniques that have been developed to improve the logistics in FFV (Fresh Food and Vegetable) supply chain. The Global Agenda Council of Supply Chains and Logistics presented that the largest quantity of food related losses in fruits and vegetables are caused by improper maintenance, and also due to misalliance between supply and demand. Implementation of techniques like Intelligent Container, using RFID (Radio Frequency Identification) tags and some other logistic principles like FIFO (First in First Out), FEFO (First Expire First Out), dynamic FEFO have been studied to understand the logistics of food in a better way. In the FEFO technique, the product that expires first is sent out of the warehouse first, for further delivery. In addition, there are sensing techniques for the reduction of food losses, and also methods for decision making. On the basis of identification of the radio frequencies, RFID helps at enabling communication between the tag and a remote computer, from a distance without the requirement of a line of sight. This paper also reviews two case studies, of berries and bananas, based on the intelligent container technology.

Keywords: Supply Chain; Logistics; Fresh Food; FEFO; FIFO; RFID; Fuzzy AHP; Fuzzy Dematel; Decision Making; DVRPTW; IACO; Flexsim; RFID; Intelligent Container; Food Losses

I. INTRODUCTION

In a report by Gustavsson, approximately a third of global fresh produce is discarded because their quality declined below the tolerance level [1]. According to a study of the recently published statistics given by, Food and Agriculture Organization (FAO) which is an organization of the United Nations, losses and wastage in food leads to the production of about 4.4 gigatons of greenhouse gas emissions every year and emits radiant energy within the thermal infrared range.

When we put these numbers into assessment, we find:

- If food loss and waste were to be a country, it would closely follow China and the United States, to become the world's third largest emitter of greenhouse gases.
- Food loss and waste produces more than 4 times of greenhouse gas emissions than the aviation industry.

This is an environmental concern, and it also has a huge economic effect. Roughly, $940 billion worth of food is wasted each year.

According to the data collected from the FAO statistical yearbook, losses in food can be credited to two primary reasons: (i) Wastage caused by overproduction and oversupply which is common in countries with comfortable economies [12] and, (ii) Natural decomposition and spoilage of food, which cannot be prevented, yet it can be reduced by maintaining appropriate temperature levels and hygiene around the food.

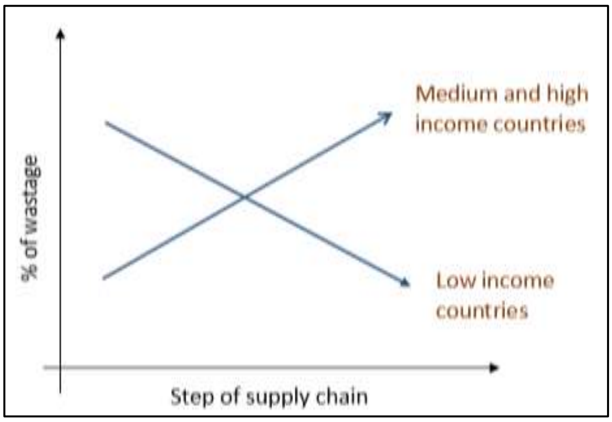

Fig. 1: Trends of percent of food wastage in countries with different income rates, during various steps of supply chain processes

The above figure shows that countries with middle to high incomes, like America and Europe, face food losses in later phases of supply chain, like consumption and distribution. Food is discarded due to lack of aesthetic value, insufficient knowledge about expiry dates, inefficient management in hotels, etc. As a result low income countries like South and Southeast Asia, face maximum food wastage during early phases like production, post harvesting, transportation and storage [1].

In a world where the population is constantly increasing and many areas are struck by poverty, food wastage is highly undesirable. A great portion of this loss is due to inadequate handling and lack of optimization during supply chain procedures.

II. THIRD PARTY LOGISTICS

The group of providers that specialize or master in combined operations of the warehouse administration and transportation is known as Third Party Logistics, which can be scaled and customized to the requirements of the clients or the customers. The basis for a supplier selection in logistic are, the conditions of the market that are needed to meet the requests and the delivery requirements of service for their products. According to a survey conducted in 2014, some type of embodiment of 3PL services are employed by 96% of all the Fortune 100 and 80% of the Fortune 500 companies. (Armstrong and Grabowski, 2015)

A provider that offers these services can be termed as a 3PSCM which stands for the Supply Chain Management Provider or they can also be referred to as a Supply Chain Management Provider (SCMSP). The 3PL aims at specific functions in the management of the supply chain, for example warehousing, shipping or provision of raw materials.

A. *Selection of third party supplier*

The market conditions and the environment are dynamic and volatile, that comprise attributes such as quality of goods, environmental conditions, hike in prices, inflation, government and tax policies, etc. Hence, we need to choose a supplier that fits our requirements better.

The sub-basis consists of the knowledge along with the information technology and management also includes the approval of the budget and the comfort, safety, security, refrigerator, convenience, maintenance management and the aesthetics outlook and the capacity of loading, together can be integrated or combined into five wide groups. When we talk about the CTPLs and the CSM area have to perform the tasks in a section that is eruptive or volatile and undetermined fuzzy environment. Therefore the integrated tool or the apparatus of the Fuzzy-AHP (Fuzzy Analytical Hierarchy Approach) and the Fuzzy-Dematel demonstrated with the guide or the aid of genuine cases from the vegetables and fruits industries of India. [18]

The methods for selection are described below.

Fuzzy AHP	Fuzzy Dematel
AHP technique for multi-criteria shaping of decision that help creators of decision to choose a choice between alternatives. Fuzzy logic is an approach that handles with uncertain data and imprecise knowledge. When decision makers need to take a decision in uncertainty situations, they can use Fuzzy AHP.[16][17]	The method of DEMATEL which is a well-known and method where there is approximately all the elements to obtain a structural model that tries to provide causal relationships between complicated real-world aspects.

Table 1: Difference between Fuzzy AHP and Fuzzy Dematel

Fuzzy Multi--Criteria is a method for taking decisions which are unique in their type. The approach is used for the progress of the losses that are seen in food via CTPLs that stands for the cold third party logistics and the process of choosing. To identify the losses in the case described, literature survey, judgement of the expert, thirty sub criteria and five criteria have been used. The tool which has been selected for the approach, makes use of the trial and evaluation laboratory resource for Fuzzy-Decision making, to evaluate values of presidency weights of the present attributes and fuzzy-analytical hierarchy process tool which estimates the best CTPLs in accordance with the attributes.

Efficiency- The output of the approaches display that the factors, refrigerator and the loading capacity, the knowledge about the cause and also Information technology were the most notable needs for the selection of the CTPLs. [7]

But if we individually talk about the two approaches they have certain limitations. To know about this better, further analysis and research are needed for the other countries that are developing, with an updating of the chosen technology, and advancing the dependency or the reliability of the imitation. [15]

III. USING RFID TAGS FOR SMARTER LOGISTICS HANDLING

Today, devices can communicate with each other using IOT (Internet of Things) principle, which has led to a revolution in the communication and information transfer technologies. This has bridged the gap between the physical world and the internet. RFID's use this same technique, to relay information about the object they are attached to, for example which a shipment container, and the surrounding physical conditions.

A. *Working of an RFID tag*

RFID stands for radio frequency identification, which uniquely identifies the object it is attached to, and can communicate this information using radio waves. This communication does not require direct line of sight [2]. It comprises of an interrogator (reader) and a tag (transponder), which have a unique identification code. RFIDs include sensors and other peripherals to transmit data of their surrounding environment like temperature, humidity and CO2, CH2 levels along with their geographical information.

The interrogator reads signals from the tag, decodes it and this is received by a remote computer or server. The computer, can take note of the readings, and may also write additional data and information to the tag, via interrogator. [19]

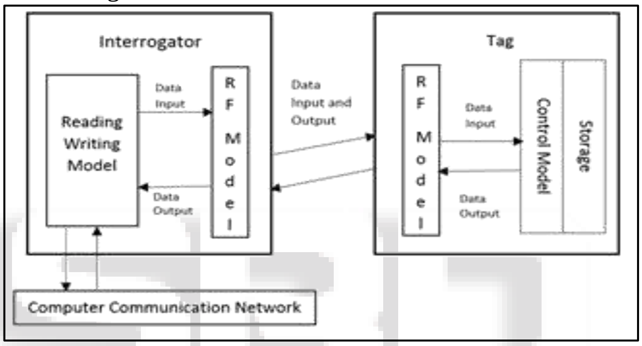

Figure 2: Block diagram of an RFID

B. *RFID to improve warehouse management*

In the shipping industry, accuracy of shipment usually exceeds 99% whenever bar code are used for capturing data and performing real-time verification [4]. This can also be applied in the food industry to improve traceability and safety by using systems that would automatically capture lot codes and date of expiration from batches that are outbound. The data collected about this shipment can then be encrypted on a bar code, which can be scanned by the receiver to congregate information on the complete contents of the batch [22].

To improve receiving productivity, workers can scan a barcode on shipment arrival. This would automatically create a timestamp and location, along with updating of records. According to the EFR (Efficient Foodservice Response), only around 64 percent to 83 percent of containers that are supplied to chains of food distribution centers make use of bar code [3], which causes major problems and hinders effective warehouse operations.

Recall of food, is a common occurrence, which distributors need to plan efficiently. By using lot codes and shipping labels, along with information like customer orders and shipping records, organizations could easily communicate a recall. The rollout operation can then be performed by the distributor. Hence, traceability is largely improved using RFID [23]. This eliminates the misalignment in the online inventory record, and the actual physical inventory.

The physical label undergoes temperature extremes and moisture variations, which is common in food operations. This could lead to unreadability in the tags, some discrepancy of collected data. Thus, ensuring that it remains affixed and readable needs special care. Also, a high degree of automation is required for optimal working.

C. Handling RFID tag collision

In the architecture based on RFID, when information is to be passed to multiple locations and multiple targets need to identified, tag collision can take place. During this, several readers and several tags try to communicate simultaneously, which leads to interference between these components. This further causes inability in data transfer and error in data reading, and also outflow of personal and confidential information. Hence, dome solutions to this include tree based algorithmic solutions [24] like, Manchester coding for collision detection and solution. Use of binary tree algorithms like dynamic binary search (DBSA) and binary search (BSA). DBSA reduces the data quantity that travels between the tag and the reader. There is also, Backtracking binary (BBA) algorithm[28], which has no collision.

To handle tag collision, we can implement above mentioned tree-based anti-collision algorithms or slotted ALOHA procedure[25]. The former has longer identification delay, but can avert tag starvation.

Roughly, 52.44 percent of the total transmission channels are saved by using the Backtracking Binary algorithm, when 180 tags are considered.[11] The backtracking binary algorithm is able to attain better performance results with respect to the number or figure of transferred data in binary form, for correct identification of the tags.

Although, one anti-collision technique cannot be applied to all the problems, and needs to consider parameters like the targeted constraints (e.g. collisions, throughput, efficiency) and the type of reader, static or dynamic.

IV. DYNAMIC ROUTING

A common optimization based problem in the distributed logistics, is the Vehicle routing problem (VRP). It generally aims at finding the optimal route for one or more vehicle, when it travels from a source (depot) to the destination (customers), such that the constraints of capacity for the vehicle are not surpassed. Dynamic vehicle routing problem (DVRP) works the same way, but it allows the system to update the route, on the basis of new information, such as changes in customer demands, spoilage of food in a lot, road blocks, etc.

A. DVRPTW (Dynamic vehicle routing problem using time windows)

Dynamic vehicle routing can be picturized and solved using graph methodology. One vertex represents the store(source) while others represent the customers(destination). The edges represent the distance and the travel time, and it changes depending on the route's real-time traffic. The edges can also include parameters like dynamically changing needs of the customer, and unforeseen spoilage of food products[29].

This graph is a Hamiltonian cycle, where the vehicle starts from the depot and returns back to it, while visiting every other vertex (customers) in the graph only once. The main objective is to cater to every customer within the scheduled time and such that the total distribution cost is minimum. Also, products that are delivered should not surpass the total capacity of individual vehicle.

B. Improved Ant colony optimization (IACO)

This optimization strategy was first introduced by, Dorigo et al. [10], a group of Italian researchers. It is based on the actual behavior that ants use to seek food.[31] They found that ants make use of the shortest path in search of food and return back to their nest, while leaving trails of pheromones.

Now, for any new ant there are more than one paths to choose from. As ants travel the same shorter path, they deposit more pheromone on that route. Subsequently, this route becomes more frequent and appealing. Finally, the pheromone deposits on the longer and less chosen paths evaporates. The effects of the change in pheromone quantities on path can be found using max-min method [13]. In turn, we obtain the smallest and quickest route from the source to food and back.

One method of IACO implementation is pheromone updating strategy. In this method, after each iteration (path for individual ant) pheromone quantity is updated, taking in consideration the pheromone's evaporation rate. This increases the chances of getting the most optimized path. In DVRPTW, there is no variable analogous to rate of evaporation of pheromones.

C. Simulation based model using flexsim

The limitation of DVRPTW is that, considering real-time traffic introduces randomness in the calculation, which hard to model mathematically. Hence, we use a combination of IACO and simulation model. We can use flexsim which is a software for discrete events simulations.

The simulation module framework of DVPTR consists of two parts:

- Simulation unit, which keeps track of the edges and vertices generated, the demands of the customer, real-time traffic, etc.
- The Optimization unit that continuously collects the data that is created during simulation, such as travel distance and time. [14]

The Optimization unit constantly improves the simulation after every iteration, and therefore produces the optimal solution. Further research on this topic needs to focus on including parameters affecting inventories and considering more factors that are parallel to real life.

V. INTELLIGENT CONTAINER

If we talk about this then we need helpful techniques for the fresh food supply, so our main concern is also for the same.
And we had read out that the solution for the losses in this section is the intelligent container. So this focusses or targets at decreasing or the reduction of food losses in the system of transporting through the use of sensors and the

technology of communication, and also have an enhanced management of the supply chain.

The common organization of any 'intelligent container' comprises of the following:

1) A connection of Wi-Fi sensors that are ascended on or inside any surface area of food pallets, that detect the changes in temperature and any other parameters,
2) An observation unit of load helps to put in the container first, after that evaluating the data that has been measured along with the computation of the estimate of the shelf life of the products that have been shipped.
3) A unit of the telematics does external communication with the help of the satellite network or mobile system communication's global system.
4) For the task of external interaction and communication a unit of telematics is used with the help of satellite network or a worldwide organization for the mobile interaction.
5) Lastly for transmission and web entrance or service of the details into the databases a remote server is used.[9]

   Given below are methods followed by some of the research papers that basically focuses on the use of intelligent containers. By making use of various techniques, we aim for proper maintenance of the shelf life of food.

A. *Methods to implement intelligent logistic containers*

1) IoT based sensing and communication
2) Magnetic Induction Based Sensing and Localization
3) Dynamic FEFO (First expire first out)
4) Vegetables Logistics Information in Supply Chain

IoT-based tools or apparatuses can decrease or reduce the losses in food or food waste that are aided by the federal data analysis and collection [27]. It can advance or progress the efficiency or the output of circulation, transportation and carriage, along with supporting rapid or quick rejection or exclusion of yields or products that are rotted and unclean from the supply chains of fresh food.

Here it has been discussed about the continuous monitoring of the product's quality, how the losses in food can be decreased, enhance efficiency of distribution and transportation and along with the support and rapid elimination or removal of contaminated or damaged food. [30]

The mechanisms in these papers have been developed to monitor and report out fresh food standard sensors surrounded inside the boxes which can be kept in a distribution center or it may be kept or stored somewhere else and came with an answer that sensor nodes can remain or last for many years where we will not require replacement of any battery and various alternatives have been monitored and they came up with the most valid conclusions. [5]

Further advances will be required in order to make successful intelligence through the use of data in practical or conditions in the real-world. The logistics operations of the real-world have complications which make rough flexible distribution, including the policies of party-specific distribution, contracts of delivery, and particular requirements for the privacy of data-privacy. In future the research must be in a way to get an inexpensive sensor module and to get the designed experimental set up in the real world and to study the effects on the accuracy or the approximation of the selected scheme of localization while utilizing metallic walls by the use of such setups.

The issue that remains unsolved is mold detection in food. New projects based on sensors are apprehensive about how mold infection in such storage containers can be detected.

There has been a next level consideration of the interaction of the product quality that has been sensed along with the position of the box inside the stack contained by the boxes in a warehouse room or it may be the truck. In addition, this is done so that the logistics must remain less wasteful more beneficial. In such environments biological media that is inhomogeneous, also water rich media and interactions based on RF or ultrasounds are not fit, interaction or communication framework that are based on MI which stands for Magnetic Induction has been used in the band of HF that is 3-30 MHz via selecting a localization scheme that is based on a novel magnetic induction which is used to localize the boxes and analyze or study the approximation or accuracy with the use of simulations that are extensive.[6]

The lack of automatic capture of data and calculation systems for shelf life to perform this task is the reason why FEFO is yet to find many actual real world applications till date, and remains to be just a concept. The present quality and state of packaged food products is many a times hard to determine and cannot be seen from the surface or exterior. [20]

Target is to minimize food losses during transportation by the use of sensors and better communication technologies to achieve a better supply chain logistics management.

For genuine determination, indicators of shelf life and other equipment that support decision making are planted in the network of sensors.

VI. CASE STUDIES

Two case studies of berries and bananas are studied below. They discuss the effects of inefficiency during operations like packaging, temperature management and proper stock rotation according to shelf life on the products.

A. *First Case Study (Berries)*

Initially the case study talks about the changes in shelf life and temperature examination for blackberries in case of a supply chain. The changes in quality are the outcomes of temperatures during transportation, pre-cooling differences and their placement in the truck. These outputs in 57% of the total berries incoming at a house of packing to lack adequate lasting shelf life for the routes of transport that are long. There will be important unnecessary losses if the pallets that have been affected are not reallocated to routes that are shorter. For berries, factors such as odor, color, weight and taste are comprised in order to attain a better accuracy level. After these all the predictions of shelf life based on the history of temperature, inside the range of locations in the shipping pallet, the sensors are required to be placed. Through an artificial neural network a precise prediction for temperature has been shown where the inputs that have been taken are measurements of sensors for the surface. [20]

B. *Second Case Study (Banana)*

In the process of transportation of bananas to Europe from Central Asia the technique of intelligent container was used for the storage. After the process of harvesting, via respiration, bananas generate huge quantity of heat. On the basis of a mathematical model for distinct pallets, where wireless sensors are provided are used for the computation of stability between the produced heat of respiration. The pallets that are at the dangers of converting into hot-spot, as no extended heat can be eliminated are predicted by the model. It was also found that less than 10% of cooling potential of the unit that is available actually reaches at the bananas at pallet load's center. Hence, the bananas do not cool effectively due to inefficient airflow during the packaging of the product. This may cause unwanted and early ripening of the bananas. [20]

VII. Conclusion

This paper presents a set of viable solutions for better handling of logistics in FFV supply chain, where we discussed how the implementation of RFID in FSC can make operations automated, which will decrease the extent of differences in physical data and computer records. We also addressed the problem of RFID tag collision, which we found is best solved by using Backtracking binary (BBA) algorithm. Dynamic Routing can be handled for DVRPTW, using a combination of simulation model and IACO, which gives the most ideal solution (route). The paper also goes through the using method of intelligent containers, where the food is kept in boxes that sense and control the surrounding environmental conditions for optimal storage during transport, and techniques like FEFO that stands for First Expire First Out have been used.

For the selection of a third party logistics supplier, we found two algorithmic approaches. The Fuzzy dematel approach simply use computations for the complicated real-word factors that helps to build a model for the just casual relationships between them. However, the other method of Fuzzy AHP provides a choice for selection between various options and a method where imprecise knowledge and data that is not certain are allocated. The method of Fuzzy AHP is better than the other but together they give more efficient output. Lastly the case studies we went through were based on the uses of intelligent container where separate cases for berries and bananas were considered.

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