Literature Review of Applications of ICT on Solar Cold Chain

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ABSTRACT

The Cold Chain (CC) is a system containing a range of processes like shipping 'temperature-sensitive' items by special kind of packaging along a supply chain, and strategic planning to ensure the safety and integrity of items that are shipped. The items of CC are transported in many ways, such as refrigerated vehicles and railcars, cargo ships, reefers, and air freight. For many years, the 'Cold' element of the system, that is, refrigerators, powered by gas or kerosene was considered the most appropriate option in areas without reliable energy sources like electricity. Nevertheless, numerous problems with these tools have made it both difficult and costly to maintain temperatures within the safe range. In the 1980s, solar refrigerators powered by batteries were introduced as a solution to those problems. But the batteries they relied on required regular maintenance, had a lifespan of only three to five years, and replacements of quality were costly and sometimes hard to get. A new solution has emerged in recent years, the design of a solar refrigerator, removing the need for costly and unreliable energy storage batteries used to power solar refrigerators. This technology uses solar energy to freeze cold storage material directly and then uses the energy stored in the frozen bank to keep the refrigerator cool at night and on cloudy days. The new ICT technology offers greater visibility and control over the entire CC network operated by the solar. Using data in real-time, ICT component Technology called the Internet of Things (IoT) will allow quicker, more appropriate reactions as well as much more informed decisions. This literature analysis is created by revising a good number of papers published in peer-reviewed journals and online sources making use of secondary data obtained. The goal of the study is to explain the use of applications of ICT in the CC System and find research gaps.

Keywords: Solar Energy, Cold Chain, ICT, Cloud Computing, AI, Big Data, Cloud Storage, Smart Sensors, Energy Grid, Bluetooth, WiFi.

1. INTRODUCTION :

Because of 'globalization', the logical distance between two parts of the world has decreased; the reality is that the physical distance between them remains the same. When items are shipped using CC, they may get damaged because of vibration or improper temperature. During transport time, the quality of a range of products considered to be perishable objects, such as good products, maybe reduced because they sustain chemical reactions that can often be mitigated under unstable temperature conditions. Reliable freight management involves effective time-consuming planning which has invariably negative effects, particularly if such a shipment is perishable. To mitigate these consequences, CC is extensively used by the food industry, healthcare sector, and pharmaceutical sectors. They depend upon the CC mainly to ensure that the items shipped are not harmed or tampered during the process of transportation. To ensure the safety and integrity of items shipped using CC, a sort of systematization or planning is very much needed. "The cold chain is a process of transportation of temperature-sensitive products along a supply chain through thermal and refrigerated packaging methods and the logistical planning to protect the integrity of these shipments. The modes of transportation are of items using CC include refrigerated trucks and railcars, refrigerated cargo ships, reefers as well as air cargo" [1].

The CC technology includes the element of science; because the items shipped using it will undergo chemical reaction or develop pathogens as the time progresses. The product perishability and integrity depend solely on physical means to guarantee the necessary temperature conditions along the transport chain and the process element comprising a variety of transport chain issues. This system has four main factors: Cooling Systems, Cold Storage, Cold Transport, and Cold Processing and Distribution.

The success of an effective 'Cold Chain' system solely depends on the performance of the critical element 'Cold'. That is 'what mechanism is used to ship the items under controlled temperature? The type of container being used for shipment and the cooling technology adopted will ensure that the items remain within the specified temperature range for a prolonged period. Approximately 20 percent of all energy used in CC logistics requires container cooling [1]. Factors such as transit time, shipment size, and observed ambient or external temperatures are critical when determining what form of packaging is needed and the related energy consumption level. These can vary from small isolated boxes containing dry ice or gel packs, rolling containers, to a large reefer with an electric cooling unit.

For many years, the 'Cold' element of the system, that is, refrigerators, powered by kerosene, gas or diesel was considered the most appropriate option in areas without reliable energy sources like electricity. Nevertheless, numerous problems with these tools have made it both difficult and costly to maintain temperatures within the safe range [2].

In the 1980s, solar refrigerators powered by batteries were introduced as a solution to those problems. But the batteries they relied on required regular maintenance, had a lifespan of only three to five years, and replacements of quality were costly and sometimes hard to get. A new solution has emerged in recent years, the design of a solar refrigerator, removing the need for costly and unreliable energy storage batteries used to power solar refrigerators. This technology uses solar energy to freeze cold storage material directly and then uses the energy stored in the frozen bank to keep the refrigerator cool at night and on cloudy days [3].

The ICT offers greater visibility and control over the entire solar-operated cold-chain system. ICT's use of data in real-time would allow quicker, more effective reactions as well as much more informed decisions. Recent technologies such as smart sensors, cloud platforms, GPS devices, network gateways, big data analytics tools, wireless networking solutions, and customized user interfaces [4] can simplify the system's integrated operation such as tracking, aggregating, monitoring, delivery, reporting, analytics and sharing [5].

The typical integrated Solar Powered CC Portfolio Management System includes - Smart Sensors such as chemical, automotive, moisture, flow, sound, weather, and humidity, the temperature that detects physical environmental conditions, processes and converts them into the signal. They contain a built-in microcontroller with wireless transmission capabilities. It performs an automated collection of data, pre-processing as well as transmission. Sensors generated data is collected by different IoT devices [6]. IoT Devices include different development boards such as Arduino, ARM, RaspberryPi, Beagle Bone, Intel Edison, Intel Galileo, etc. The IoT device communicates with the gateway using protocols such as ZigBee, Z-wave, Bluetooth, BLE &Wi-Fi, Wireless Sensor & Actuator Networks, GPS and Cellular Gateways. The data from the gateway to the cloud is communicated usually using protocols like MQTT, CoAP, and XMPP [7], [8]. Cloud infrastructure provides a platform for quick, easy and complex processing of events in real-time needed to perform advanced sensor data analytics. Cloud computing technology harnesses a Big Data platform which allows large amounts of data to be stored in a decentralized site, ensuring easy access to data, high protection, and reduced storage costs. Notable cloud platforms are Amazon Web Services, Microsoft Azure, VMWare, and Google Cloud. Each Cloud Platform offers a suite of tools that make it easy to gather, process and store data[9].Machine Learning and Artificial Intelligence tools such as Google Cloud ML Engine, Amazon Machine Learning (AML), Apache Mahout, Google ML Kit for Mobile Azure Machine Learning Studio, Eclipse Deep-learning facilitate the discovery of information and the generation of insights to provide empirical solutions. These include Energy Forecasting, Operational Intelligence, and Predictive Maintenance. They are considered key factors for improving the efficiency and profitability of power plants.

The system would increase the quality and effectiveness of food, pharmaceutical, and other perishable supply chains over long distances. The "cold chain" or 'temperature-controlled' supply chain, is now gradually integrating digital technological systems, stable cloud infrastructure, and open architecture rather than pure freezers and freight trains. Besides, the integration of eco-friendly renewable solar energy instead of non-renewable eco-unfriendly fossil energy controlled and managed by ICT results in a more intelligent solar-powered CC system that provides managers with live temperature and location data, minimizing any problems along the chain before they occur [10].

2. RESEARCH AIM AND METHODOLOGY :

This paper mainly focuses on Applications of Information and Communication Technology (ICT) in Solar Cold Chain Portfolio management. The main objectives of this research article are mentioned below:

- To familiarize the application of ICT in solar cold chain
- To identify the Research Gap based on the existing literature study
- To construct the Research Agenda

In this literature review paper, applications of ICT in Solar CC are reviewed and studied. The ICT system consists of many recent technologies such as smart sensors, cloud platforms, GPS devices, network gateways, big data analytics tools, wireless networking solutions, and customized user interfaces. This literature analysis is created by revising a good number of papers published in peer-reviewed journals and online sources using the secondary data obtained. The paper finds the research gap.

3. LITERATURE REVIEW :

In recent years a considerable extent of growth and development had been established in the field of CC, Solar-powered CC, and ICT. A significant number of published papers on the Solar CC perspective have been reviewed and examined in this paper in the peer-reviewed Journals and on the Internet for the last 15 years (2005-2020). Based on the analysis, the literature section has been logically classified into three subdivisions. This review outlines the different investigations on ICT technology and how it affects the Solar Energy-powered CC Portfolio Management.

CC managers used electronic temperature loggers that provided accurate data on the temperature of products delivered using the CC. The quality of temperature-sensitive items depends on a variety of unpredictable variables. Therefore, recording only the temperature data was not necessary. They indicated the need for an efficient monitoring system that would take care of several variables such as time, temperature, humidity and vibration (Bishra, 2006) [11].

"The system is a set of elements that interact over a while to create a coherent whole. Dynamics means that it is continuously changing. In the case of CC temperature, humidity and time are continuously changing parameters. To ensure the quality of items delivered using CC, these parameters must be controlled effectively. The model used RFID tags to generate temperature logs and, before unloading items, these logs were reviewed and only items that met the pre-determined temperature conditions were unloaded. It saved a lot of time and money (Oliva & Revetria, 2008) [12].

CC Information, hybrid technology produces huge data that is stored in the database, evaluated for resource development and fair use using modern technologies such as sensors, networking, network, and database. These integrated approach guarantees cost savings in CC logistics and product quality & safety of goods (Zhang *et al*., 2018) [13].

The success of any CC Portfolio Management system solely depends on the management of its core requirements of maintaining a suitable temperature environment to guard the reliability and quality of temperature-sensitive goods and perishable products (Yan & Lee, 2009) [14].

The requirements of such a system are generally higher compare to the regular supply chain system or managing the logistics system at room temperature. The process involves a large number of critical issues starting from production to last-mile delivery. It includes a temperature-sensitive logistics management process at every stage of the system such as production, storage, package, transport, delivery, and sales (Rodrigue & Notteboom, 2020) [15].

Lots of risks involved in it. To minimize the risk factor, manufacturers & producers of such goods and the companies involved in managing the logistics implement various devices that operate, monitor, track and automate the management process (Atzire & Yamaura, 2016) [16].

The incipient technologies such as the Internet, Smart Sensors, Mobile Technology, Wireless Connecting options, Cloud Computing, BigData Analytics, Artificial Intelligence and Machine Learning opens-up a plethora of opportunities to assure quality and efficacy of the CC goods. The use of technologies in the evolution of intelligent Solar CC systems is analyzed here in the chronological order.

Shivakumar & Deavours (2008) [17] introduced a microstrip-like antenna to address the technical shortcomings of deploying RFID in the CC. RFID (Radio Frequency Identification), an automated identification technology has the potential to serialize each container and provide accurate and automatic tracking inside the supply chain, greatly enhancing precision, speed, and cost while improving product quality.

As RFID's performance degrades when it is used with objects contains water fields, a new microstrip antenna was introduced. The antenna was proposed in two forms: i) To encourage a low cost and no effective profile, the cardboard itself is proposed as a substratum of the microstrip antenna, which has the advantage of protecting the antenna from the contents of the package and ii) two-element array and feed structure for providing a steady level of performance over a broad range of humidity conditions. By implementing new low-cost innovations such as these, authors believed off to overcome RFID's technological limitations and promote its use within the CC and the quality of items.

In their work Fu *et al.* (2008) [18] proposed integration of relatively new technology Wireless Sensor Network with RFID to make RFID more intelligent on its operational environment such as temperature, humidity, etc. WSN consists of several small tools that are capable of processing and sensing. Tracking and tracking operations with product position and quality perspective are enhanced if RFID systems are combined with condition monitoring systems such as WSN.

Moreover, the historical data so derived will enable the system to take decisions. The proposed system was developed using the Nano-Qplus platform-based sensing system which consists of NANO HAL to abstract the sensing and actuation of the hardware component, task management, power management, and message handling module. It also includes the ATmega128 MCU and the IEEE802.15.4 RF communication module, CC2420 Zigbee. And it was implemented using LabVIEW (Laboratory Virtual Instrumentation Engineering Workbench) and VISA tools.

In 2009, Carullo and his team proposed a measurement device for calculating container temperature along the supply chain logistics route to verify product integrity. It has been developed using Wireless Network Sensor technology. This was able to track the temperature inside a refrigerated vehicle with the packed goods. The layout consisted of a base station and several temperature measurement nodes that communicate with the base station through wireless communication options. Two types of nodes were used for measuring -One for measuring the temperature inside the vehicle's container, and the other for determining the temperature of the product. The nodes enclosed with the circuitry to track and acquire sensor data, data storage memory and transmitter for transmitting data to access point. The base station is designed to gather transmitted node data, store it in its memory, process it and make decisions. The base station sends an alarm signal to the cell phone when an abnormal situation occurs which compromises the product's integrity. The solution provided improved calculation and control of temperature measurement processes in the refrigerated vehicle. The center of the circuit is the CC2510F32RSPR system-on-chip provided by Texas Instruments that integrates both a microcontroller unit identical to the integrated circuit 8051 and a 2.4-GHz radio transmitter CC2510. As temperature sensors, three T-type thermocouples are used (Carullo*et al.*, 2009) [19].

RFID is a radio-signal-based technology that uses the Radiofrequency (RF) signal for the detection of stagnant or moving objects and the sharing of digital information. The RFID system comprises of three parts, namely tags, readers and antennas. The reader sends a fixed-frequency RF signal to the antenna. The tags create faradic impulses whenever they enter the working region of the antenna. Tags are triggered by electricity, and automatically transmit the coded messages via the built-in antenna of the cards. Carrier impulses sent by RF cards are received by the receiving antenna system, sent by the reader to the reader via the antenna controller, regulated and decoded, and then forwarded to the Backend Management System for disposal. Yan & Lee (2009) [20] developed a system using RFID technology to analyze the current location and measure the temperature to assure the quality of supply chain products. The system includes hardware such as RFID tags with 915MHZ ISO18000-6/EPC standards, Temperature sensors, that are pasted into a fixed product location, EPC Globe standard Double-standard network interface readers, fixed scanners, portable terminals, real-time data analyzing software framework, site computer terminals, and wireless networking devices. The device was able to monitor and process products for temperature and tracking & positioning.

Abad *et al.* (2009) [21] introduced the prototype of an RFID-based smart tag for object traceability in real-time and food-specific monitoring of CC systems. a Smart RFID tag and a card reader/writer. The tag attached to the product to be tracked and monitored includes photosensors, temperature and humidity, a microcontroller, a memory module, low-power electronics, and a communication RFID antenna.

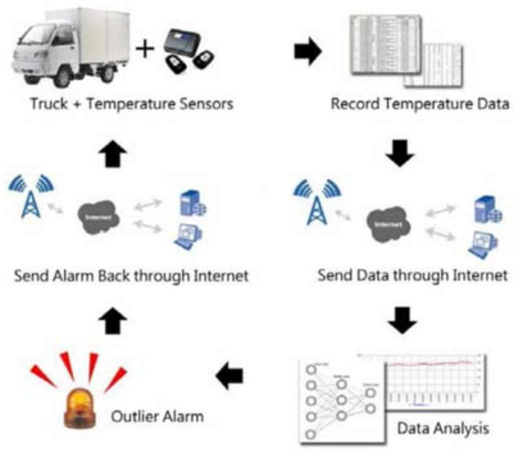

Fig.1: System Architecture (Abad *et al.*, 2009) [21]

The data collected from the sensor and the traceability information are stored in the memory module. The card reader / writer was used for interpreting tag data and for inserting data into log. Compared to traditional traceability tools and widely used temperature data loggers, the system shows major advantages, such as enhanced memory, reusability, minimal human involvement, zero tag exposure needed for reading, ability to read multiple tags at the same time, and greater tolerance to humidity and weather.

A power-efficient WSN for CC monitoring was proposed in 2009 by Kaucimi and his team. Their model was based on self-organizing protocols for monitoring energy consumption by the sensors resultantly increases in sensor lifetime and network longevity. Several plans seek to automate network operations at different levels to reduce energy usage. Protocols operating in the MAC layer such as S-MAC, T-MAC, B-MAC, and WiseMAC have been shown to save energy and are commonly used when a large number of sensors are operating under a process. Protocols based on IEEE802.15.4 MAC & PHY layers were used to distinguish various phases of operations: i) Initialization protocol -where the sensors begin a process of mutual recognition to determine the topology of the chain, ii) Addition protocol - when the introduction of other pallets, add one or more sensing devices to the network throughout the trip, iii) Protocol for reported/unforeseen loss of sensors-manage the absence of sensors when they are low in the battery or when the pallets are unloaded; iv) Steady-state protocol - for timing the regular waking of nodes to share and collect their alarms, v) Data collection protocol - to give the entire collected data to the operator during transport (Kacimi*et al.*,2009*)* [22].

In their research, Guanpeng Lv and his team described a real-time web-based CC monitoring system. The system had been broken down into three tasks. 1) Wireless sensors, sensing and relaying data to the database server through an outdoor network via the outdoor network using GSM (Global System for Mobile Communication) set-up and internal intranet, 2) Web application reviews sensed data stored in the database and 3) Alarm mechanism which fires alarm there is a deviation in the temperature or humidity. In four separate methods, an alarm is shot – email, SMS, dialing, and pup-up. The hardware/software of the system consists of *Sensors* - indoor sensors are used to sense the temperature or humidity of the surrounding air and outdoor sensors transmit data via GSM network to GSM base station, *Repeater* – Two types of repeaters are used, actual repeaters obtain data packets from wireless sensors and transmit data via the intranet to the network and virtual repeater in ta way of mobile sensors transmit data to the base station of GSM which acts as a repeater for sending data to the network, *GSM Base Station* - GSM base station has GSM MODEM and receives GSM network sensing data, *Software* - the framework is architecturally based on J2EE MVC (Model-View-Controller). Ajax, JSP, SERVLET, Java Bean, ADO, and MySQL were the tools used (Lv *et al.,* 2009) [23].

Liu &Jia (2010) [24] suggested a business model for CC management using IoT. IoT is a world of interconnected objects that are uniquely identifiable. These objects can interact with one another. The model uses Sensors, RFIDs and Smart Technology. The CC now consists of network operators, providers of terminal equipment, developers of software, manufacturers, inspection department, suppliers, distributors, buyers and finally consumers. There are two variants of the pattern. One is called the Terminal

Equipment Provider-centered model where the terminal equipment provider conducts as many activities as possible. The service charges are fixed by terminal equipment provider along with network operator, manufacturer and application developer. In-network operator-centric model, the service charges are fixed by the network equipment provider.

Wang *et al.* (2010) [25] are proposed a multi-level instrumented physical monitoring using RFID, ZigBee, 3G networks and grid computing technology. The temperature of the products delivered is tested at each Critical Control Point (CCP) in the conventional CC. Since temperature is the most significant factor in maximizing the shelf-life of the shipped goods using CC, it must be controlled continuously. RFID tags are incorporated into goods which are shipped using the CC. The core of the model is the Electronic Product Code (EPC) which uses RFID to uniquely identify the object. Temperature sensors placed on the product can continuously transmit information about the temperature. The RFID reader reads the data and sends it to the ZigBee system which, by using the 3G network, sends it to the computer. Grid computing is used to regulate the temperature of products delivered using the CC, effectively. The tracking process starts at the production stage and lasts until the commodity reaches the buyer's doorway.

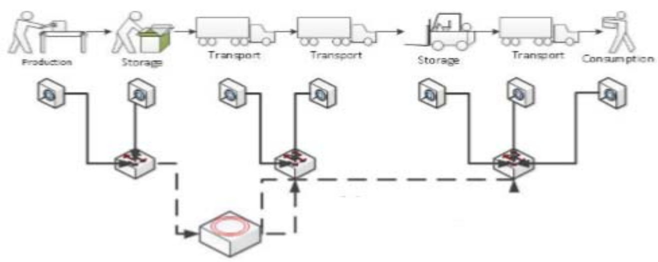

Fig.2: Multi-level instrumented physical monitoring (Wang *et al.,* 2010) [23]

Provided that the sensors connected to CC's logistics move with the goods from their origin to the final destination together with the transportation in heterogeneous network environments. Some protocols are more appropriate than others depending on the situation prevailing. The system expects to be able to turn to appropriate protocols and adapt it according to its requirements. In their research, Nicolas and his team are proposing these methods. The proposed system enables a sensor to adjust to the situation to suit the best protocol. A hybrid synchronization system is introduced to ensure that nodes are synchronized with power efficiency and context adaptability. The system also dynamically chose routing protocols, based on their access to the network available. (Nicolas *et al.* 2011) [26].

The CC logistics includes a wide variety of processes such as production, packaging, warehousing, transportation, distribution, feedback, etc, involving contributions of different departments of enterprise-wide players. There is a demand for a collaborative business process between different entities related to business and expects greater and viable support for the IT system. Cloud computing is used to make CC logistics more efficient with minimal investment as the cloud is owned by a third-party. With the help of cloud technology, entire CC management can be integrated and optimized to form a single unit although there are several entities are involved. The CC logistics system based on cloud technology is will contain a database. The CC infrastructure should be structured to guarantee that the services are paid for by all consumers who have access to them. To do this, the framework must have functions such as real time CC logistics control, calculation of data, logbook recording, querying the database, generating reports, etc. (Li *et al.* 2011) [27].

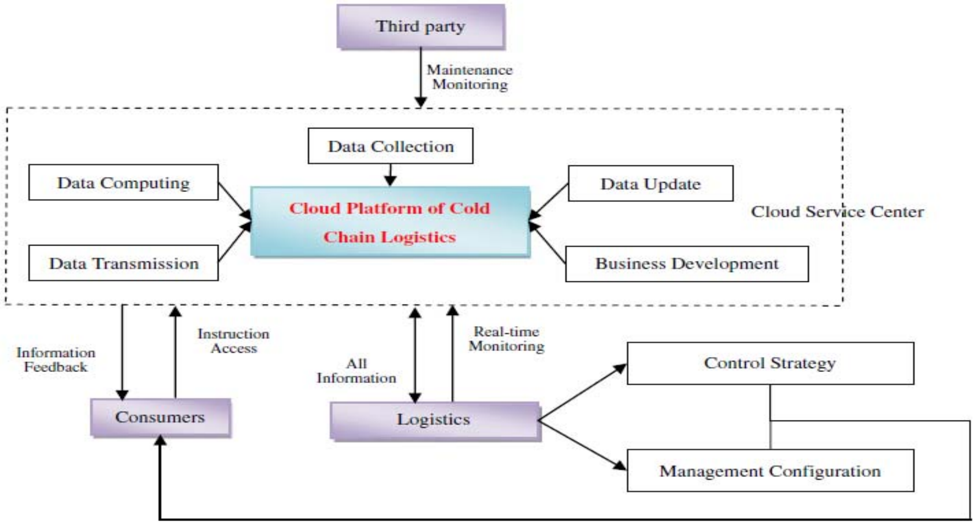

Fig. 3: The CC logistics system using Cloud Technology (Li *et al.,* 2011) [27].

As demand for the CC logistics increases, more researches are conducted to make the CC more effective. Cloud storage technology helps the CC framework to deliver high-quality services with limited investment because a third party owns the cloud. Accessing and analyzing the data can be done seamlessly with the ubiquitous availability of data. With the support of any portable device with Internet connectivity, data can be accessed anywhere at any time. The requirement for IT resources and equipment is reduced as pay for use policies are implemented. CC data can be accessed via the Cloud platform in real-time. Cloud computing is more useful when security and privacy problems that are associated with it are addressed effectively (Adhianto *et al*., 2011) [28].
Service-Oriented Architecture (SAO) has enabled supply chain organizations to exchange information to improve the supply chain network, which is fairly important for e-commerce requiring a single forum for information sharing. IoT can incorporate technologies such as RFID, Sensors, GPS, Laser Scanners, etc. to create a Global Network with the Internet. The ultimate goal is to provide a single network such that the SC elements can be easily defined and controlled. Through a case study, Sun and his team showed utility. The product framework includes storage reader, position reader, handheld reader, RFID tags, etc. The self-developed app uses a wireless network to communicate with readers. The system identifies the goods during loading & unloading for transport, records cargo inventory, storage records and out-store information (Sun *et al.,* 2011*)* [29].

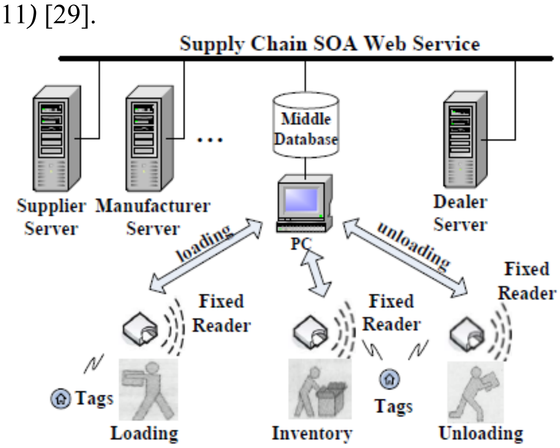

Fig. 4: Construction and implementation of IoT-based manufacturing enterprise knowledge transformation system (Sun *et al.* 2011*)* [29].

Aung *et al.* (2011) [30] demonstrated the design of the Intelligent CC Management model by using RFID & WSN to track temperature-sensitive objects during their life cycle, such as production, shipping, warehousing, and quality support, thereby improving the operation of the CC. A Nano-Qplus platform based sensor network framework was implemented in tandem with Nano Hardware Abstraction Layer (HAL) for sensing & actuating. It also takes care of some other tasks like energy management, and message handling. Besides the communication module ATmega128 MCU and CC2420 Zigbee, IEEE802.15.4 Radio Frequency (RF) was also used.

Over the years, efficient management of CC is becoming increasingly popular because of the high demand for the 'Cold items'. Kim *et al.* (2012) [31] proposes RFID/USN (Ubiquitous Sensor Network) based CC for the efficient shipping of temperature-sensitive items. CC management ensures that high-quality items are delivered effectively to the customer. If the entire process is carried out by using technology, this can be achieved effortlessly.

While packing, the manufacturer has to indicate the materials used, ideal temperature, shelf-life, etc on every unit being shipped using CC. The data is stored in the cloud automatically as RFID tags are deployed on the product. At every Critical Check Point (CCP) the details can be verified automatically because of RFID tags and temperature sensors on the items. If the item fails to satisfy the desired quality criteria, the consumer will specify the same and reverse chain starts. At each CCP status can be updated automatically. The process gets terminated at the manufacturer-end where the manufacturer disposes the items and updates the inventory. At every level, confirmation of distribution, confirmation of product quality and confirmation transportation is done using RFID/USN technology.

Li *et al.* (2012) [32] suggested the use of a Wireless Sensor Module (WSM) implemented using the wireless microcontroller JENNIC5418 and the thermocouple converter MAX31855. Automation is employed to increase the CC's performance. The WSM is embedded. Data is sent from each sensor to the access point. If the temperature detected is more than the temperature specified, then the alarm will be turned on. The access point is incorporated with GPS and a 3G communication network. Thus, monitoring can be performed at remote points periodically.

To address the limitations associated with RFID, Chou *et al.* (2013) [33] developed a model called Intelligent Insulating Shipping Containers with low power consuming Bluetooth 4.0 Low Energy Devices (BLE). BLE sensors are implanted on each container and are continuously monitoring the interior temperature and sending the same to PDA using BLE. This also uses geo-coordinate stamped GPRS to map the location of the item that is shipped using CC.

Thoma *et al.* (2013) [34] introduced a model that monitors the whole CC and even the retail sector effectively. The transportation of 'cold objects' in their system is 'smartened' by technology sensor-enabled technology. Sensors are mounted on every pallet or container delivered using CC. The sensors transmit information related to temperature and location to other connected devices. If any temperature difference is observed, the warning message is sent to the authority concerned for further action. Studies show that more than 20% of perishable products shipped through CC are not reaching the customer. They will either be damaged during shipping or discarded by the retailer. Sensor-based quality control is used to fix the price of items sold in retail stores. This is used to determine the future quality of perishable items based on the brightness, temperature, and humidity of the atmosphere rather than based on data on their shelf-life retrieved from the database. The use of sensor-driven quality control and dynamic pricing guarantees that products are delivered before their deterioration occurs.

Ding *et al* (2013) [35] proposed a model called Multidimensional Information Sensing Surveillance for the identification of suspicious events occurring during the shipment of products using CC. The model uses Computational RFID tags known as CRFID, due to the inherent shortcomings of GPS and RFID tags. It also uses the entropy and the AVC algorithm to track the movement patterns of things and conveyances. The model uses WISP, a passive CRFID unit with numerous sensors like temperature sensor, photo-sensor, etc. The model can effectively monitor the temperature of the objects inside the vehicle as the sensors track the data and send it to the control center in real-time. Besides, irregular circumstances such as stealing, leaning and dropping of items may also be detected during transport. Minimum entropy is calculated using the Naïve Baye classification, and a theft alarm can be produced if there is a difference between the measured value and the calculated value. GPS fails as the vehicle passes through tunnels. CRFID is used to solve this problem. The CRFID tracking module is only enabled when the vehicle leaves for its destination. The model can, therefore, be used to identify multiple irregular circumstances.

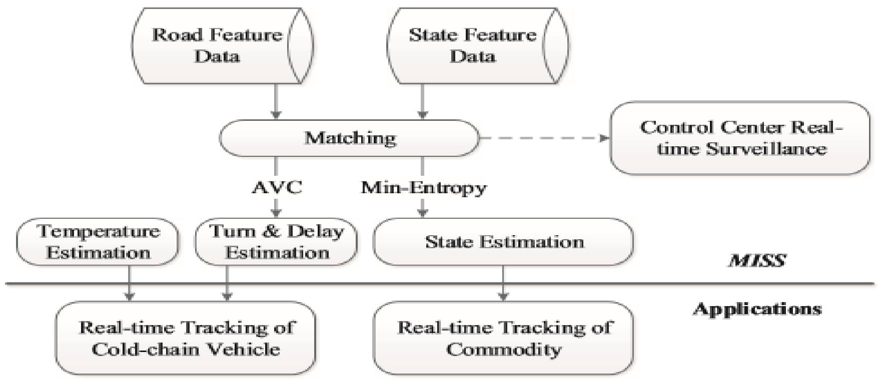

Fig. 5: The MISS framework for CC (Ding *et al.,* 2013) [35]

When the demand for 'cold products' grows, demands for quality are growing in several ways. To satisfy this requirement, Lee *et al*. (2013) [36] recommend a model that uses sensors and ZigBee to track local data and GPS to track location-sensitive data for successful CC monitoring. Real-time monitoring of empirical data like temperature, humidity, etc. is carried out by employing a network of sensors. This network is developed using ZigBee technology that is cost-effective and energy-efficient. The data will be sent to the smart device. In addition to local data, the location of specific data is sent through GPS. This data is used by the central administrative system, which controls the efficient management of the CC.

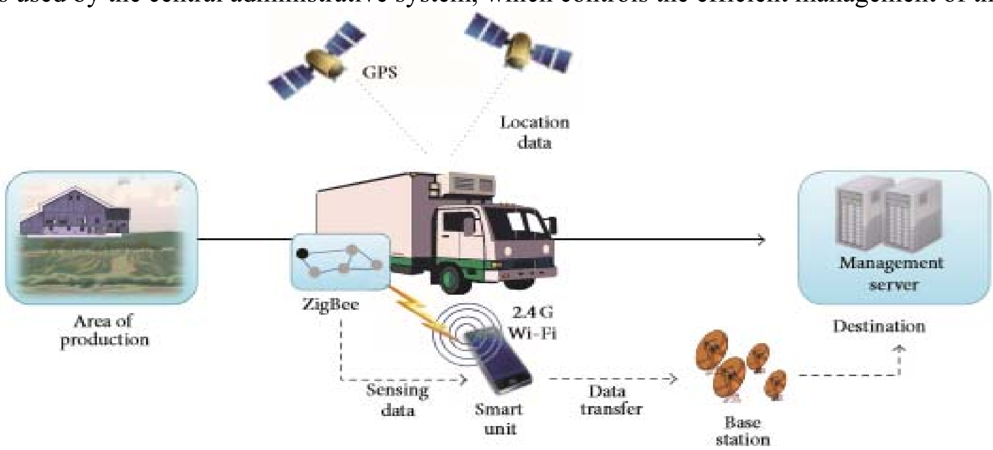

Fig. 6: Monitoring of CC using ZigBee (Lee *et al*., 2013) [34]

Engel & Supangkat (2014) [37] suggest a model that uses temperature sensors, RFID tags, humidity sensors, gas sensors, GPS, time sensors, tilting sensors, congestion sensors to effectively track the CC. The data obtained from various sensors is analyzed for correctness and accuracy. If the data is incomplete or bad, the data will be filtered out. The model provides a knowledge base that stores the domain-specific information required to understand the context. Data from different sensors is stored in the reference engine. In this Context-Aware Inference model, artificial neural networks, vector support machines, and machine learning are used to turn sensor data into useful information.

Chen (2015) [38] proposed a model used to ensure the traceability and safety of products delivered using CC. It uses fog technology that uses a local database or private cloud, sensing equipment and uses an artificial neural network or fuzzy logic to perform local-level computing and data transfer. Fog Computing-based intelligent analysis is the performance measurement framework for the CC. The fog computing network will meet the specifications of the CC, such as flexibility, protection, location recognition, and low power consumption.

Đorđević *et al*. (2016) [39] recommend a method used to measure the remaining shelf-life of products delivered using CC and suggest corrective steps to be taken to maximize shelf-life. The conventional CC system focuses on temperature management over single CC logistics rather than over-viewing the transportation cycle throughout logistics. To overcome this limitation, Shih and Wang have proposed a Time-Temperature Indication (TTI) model based on IoT that uses Wireless Sensors to monitor data through logistics distribution semantics (Shih & Wang, 2016) [40].

Lu and Wang proposed a cloud based IoT system to provide unprecedented transparency for frozen item delivery in a cost-effective manner. Sensing devices and RFID tags are combined to form an all-encompassing computing framework to create context-sensitivity for perishable goods. For certain applications, every perishable product is attached with a sensor-controlled UHF RFID tag for collecting atmospheric identity and environmental data. Every perishable product holds a passive RFID tag in some other affordable but less reliable applications and the sensors are housed within the storage area at various sites. Frozen Transportation Management System The system includes modules like i) refrigerated transportation – where a cold truck is fitted with sensors that send data on 'cold items' and the status related to door through a Zigbee coordinator and a GPRS/3G / LTE module, ii) warehouse management – through established WSN to observe the temperature and humidity, iii) traceability - Electronic Product Code Information Services and IoT to track the perishable products throughout the CC, iv) business intelligence – to deal with more complex jobs Through incorporating IoT with the Internet to exchange essential data, analyze data and provide decision-making capabilities, such as load planning, vehicle scheduling and coordination of the entire CC, and v) web-based platform. (Lu & Wang, 2016) [41].

Controlling the temperature remains the essential function of any CC Management System. In most use cases, the monitors attached to the packaging containers perform the task of monitoring temperature. New self-powered time-temperature tracking has attracted designers because it can be configured with passive RFID tags. The advantage is that no external power is used to monitor time-temperature by these devices, in turn, they are self-powered. The sensors used in the model by applying the physical theory Fowler-Nordheim (FN) tunneling monitor the air temperature over the entire life-cycle of the CC (Zhou & Chakrabartty, 2017) [42]

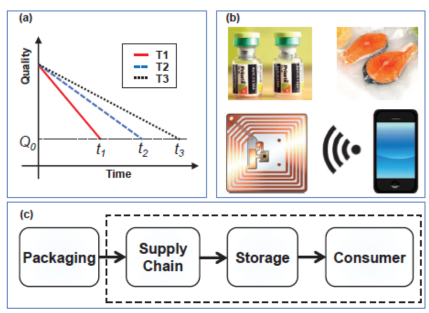

Fig. 7: Time-Temperature monitoring in the CC [41]

The above model represents a) how the product quality relies on time-temperature constituents (b) the use of the innovative sensor for auto-powered time and temperature management, and (c) the supply chain management. Zhang *et al.* (2018) [13] presented a prototype of the CC logistics model "New Food Sensory Perception Framework," based on IoT, RFID, Planar Bar Code, BigData and Cloud Computing technologies. It is made up of three parts – (i) information awareness, (ii) real-time monitoring and data collection and (iii) information dissemination. Real-time data collection, data analysis, the transmission of data, early warning, remote monitoring, etc. significantly increase the level of intelligence on the CC logistics and increase functional efficiency.

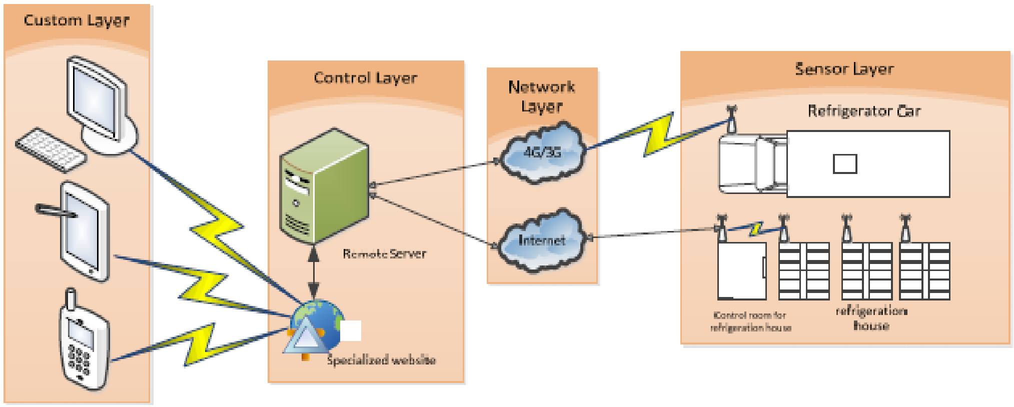

Fig. 8: The block diagram of food sensory-perceptual system (Zhang *et al.,* 2018) [13]

The system consists of four layers: (i) Sensor Layer – is tasked to acquire and process environmental elements like temperature.(ii) Network Layer – to collect and store real-time information received from the sensor layer with the help of 4G/3G network and GPS communication, (iii) Control Layer – analyze stored data and perform decision-making activities such as forecasting, warning, query processing and keeping track on the quality and safety of goods, and iv) Customer Layer – consists of applications with GUI to view transmission status, track, monitor and aware of goods under logistics process.

Zhang & Liu (2019) [43] introduced an "Intelligent CC Transportation Terminal System" to handle and control the temperature of CC logistics mainly integrating Narrow Bound IoT communication and GPS/Beidou position technologies along with other similar technologies. The core components of the system are the smart terminal, data transmission, and remote-control system.

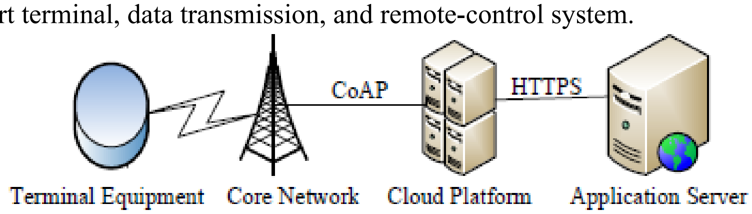

Fig. 9: Architecture of the intelligent terminal (Zhang & Liu, 2019) [42].

Intelligent Terminal is a 'data center' positioned on a refrigerated container and is responsible for gathering its geographical location, temperature and humidity level, and so on. Wireless Communication acts as a bridge between smart terminals and remote monitoring platforms for data exchange. The Advanced Surveillance system extracts from the server the original data submitted by the smart terminal and shows the data collected to the user within a framework

LEVERAGE used Google Cloud Platform (GCP) to deliver a solution for CC Management. GCP was chosen by the company because it comes with a set of tools that are used to safely capture process and store data from vehicle sensors. A robust approach from data collection to user interface display built using a range of available resources such as Cloud IoT Core, Cloud Pub / Sub, Cloud Functions, BigQuery, Firebase and Google Cloud Storage (Gifford, 2019) [44].

Management of the CC product transit is simplified by the use of sensors that ensure live visibility of the logistics movement through the supply chain. IoT sensors monitor temperature, friction, humidity, manipulation, position and product identification at the point of its transit through the wireless networking options like NFC, WiFi, and Bluetooth, these sensors record data that are available to the managers. Mobile devices act as display terminals, data scanners, warning modules, and local data aggregation hub and provide a convenient Cloud gateway. Cloud provides a convenient way for logistics companies to control supply chain events. (Sreeremya, 2019) [45].

In his web article Joshi (2020) [46] summarized how ICT is useful for CC logistics operations. He has highlighted numerous areas where ICT can play its part. Implementing IoT solutions helps companies to track the food product temperature, which is probably the most important parameter in CC logistics. Sensors may be used to track the temperature of the food products on transport modes such as trucks, rail freight, or air freight. The sensors gather these data and share them in real-time. Accordingly, businesses have full control over temperature management and process monitoring. Everything obtained by IoT devices is evaluated and shared with other users in regular intervals. This means businesses can have control of the logistics process as they can be alerted as soon as they occur of any issues occurring in the transportation process. IoT applications interact with the machine as much as they do with devices. The data obtained by the IoT devices can be used by advanced artificial intelligence applications running on those devices to auto-generate reports.CC logistics processes can be enhanced with artificial intelligence and machine learning by analyzing the data obtained from IoT devices. Businesses must have complete knowledge of their shipments. This is the aim of using IoT for CC logistics. Companies may track their shipment with IoT devices 24 * 7. When the chain is running at a slower pace than expected, they can make some changes to the logistics schedule easily.

Table1: Use of ICT in CC/Solar CC process management (2005-2020)

SN	Authors	Year	Inventions/Findings/Results
1	Shivakumar & Deavours	2008	Introduced an antenna that resembles amicrostrip-like which is used to address the technical limitations of deploying RFID in the CC.
2	Fu *et al.*	2008	Integration Nano-Qplus platform-based Wireless Sensor Network with RFID to make RFID more intelligent on its operational environment such as temperature, humidity, etc.
3	Barullo *et al.*	2009	A measuring system to measure the containers' temperature throughout the CC logistics path to verify the integrity of the product using WSN
4	Yan & Lee	2009	RFID technology to monitor location-related real-time data and to measure the temperature for the assurance of quality and integrity of items shipped using CC
5	Abad *et al.*	2009	Introduced the prototype of an RFID-based smart tag for object traceability and food-specific tracking of CC systems. The machine consisted of an RFID smart tag and a commercial card reader/writer.
6	Kacimi *et al.*	2009	An energy-efficient WSN based on self-organizing protocols to monitor energy consumption by the sensors
7	Lv *et al.*	2009	Introduced a real-time CC monitoring method based on the web using Wireless sensors and GSM communication network.
8	Liu & Jia	2010	Proposed business models for the effective management of CC using IoT.
9	Wang *et al.*	2010	Introduced a multi-level-instrumented physical monitoring system for the CC using RFID, ZigBee, 3G network and grid computing.
10	Nicolas *et al.*	2011	Proposed a cloud computing-based CC logistics system for continuous monitoring of items shipped. The system maintains a logbook and generates reports based on the logs
11	Li *et al.*	2011	Cloud-based CC logistics framework with functionality like continuous monitoring, data estimation, logbook processing, query, report generation etc.
12	Sun *et al.*	2011	IoT can incorporate technologies such as RFID, Sensors, GPS, Laser Scanners, Internet, etc. to create a unified network to provide a single network wherein SC elements can be easily defined and controlled.
13	Aung *et al.*	2011	Intelligent CC Management System based on RFID & WSN to track temperature-sensitive objects during their

			life cycle, such as production, shipping, warehousing, and quality support, thereby improving the operation of the CC.
14	Adhianto *et al*.	2011	Cloud storage technology is applied to the CC to enable secure access to real-time data.
15	Kim *et al*.	2012	Use of RFID/USN for the efficient management of CC that contains quality check mechanism at every CCP
16	Li *et al*.	2012	Introduced a Wireless Sensing Module that contains a microcontroller, thermocouple converter, GPS for the effective monitoring of temperature at remote destinations
17	Chou *et al*.	2013	Designed a special type of container called IISC which is used to deliver temperature-related alerts using BLE to the smartphones
18	Thoma *et al*.	2013	Proposed a model that manages the CC and the conventional retail environment efficiently by making use of dynamic price tags which are shown on the perishable products
19	Ding *et al*.	2013	Introduced Multi-Dimensional Information Sensing Surveillance using CRFID tags to identify irregular circumstances when transporting objects using CC
20	Lee *et al*.	2013	Suggested a conceptual model for the continuous tracking of CC using sensors and ZigBee network
21	Engel & Supangkat	2014	Proposed context-aware inference model that uses multiple sensors that detect the environment and emerging technologies for decision-making.
22	Chen	2016	Recommended Fog Computing Intelligent Model to ensure traceability of items shipped using CC
23	Đorđević *et al*.	2016	Recommend a method used to measure the remaining shelf-life of products delivered using CC and suggest corrective steps to be taken to maximize shelf-life.
24	Shih & Wang	2016	Proposed a Time-Temperature Indication (TTI) model based on IoT that uses Wireless Sensors to monitor data through logistics distribution semantics
25	Lu & Wang	2016	A cloud-based IoT platform where sensors and RFID tags are combined to create an all-encompassing computing framework to establish context awareness for perishable goods
26	Zhou &Chakrabartty	2017	Proposed a new self-powered time-temperature monitoring embedded into passive RFID tags. The advantage is that no external power is used to monitor time-temperature by these devices, in turn, they are self-powered.
27	Zhang *et al*.	2018	Presented a prototype of the CC logistics model "New Food Sensory Perception Framework" based on IoT and Cloud platform along with RFID and Planar Bar Code
28	Zhang & Liu	2019	Introduced Intelligent CC Transportation Terminal System that controls and manages the temperature of CC logistics mainly integrating NarrowBound IoT communication and GPS/Beidou position technologies along with other similar technologies.
29	Gifford	2019	CC Management solution using Google Cloud Platform (GCP)

30	Sreeremya	2019	Proposed IoT Transit Medication Management (ITMM) for the live visibility of the logistics movement through the supply chain
31	Joshi	2020	Narrated how ICT is useful for CC logistics operation and pinpointed the different areas where ICT may be applied.

4. RESEARCH GAP :

Our analysis reveals that the CC data do not only correspond to Factors to the atmosphere, such as humidity levels and temperature of the products being delivered. It also includes other useful details such as vibration, the temperature during packaging time, shifting time from packing to cold storage, etc. The study also implies that the implementation of automated traceability systems to promote the food supply chain was not as swift as expected. The development of temperature monitoring and ensuring traceability throughout the CC will be required before the data collected from these systems can be monitored and scrutinized continuously for accurate perception in the CC. Suitable technology solutions for networking, middleware, and applications that can be used in different CCs, for example in the dairy segment, that has minimum research on the technology infrastructure required to collect data need to be identified. In order to guarantee traceability, effective technical procedures must also be implemented to collect data from earlier phases of the CC, i.e. pre-packaging and manufacturing. It is also necessary to understand how persistent monitoring of temperatures and other atmospheric measurements can be turned into an assessment of the quality of the items in full detail, the calculation of the real shelf-life of the objects, and the use of those for decision taking in CCs, such as product rerouting. Assessment of such data over a prolonged period of time may also give indications of product degradation under various transport conditions that can lead to a transportation system redesign to reduce quality losses or take steps to avoid unfavourable travel circumstances. There is very little discussion on how these analytics capabilities can affect the CC's overall performance in terms of efficiency, cost-effectiveness, impact on the environment, and productivity. Via the CC process, some relevant variables for the capture of commodity parameters and also transaction data for temperature-sensitive products can be defined and these factors can be used to improve the planning of procurement, development and production schedules, transport and storage schedules and even the pricing of such goods in retail stores based on production. Attempting to resolve any of the above research gaps will involve interdisciplinary collaborative research work comprising researchers in food technology and engineering, information technology and computer science and logistics, and supply chain management.

5. RECOMMENDATION BASED ON THE EXISTING STUDY :

CC administrators need to handle more than dry stock. The highest energy users are inventory refrigeration systems and distribution centers frozen items equipped with freezers and requiring strict design and construction specifications. Devices must work for 24 hours a day for a wide variety of materials while maintaining the appropriate temperature levels. CC administrators will also tackle issues such as energy conservation; temperature regulation and smooth functioning of the CC. Cold storage providers implement ICT-enabled monitoring technologies, such as built-in sensors, to avoid disruption. The sensing devices deployed in the CC plants, refrigerators as well as containers of 'cold items', collect data related to temperature and humidity. They send aggregated data to CC management systems which use the same to track the items. The collected data is used to provide timely alerts. Undoubtedly, the introduction of ICT-based solutions entails ongoing restructuring of the CC. The conventional CC elements will be converted from obsolete cooling packages into smart shipping deliveries ensuring better temperature control and pervasive data monitoring. Intelligent shipping packages will also contain additional features such as automatic reporting and predictive analysis of data. Off late, ICT has been used actively used to provide user-friendly CC management solutions. Ultimately, CC needs to consider the application of ICT use cases for untapped ICT applications, e.g. container tracking can aid both in freight and fleet management.
CCs will make the most use of ICT given that an intelligent network of assets is established. To achieve this objective, a range of main factors have been suggested:

- Establishment of coherent and transparent policies for the application of asset identifiers throughout the CC
- Establishing a smooth data-sharing framework among sensors; proposing roles for data ownership
- Creation of privacy and security policies to resolve major risks

6. CONCLUSION :

The CC has always been a challenging logistical sector because of its capital-intensive machinery, strict temperature specifications, and energy dependence. In recent years, the sector has faced additional challenges, from increasing vulnerability, quality requirements and the volume of many of its goods to still-increasing restrictions. CC also faces many of the same challenges that affect the entire conventional supply chain: targeting the global market, driving out prices, becoming more competitive, overcoming power and resource constraints, and at the same time meeting the challenging needs of the essential cargo sector — primarily food and pharmaceuticals. The data collected from self-powered sensors, apart from the monitoring of real-time properties, enables participants to further know the risks associated, to increase efficiency and productivity and delivery timelines. At the end of the day, it results in good retention of customers as CC management becomes more organized and transparent. When IoT-based solutions are adopted, the need for checking cold storage period or environmental conditions manually is not at all necessary. However, even the freshness of the products can be checked without human assistance. One solution deploys IoT sensing devices inside palettes to continuously monitor the temperature and analyze their quality and predict the expiry dates. Such a system makes it possible to handle supplies more effectively as ripe pallets can be detected and used on time to avoid unnecessary waste. Another solution is to automate the monitoring of inventories with fewer wireless devices. Earlier, any item on stock needed manual scanning at checkpoints with a device. Failure to do so may result in inconsistent data obtained operators leading to audit anomalies. ICT does make a difference, reducing the possibility of shipping delays. Similarly, earlier managers of CC had to be present in -person at cold storage facility to check the deliverables and ensure their integrity. Efficient management has to take into account the large geography of dispersed distribution centers, which puts a lot of constraints on the functioning of CC. With the implementation of smart sensing tools and cloud-based data aggregation technology, CC partners will remain aware, irrespective of their remote location. They can now track shipments, storage, and even last-mile deliveries through mobile applications. Such examples are just evidence of ICT's effectiveness in CC Management. The sector is open to innovation and entrepreneurial ventures. This paper attempted to shed light on the growth of the Solar CC field and to conclude with the hope that there would be more and more research work will follow.

REFERENCES:

[1] Rodrigue, J.P.,& Notteboom T. (2020). The Cold Chain and its Logistics. Retrieved on 03/04/2020 from https://transportgeography.org/?page_id=6585 =

[2] How Cold Chain Uses IoT Solutions to Propel Its Growth and Efficiency. Innovecs. Retrieved on 03/04/2020fromhttps://innovecs.com/blog/iot-solutions-in-cold-chain/.

[3] Kurian A. P. (2012). An Investigation into Solar Refrigeration Technology And Its Application To The Indian Agricultural Cold Chain.

[4] Cold Chain Monitoring in Times of IoT. (n.d.). Retrieved on 03/04/2020from https://www.avsystem.com/blog/iot-cold-supply-chain/

[5] Cold Chain Monitoring in Times of IoT. (n.d.). Retrieved on 03/04/2020from https://www.avsystem.com/blog/iot-cold-supply-chain/

[6] Saur News Bureau. "SMARTER SOLAR: How IoT Is Revolutionizing Solar Energy Efficiency. "Saur Energy International, (2017). https://saurenergy.com/solar-energy-articles/smarter-solar-how-iot-is-revolutionizing-solar-energy-efficiency.

[7] Salunkhe P. G., & Nerkar R. (2017). IoT driven smart system for best cold chain application. *Proceedings - International Conference on Global Trends in Signal Processing, Information*

Computing and Communication, ICGTSPICC 2016, 64–67. DOI: https://doi.org/10.1109/ICGTSPICC.2016.7955270.

[8] Mohsin A., & Yellampalli S. S. (2018). IoT based cold chain logistics monitoring. *IEEE International Conference on Power, Control, Signals and Instrumentation Engineering, ICPCSI 2017*, 1971–1974. DOI: https://doi.org/10.1109/ICPCSI.2017.8392059.

[9] Al-Fuqaha, A., Guizani, M., Mohammadi, M., Aledhari, M., & Ayyash, M. (2015). Internet of Things: A Survey on Enabling Technologies, Protocols, and Applications. *IEEE Communications Surveys & Tutorials*, 17(4), 2347–2376. DOI: https://doi:10.1109/comst.2015.2444095.

[10] Cold Chain System; Smart Cold Chain Management Solutions (2019). Retrieved on 03/04/2020 from https://www.hiotron.com/smarter-cold-chain-system/

[11] Bishara, R. H. (2006). Cold chain management - An essential component of the global pharmaceutical supply chain. *American Pharmaceutical Review*, 9(1), 105–109.

[12] Oliva, F., & Revetria, R. (2008). A System Dynamic Model to Support Cold Chain Management in Food Supply Chain. *University of Genoa 12th WSEAS International Conference on SYSTEMS*, 361–365. ISBN: 9789606766831.

[13] Zhang, Y., Cheng, R., & Chen, S. (2018). Design of fresh food sensory perceptual system for cold chain logistics. *ITM Web of Conferences*, WCSN 2017, 17, 03017 (2018). DOI: https://doi.org/10.1051/itmconf/20181703017.

[14] Yan D, & Lee D. (2009). Application of RFID in cold chain temperature monitoring system. *2009 Second ISECS International Colloquium on Computing, Communication, Control, and Management*, CCCM 2009, 2, 258–261. DOI: https://doi.org/10.1109/CCCM.2009.5270408.

[15] Rodrigue, J.P., & Notteboom, T. (2020). The Cold Chain and its Logistics. Retrieved on 03/04/2020 from https://transportgeography.org/?page_id=6585 =

[16] Atziri H. B. & Yamaura, M. (2016). Cold Chain Management with Internet of Things (IoT) enabled solutions for Pharmaceutical Industry. 2011, 1–6.

[17] Sivakumar, M., & Deavours, D. D. (2008). A dual-resonant microstrip antenna for paperboard in the cold chain. *Proceedings of the 2008 IEEE Sarnoff Symposium*, SARNOFF. DOI: https://doi.org/10.1109/SARNOF.2008.4520112.

[18] Fu, W., Chang, Y. S., Aung, M. M., Makatsoris, C., & Oh, C. H. (2008). Wsn based intelligent cold chain management. *The 6th International Conference on Manufacturing Research (ICMR08)*, (September 2008), 353–360.

[19] Carullo, A., Corbellini, S., Parvis, M., & Vallan, A. (2009). A Wireless Sensor Network for Cold-Chain Monitoring. *IEEE Transactions on Instrumentation and Measurement*, 58(5), 1405–1411. DOI: https://doi.org/10.1109/tim.2008.2009186.

[20] Yan B.& Lee D. (2009). Application of RFID in cold chain temperature monitoring system. *2009 Second ISECS International Colloquium on Computing, Communication, Control, and Management*, CCCM 2009, 2, 258–261. DOI: https://doi.org/10.1109/CCCM.2009.5270408.

[21] Abad, E., Palacio, F., Nuin, M., Zárate, A. G. De, Juarros, A., Gómez, J. M., & Marco, S. (2009). RFID smart tag for traceability and cold chain monitoring of foods : Demonstration in an intercontinental fresh fish logistic chain. *Journal of Food Engineering*, 93(4), 394–399. DOI: https://doi.org/10.1016/j.jfoodeng.2009.02.004.

[22] Kacimi, R., Dhaou, R., & Beylot, A. L. (2009). Using energy-efficient wireless sensor network for cold chain monitoring. *2009 6th IEEE Consumer Communications and Networking Conference*, CCNC 2009, 1–5.DOI: https://doi.org/10.1109/CCNC.2009.4784847.

[23] Lv, G., Guo, Z., Xie, S., & Pan, W. (2009). Web-based real-time monitoring system on cold chain of blood. *2009 IEEE Instrumentation and Measurement Technology Conference*, I2MTC 2009, May, 1300–1303. DOI: https://doi.org/10.1109/IMTC.2009.5168655.

[24] Liu, L. & Jia, W. (2010). Business model for drug supply chain based on the internet of things. *2010 2nd IEEE International Conference on Network Infrastructure and Digital Content*. 982–986. DOI: https://doi.org/10.1109/icnidc.2010.5657943.

[25] Wang, G., Xu, W., & Wang, M. (2010). The grid-computing based instrumented monitoring platform for cold chain logistics. *2010 International Conference on Logistics Engineering and Intelligent Transportation Systems*, LEITS2010 - Proceedings, 402–404. DOI: https://doi.org/10.1109/LEITS.2010.5664946.

[26] Nicolas, C., Marot, M., & Becker, M. (2011). A self-organization mechanism for a cold chain monitoring system. *IEEE Vehicular Technology Conference*. DOI: https://doi.org/10.1109/VETECS.2011.5956518.

[27] Li, F., & Chen, Z. (2011). Brief analysis of application of RFID in pharmaceutical cold-chain temperature monitoring system. *Proceedings 2011 International Conference on Transportation, Mechanical, and Electrical Engineering*, TMEE 2011, 2418–2420. DOI: https://doi.org/10.1109/TMEE.2011.6199709.

[28] Adhianto, L., Banerjee, S., Fagan, M., Krentel, M., Marin, G., Mellor-Crummey, J., & Tallent, N. R. (2011). HPCTOOLKIT: Tools for performance analysis of optimized parallel programs. Concurrency Computation Practice and Experience, *Wiley InterScience*.22(6), 685–701. DOI: https://doi.org/10.1002/cpe.

[29] Sun, Z., Li, W., Song, W., & Jiang, P. (2011). Research on manufacturing supply chain information platform architecture based on Internet of Things. Advanced Materials Research, 314–316, 2344–2347. DOI: https://doi.org/10.4028/www.scientific.net/AMR.314-316.2344.

[30] Aung, M. M., Liang, F. W., Chang, Y. S., Makatsoris, C., & Chang, J. (2011). RFID- and WSN-based intelligent cold chain management. International Journal of Manufacturing Research, 6(2), 91–109. DOI: https://doi.org/10.1504/IJMR.2011.040005.

[31] Kim, H., Jeong, H., & Park H. (2012). A Study on RFIDIUSN based e-pedigree System for Cold Chain Management. *2012 IEEE International Technology Management Conference*, June 25-27,2012. (3), 137–143. ISBN : 9781467321341.

[32] Li Xuefeng, Wang Ying and Chen Xi (2011). Cold chain logistics system based on cloud computing. Concurrency Computation Practice and Experience. *Wiley Online Library*. Pract. Exper. (2011). DOI: https://doi.org/10.1002/cpe.1840.

[33] Chou, P. H., Lee, C. T., Peng, Z. Y., Li, J. P., Lai, T. K., Chang, C. M., … Hung, S. C. (2013). A bluetooth-smart insulating container for cold-chain logistics. *Proceedings - IEEE 6th International Conference on Service-Oriented Computing and Applications*, SOCA 2013, 298–303. DOI: https://doi.org/10.1109/SOCA.2013.46.

[34] Thoma M., Fiedler M. & Benedikt M. (2013). End-2-End Cold Chain Supervision based on Internet of Things Architecture. *1st International Workshop on Internet of Things Communications and Technologies*. 978-1-4577-2014-7/13.

[35] Ding, H., Li, R., Li, S., Han, J., & Zhao, J. (2013). MISS: Multi-dimensional information sensing surveillance for cold chain logistics. *Proceedings - IEEE 10th International Conference on Mobile Ad-Hoc and Sensor Systems*, MASS 2013, 519–523. DOI: https://doi.org/10.1109/MASS.2013.87.

[36] Lee, C., Jung, D., & Lee, K. (2013). A-Monitoring Using Sensors and ZigBee for Cold Chain System. *International Journal of Distributed Sensor Networks*, 9(7), 463917. DOI: doi:10.1155/2013/463917.

[37] Engel, V. J. L., & Supangkat, S. H. (2014). Context-aware inference model for cold-chain logistics monitoring. Proceedings - *2014 International Conference on ICT for Smart Society: Smart System*

Platform Development for City and Society, GoeSmart 2014, ICISS 2014, 192–196. DOI: https://doi.org/10.1109/ICTSS.2014.7013172.

[38] Chen, R. Y. (2016). Fog computing-based intelligent inference performance evaluation system integrated internet of thing in food cold chain. *2015 12th International Conference on Fuzzy Systems and Knowledge Discovery*, FSKD 2015, 879–886. DOI: https://doi.org/10.1109/FSKD.2015.7382059.

[39] Đorđević, V., Paraskevopoulou, A., Mantzouridou, F., Lalou, S., Pantić, M., Bugarski, B., & Nedović, V. (2016). Emerging and Traditional Technologies for Safe, Healthy and Quality Food. Emerging and Traditional Technologies for Safe, Healthy and Quality Food, *Food Engineering Series*. 329–382. DOI: https://doi.org/10.1007/978-3-319-24040-4.

[40] Shih, C. W., & Wang, C. H. (2016). Integrating wireless sensor networks with statistical quality control to develop a cold chain system in food industries. *Computer Standards and Interfaces*, 45, 62–78. DOI: https://doi.org/10.1016/j.csi.2015.12.004.

[41] LuSichao, & WangXifu. (2016). Toward an intelligent solution for perishable food cold chain management. *2016 7th IEEE International Conference on Software Engineering and Service Science (ICSESS)*. DOI: https://doi.org/10.1109/icsess.2016.7883200.

[42] Zhou, L., & Chakrabartty, S. (2017). Self-powered Continuous Time-Temperature Monitoring for Cold-Chain Management. 879–882. ISBN : 9781509063895.

[43] Zhang, N., & Liu, Y. (2019). NB-IOT drives intelligent cold chain for best application. ICEIEC *2019 - Proceedings of 2019 IEEE 9th International Conference on Electronics Information and Emergency Communication*, 188–191. DOI: https://doi.org/10.1109/ICEIEC.2019.8784621.

[44] Gifford Matthew (2019), Building a Cold Chain Management IoT Solution. Retrieved on 10/04/2020from https://www.leverege.com/blogpost/building-cold-chain-management-iot-solution

[45] Sreeremya P (2019). IOT Cold chain management sensors, dashboard, gateways, IOT platform. Retrieved on 03/04/2020 from https://www.softwareassociates.co.in/cold-chain-management-healthcare-pharma/

[46] Joshi, N. (2020). IoT is a Hot Topic in Cold Chain Logistics. Retrieved on 12/04/2020 from https://www.bbntimes.com/technology/iot-is-a-hot-topic-in-cold-chain-logistics.

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