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REVIEW ARTICLE
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Agro-product Transportation Systems and its Subsequent Development

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ABSTRACT

Transportation and communication are the top factors that ensure the sustainability and development of a civilization. The more the world is growing the more scientists are in the way of discovering the most convenient way of communication and transportation system to make life easier. Due to geography, environment and climate food production is limited to specific areas. Thus, it is a challenging and gigantic task to maintain the supply chain worldwide. Consequently, this review depicts some key strategies to increase the efficiency of transportation system particularly the application of Internet of Things (IoT) in transportation systems. A thorough search of secondary data/ materials from PubMed, Google Scholar, and Scopus were used to locate articles on smart agro-food transportation systems. The context analysis method was used to evaluate the selected articles. To continue a sustainable market linkage efficient vehicle utilization, backhauling, vehicle selection, on time and frequent delivery, third party logistics and transportation collaboration were noted with much importance. Successful integration of smart or intelligent transportation in agro-food item transportation will lead to less loss of perishable items and ensure the maximum utilization of time, money and visits. Overall, future of the food transportation system was found to be more technologically advanced in terms of the strengthening of ICT-based tools and applications of IoT. In the coming days agricultural food goods carriers should be completely automated, coordinated and equipped with emerging ICT tools including hardware and software.

Keywords: Agro-food product, Smart transportation system, Perishable, Information & communication technology, Freight intelligent transport systems.

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INTRODUCTION

Transport is widely considered to be a key component in agricultural development around the world. It is the only way for food produced on the farm to be transported to households and markets. Transport develops agricultural markets, strengthens communication among regional and economic groups and unlocks new potential focusing financial sectors (Tunde and Adenyl, 2012). One of the most important areas of social development is the agricultural industry, which has an impact on many facets of daily life including the economy, food industry, retail, and so forth (Allen, 1999). Agricultural goods supply chains become more complex as the industry and business model develop, with links in the chains interacting and relating to one another to produce high dynamics and operational uncertainty (Verdouw et al., 2013). Meanwhile, due to its perishability and health relativity, freshly produced farm products are expensive to deliver maintaining food quality (Haji et al., 2020). The food security in the face of climate change becomes a big challenge for us (Zafar et al., 2022). Together with public and private partnerships as well as other stake holders can create novel concepts that have exact solutions regarding the food supply in such a way which will be resource-efficient, environmentally friendly and climate

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change-resilient (Latruffe, 2010). A high-level expert panel will discuss how climate-smart agriculture, landscaping and seascapes, and more efficient supply chains will assure food security. Thus, we should consider overcoming such a challenge by paying greater attention to how logistics and transportation can play a part of promoting food security. Therefore, by 2050, we can feed 9 billion people while mitigating the effects of climate change (Bahar et al*.,* 2020).

Many factors must be taken into consideration by legislators, from the regulation of the safety and quality of food to the possibility of supply variations about the marketplace and the environment. Furthermore, transportation for agricultural goods has recently received increased attention in research, industry, and consumer associations. With the improvement of living standards, demand for fresh agricultural products and food has risen (Jevsnik et al. 2008; Lehmann et al. 2012). So, modern agro food serving systems should ensure the safety and quality of the produce from farm to retailer level during supply and transportation. The main facts that should be considered for ensuring food security are about 15% of total greenhouse gas emissions are related to transportation and road transport accounts for 60% of those emissions, and up to 50% of the harvest is lost between farm and fork, the point at which we eat food. Another fact is logistics expenses are particularly significant for small farmers (up to 23% of total costs) (Harvey et al. 2014). So, logistics services, information, and set-up which allow freedom for transporting goods and people are now realized as a critical component in achieving long-term food security, as well as a driver of business competition and economic growth. For instance, the growth of agro-logistics has made it possible to approach the problem of food security more comprehensively, from "farm to fork" and all points in between. It is thought that a large portion of food losses or wastage is happens at the production, handling, and storage steps. According to earlier research, the consumption stage of the value chain can also result in significant losses or waste. Various studies applauded modernized value chains and technology, noting the importance of proper handling, transport and storage control, and stated that significant progress has been made in lowering post-harvest losses from field to storage (Chowhan et al*.,* 2016). Nevertheless, for the small farmer to make economic profit further, it is also necessary to control losses higher up to the value chain. These are compelling justifications for emphasizing locally produced foods, according to many. It is not a given that a chain's complexity rises with distance from its origin, though. Farmers frequently experience higher net profit when their crops are exported to foreign markets using this transport method because maritime shipping costs, for instance, are typically low. Additionally, bulk transportation typically leaves a smaller carbon footprint. Determining the best balance between economic returns, total transportation costs, and overall greenhouse gas emissions must therefore be done on a case-by-case basis.

The global system for transporting agricultural products is divided into four sections: overland road service, rail transportation, inland river and maritime transportation, and air transportation on passenger and cargo aircraft (Anonymous, 2023a, b). But the specific type of transport may be largely dependent on the geographical position, distance, economy and local community. Due to the uneven development of countries each has a different type of transport management information system; but the common thing is internet, computer and smart phone/cell phone communication. However, if internet access is ensured transportation information system can be much improved allowing managers to better management of vehicles, drivers, agro-products (as per type of commodity), money and eventually time (Kovynyov and Mikut, 2019; Zhu and Shang, 2021). Traditional Transport Management Information System (TTMIS) can provide a solution regarding the info exchange between the stake holders of agro-supply chains, the ability for users to instantly access the transporter's location, the driver's driving style, swift access to weather forecasts for the location of agro-goods, traffic jams condition with routing choices in cities, and accuracy in the delivery time estimation are some of its drawbacks, though (Nchimbi et al., 2022). Contrary, intelligent or smart transport system (ITS/STS) refers to the utilization of information and communication technology (ICT) to accomplish secure, more reliable, and effective transportation services. Smart mobile devices, such as smartphones and intelligent PoS, Global Positioning System (GPS) and accelerometer sensors (Dharani, 2018), critical features to support ITS/STS services. Smart transportation systems can help developing countries address climate-related and local environmental impacts caused by goods transportation while also increasing export competitiveness through less carbon emission. Smart intelligent systems intend to help developing countries strengthen food security and optimize agricultural export competitiveness by reducing cost of logistics and food wastage in a sustainable manner. A smart transportation system also assists developing nations in reducing urban crowding occurred by retail distribution of goods and also enhances the environmentally friendly planning and management of port cities. We aimed to study the advances in agro-food transportation systems based on vehicle, IT hardware and software to make transportation more convenient and timelier without wasting food produces. Therefore, this review elucidates the different aspects and benefits of ITS/STS in agricultural goods delivery.

Methodology

This review was based on secondary source of information. Secondary information was collected and gathered from available literature review. Articles and reports which included the STS/ITS based on IoT technologies were considered for collecting relevant data/info for preparing this review paper. Approximately 100 papers were collected initially then 60 papers were discarded and remaining 40 were considered for this study. The above secondary data was assembled from different journals, websites, articles and books, national and international newspapers. Smart transport systems for agricultural goods and its future perspective were evaluated in this report.

Factors Influencing the Efficiency of Agricultural Food Transportation System

Important techniques for boosting transportation effectiveness in agricultural supply chains include effective vehicle usage, minimizing vacant backhauling, suitable vehicle determination, often and timely shipment, utilizing third-party logistics suppliers' services, and establishing transportation partnerships. These are explained briefly in Table 1. The ultimate goal of all practices is to manage every step and process easily and conveniently so that it will consider time, cost, effectiveness and consumer satisfaction.

Future Scope of Agricultural Goods Transportation System and IoT Applications

Internet of things or IoT refers to a network of physical devices, vehicles, home appliances, and other items surrounded with electronic devices, software, sensors, and network connectivity, allowing intercommunication and exchange data. Through inter exchange of info among the device,

Table 1: Key parameters for increasing transport efficacy in the agro product transportation system

Indicators	Step/functions	Outcomes	References
Efficient Vehicle Utilization	Increasing produce amount in vehicle	reduce its carbon footprint, increase its logistics efficiency, and reduce transportation cost	Dey et al. 2011; Blanchard, 2010
	use of a transportation management system (TMS)	automation of key transportation functions, including optimal carrier selection, load building, fleet management, routing and scheduling, and freight audit payment.	Sbihi and Eglese, 2007
Backhauling	carrying goods on return trips, rather than returning with empty trucks	increases overall fleet efficiency and reduces transportation costs for suppliers and customers, as well as help reducing environmental impacts	Dey et al. 2011; Ubeda et al. 2011; Mckinnon, 2000
Vehicle Selection	determining fleet size and vehicle types, sizes, and ownership	ensures fuel and better product delivery efficiency, aids in decision making on leasing vehicles	Dey et al. 2011; Rizet et al. 2012; Dasgupta et al. 2007
On-Time and Frequent Deliveries	ensuring timely delivery	business network, credibility and future reference by clients develop. Reduce outbound truck wait times to facilitate effective and efficient cross docking.	Reibstein, 2002; Vogt, 2010
	frequent delivery of small quantity	lessens vehicle load rates and causes financial loss for growers and consumers	Mckinnon, 2000
Third-Party Logistics or transportation/warehousing for another company (3PL)	Using specialized software, integrate multiple customer loads to improve load rates and enable product traceability.	provides aggregate info of suppliers in a particular location enabling to reduce consumers search and distribution cost	Chopra and Meindl, 2007; Van der Vorst et al. 2005; Kim et al. 2008; CLECAT, 2010
Horizontal Transportation collaboration	partnership between organizations in different supply chains for better utilization of assets and costs.	For maximum transportation efficiency, joint trucking routes, shared consolidation facilities, and network optimization across multiple competing supply chains can be used.	Audy et al. 2012; Mason et al. 2007
	Individual organizations can cluster their logistics activities and assets through shared transportation and processing facilities	Results improved supply chain	Van der Vorst et al. 2005; Blanchard, 2010
Vertical Transportation collaboration	Alliance with individuals who are a part of the same supply chains, whether in upstream (distributors), downstream (consumers) or internally in an organization.	⇒ Information transfer between successive supply chain partners via an interconnected system. ⇒ Supply chain optimization of transportation network to reduce costs, improve service levels, supply, delivery reliability.	Ballou, 2007; Audy et al. 2012

network and environment a smart system or service is developed. A model IoT should have- connectivity, intelligence and identity, scalability, dynamic and self-adapting (complexity), required architecture, safety/security, self-configuring ability, interoperability, embedded sensors and actuators, autonomous operation, data-driven, ubiquity, context awareness (Anonmyous, 2023b). The upcoming era of transportation is both thrilling and frightful with 'road transport' having the greatest chance of change as an ever-increasing number of vehicles compete for limited space on the road. This 'race for space' on roadways raises numerous environmental and moral concerns about the future development of highways, along with the increase in agricultural production. This marks a substantial investment in a more sustainable method of transportation of agricultural goods through vehicles are adapting and evolving into the digital era. The main aim of smart agricultural goods transportation system is to reduce the major post-harvest losses that occur during transportation. By simply implementing a controlled-temperature transportation system, there is a huge opportunity to reduce food waste and improve food distribution. The use of wireless sensors to electronically measure and record temperatures in an automatic temperature measurement method can significantly improve food safety. This method enables a continuous data stream of temperatures 24 hours a day, seven days a week. Temperatures can thus be recorded consistently and on time, leaving little room for interpretation; in short, the entire process is based solely on facts. Besides, data captured can be preserved in the Cloud and accessed via any kind of internet-connected device using LoRa (long-range) wireless technology. Notifications can be set up to send real-time alerts if the temperature exceeds preset limits, enabling rapid action to be taken to fix the issue. A device with supported technology can be installed at the storage site, even in transport trucks, to provide the storage recommended environment. It is also linked to an online dashboard, which can be configured to send alerts in the event of abnormal temperature levels, triggering prompt correction.

Smart Agricultural Transport System

Agricultural transportation may look very different in the years ahead as a result of the advanced satellite technology applications. Food transportation could become much more convenient. In the future, a signal from the phone to the truck detailing the location and pick-up time will be possible,

allowing the nearest vehicle to pick up the goods. Maintenance and repair of agricultural vehicles may be considerably strengthened. Train companies will be able to take appropriate action by receiving data from trains about losses or congestion in particular carts and sending it to a transfer hub. It may deliver an urgent boost in the effectiveness allowing problems to be addressed more quickly and precisely.

However, ITS/STS of agricultural food products offer utilization of ICT and sensors to cleaner, efficient and safer road transportation. The ITS allows Information Systems to make decisions that will benefit stakeholders intelligently (GSMA, 2015; ESCAP, 2017). Yet due to various factors like geography structure, way the transportation system is planned, availability of technologies, socioeconomic differences and others, the needs for establishment and operation is contingent upon the country (Nchimbi et al., 2022). Now a day's adoption and application of ITS/STS in developed countries like USA, Japan have escalated greatly after its inception over three decades (Yokota and Weiland, 2004). Today the developments and impacts of STS/ITS are highly realized in developed countries (Gebresenbet and Bosona, 2012), particularly in carriage facilities like self-directed vehicles and applications in smart cities. Meanwhile looking at the regional circumstances in countries that are developing, Freight Intelligent Transport Systems (FITS) receive little attention (Chan et al*.,* 2019). For effective FITS management combination of hardware and software is essential. Previously Chowhan and Ghosh (2020) stated the importance of smartphone apps and ICT tools for marketing and distribution of agricultural products. Smart technologies like ubiquitous computing, IoT, wireless sensor networks, RFID, GPS, GPRS, GIS-T, artificial intelligence, big data and smart mobile phones are prerequisite (Fig. 1). Some major points comprehending to STS/ITS that are necessary to ensure food quality, safety and better transport are mentioned below-

Satellite Technology

Detecting and possibly eluding risky situations like traffic accidents would be made easier if vehicles could receive data from transfer hubs. For standard, satellite technology might be employed to trace severe weather conditions, notifying all nearby vehicles and guiding them in the prudent direction. Cars will be able to send a signal to the transportation hub reporting it of a traffic accident, its time and severity, allowing proper assistance to be dispatched. Through satellite navigation and imagery, the project aims to improve road maintenance during the winter. By implementing automated procedures while decreasing the need for manual repairs, safety can be improved and drivers can focus on driving. This technology could improve safety for long-haul truck drivers by managing their rest breaks. It will reduce the cost of goods transportation. When a break is needed, a tachometer will alert the driver and direct them to the nearest rest and refueling location.

Delivery Drones

Drones flying around nowadays are very common, but their use in daily life is about to increase significantly. Drones that deliver everything from takeout to essential documents, food or daily household groceries may become prevalent in our cities. Advantage is it can provide a green image (ecofriendly) towards the target users (Hwang and Kim, 2019). Therefore, satellite technology is going to make it simpler to track drones so that packages are delivered safely and to keep track of their battery life. Along with being cheaper and more compact, this method of product delivery is much more environmentally friendly.

Compliance Mate

This is a food quality and safety monitoring program that continuously records temperature information inside coolers and other appliances in the kitchen is provided by hazard analysis and critical control points (HACCP) compliance. Such as its Touchblock integration is used to record the temperatures every minute in coolers and preparation rooms (Booth, 2015).

LPWAN Technologies

LPWAN or low-power wide area network is a wireless network technology that allows devices to communicate over long distances while using less power. It was developed to connect devices that require less bandwidth, low power, and longer battery life which are spread across a greater area. LoRa and Sigfox are communication technologies that utilize LPWAN to deliver long or short-range connectivity. But a battery-powered, distant ranged integrated sensor platform uses LoRaWAN and Bluetooth Low Energy (BLE) communication. It supports LoRaWAN at 868/915 MHz and based on the Semtech SX1272 and Nordic nRF51 silicon. Additionally, it delivers superior RF performance in an environment with precise humidity and temperature levels. To provide cloud-based services, two major series, including RS1xx and RG1xx (multi-wireless gateways), collaborate. Most importantly, it necessitates the use of a low-cost radio terminal (end point) and a more advanced base station to control the network. When compared to LoRa, Sigfox communication is better when it is directed upward from the terminal point to the base station. Though it encourages two-way communication, its capability from the base station to the terminal point is limited because it delivers less downlink compared to the uplink width (Ayaz et al., 2019). A brief comparison of LoRa and Sigfox communication systems (Mekki et al*.* 2019) is illustrated in Table 2.

Table 2: Major differential characteristics of LoRa and Sigfox communication technologies

Indicators	LoRa	Sigfox
Bandwidth	Higher than Sigfox (125 kHz and 250 kHz)	lower (100 Hz)
Data transmission rate	higher than Sigfox (50 Kbps)	less (100 bps)
Messaging capacity/day	Infinite	maximum 140 upload and 4 downloads
Modulation	Chirp spread spectrum	Binary Phase-shift keying
Operating range (Km)	5-20 depending on barriers	10-40 depending on barriers
Network Architecture	distributed network architecture, where nodes communicate directly with each other and gateways forward data to the cloud	uses a centralized network architecture, where nodes communicate with base stations that forward data to the cloud
Applications in agro-product transportation systems	have limitations as they can drain out batteries due to higher transmit power	commonly used for tracking shipping containers, transport vehicles, and equipment, due to their long battery life and low power consumption.

Source: Mekki et al. (2019).

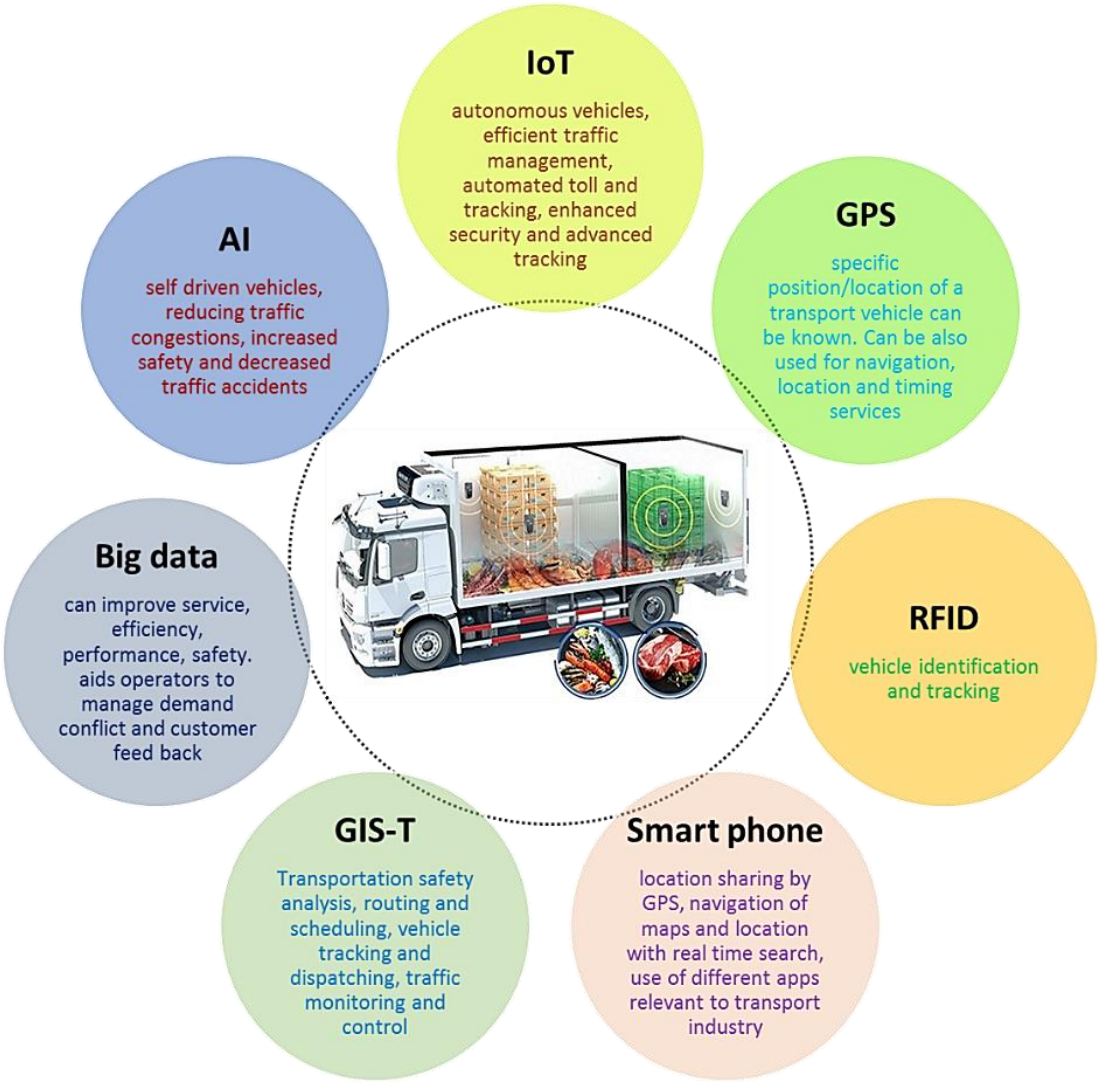

Fig. 1: Improved Freight Intelligent Transport Systems (FITS) incorporates the major ICT tools

CCP Smart Tag (RC4)

CCP (Critical Control Points) Smart Tag (RC4) declares itself as a comprehensive monitoring answer for food service and selling industries (Tchetvertakov, 2018). It can automatically adjust the temperature environment required to meet the food safety guidelines for different kinds of food. Furthermore, temperature and other data are perceived and seen via web and mobile applications on a service provider cloud platform.

TempReporter

It is used to monitor temperatures around the clock in accordance with HACCP (Hazard Analysis and Critical Control Points). Moreover, it automatically logs the readings. Temperature monitoring reports are auto-filled based on HACCP and HPRA (Health Products Regulatory Authority) recommendations. Finistere Ventures reported that about $2 billion was invested in AgTech globally in 2018. Several investments exceeded these numbers in 2019. Considering the future needs of IoT in agriculture applications, almost all leading technological giants are supporting this progress in some way.

Conclusion

Our current study will enrich the knowledge on STS/ITS of agro-food transportation as, we mentioned the role of several ICT-based tools and their application which if implicated on the suitable vehicles and areas, it might be possible to reduce the post-harvest loss and ensure food quality and price favorable for the ultimate consumers. However, food production and marketing setup is critically reliant on transportation. Furthermore, widely accepted market transportation can make a difference in rural-income levels and improve the standard of living of the farmers as well as the inhabitants of the communities in a country. From the observations, it could be ascertained that future of agriculture farming will undergo a tremendous change in terms of ICT interventions in the transportation sector. Market linkage and supply chain will also face a big change. Particularly preventing loss of perishables (post-harvest loss) during carriage and distant item carrying would be done easier thus it will be possible to ensure food security globally. Finally, appropriate means of transport was seen as an important facilitator in mobilizing farmers and other allied workers in the overall development of the states as it will contribute to saving time, cost and delivery frequencies.

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Authors' Contribution

SC and SRG conceptualized and prepared the draft article. SA, MAE searched for the relevant review of literatures and formatted the citations. TC, MMR, NA and SR did the final editing and sentence/grammar check. All authors read and approved the final version of the review manuscript.

Conflict of Interest

The authors declare no conflict of interest.

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