Implementation of RFID Technology in Perishable Goods Transport

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***Abstract* - In this paper, the authors research the possibilities of RFID technology implementation in transport of perishable goods. Transport, perishable goods transport, tracking and tracing, and RFID technology are explained. To demonstrate the importance and the complexity of the topic, a case study is constructed where RFID technology is combined with tracking and tracing to illustrate the transport of perishable agricultural goods. Possible applications of RFID technology in combination with Internet of Things are investigated, and future possibilities in transport are presented.**

Keywords - transport; perishable goods; RFID technology; tracking and tracing, Internet of Things

I. INTRODUCTION

Perishable goods are exposed to various environmental changes during transport (temperature, humidity, light, etc.). Temperature is the most important environmental parameter, and it must be controlled in order to extend the shelf life of the perishable goods. Controlling and monitoring the perishable goods during transport can be improved by the implementation of digital technologies, such as Radio Frequency Identification (RFID).

New EU Regulation 2019/1381 on transparency and sustainability of EU risk assessment in the food chain was introduced on March 27, 2021, and this paper will be focused on the segment of this regulation dealing with transparency, which states that consumers should have access to information regarding risk assessment in the food chain [1]. In this context, the authors propose implementing the track and trace system into the perishable goods transport, combined with RFID and Internet of Things (IoT) technologies. Another important regulation is the "Regulation EC No 178/2002 laying down the general principles and requirements of food law, establishing the European Food Safety Authority and laying down procedures in matters of food safety", which ensures a high level of protection of consumers' interests in relation to food [2]. It sets out an overarching and coherent framework for the development of food and feed legislation both at Union and national levels. This regulation provided the impulse for this research and is the basis of this paper [3].

The paper is organized as follows: in section two, the theoretical framework of transport, perishable goods transport, track and trace, and RFID technology is provided. The third section of this paper will expand on the information provided in section two and construct an example to illustrate the possible usage of RFID technology for tracking and tracing of perishable agricultural goods, which are, in this case, strawberries. In the fourth section, the possibility of improving the transport of perishable goods with IoT technology will be investigated. A discussion and conclusion are drawn in section five.

II. THEORETICAL FRAMEWORK

In this section, the authors introduce the topics of transport, perishable goods transport, tracking and tracing of goods, and RFID technology.

The principal task of the modern freight transport system is to meet the transfer requirements that arise from the allocation of procurement, production, and consumption activities in geographically increasingly distant locations. Transportation has a linking function in the area of raw material supply for production needs and the distribution of the final product [4]. More specifically, transportation is a part of integrated logistics management and, as such, is of vital importance. It is a part of value creation that is incorporated into strategic management and decision-making through transportation logistics. A well-developed transportation system provides better efficiency, reduced operating costs, and higher service quality of logistics systems [5].

A perishable good is any product in which the product quality deteriorates due to various environmental conditions through time, such as meat and meat by-products, fish and seafood, dairy products, fruit and vegetables, flowers, pharmaceutical products, and

chemicals [6]. Transporting perishable goods and fresh produce is fraught with higher risks than most surface transportation, there is a risk of spoilage, loss of freshness and quality [7].

Tracking and tracing is a system used by freight forwarders or courier services to record the movement of goods during transport [8]. Every time the goods change the location, they are scanned, and the data is forwarded to the central processing system. This way, the consumer can track their shipment on websites and mobile phone applications with either a provided link from the retailer or a tracking number [9]. In combination with GPS location transmission, as in the cases such as DHL Germany, Hermes or Amazon Delivery Service, the parcel can be tracked back in the distribution and the exact location of the parcel on its way can be made available to the consumer [10].

Because the EU's Regulation EC No 178/2002 sets consumer safety as its first objective, it impacts every stage of food production, processing, and supply chain. This Regulation compels food companies to implement the tracing system to provide information about purchased products to the consumers. Mandatory traceability data includes the documentation of lot number, product ID, product description, supplier ID, quantity, unit of measure, buyer ID [11]. Further data such as supplier's name, contact information, receipt date, country of origin, date of packing, trade unit, vehicle ID, logistics service provider ID, buyer's name, and dispatching date are optional data [11]. At the end, the consumer can receive information about the origin and type of food/feed, the ingredients, if it is meat - then the species and age. Further, every processing stage (primary production, processing, storage, and distribution) and resource used for the product plus transport equipment is noted. The emphasis is not only on where the food/feed came from or to whom it was sold, but also how it was transported [11]. Complete transportation information would include the distribution route to trace the cargo/goods if damaged or contaminated on the transport from the farmer/producer to the consumer [2].

To illustrate such a tracing system, the authors considered the tracing system for meat and fish products used in German "Aldi Nord" supermarket chain. It gave the authors the initial idea that this system can be transferred to other goods, which can be found in section 3 in the constructed case study. Their system is called ATC code (ALDI transparency code) (see Figure 1 [12]). The consumer can scan a QR code on the product package or enter the ALDI transparency code on a website and trace the product's origin back to the country and specific region of origin. In addition, it is possible to see what kind of product it is, and which part of the animal was processed and where. The QR code can be scanned with the smartphone, and all information regarding the origin of the product can be received quickly [13]. The case study was developed based on tracking system elaborated above.

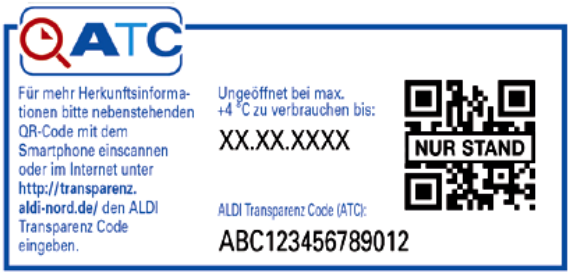

Figure 1. ATC Code Example [12]

RFID has the possibility to reduce uncertainties and to monitor real-time information of products for optimal decision-making processes from commodity design, raw material purchasing, production, transportation, storage, distribution and sale of semi-products and products, returns processing and after-sales service [14]. Nowadays, the transport sector uses RFID technology more frequently because it is suitable wherever automatic marking, recognition, monitoring, or registration storage is required, such as logistics when scanning incoming and outgoing goods [15].

RFID technology is increasingly used nowadays to make the transport of goods easier, faster, and more controlled. For example, recent food scandals such as BSE, foot-and-mouth disease, and the contamination of milk with melamine have proved the importance of food tracking within the supply chain, in order to minimize such risks in the future [16]. It is helpful in such unfortunate events to trace the problem back to its origin, beginning with importation, production, manufacture, storage, transportation, distribution, sale, and supply. It also provides consumer satisfaction and contributes confidence in the food industry. RFID-Technology is the critical element of this process because it is possible to record and read all data and information about the product while it is transported using RFID tags [17]. In connection with other systems, such as the Internet of Things and Wireless Sensor Network it is possible to track the movement of goods throughout the supply chain. Every stakeholder receives information in advance about the number of goods, their origin, and location [18].

Furthermore, RFID technology can be used to track goods from consumers or when transporting foodstuff to check whether a specific temperature has been maintained in the container [19]. Besides this, logistics companies can also use RFID tags for trailer identification. As a result, the driver receives information about the trailer coupled via a telematics system. In this way, the driver knows whether the correct trailer has been picked up or not. Furthermore, RFID tags can identify the trailer load without the need to secure the load. The only requirement is that the trailer is equipped with sliding curtains. In this case, pallets equipped with passive UHF RFID tags can be scanned at the gate without moving the curtain. By slowly passing the gate, the goods are identified, and the information is forwarded to IT systems such as Enterprise Resource Planning and Warehouse Management System [20].

III. CASE STUDY: TRACKING AND TRACING WITH THE HELP OF RFID TECHNOLOGY

An example is constructed to illustrate and research the RFID technology in the supply chain, with the emphasis on the transportation and distribution, and this will be further described in the subsection *Track and Trace of Strawberries*. As the main actor of the following sections, we point out the farm/farmer who produces the strawberries. The processor organizes the strawberries into sellable packages and organizes further distribution. A distribution center serves only as a stopover for agricultural goods until they reach the supermarket or retailer to be sold to the consumer [21]. The focal point is on the delivery system through each of those stops (Figure 2).

In the proposed example, the authors elaborate tracking and tracing a particular batch of strawberries from the farmer to the consumer along the supply chain. Tracing in this context is limited to the origin of the strawberries, from the consumer to the farmer [11]. Therefore, the farmer/producer needs to generate a procedure to gather the necessary data and transcribe this on the RFID tag. This will, in the end, give the consumer the wanted information about the product. It is necessary to transmit the initial information about the product collected at the beginning of the supply chain until the very end. This means that information will be added to the tag in each stop (processor, distribution center, and every truck) and never deleted or otherwise manipulated. The tracking of this information will give the farmer/producer the chance to recall his product/strawberries more easily. Additionally, if the strawberries have not reached the consumer yet, every step of the supply chain can be tracked regarding the particular batch of strawberries in question [22].

A. Tracking and Tracing of Strawberries

Based on the information provided in the previous sections, the authors have developed a case study which emphasizes the importance of the implementation of RFID technology, as well as the connection of RFID technology with the aspect of tracking and tracing the transport of perishable goods. To be specific, it is the tracking of the transportation of strawberries from the supplier to the supermarket. Because strawberries are perishable goods, certain conditions must be satisfied, i.e., temperature and humidity, which must be observed during the entire transport. This can be controlled with RFID tags and specific sensors attached to the transportation goods/pallets/rolling containers/bins of strawberries [23]. The transport aid, pallet, or rolling container has a tag and sensor as well to record the surrounding temperatures along the supply chain until the goods are handed over to the consumer. It is suggested to have transponders at every transportation aid so an electronic content slip can be established, which holds all the sensors' information from the beginning of the transport until the strawberries reach the next station on their route [24]. This process can confirm cold chain compliance, and the receiving station confirms it by signing the receiving invoice on a smart device or similar. This form of transportation control will be repeated in every step between the stations [21].

To clarify, the first truck will deliver the strawberries to the processor, where other trucks from the region arrive with the same goods. Every delivery is checked using appropriate RFID sensors. In particular, the correct temperature and air condition are checked during the entire transport. According to the specified temperature values, the strawberries will be stored at the processor [23]. As EU's Regulation EC No 178/2002 demands, the tags should have other information, such as the region where the strawberries come from and when they entered the supply chain. The strawberries will be temporarily stored at the processor before moving further into the supply chain. This processor is only for accumulating strawberries from the region. The supermarkets' distribution truck fetches their batch of strawberries and brings them to their distribution center. From there, the strawberries are delivered to the supermarkets themselves. Of course, it has to be noted that strawberries and other goods will be delivered to the supermarket from the supermarkets' distribution center. The whole process is illustrated in Figure 2. With the help of RFID tags, the supermarket can monitor the whole transportation process of the delivered batch of strawberries. This includes the

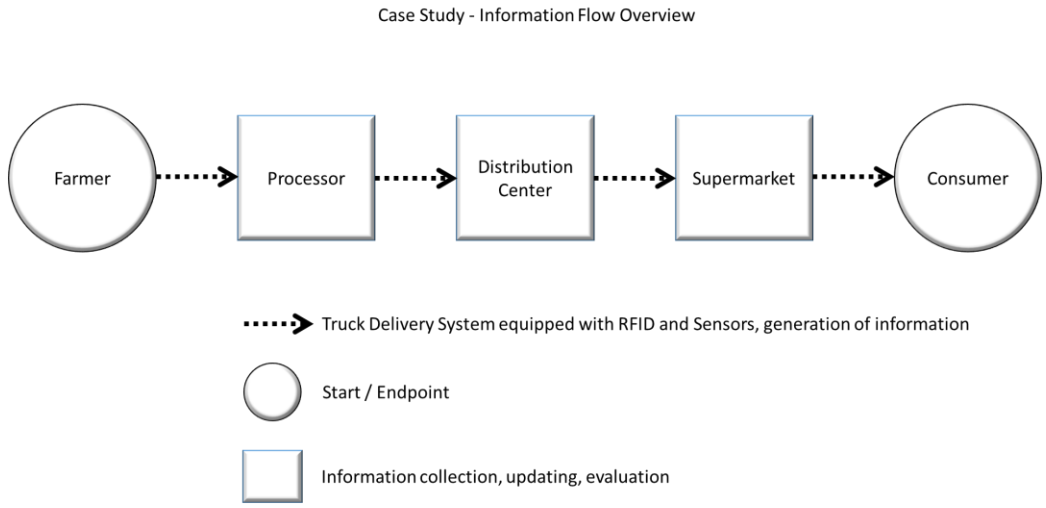

Figure 2. Case Study – Information Flow Overview, Source: own illustration based on [11]

transport conditions such as weight and further information, namely origin, temperature, and humidity of the strawberries [25]. Also, the time of arrival and departure of the truck at the different distribution centers can be evaluated.

B. RFID Usage in Strawberry Transportation

The entire supply chain must be equipped with RFID technology to provide the seller (in this case, the supermarket), with the highest level of security for transport.

First of all, the strawberries are transported from the farmer to the processor. The truck must be equipped with additional sensors to record the temperature and humidity. These sensors communicate via the wireless sensor network (WSN). The WSN technology can control all devices through a central network or cloud system in coordination with RFID technology, sensors, and a global positioning system. If the RFID tags are created at the processor, the WSN can directly save all information recorded from the cultivation to delivery to the processor on the RFID tags [26]. While the RFID tags are created, the strawberries are temporarily stored and cooled in the warehouse at a specific temperature.

It should be noted that the created RFID tags are passive UHF RFID tags. This type of tag is considered because they guarantee high performance in the presence of multiple readings. Furthermore, passive tags do not have an own power source because the chip takes its power through the radio waves emitted by the reading antennas [27]. In addition, the processor, the distribution center, and the supermarket are equipped with passive UHF RFID gates for multiple readings. Once the processor tags the strawberries with passive RFID tags, the transportation can begin with picking up the batch of strawberries [28]. Due to the RFID tag, the exact location of the strawberries can be allocated in the system, which makes it easier for the next step of transportation. The staff is alerted to the truck's arrival because the truck is also equipped with an RFID tag that serves as vehicle identification and as visual feedback for the driver. Furthermore, the sensors in the truck continuously measure the temperature and humidity of the strawberries. As soon as the truck arrives at the gate of the distribution center, the information about the vehicle and its cargo is fed into the IT systems (Warehouse Management System, Enterprise Resource Planning or Transport Management System), which expedites the planning to a loading bay and subsequently the unloading process. When unloading the strawberry boxes, they are passed through a passive UHF RFID gate. During temporary storage, the strawberries are stored again at a specific temperature. Aside from strawberries, other foods are also stored [29]. As soon as the supermarket places a subsequent order of several groceries, the strawberries are removed from storage with other products according to the FIFO (first in, first out) principle and then loaded into the truck [30].

Further, the FIFO pattern can be ensured, and the quality of the strawberries supported with the correct inventory pattern. Sensors in the truck continuously measure the conditions. Because of the perishable nature of strawberries, the inventory cycle needs to be shorter. Seamless exchange of information takes place as soon as the truck with the delivery reaches the supermarket. The strawberries are again passed through a passive UHF RFID gate and displayed in the supermarket for sale. The information regarding the strawberries is deposited in the supermarkets' information system and used for coming deliveries [23].

By constantly monitoring the temperature and humidity, the retailer has a good overview of the products he is selling and can track the entire process of the strawberries - from cultivation to intermediate transport to sale. In addition, every buyer in the supermarket has the opportunity to trace the origin and transport of strawberries. In this case, the RFID tag must be read with a particular app on the smartphone. All data about the transportation of the respective strawberry box could be displayed. However, this also results in a very high level of transparency from the buyer's perspective. Therefore, they can be sure where the strawberries come from and how they have been transported through the region.

IV. IMPROVING PERISHABLE GOODS TRANSPORT WITH IOT

In order to improve tracking and tracing of the transport of goods and especially perishable goods, the following technologies such as IoT and WSN serve as assistance.

The IoT or the so-called Internet of Things is one of the essential technologies used in connection with the RFID system in tracking and tracing the transportation of goods. Li et al. [31] defined IoT as "*a global dynamic network infrastructure with auto-configuration capabilities based on standards and interoperable communication protocols; physical and virtual things have identities and attributes and are able to utilize smart interfaces in order to connect to an information network*." Internet of Things, with the help of sensors enables improved monitoring of each product during transportation. This results in a massive amount of data that has to be stored and processed for efficient decision-making, which is crucial for the transportation of perishable goods. Furthermore, this data can be helpful for demand forecasting, inventory management, and preventing a bullwhip effect [32]. RFID technology has captured the market in many different areas, such as material logistics, inventory in supply chains, production lines, asset tracking, and retail. This has contributed to a stronger connection between RFID and IoT [33].

According to Jia et al. [34], by "connecting the RFID reader to the Internet, the readers can identify, track (and even monitor if the tags are active) the objects attached with tags globally, automatically, and in real time, if needed", and this is the essence of the Internet of Things. This connection needs to be supported by Wireless Sensor Network. Here, the WSN domain is characterized by devices with limited power in terms of computational, processing, storage, and energy resources. All sensor nodes are interconnected by wireless transmission in a non-fixed and ad-hoc based approach. The main task of these nodes is to collect the information and forward it to

the endpoints through intermediate devices. For improving the routing performance, secure and authentic end-to-end routing channels need to be established so that only trusted IoT devices could exchange information. In doing so, the information is received from the IoT devices to initiate certain functions [26].

The development of these two technologies is significant. Through this technology application, transport and logistics management become more efficient, effective, and leaner [19]. For example, movement of goods is tracked via GPS, RFID and IoT, and up to date reports can be accessed whilst in transit [19]. This can include notifications via alerts online or apps on a mobile device informing of dispatch of stock en-route to a designated location including change of mode of transportation, issues along the way and arrival [19]. Integrating GPS technology into transport vehicles makes it possible to monitor all the relevant information (e.g., route, shipping/transport conditions, and shipment status related to transporting goods [9].

Lee et al. [35] proposed a smart warehouse framework using IoT, RFID, and wireless sensors to track and trace the raw parts, semi-finished goods and finished goods. They evaluated the effectiveness of the IoT-based Warehouse Inventory Management System for the low-volume, high-product mix situations faced by manufacturers, so as to achieve better performance of the receiving, storage and picking activities in the warehouse. Also, IoT can also be used in various processes such as distribution and material handling (packages, rolling containers, etc.). [36].

V. CONCLUSION

The case study discusses the transportation of perishable goods, in this case strawberries, but can easily be transferred to other agricultural or cold chain products. In this way, consumers can track their food down the supply chain, giving them confidence in food safety and better product satisfaction, as it is already possible with meat and fish products as mentioned in section 2 on the example of ATC.

Furthermore, questions that arose while constructing the case study were related to the cost reduction. In this respect, with using passive tags, high expenses do not incur. As already explained, passive tags are mass-produced and are therefore highly cost-effective. Furthermore, they have a long service life due to the energy utilization of the reader. Despite all this, a cost-benefit analysis should be performed to determine whether it is beneficial overall.

RFID tags may completely replace barcodes because mass production will make them more affordable in all business aspects. Moreover, RFID tags serve in monitoring and tracking of transportation, resulting in more transparency, adding value for the consumers. Apart from its use in transportation, RFID technology may be further developed in combination with Internet of Things. This further development increases the transparency of the food supply chain for the consumers.

Tracking and tracing of perishable goods may be improved by combining IoT, RFID and GPS, thus enabling the monitoring of all the relevant information such as status related to transporting goods, change of transportation mode, and any issues along the way. Some authors have focused on the role of IoT and RFID in warehouses in order to simplify tracking and tracing of the raw parts, semi-finished goods and finished goods, and to improve receiving, storage and picking activities in the warehouses. IoT can also be used in processes such as distribution and material handling (packages, rolling containers, etc.).

In this paper, the authors have concluded that tracking and tracing of the perishable goods during transport can be improved by the implementation of RFID technology, which is important since perishable goods are exposed to various environmental changes during transport. Temperature is the most important environmental parameter, which should be controlled in order to extend the shelf life of the perishable goods.

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