ICTs in Agri-Food Logistics

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A major challenge of Sustainable Development Goal 12 "Responsible Consumption and Production" is to reduce food losses along production and supply chains. This is particularly critical for fresh food products, due to their perishable and fragile nature, which makes the coordination of the actors all the more crucial to avoid wastes and losses. The rise of new technologies, referred to as "Industry 4.0" powered by the internet of things, big data analytics and artificial intelligence, could bring new solutions to meet these needs. Information and communication technologies (ICTs) allow for frequent exchanges of huge amounts of information between actors in the agrofood chains to coordinate their activities.

Keywords: food sustainability ; food supply chain

1. Introduction

Driven by the evolution of consumer demand towards increased sustainability and the desire to improve efficiency, agrofood supply chains are following a trend of redesigning their logistics [1]. Citing Target 12.3 of Sustainable Development Goals [2], ensuring sustainable consumption and production patterns means to "reduce food losses along production and supply chains, including post-harvest losses". For instance, between 25% and 30% of the fruit and vegetables produced in India are lost due to insufficient transportation and distribution facilities [3]. Logistics management is acknowledged as one of the essential processes to reduce food waste within supply chain management [4].

Concomitantly, the rise of new technologies could bring new solutions to meet these needs [5]. Among them, information and communication technologies (ICTs) promote frequent exchanges of huge amounts of information between actors in the agrofood chains to coordinate their activities [6]. Organizations are using digital technologies to change the value-creation paths they previously relied on to remain competitive [7].

A special focus concerns the case of fresh fruits and vegetables [8], due to the perishable and fragile nature of these products. Indeed, it makes the coordination of the actors all the more crucial to avoid waste and damage during the order [9]. As distribution channels increasingly make use of ICTs [10], and as the tools and practices are not evenly shared, there is a need to improve knowledge on how they relate to digital resources. ICT tools used in the fresh fruits and vegetables sector are the same as for other goods. However, supply chains experience short lifetimes and fragility of commodities. Inventory turnarounds are faster, under cold chain conditions, and handling operations are more delicate to avoid damage. Moreover, the margins obtained from these value-chains are tiny, so one can expect that any new tool (like ICTs) will not be adopted in the long run unless it provides a clear advantage.

By ICTs, the paper refers to all telecommunication, information, internet, multimedia and audiovisual technologies [11] that make it possible to process, modify and exchange information, and more specifically digitized data. Those allowing exchanges between actors in agrofood supply chains including consumers [12] are highlighted in this paper, focusing on ICTs used in the logistics activity in B-to-B (business to business). For food products, logistics is the series of operations from the purchase of raw materials to the distribution of the final product. It aims to provide the consumer with the desired product in the right quantity, at the right place, at the right time and at an acceptable cost [13].

The paper will examine the diversity of ICTs in different agrofood supply chain contexts, and their different functionalities. Moreover, it is an exploratory research work, relating to ICTs seen as "resources" [14]. From [14], a resource is "all the assets, capacities, organizational process, attributes of the enterprise, information, knowledge, etc., controlled by the enterprise allowing for conceiving and implementing strategies to improve effectiveness and efficiency" [15]. The authors will examine the conditions that mean ICTs are becoming a strategic resource, through the presented examples. In the theory of management known as the "resource-based view" (RBV), the strategic resources are the ones that confer "core competencies" [16] to the firm, or to the value-chain. The building and conservation of the core competencies are necessary conditions for the long term of the company/value-chain. The research question is therefore, "what are the conditions for ICTs used in the agrofood supply chain to be a strategic 'resource' for the agrofood supply chain?"

The research questions addressed are therefore two-fold: What is the adoption, difficulties and future of ICTs in the fresh fruit and vegetable supply chain in France, from the representation of the supply chain's actors? What are the conditions for ICTs used in the fresh fruit and vegetable supply chain to generate knowledge which would be a strategic 'resource' for the company or the supply chain?

The aim of the paper is to obtain knowledge about adoption of ICTs in the fresh fruit and vegetable supply chain in France, with four objectives:

- Discuss the difficulties to implement ICTs in this sector.
- Qualitatively analyze the potential in certain ICTs leading to building of strategic “resources”.

2. A Classification of ICTs According to Their Functionalities

The complexity of different ICTs governs their use. Those requiring longer learning will be considered sophisticated, and they will tend to be more expensive. They will preferentially be found in developed countries. In general, the more sophisticated the ICTs, the more specific they will be to Western distribution channels. Whatever the tool, their common purpose is to improve coordination of actors. Indeed, it is vital for the food network “to work as a single entity to plan and control the logistics of food products in a more effective and efficient way and supply consumers with high quality and secure food.” [17] (p. 138). As [18] highlighted it for IBM workers, ICTs allow connected actors to effectively coordinate their activities when they are in the same place, but also when they are distributed in different locations, which is common in globalized food chains.

2.1. Multitasking Tools Common in All Contexts Such as the Mobile Phone

Mobile phones have the advantage of allowing live conversations with a spatially remote partner. They are in common use whatever the socioeconomic context, i.e., even when other more sophisticated tools are available [19]. They provide several functions [20]. The first is the provision of information. The actors are able to know the quantities, the quality and the prices of the goods handled by the upstream actors [19][21]. Negotiations can begin during the call [19], followed by the order placement and organization of the transport [21]. Wholesalers also use their phones to sell perishable goods as quickly as possible [19]. Unless SMS or voicemail are used, there is no physical trace of the exchanges. Mobile phones are usable by illiterate people [22]. In the event of a dispute, telephone exchanges cannot be considered authentic.

In case of Collective Sale Point (e.g., “Coopérative Couleurs Paysannes”, France, Alpes de Haute-Provence), the mobile phone provides information about the state of stocks in the shop. The requests for information stem from the manager towards the producers, or the other way round. In the longer term, this cooperative plans to set up a tool to obtain this information online. Otherwise, the low predictability of sales makes transportation and production difficult to plan.

Mobile phones are usable by illiterate people [22]. In the traditional retail markets of developing countries, with a relatively high rate of illiteracy, the other “multitasking tools” are landline phones, and courier and messengers carrying a verbal message. However, the mobile phone is the most common one. A total of 80% of households are equipped with smartphones, although most of them have no web access, as the infrastructures are not connected. According to [23], 60% of the world’s population has no web access.

2.2. Generalist ICT Tools to Formalize Interactions between Actors in the Agrofood Supply Chain

The generalist tools require internet access and deliver three functions. First, as for mobile phones, they support exchanges in B-to-B or with customers. Second, unlike mobile phones, e-mail or EDI (Electronic Data Interchange) systems keep a written record of the interaction. EDI is a standardized system for the exchange of physical documents (orders, invoices, delivery notes, etc.) thanks to computers connected by specialized links such as extranets [12][24]. Farmers also use websites [25]. They present on-line the products they offer to customers, and some websites even allow online ordering and payments [26]. Third, the internet also makes it possible to search for more general information. For example, it can be useful to search for business partners via directories of professionals. Various types of information are posted on product information platforms. The Fructidor site for instance, mainly contains information on market trends. Nevertheless, articles on technological innovations or upcoming professional events are also present. The site offers the possibility to subscribe to newsletters. The company Huercasa plans to set up a platform gathering technical information on their products (origin, applied phytosanitary treatment, quality control checks, etc.).

Unlike the mobile phone, the use of these generalist tools requires one to be literate and have some know-how about the basic functions of a computer. These ICTs are particularly usual for short circuits in advanced socioeconomic contexts. Long circuits also use them, whereas their presence is much rarer for traditional retail markets [21].

2.3. Specific Software to Optimize the Internal Logistic of Companies

Degrees of complexity differ one from the other in this category. For short circuits in advanced contexts, inventory management and order preparation can be done using spreadsheets. The most advanced short circuits are able to use specific software for the inventory and order preparation functions, or to borrow the Transport Management System (TMS) from their Agricultural Equipment Utilization Cooperative (CUMA) according to [26]. For circuits where the flow of merchandise is larger, a hub or long circuit, the use of software such as ERP (Enterprise Resource Planning) or WMS (Warehouse Management System) is usual.

ERP mainly supports companies in tracking orders. It collects all the data relating to a commodity from entry to exit. It is used to trace the products and to list the different transactions for each customer. Thanks to the data collected via ERP, some platforms enable companies to compare themselves with others. The digital pallets management system PAKI is a simpler tool. For each transaction, the parties indicate on their online account the variation of their pallet stock. The operations described by e-vouchers indicate a credit or a flow of pallets. The company picks surplus pallets up from customers for redistribution and offers the replacement of damaged pallets.

Warehouse management system (WMS) software is designed to optimize pallet storage in a warehouse. It also states which pallets are to be removed first, on a “First In–First Out” basis, for example. Today, with the replacement of humans by mechanization, WCS (warehouse control system) software is developing. It directs the activity in real time within the warehouses (Source: KLS Group).

New tools to optimize internal organization are continuing to emerge. The “Easy Check In” smart terminal smooths and optimizes delivery truck traffic in warehouses [27]. The reception desk at the entrance of the warehouses is comparable to the warehouse’s secretary. It identifies incoming trucks by scanning their license plates and tells them where to stand on the dock while waiting for their turn to load or unload the goods. Before the truck leaves, it directly prints the administrative documents that the drivers must sign after their operations. The “ZetesOlympus” platform provides a real-time panorama visibility to the distributor throughout its supply chain [27][28]. Alerts are given to anticipate any disruption to product availability. This platform is particularly relevant for entities with many partners. The Marks & Spencer group, which has numerous suppliers and logistic partners, employs this platform to monitor the supply chain of its fresh products [28].

The abovementioned software programs are helping companies optimize their logistics activity. Because of their high price, small and medium enterprises employ basic, cheaper software (such as office suite tools) instead. As expected, the larger the agrofood companies, the greater the use of ICTs [29].

2.4. ICTs to Manage Conflicts

The technologies presented in this section help long-chain companies in functions facilitating and accompanying transport. This is called “litigation management”, or proceedings for insurance covering goods, such as claim declarations or following up a refund. In this sector, the most frequently encountered disputes concern sales and transport. These specific ICTs are present in long circuits of advanced socioeconomic contexts.

Some platforms allow actors to choose partners on an informed basis. For example, “Blue Book Services” is a directory of professionals that indicates whether the listed members have ever been involved in commercial litigation. The Blue Book Services structure and Fruit Insurances Services also offer legal support to their clients. They guide applicant clients to lawyers specializing in transport law, or with knowledge of the fruit and vegetable sector.

Other instruments are used to track the course of products along the chain, and then enable more effective management of conflicts. “BlockChain” emerged for this purpose, as a collaborative process [30] that stores information across the entire supply chain. It tracks the commodities via a variety of information, such as the origin of the products and the operations carried out by the different actors. Conversely, today the majority of information is still circulating in paper format. The search is therefore long and the information provided is not uniform between the actors. Blockchain is also allowing the fresh fruit and vegetable sectors to act faster in the event of an incident, by facilitating access to information [30]. Due to the multiplicity of servers involved, it is almost impossible to erase or falsify information. This would require changing the data on each server in the chain. The information flows through the QR and RFID codes that follow the products. At each step, the actors report their operations via this code [31]. Scanning the code with a smartphone allows anyone to access data. A variety of information is provided in the case of fresh fruit and vegetables. First, there is technical information on agricultural products. Blockchain, developed by IBM and Walmart on tomatoes, records the maturity of food products, their color and their sugar and salt levels. Agricultural sensors on the plots help collect this information as early as the production stage [32]. The same tool can also quickly authenticate labeled foods. It certifies that the product is compliant with the specifications—for instance, certifying that a grape belongs to a particular region (“terroir”), guaranteeing the authenticity of a wine or champagne [32]. Finally, the Blockchain can record economic transactions between actors. It is easier to bring in new information (such as a new supplier or new contractual arrangements). The data are often coupled with an ERP [33].

Managing conflicts is also the main purpose of positioning sensors in containers (with a USB port that can be stuck in the container or hold of an aircraft). By recording at regular intervals the temperature, the ethylene concentration or the hygrometry, it is possible to detect at what moment of the journey the problem occurred. Several product lines exist. The most successful models also record photometry, geolocation or shocks suffered. A peak of light intensity corresponds to the opening of the container during the trip. This event can potentially alter the storage conditions during transport. However, the place of the sensor in the container can influence the results. Pelletier noted temperature differences of up to 5 °C in the same container [34]. At the end of the trip, the data is read by connecting the sensor to the USB port of a computer (live tracking of the claims is possible from computer, tablet or smartphone). The results appear in PDF format, which makes it impossible to falsify the data. An alert message reaches the partner when the file is opened. The system forwards a link to the partner so that they too can access the data. In some countries, lack of GSM or 4G networks makes the use of land tracking in real time impossible [35]. Other companies offer simpler sensors that change color when the temperature is out of compliance. They can also give an idea of the duration of temperature noncompliance. This is especially valuable in large developing countries (like India) where the cold chain is under construction [3].

Finally, some short circuits also use sensors to ensure compliance with the cold chain. The platform “Péligourmet”, which facilitates the delivery of goods from short circuits between individuals, uses “cool chips”. Stuck on the products, they turn red if the product has spent more than a minute outside the cooler [36].

2.5. Collaborative ICTs

Innovations based on collaboration have emerged in recent years, and some are supported by ICTs. Collaboration is defined as “when two or more companies share responsibility for pooling their planning, information on their performance indicators, managing and building their supply chain” [37]. Certain ICTs facilitate use of collaborative devices [9].

2.5.1. In Long Chains

With a view to collaborative work, CAD (computer-aided design) type software has emerged. These computer-aided design techniques enable joint design of digital product models [29]. Based on the complementarity of the needs of different actors, they provide the supplier and the recipient with storage space in warehouses and cold rooms [38]. In addition, recent months have seen the emergence of numerous partnerships between retail and logistics companies. For example, Walmart and JD, a retailer and an e-merchant, have put together a common inventory system. When an order is placed, the nearest warehouse containing the commodity is located. It may be a Walmart or a JD warehouse [39]. Other alliances have also emerged with actors specializing in urban logistics. “Carrefour” launched a partnership with “Stuart”, while “Intermarché” has opted to use “Shopopop”. In the former case, individuals make the delivery by bike. This is the same operation as for takeaway delivery [40]. Conversely, Shopopop offers delivery between neighbors. A customer shopping in-store could deliver, on their way home, another individual’s order [41].

3.5.2. In Short Chains

On the same principle as the CAD mentioned above, actors share text documents or spreadsheets using collaborative solutions such as Google Drive. In the case of the La Louve grocery store, the tools can also be modified online by several members, and collaborating members use it to jointly place orders with suppliers [25].

Lacombe described in his thesis dissertation the “energy inefficiency” that short circuits in France had to face because of the nonpooling of production factors. Cold rooms and trucks are used individually and often do not reach their maximum capacity [26]. Route optimization of the logistics can improve efficiency up to 90% as experienced in Sweden [42]. Recent years have seen the emergence of two devices enabled by the ICTs to make up for this deficit. The first is called “Agriflux”. It specializes in the management of logistics activities for farmers with short selling circuits to retailers. It has a platform listing the farmers’ products. Merchants can select them and place their order via this tool. The company will pick up the goods from the farms. It will store and prepare orders from its logistics platform before delivering them to the retailers. The second, called “La Charrette”, pools only the transport of commodities. It stems from the same principle as the carpool platform “BlaBlaCar”. Users post or search for trips to transport their food [43].

Simpler digital platforms reappear regularly to pool the farmers’ production—in most cases the producer group’s website. Farmers specify the nature of the products they are selling, the quantities available and the price. They can also provide a description of the commodity. Because the platform includes an online catalog, some websites prompt customers to order directly online [25]. In some cases, customers can also raise their expectations about the contents of the baskets. A third party will then be responsible for reconciling supply and demand for picking the baskets. In the association “La ruche qui dit oui !”, this third party is a consumer who plays the role of coordinator. Payments are made on the online platform. As a result, billing and customer tracking activities run through the platform. Once an order is placed via the online platform, the farmer can be notified by e-mail. The association “Eat-Farmer” (France, Haut-Rhin) too has a similar process. An ICT tool synthesizes the orders and facilitates their preparation.

2.5.3. In Traditional Retail Markets

The lack of market information likely hinders traditional retail market actors. Data that are lacking include commodity prices demanded by the upstream segment, export prices, volumes supplied, product quality, or transport price [21]. Since 2009, a mobile-phone-based platform has been in place in Vietnam. Through an SMS system, the identified actors can enter the selling prices, consult the average price of a commodity, or the prices applied by a given actor.

3. Difficulties for ICT Adoption

The literature and respondents agree about the main difficulties to adoption of ICTs, mentioned as misunderstanding of ICTs (Section 3.1), issue of confidence (Section 3.2) and cost (Section 3.3).

3.1. Misunderstanding of ICTs

From the literature, the main obstacle to digital technology is misunderstanding of ICTs [6][35][38]. Fear of change and misunderstanding a concept can prevent the implementation of an innovation. The lack of understanding of the Blockchain concept thus remains its main drawback [38]. ICTs that are easy to access and use encourage adoption. This is also true for short circuits or traditional retail markets where players may be less comfortable with new technologies [25].

From the interviews, in some developing countries, there are large fresh fruit and vegetable businesses that do not use the internet every day, even if they have access to the web. The respondents think that this hinders the circulation of information between the actors and especially the distribution activity more comprehensively. For ICTs in developing countries, the low literacy rate of the population hampers some usages [22].

3.2. Confidence and Defiance

Specific to the logistics sector, the current “paradigm of ownership” hinders the development of collaborative tools [44]. Companies that have made significant investments in their production factors are not keen to share [38]. The Stock-Booking company, which connects warehouse space suppliers and recipients, notes that many members of the sector are reluctant to adopt the concept. In addition to the organizational inconvenience this may cause (too frequent recovery of food products can alter the cold chain, contamination between products, etc.), lending space and indicating the filling percentage of its warehouse still hinders business players. This information may be confidential. The historically rather bad relations between distributors and suppliers also make them reluctant to collaborate [45]. This attitude hinders the entire supply chain. Many companies delivering food, especially in cities, create maps where they list information. They can indicate their locations, their clients’ addresses, or other informal information, such as places often available for parking. Because of the sensitive information they carry, the cards shared with competitors are highly simplified. A collaborative map, where everyone would indicate information and be able to access data of other users would be of much better quality [35]. Interviews revealed data maintenance problems. The issue most often recorded relates to information storage systems. In general, companies use their own storage systems to manage information [46]. The information tracking the same product is therefore split between the various systems of the different actors. The solution might be to integrate these databases in order to design shared databases. However, changes of tools or operating systems may encounter the problems of confidence mentioned above.

Paradoxically, collaboration is easier to implement horizontally than vertically. The cases of “coopetitions” [47] are numerous and can be found in the various circuits. Long-circuit wholesalers can exchange their goods, and collectors can purchase for their peers [21]. As explained above, vertical collaboration is more difficult because historically the relations are strained. This is mainly due to long and difficult price negotiations [45]. Some large groups use questionable bullying strategies to obtain the lowest prices [48]. It is obvious that one must start by maintaining good relations with partners before thinking about sharing potentially confidential information [49]. Confidence is a key for adopting certain collaborative ICTs, and therefore for building new core competencies supported by ICTs.

3.3. Cost of Digital Transition

The fear of change, a brake for human behavior, can also be associated with economic brakes. The adoption of new technologies can be costly [50]. It may be difficult to adopt new tools when one has adopted another technology, which was the technological optimum at a given moment. “Path dependency” generates high transition costs [51]. People in the company (or even in the whole supply chain) have trained to use the past technology, while the facilities and time schedules are adapted to this past technology. As a result, not only potential benefits but also likely important costs are associated with replacing an old tool with a new one. It is the main obstacle to implementation of ICTs identified by [52] in the UK survey of SMEs. The inception of the new tool often entails a period of low activity in the company, to avoid the failures caused by learning new techniques too quickly. However, in the fruit and vegetable sector, business moves at a frenetic tempo, and rarely offers such breaks. Managers have to weigh costs and benefits against adoption of new technology [53]. Moreover, research and innovation are expensive for a company, and firms do not necessarily want to share their results [35]. Sometimes, regulatory issues are triggers for digitalization of companies, but they can also work against it. In some cases, managers choose an innovative system which proves obsolete because of the next regulation, with a huge financial loss for the company.

Accordingly, regarding the less developed countries, the adoption of new digital tools seems easier when starting from a low technological level. For example, South Africa has experienced almost directly 4G without going through the telephone network. The country has thus directly acquired advanced technologies, and tends to be more inclined to adopt new technologies [54].

From interviews, some places in developing and in developed countries are not equipped for cost reasons. Thus, part of the course occurs in places where there is no 4G, which penalizes the collection of information of trackers in real time.

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