DESC – Digital Evolution of Supply Chains

IT in Food & Supply Chain*

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Abstract

This paper investigates how emerging information technologies can improve the food supply chain management. There is a wide range of innovations that businesses and consumers are looking forward in the agro-food industry: sensors providing more accurate data; visualization and predictions of farming conditions; autonomous monitoring and interventions in farming and food production processes; highly integrated communication from sensors to tractors to processing and logistics infrastructures; monitoring and control systems to inform and assure consumers about food safety and sustainability.
We will analyze how the concepts presented above could affect each step of the supply chain, and the potential impact on the business organization.

Purpose
Our work aims at investigating how IT can modify the current supply chain-managing processes in food industry. By observing different contests (such as the "smart farm"), we want to examine how the actual organization could change and the potential social impacts that can be arisen by these changes.

Design/Methodology/Approach
This paper starts with a definition of IoT and Big data and their actual pervasiveness in the industry. The second section discusses the potential application of technology along the Supply Chain Model (SCM) focused on the food industry, and what projects are running. The third section describes the impact of IoT and Big Data on the supply chain management. Conclusions and limitations are drawn on the impacts brought by technologies adoption discussed above. The research paper uses different methods that include a review of the existing academic literature, using journal articles and sources from different databases.
Different case studies and ongoing projects are then analyzed in order to figure out the possible future in the food industry and possible benefits and/or problems are then evaluated considering the technical aspects and the possible social impacts (e.g. small farms can disappear, food sector controlled by few multinational

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enterprises). Furthermore, the work aim proceeds in a bottom-up logic to explain implications and changes in Supply Chain context.

Keywords Internet of Things, Food factory, Supply Chain, IT, Big Data, Smart farms.
Paper type Research paper

Summary

1. The Technologies

1.1. *What "Internet of Things" is?*

The idiom "Internet of Things" (IoT) is not a new concept. It was coined for the first time in 1999 by a British technology pioneer: Kevin Ashton, assistant brand manager at Procter & Gamble. IoT is a complex emerging phenomenon that involves technologies and methods; it refers to the internet extension on objects and places. In 2007, he deepened the meaning of his neologism:

"If we had computers that knew everything there was to know about things – using data they gathered without any help from us – we would be able to track and count everything, and greatly reduce waste, loss, and cost. We would know when things needed replacing, repairing, or recalling, and whether they were fresh or past their best.
We need to empower computers with their own means of gathering information, so they can see, hear and smell the world for themselves, in all its random glory. RFID and sensor technology enable computers to observe, identify and understand the world – without the limitations of human-entered data ."

Later, in 2012, Rand Europe attempted to define "Internet of Things" through a research report to the European Commission. The report states:

"The Internet of Things builds out from today's internet by creating a pervasive and self-organising network of connected, identifiable and addressable physical objects enabling application development in and across key vertical sectors through the use of embedded chips, sensors, actuators and low-cost miniaturisation."

Both definitions are valid and connected: in fact, Rand annexes "physical objects" to the previous idea of "empowered computers". In other words, the "Internet of Things" existence is not strictly related to computers. As matter of fact, IoT could involve every object, even the human body, if they are equipped with some specific technological devices such as embedded chips and sensors. This is the result of the continuous development in the electronic field, which allowed to have a doubled number of transistors in a dense integrated circuit every two years (Moore's Law). Therefore, costs for miniaturization decreased steadily, favoring the use of devices with improved computational performances. Thus, those devices can be distinguished into two wide categories:

1. Sensors, able to capture data from the environment
2. Networks and Standards, to transmit and aggregate data.

Therefore, the two main electronic elements of Iot are sensors and connection.

The following table depicts an “Internet of things” model.
(Source: Cambridge Consultant)

The Internet of Things is enabled by

Generates Data	**Data are digitalized and placed into network**	**Actionable and meaningful information**	**Digital Services**
SENSORS	**CONNECTIVITY**	**ALGORITHMS**	**VALUE ADDED SERVICES**
Position/Presence/ Proximity	**Bluetooth**	**Customer relationship & support**	
Motion/Velocity/Proximity/	**Bluetooth Smart**	**Analytics & cloud**	
Temperature	**Mobile Connectivity**	**Upgrades & Configuration**	
Humidity/Moisture	**Wi-Fi**	**Remote Monitoring /Maintenance**	
Acoustic/Sound/Vibration	**Zigbee**	**Control & Automation**	
Chemical/Gas		**Supply Chain Management**	
Flow		**Security/Energy**	
Force/Load/Torque/Pressure		**Mobile devices & Apps**	
Leaks/Levels		**Locations & Tracking**	
Electric/Magnetic		**Financials**	
Acceleration			

The explosive growth of mobile devices and the wide availability of wireless connectivity are the two main factors that drives IoT as a global phenomenon. Indeed, society and industries are strongly affected by this powerful force.
According to Gartner Inc. forecasts, 25 billion of connected objects will be operating in 2020. Gartner estimates that IoT will support total services spending of $69.5 billion in 2015 and $263 billion by 2020. The following table shows the IoT units installed in 2014, base by category (Source: Gartner November 2014).

Category	2013	2014	2015	2020
Automotive	96.0	189.6	372.3	3,511.1
Consumer	1,842.1	2,244.5	2.874.9	13,172.5
Generic Business	395.2	479.4	623.9	5,158.6

Vertical Business	698.7	836.5	1,009.4	3,164.4
Grand Total	3,032.0	3,750.0	4,880.6	25,006.6

However, digital sensing, computing and communications capabilities allowed the development of new devices and the modernization of many ordinary objects. Consequently, such progresses have an effective influence on the market. They also reflect on global business and drives it into a transformation in order to create new services and usage scenarios.

1.2. *What "Big Data" is?*

The idiom "Big Data" cannot be defined in a unique and precise way, however it can be considered as a huge amount of uncorrelated and not formatted data coming from the most different sources such as sensors, apps, social networks, etc.

Doug Lanely, a Gardner analyst, in a 2001 report, explained Big Data as "high-volume, high-velocity and/or high-variety information assets that demand cost-effective, innovative forms of information processing that enable enhanced insight, decision making, and process automation".

It has been known as "three V definition":

- Volume: high quantity of data coming from the observation and tracking of what is happening, it does not sample;
- Velocity: real-time availability and data processing;
- Variety: Big data can be unstructured data (images, audio, video etc. from the text, or structured data;

This new model differs from Data Base Management System's one (DBMS), because of variety: it can be considered the real innovation.

Afterwards, two other "V" were added to the previous definition:

- Variability: data inconsistency can hamper processes to manage;
- Veracity: the quality of captured data can vary greatly, affecting accurate analysis.

According to our opinion, the definitions above describe only the most evident characteristics of Big Data; nevertheless, the enabling technologies which allows the availability of them are:

- Storage: storage architecture is a vital factor, due to the large amount of data (order of magnitude petabytes: 10^{15} bytes). Classic storage systems such as "Storage Area Network" could not be enough capacious and performing in order to support huge records volume, therefore cloud technologies are developing;
- Communication: high band communication lines are required, due either to dimension of information and velocity of data changes;
- High performance processors: necessary to analyze data, extract, select as well as contextualize insights and decision making through analysis (descriptive, predictive and prescriptive), augmented intelligence and augmented behavior.

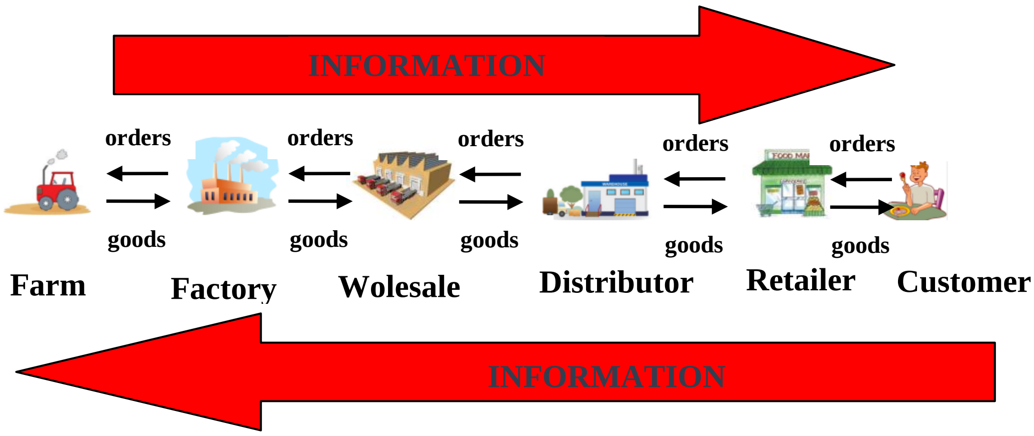
2. The Agri-Food Supply Chain & Supply Chain Management

2.1. *The Model*

An Agri-food system is influenced by social, political, economic and environmental context and subject to critical factors, which could increase the complexity of this kind of business:

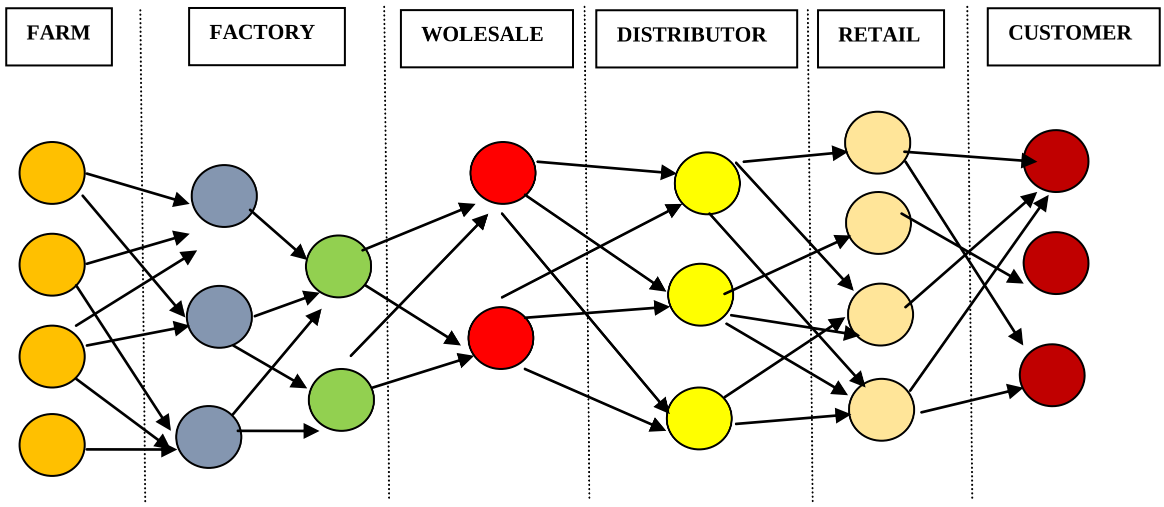
- Seasonality: unpredictable variations such as conditions of weather and pestilences could not allow to provide exact information of quality and quantity of supply, affecting forecasting for flexibility in logistic processes;
- High perishability of fresh products, affect transportation, special storage and delivery lead times;
- High flow and network structure complexities, due to the combination of continuous and discrete product flows which require an advanced traqcking for logistic planning;
- The role of import/export, affect SC process to respect the minimum standard;
- Complex network structure where demand meet suppliers (small, medium and multinationals enterprise), require regional logistic orchestration to manage main ports and granter better allocation of supply;
- The huge products variety and consumers preferences make the planning process more complex.

In this section, we look at the Agri-Food supply chain (ASC) as a domino-like motion. To be precise, a sequence of procedures (i.e. decision-making and execution) and flows of materials, information and money from farm to fork. ASC describes how food is shipped from a farm to our tables, in order to meet customer requirements. A simplified macro model of the ASC is depicted in the following figure:



Nevertheless, in the real world this model is more complex and fragmented.
In an increasingly globalized market, we notice a growth in relationships and connections between ASC actors. For instance, several farms supply food to several transformation factories, these are suppliers of several wholesale and distributors.

The picture below shows the increasing in the complexity.



The model discussed above is applicable to only to big firms operating in a globalized market; those are mainly located in USA and South America.
European situation is quite different: there are few big firms operating in the global market and a great variety of small-middle size farms and factories, often grouped in farmers' cooperatives. In addition, a social phenomenon known as "Customer Associations" is growing up, especially in France and Italy. Those associations (GAS in Italy for instance) are growing up more and more, asking for fresh products at a cheaper price. Due to the continuous increase in demanding safe, healthy, high quality and environment friendly products on one side food industries are facing great challenges in order to meet consumer's needs.
On the other side, small and medium farmers look at this social phenomenon as an alternative market, as a valuable opportunity to survive against the big firm competition. As a result, it is possible to distinguish two different logistic flows:

- Direct relationship between farm and customers, the so called "face-to-face supply chain";
- Short supply chain: retailer's position is between the farm and the customer.

In the second case, the agro-food short supply chain (ASSC) can be considered as a supply chain of maximum three level of complexity (farm → retailer → customer). This definition has been adopted and regulated by the French legislation as well as the Italian one; some actions are in place in the European Commission.

2.2. *Governing the Complexity*

The complexity of the global supply chain model discussed in the previous chapter need to be governed; supply chain management (SCM) could be the right answer.

SCM can be defined as the whole processes, together integrated, which are needed to meet customer requirements with goals of efficiency and profitability. It is an efficient and effective way to govern the complexity of the agri-food system**.** In the Agro Supply Chain Management (ASCM) sustainability should be considered as an additional goal. Three processes are extremely important in ASCM, planning, logistic, compliance with the international standards.

Planning is certainly the most vital process in order to achieve accomplishment in governance of the ASCM. The key factors should be summarized in two words, cooperation and integration. Cooperation means that all the actors of the ASC must be involved in the planning process; integration instead means that the planning process must include forecasting and scheduling to aim effectiveness.

Traceability is the second main procedure; it allows to be accordant with the international and local guidance.

Logistics is the third most important process in ASC: actually European committee estimates that the food transportation represent the 20% of the traffic on the European roads.

3. IT Impact in ASCM

Farming has multiple obstacle to overcome; the first one is producing enough food to support growing population. Once explained what are IoT and Big data and what a Supply Chain Model is, we now analyze as a final point how IT could influence and improve SCM in Food Sector.

Integrate technology to increase productivity without losing the quality of the products, is a top priority. Big Data technologies can greatly improve the integrated ASCM; a huge amount of data is generated all along the whole supply chain, from fork to farm and vice versa. Predictive and analytic algorithms must process all these data in order to produce an accurate forecasting of the total demand and, as a consequence, an efficient planning of the whole ASC. The main consequences would be the greater effectiveness, saving of resources and increasing sustainability.

The farm level of the ASC should be heavily affected by IoT and automation technologies, as mentioned in Bayer and Texas Agriculture Law Blog. The use of drones to supervise the work of automated agricultural machinery, sensors to control the health of cultivations in order to reduce chemical treatments assuring at the same time a strength traceability, sensors to plan the use of water, reducing the waste of this important resource, is not a future scenario, but a close reality.

Customer, in the last decades, starts to give more attention from where the food is coming, and may country many countries have enacted more or less stringent laws to guarantee the food quality and origin. Expo 2015 has called attention on food security and sustainability as well as environmental, social and economic. Moving one item from one place to another is expensive; the complexity increases if this product could be compromise for physical and environmental stress. Researchers are developing new technologies, methods and devices in order to control and manage products handling with the respect of both quality and efficiency. IoT is already integrate in the majority Supply Chain to track products. Radio- Frequency IDentification (RFID) allows the traceability of the product as quoted in “Study on the Factors Effect of Adopting Application in Agricultural Products” article.

Agricultural market would be purified thanks to strengthen quality control, and to the control of import and export channels.

Knowing location and state of the vehicles, temperature etc., being able to adjust driving direction are the basic functions of a GPS system integrated in the transportation stage,

At the same time, installing wireless data acquisition system on the vehicles can detect and prevent the lost and stolen goods, but also learn the basic information and quantity of the goods.

The application of IOT in the sale stage consists of security and monitoring forms. For instance, on one side, farmers can determine if a product is expiring, thanks to the production date or EPC tags, and judge its quality. In addition, producers can find the final consumer by traceability RFID. On the other side, customers will face directly producers and eliminate fake products from the market.

These devices could strengthen quality control systems and help a new configuration of a more efficient food supply chain in terms of management and query.

A great number of projects are now ongoing all over the word both managed by huge firms as well as by international organizations; the picture below illustrates, for instance, a prototype of a robotized spray machine, controlled remotely.

In particular, EU has a large number of project related to logistics and ASCM integration. The following table illustrates some of the projects sponsored by EU:

Project Title	Project Acronym	Programme	Start date	End date
Evolution of agro-food production systems		FP6-JRC	2003	
Quality, safety and value optimisation of the milk supply chain in rapidity evolving Central and Eastern European markets	OPTIMILK	FP6-FOOD	2003	2004
E-platform technologies for the European agro-food supply chain	E-MENSA	FP6-FOOD	2005	2006
GM and non-GM supply chains: their CO-EXistence and TRAceability	CO-EXTRA	FP6-FOOD	2005	2009
Developing and integrating novel technologies to improve safety, transparency and quality insurance of the chilled/frozen food supply chain	CHILL-ON	FP6-FOOD	2006	2010
Safe and high quality supply chains and networks for the citrus industry between Mediterranean partner Countries and Europe	EUROMED-CITRUSNET	FP6-FOOD	2006	2008

European mountain agro-food products, retailing and consumers	EURO-MARC	FP6-POLICIES	2007	2010
Secure supply chain management	SECURESCM	FP7-ICT	2008	2011
Impact of climate change and globalisation on safety of fresh produce governing a supply chain of uncompromised food sovereignty	VEG-I-TRADE	FP7-KBBE	2010	2014
PRactical Implementation of Coexistence in Europe	PRICE	FP7-KBBE	2011	2014
Retailer and Consumer Acceptance of Promising Novel Technologies and Collaborative Innovation Management	RECAPT	FP7-KBBE	2011	2014
Food Planning and Innovation for Sustainable Metropolitan Regions	FOODMETRES	FP7-KBBE	2012	2015
European Platform Driving KnoWledge to INNovations in Freight Logistics	WINN	FP7-TRANSPORT	2012	2015

3.1. *ASCM In Italy: new logistic projects*

ORTOFRULOG is a logistic platform for national foreign markets that handle vegetables and fruit. The project is sponsored by the Italian Ministry of Agriculture and the idea is developed by an ICT-based with the intention of improving competitiveness of common products, environmental protection, and better cargo use and, maximize customer satisfaction. Aimed at reduce delivery times, hardware and software technologies are standardized in order to consent a correct monitoring. Real-time recording of the critical parameters permit to have information for traceability during productive chain, monitoring storage of products respecting hygiene rules to fight against waste (failed deliveries) that have a direct consequence on the costumers satisfaction.
“Travelling Warehouse” is a project sponsored by the Italian Ministry of Economic Development and University LIUC Carlo Cattaneo: it played a primary role in developing a new logistics model, transport units and opening an interoperable platform. This kind of system agree to reach a high level of efficiency through collaboration during chain.

3.2. *ASCM in Germany: a modern farm*

The agricultural farm in Germany, “Gut Derenburg” in Saxony-Anhalt, is most modern agricultural complexes that using IT and IS to collect huge amounts of data. The quality of the soil is analyzed with drones’ pictures. Nevertheless The farm does not bases only to drones’ picture: it build up self-driving tractors by means of transmitting system for working with more precision than normal GPS-System with accuracy of 2cm. From these implementations, there are some advantage and disadvantage. Advantage are, for instance: decreasing of petrol use (from 20% to 10%) and decreasing herbicides used in order to obtain better quality of the food. For small farmers a disadvantage is that their job could be replaced by machines.

3.3. *ASCM in Spain: Big Data against wastes*

Bynse, a Spanish startup, develops technology solutions in farming aimed at optimize resources by reducing electricity, phytosanitary products and water. It take advantage of Big Data algorithms used for control all the stages of processes, and aids to prevent plagues in real time or reduce the impacts of the weather conditions, like frozen, heavy rain, and other meteorological factors. The Data are collect with some basic and not expensive sensors like pluviometer, sun radiation sensors and anemometer. They are shared by, Wi-fi connection every 10 minutes meant for monitoring possible changing in field or weather. If it is happen, some Alert Messages are sent by using Social Networks (Twitter, Facebook).
This system has the advantage of saving more than 40% of water in a Jaén olive fields company. The collected information are used to undertake better decision for intervention on the field, but some disadvantage are born. One of these solutions is not available and affordable for all sectors because rural areas have not Internet access.

4. Some Considerations

For each possible advantages, there are many downsides

- Technology accessibility – The costs of the technologies could be prohibitive for small-medium farmers; as a consequence they have a continuous loss of competitiveness against big firms as Monsanto, Bayer, Syngenta etc., ;;
- Education – The use of such technologies implies a growth in the level of the farmer culture;
- Digital gap – IoT and Big Data implies communication infrastructures able to support a wide traffic of information; rural areas are often out of the development programs of telecommunication companies;
- Security – A huge flow of information means a huge problem in security. For

5. Study Limits

This study collects huge information about a sensible topic for all European and non-European country. It is reasonable from large data and articles that is possible to find in databases. For this reason, according to the EuroWeek 2016 limitations, we choose to analyze some topics rather than others. These choices can affect the studies in a hazardous way; definitely is possible to lose some important information that could give better explanation and motivations on agro food supply chain movement towards IoT and IS direction and on the reason why this moving is central for a future social and economic impact. An example of this possible loss of information is verifiable in the SCM: we have just reported a Short Supply Chain without a deep detailed analysis of the topics previously mentioned. In this paper is possible to integrate a specific analysis about how IoT is evolving in a definite country with the reference to the concerning issues and/or resources. In the real cases presented about Italy, Germany and Spain, it is possible to find some points of connections on how IT are employed and which benefits they could provide. However, the implementation and the solution for a specific problem that could emerge from society's thought are very different.

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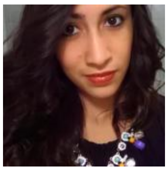

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