New Classification Framework of ICT Deployments in Supply Chain

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Abstract

This paper aims at proposing a new framework for the classification of ICT deployments in supply chain management. The framework encompasses several different use cases pursued by supply chain managers in the last decade including: Automated warehouse management, automated transportation management, anti-counterfeit, anti-theft and product's quality monitoring. We carried out a comprehensive literature review on ICT deployment in supply chain management, structured the new framework along categories and performed a critical analysis of deployment success as well as benefits achieved. From a practitioner's perspective, the framework offers a comprehensive and well-structured overview of ICTs implementation potentials in the industry. Researchers on the other hand, may use the framework to identify opportunities for further research regarding ICT deployments in supply chain.

Keywords

Supply chain management, ICT deployment, barcode, RFID, WSN, GPS, Indoor Positioning System, integrated RFID and WSN, use cases.

I- Introduction:

Supply chain management refers to "having the right item in the right quantity and condition at the right time and place for the right price and to the right customer" (S. Malik 2010), However, due to the complexity, uncertainty and other factors involved, most of supply chains are facing many supply/demand mismatch problems such as: overstocking, stockout and delivery delays, which have long been popular research topics in the business management literature (Wong et al 2012). To deal with the increasing challenges, supply chains must take advantage of improvements in such areas as computer sciences, communication and localization technologies, MEMS-based small sensors and actuators, web services, together with the enterprise resource management to achieve visibility of products and operation processes across supply chains (Sara El ouadaa et al. 2015). Product visibility is achieved by tracking and tracing the product throughout its lifecycle, using a variety of ICT technologies, like barcode, RFID, GPS, sensor networks and communication technologies. Supply chain tracking is the ability to follow the location, quality and processing of a product downstream the supply chain. Tracing, on the other hand, is the ability to ascertain the origin, path, history and integrity of the product upstream the supply chain. Tracking and tracing are complementary activities and they aim at reducing supply chain problems related to lack of visibility.

To date, there exist many ICT architectures and deployments in supply chains. Some have been simply proposed and possibly prototyped in the literature while a few others have actually been deployed by the industry. They do not always satisfy the same set of requirements. Therefore it is relevant to seek to determine and characterize the use cases as well as the similarities, differences, advantages and disadvantages between different deployment configurations and designs. This paper proposes a new framework of classification of ICT deployments in supply chain management. It is organized as follows. Section 2 presents the related work, section 3 determines our framework parameters (ICT deployment factors and services requiring ICTs deployment), section 4 presents and discusses the results of the classification and section 5 concludes the paper.

II- Related Work:

Frequently, innovation in information and communication technologies has shaped supply chain business dynamics; accordingly researchers have paid significant attention to factors that influence the organizational adoption of innovative ICTs. In 2009 (J. J. Roh et al 2009) proposed a classification of RFID adoption through its expected benefits (cost saving, supply chain visibility and new business process creation). (A. Musa, A. Dabo 2016) reviewed the RFID applications across supply chain management over the previous decade, reporting its benefits and challenges. In 2014 (A. Musa et al 2014) greatly analyzed some new recent supply chain visibility systems(EPC network, Microsoft BizTalk, Sun Java System and SaviTrack), it compares its design, choices and results according to four factors (technology, tagging/tracking level, level of product intelligence and the location of intelligence). To the best of our knowledge we have found only three papers in the literature with an attempt to categorize ICT deployments in supply chain. Although two of them are talking about RFID technology only, and the third one is specific to some known visibility systems. Our framework instead encompasses several use cases in order to categorize theme according to a two dimension classification. It separates the use cases in a way to distinguish between innovative supply chain services and the corresponding ICT configurations.

III- Presentation of the classification framework:

Our framework aims at proposing a two dimension classification of ICT deployments use cases. It categorizes them under both the corresponding business services and the related ICT deployment factors. Each use case is carefully analyzed to determine which services it handles and what ICT parameters it uses.

1- ICT deployment factors:

ICT deployments are made up of hardware and software components. It usually includes a data capturing frontend, a middleware for pre-processing the data and a backend module for information analysis, exception handling and decision making. Inspired from (A. Musa et al 2014), we propose the following factors that may be used to distinguish ICT deployments:

(a) Data carrier technologies (barcode, RFID, WSN, GPS, sensors). (b) Communication technologies (GSM, GPRS, Ethernet, Wi-Fi, Bluetooth, Zigbee). (c) The system parameters (auto-ID, location, temperature, humidity, pressure, states of motion, smoke, light, time). (d) The locations of data capture points (mobile, fix). (e) The depth of identification (Item level, case level, pallet level, shelf, forklift, vehicle, staff, warehouse). (f) Type of RFID tags (passive, semi passive, active). (g) Indoor positioning system (WSN based IPS, active scheme of RFID based IPS, passive scheme of RFID based IPS). (h) Integration forms of RFID and WSN (integrating RFID tags with sensors, integrating RFID tags with wireless sensor nodes, integrating RFID readers with sensors, integrating RFID readers with wireless sensor nodes and software integration). (i) Where the product's information is stored (product itself, backend system).

Researchers like (H. Liu 2008), (Z. Xiaoguang, L. Wei 2008), (U. K. Vishwakarma, R. N. Shukl 2013), (Ms. Ashwini 2015) have presented three to four kinds of integration modes of RFID and WSN technologies, while we see that it can be classified into five types as bellow:

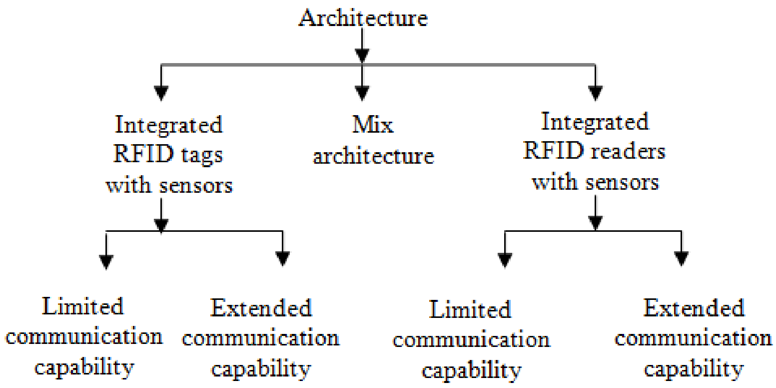

Figure 1. RFID and WSN integration forms

(1) Integrated tags with sensors (with limited communication capability) rely on single-hop communication; tags are used for identifying products, while sensors integrated on it are used for sensing information related to each product. The RFID tags with sensors use the same RFID protocols and mechanisms for reading tag IDs, as well as for collecting sensed data, because integrated sensors with RFID tags are used only for sensing purposes. This integration form is similar to the second form (2) Integrated readers with sensors (with limited communication capability) except this one aims to sense data about specific areas within reading range of RFID readers rather than specific products. The third form (3) integrated tags with WSN nodes have more powerful communication capabilities, in addition to identifying and sensing data about specific products, the wireless sensor tags are capable of forwarding the gathered information to any other node in the network. The forth (4) hardware integration is the combination of WSN nodes with RFID readers. The integration extends functionalities on both RFID readers and sensor nodes, the integrated readers are able to sense environmental conditions, communicate with each other wirelessly, read IDs from tagged products and effectively transmit this information to the system. The last form (5) is a mix architecture where RFID system and wireless sensor network both exist in a network and work independently. The integration performs in the software layer after receiving the data from both RFID tags and wireless sensor nodes.

Indoor positioning systems are based on some prior knowledge about position of special nodes, namely the anchor nodes, and aim at estimating position of one or more mobile nodes, whose positions are unknown, by processing data collected and exchanged by both mobile and anchor nodes. While in WSN-based IPSs, anchor and mobile nodes are normally realized using the same hardware and exchange ranging information in a peer-to-peer fashion; in RFID-based IPSs, two distinct schemes are instead generally possible: an active scheme where RFID tags are fixed and RFID readers are moving; which is used for locating the RFID readers, and a passive scheme where RFID tags are instead objects to be located while RFID readers are in known position (C. Wang et al. 2007), (M. Bouet, A. Santos 2008), (Li Hong-sheng et al. 2012), (A. Motamedi et al. 2013), (F. Kamoun et al. 2015).

2- ICT business services:

2-1 Operation based services:

2-1.1 Warehouse operations management:

The core warehouse operations revolve around the flow of materials in the facility, which are receiving, storage, order picking and shipping (J. Gu et al. 2007). Receiving regroups all the activities related to the receipt of products, verification of products against expected delivery (purchase order) and sorting of products by type. Storage consists of assigning storage locations to the received products according to their type, and checking them during put-away process (Tompkins et al. 2002). Order picking is the process of retrieving products from the shelves to meet the specific demand; it relies on checking the availability of products inside the warehouse, locating products near to be expired and assigning material handling equipment. Shipping includes checking order completeness, appropriate packaging, and loading the trailers (Tompkins et al. 2002). The following sequence of warehouse operations stands mainly on identification, counting, and indoor positioning systems.

Many warehouse managers think that they can greatly improve their operations by reducing the number of human touch points of the products in their systems (Twist, D.C. 2005). These warehouse systems suffer from inefficiency due to human errors resulting in reduced accuracy of inventory levels (e.g. miscounting received items), and increased labor cost. For example the receiving operation is highly time consuming, and labor intensive, involving more than one level of employee and, hence, a potential source of errors. Similarly, checking the integrity of the order before shipment is essential because the claims and returns are costly to process and settle, but it is also a lengthy and labor intensive process. Whereas mislocated items and/or incorrect inventory information leads to inefficiency of order picking.

An increasing number of automated warehouse operations systems have been observed over time, often accompanied by the adoption of information and communication technology (ICT) systems to enable immediate identification, counting and locating processes, and avoid nearly all the errors associated with manual operating (T. C. Poon et al. 2009), (L. Minbo et al. 2011), (K. L. Chow et al. 2014).

Automated warehouse operations are enabled by auto-identification (auto-ID) technologies. Auto-ID systems are also called automatic identification and data capture (AIDC) systems. Technologies typically considered as part of AIDC include bar codes, Radio Frequency Identification (RFID), biometrics, optical character recognition (OCR), smart cards, and sensor technologies. However, not all auto-ID systems are amenable to supply chain applications. Thus far only the barcode, RFID and Wireless Sensor Networks have been used for warehouse operations visibility (A. Musa et al 2014). RFID is helpful in reducing the errors at the receiving shipping docks. The product receipt/shipment can be automatically verified without even unloading from the truck or breaking down a mixed pallet load. RFID and WSN based IPSs provide accurate information every time about the products/ resources location, resulting in considerable savings in time to search and retrieve, then the travel time of the order pickers will be the only productive time.

2-1.2 Transportation management:

Operating transportation encompasses the management of vehicles, routes, drivers, and products handling using a variety of technologies, including vehicle tracking (GPS,GSM), telematics, and smart surveillance (F. Li, Y. Wei 2008), (D. Joche et al. 2015). Advanced fleet management allow driver behavior monitoring, fuel consumption estimation and tire pressure monitoring (D. Joche et al. 2015), fleet operators can also avoid vehicle theft with remote vehicle disabling systems (RVDS) (A. Abdelrahman et al. 2015) that can stop engines from starting, and stop or slow down moving vehicles. These systems use GPS technology to let operators know precisely where vehicles are located, significantly increasing the chances of recovering a stolen vehicle. Multiple intelligent transportation systems have been explored over time as summarized in Table I.

While in cargo tracking systems the ICT applications are limited to products loading, routing unloading and locating activities. This allows the logistics management center to know whether the products are secure and safe, whether the products are damaged or stolen, how many and what kind of products should be unloaded at destination and what is the real time geographic position of the vehicle during transportation. The cargo tracking systems in general require the setup of five units (L. H. sheng et al. 2012): 1) Sensing unit to automatically identify the tagged products and provide visibility of real-time events and environmental conditions, 2) localization unit to trace and locate the transportation vehicle, 3) Processing unit to perform signal analysis, command execution and logical judgments, 4) communication unit to transmit product tag messages, location messages or emergency rescue messages, and receives command from the remote monitoring center, and 5) A human machine interface to enable human and machine intercommunication; that could be a Smartphone, an LCD or a PDA.

Table 1. Summary of recent ICT applications in transport

Category	**Subject**
Bluetooth	Link between truck and trailer
GPS, WLAN	Container tracking systems
RFID	Automatic container identification
RFID	Tracking containers
RFID	Electronic seals
WWAN, GPS, GIS	Tracking and monitoring containers worldwide
GPS, WSN	Securing and/or tracking cargo containers
Zigbee	WSNs in refrigerated vehicles
WSN	Tracking system for containers in ports
WLAN, WWAN, RFID	System and method for asset tracking and monitoring
RFID	RFID tags in container depots
RFID, GPS, Sensors	Integrated tracking, seal and sensor systems
WLAN, WSN	Smart container monitoring systems
RFID	Monitoring electronic container seals
Zigbee	Mesh-network in cargo containers
RFID, WSN	«Smart packing», improve traceability

RFID, WSN	Autonomous sensor systems in logistics
GPS, GSM	Monitoring animals during transport
WSN, GPS	Tracking and monitoring nuclear materials

2-2 Products based services:

2-2.1 Anti-counterfeiting:

Counterfeiting is an illegal practice of manufacturing inferior goods for sale under a brand name without the owner's authorization. Medicines, fashion and cosmetic products are the most targeted to be tamper with, for example counterfeit medicines could contain wrong ingredients, wrong doses of ingredients, no active ingredients at all, or in worst case, they might contain harmful substances that can lead to illness or even death. Hence, there is an intense need to secure and authenticate pharmaceutical products in the emerging counterfeit product market.

Medicine packages only equipped with barcodes are not unique for each product and they are easy to copy (D. Taylor 2014). RFID tags, on the other hand, are unique for all items and significantly harder to copy or tamper with. In RFID-based track and trace anti-counterfeiting, each product item is attached with an RFID tag, to which a unique product identifier (PID) is programmed. The RFID tag becomes a physical part of the product item and can provide information regarding the ingredients source and quantity, manufacturing date, expiry date, and product's specifications (Weight, shape, size, color of pills…) (Z. Hamid, A. Ramish 2014). The movement of the product item in the supply chain can also be collected by RFID equipment and synchronized to back-end database in real time to form an electronic pedigree (e-Pedigree).The term ''e-Pedigree'' refers to the electronic history of a product item's life from the manufacturer to retailers (S. H Choi et al. 2015). Scanning RFID tag and analyzing the corresponding e-Pedigree allows the distributors, wholesalers, pharmacies and hospitals to authenticate and reject products with suspicious e-Pedigree.

2-2.2 Anti-theft:

Product's anti-theft system in supply chains involves many applications that may require selective access to some areas, product's movement tracking or cargo security monitoring.

Important RFID application in the anti-theft systems is the implementation of smart areas such as shelves and vehicles that can detect RFID tags attached to individual items. The readers located in the smart area periodically emit a radio signal, which then power products tags in response the tags send back their ID to confirm their presence within the smart area. By identifying and quantifying each product at its reading area, any unexpected event can be immediately reported. Besides loss prevention, smart shelves provide automatic inventory management and accurate stocktaking.

2-2.3 Quality monitoring:

In traditional quality monitoring systems, thermometers and humidity sensors are installed in vehicles and warehouses. This method has some obvious defeats; it can only display and record environment information locally but fails to share the real time data with remote users, it monitors only the microscopic environment in the warehouse or vehicle, not microscopic environment of products itself or boxes containing products; it cannot record the environment condition during truck loading, vehicle switching or temporary storage

WSN is a promising technology for products quality monitoring since it can provide real time environmental information of products with good performance and affordable cost; the sensor nodes can be made small enough to be installed in pallets, boxes or even products. With appropriate configuration, WSN nodes can be used to detect different kinds of environment parameters related to products safety and quality, such as temperature, humidity, pressure and states of motion that include abnormal vibration, unexpected fall, excessive tilt and illegal opening of the containers/cases. WSN also can be integrated with RFID technology to expand its function and capacity and has a wide application prospect.

IV- Results and discussion:

After classifying the use cases according to their business services and ICT deployment factors we gave a notation from 1 to 10 to determine what factors are mostly used in the literature. 1 presents the lowest usage while 10 refers to the highest one. Table 2 illustrates the classification of operation based services, while Table 3 presents the classification of products based services.

We note that storing and retrieving operations are the most requiring of ICT deployments, they use RFID technology at first level while barcode and WSN are rarely used. Most of barcode and WSN applications are combined with RFID technology. (M. L. Mckelvin 2005) proposes to integrate a RFID system with wireless sensor network to extend the radio frequency coverage in an automated inventory management and tracking application. Since the application doesn't require environmental conditions sensing, the use of wireless sensor network for extending communication capabilities only is not an efficient solution. While routing applications opt for GPS technology despite its coverage limitations. The signal can be broken in mountains and under tunnels. Some researchers tried to overcome this problem (Guangxi Key Lab of Manufacturing System & Advanced Manufacturing Technology 2013) by adopting fixed RFID readers on roads and tagging vehicles with RFID tags, but the same problem arises when there is no or week coverage of 3G/4G signal. Furthermore it remains a costly solution since it requires a great number of RFID readers to be installed all over the roads. In addition the readers cannot be used for further applications of cargo tracking during transportation.

Not all papers are giving information about the communication technologies they are using, but we can see that Wi-Fi is often used in warehouses while 3G/4G is used during transportation. We know that both are not very reliable, a failure of the network can break all the system especially when in transit where products are more insecure and can be tamper with. (Meng et al. 2010) suggests the use of SMS alarms to transfer data from the frontend system (RFID readers) to the backend system, to overcome the limitations of WAN and LAN in some critical conditions (assets are distributed in different locations; no network environment is available…). However, scheduling and processing SMS alarms is time consuming and presents a key technical issue when business processes are time critical.

Data capture pointes are usually installed in fixed locations such as entrance doors, shelves and cold rooms, (Li Hong-Sheng et al. 2012) proposes to place a fixed reader on each shelf of the warehouse which can read real time inventory information and update the database management system to confirm the material storage. It also suggests a handheld device composed of RFID reader and wireless sensors to achieve a dynamic identification and status monitoring of cargo. (Liu Bingwu et al. 2016) proposed two deployments schemes of shelf reading points the first one place an antenna in each level of the shelf and connects the antennas to one reader and the second choose a mobile antenna to scan the tags. Two schemes have both advantages and disadvantages. As to the first kind of scheme, the number of antenna is required more than the second, which brings the high cost, but it can be achieved without human intervention. While the second scheme is reasonable on the cost to some extent, but the whole information acquisition work needs the personnel participation.

Depth of identification means the level of RFID tagging which varies according to their specific applications. (K. L. Choy et al. 2014) designed an RFID-based storage assignment; it associated SKUs with RFID tags which store features of SKUs such as their dimensions, weights and loading values. Whenever they pass through an RFID gateway, RFID readers detect signals from the tags and pass them to RFID middleware for processing, where appropriate storage locations for SKUs is provided using fuzzy logic. While (Li Minbo et al. 2011) embedded RFID tags in pallets and shelves in order to check storage location conformity by the forklifts equipped with RFID readers. It also placed tags on the floor and associated their coding information to the actual position (x,y) in the warehouse so as to perform forklift location tracking and task scheduling. (Chiu C. Tan and Qun Li 2006), (S.H. Choi and C.H. Poon 2008), (Ioan Ungurean et al. 2011), and (Weili Han et al. 2012) proposed item-level RFID tagging for anti-counterfeiting purpose.

The majority of RFID applications are using passive tags in warehouses and during transportation, in spite of its shorter range (less than 10 m), by setting up readers at choke points to monitor asset movements (Li Heng-Sheng et al. 2012), (F. Kamoun et al 2015) (H. Y. Lam et al. 2015).

The passive scheme of RFID positioning system is widely used in the literature (Li Heng-Sheng et al. 2012), (H.Y. Lam et al. 2013), (Liu Bingwu al.2016), (Meng et al. 2010), (Z. Xiong et al 2013), (H. Y. Lam et al. 2015).

It is important to note that the sub-mentioned factors are obviously influencing the choice of each other; for instance, the type of indoor positioning system influence the choice of RFID tags. As mentioned in section 3, the passive scheme of RFID-based IPS corresponds to moving tags that are objects to be located by fixed readers. In order to track the precise location of the moving tags, they should not be passive because the passive tags are powered on by reader's signal and readers are event dependent. So while the read event is not triggered, the moving tags may pass by the reading range without being scanned and located. Active tags instead, emit signals at pre-set intervals. Depending of the level of locating accuracy required, the tags can be set to emit signals every few seconds. However the reader can also be set to scan tags continuously but instead of detecting the moving tag only, all the tags in the reading range are detected which require more data processing and resource consumption to locate the moving tag. Although many of the proposed solutions in the literature are not paying attention to such details and are suggesting inappropriate ICT deployments.

Table 2. The classification of operation based services.

		Operation based services					
		Warehouse management				Transportation management	
		Receiving	Storing	Retrieving	Shipping	Loading/Unloading	Routing/tracking
Data carrier technologies	Barcode	—	1	—	—	1	—
	RFID	4	8	7	4	4	1
	GPS	—	—	—	—	1	5
	WSN	—	1	1	—	—	—
	Sensor nodes	—	—	—	—	—	—
Communication technologies	GSM	—	1	—	—	1	1
	GPRS	—	—	—	—	2	4
	Ethernet	—	—	1	—	—	—
	Wi-Fi	—	1	1		1	2
	Bluetooth	—	—	—	—	1	—
	Zigbee	—	—	—	—	—	—
System parameters	Location	—	—	5	—	1	5
	Temperature	—	—	—	—	—	—
	Humidity	—	—	—	—	—	—
	Pressure	—	—	—	—	—	—
	States of motion	—	—	—	—	—	—
	Auto-ID	4	8	7	4	4	1
	Smoke	—	—	—	—	—	—
	Light	—	—	—	—	—	—
	Time	1	1	—	—	—	—
Data capture points	Mobile	2	3	2	2	2	2
	Fix	3	6	4	4	2	1
Depth of identification	Item level	4	8	7	4	4	—
	Case level	4	6	6	4	4	—
	Pallet level	4	4	4	4	4	—
	Shelf	—	1	1	—	—	—
	Forklift	—	2	2	—	—	—
	Vehicle	—	—	—	—	—	1
	Staff	—	—	—	—	—	—
	Warehouse	—	—	—	—	—	—
Type of RFID tags	Passive	10					
	Semi-passive	1					
	Active	—					
Indoor positioning system	WSN based IPS	—	—	1	—	—	—
	Active RFID based IPS	—	—	2	—	—	—
	Passive RFID based IPS	—	—	5	—	—	—
RFID and WSN integration forms	Integrating RFID tags with sensors	—					
	Integrating RFID tags with WSN nodes	—					
	Integrating RFID readers with sensors	—					
	Integrating	—					

	RFID reader with WSN nodes	
	Software integration	—
Where the product information is stored	Product	10
	Backend system	4

Comparing to operations based services; the products based ones are tacking less attention from researches. No one application has designed or developed an anti-theft solution for warehouses and very few take anti-theft solution into consideration during transportation. (Huiping Li et al. 2010) proposed an alarm that is triggered once an invalid unload is detected. Among the anti-counterfeiting solutions (Chiu C. Tan and Qun Li 2006) has recommended to add pedigree data onto the RFID tag itself to provide a more convenient access to the pedigree information, but the memory of the tag can't record all the transactions when there are too many intermediaries and the history of products will be lost. While quality monitoring systems have been widely present in the literature under different methods and architectures. Some applications have proposed the use of WSN only for products environment conditions tracking (Abel Avitesh Chandra , Seong Ro Lee 2014), (J. Wang et al. 2015), and some others opted for integrating WSN and RFID technologies in order to respond to different requirements of identification, sensing and locating. (Lorite et al. 2016) has developed a prototype of smart sensor tag that integrates a temperature sensor to a passive tag in order to monitor the supply chain and storage conditions of fresh cut fruits. Where (H. Y. Lam et al. 2013) and (H .Y. Lam et al. 2015) proposed semi- passive RFID tags to assist in collecting the environmental parameters using the sensors attached to them. Unlike general passive RFID tags, semi-passive tags contain a built-in power battery that uses its own power source to emit signals and communicate to RFID readers. This can avoid the chance that the important data is missed due to insufficient energy received to give a response to the reader. Instead of integrating RFID tags with sensors, some other applications have been interested in integrating RFID readers with WSN nodes (Guomei LIU 2010), (S. Mirshahi 2013) in order to extend the communication capability of the RFID system while monitoring the environment conditions.

Table 3. The classification of products based services.

		Products based services				
		Anti-theft		Anti-counterfeiting	Quality monitoring	
		Storage	In transit		Storage	In transit
Data carrier technologies	Barcode	—	—	—	—	—
	RFID	—	1	2	4	1
	GPS	—	1	—	—	—
	WSN	—	—	—	4	2
	Sensor nodes	—	—	—	2	—
Communication technologies	GSM	—	1	—	—	—
	GPRS	—	1	—	1	2
	Ethernet	—	—	—	—	—
	Wi-Fi	—	—	—	1	1
	Bluetooth	—	—	—	—	—
	Zigbee	—	—	—	1	1
System parameters	Location	—	—	—	—	—
	Temperature	—	—	—	5	2
	Humidity	—	—	—	5	2
	Pressure	—	—	—	1	—
	States of motion	—	—	—	1	1
	Auto-ID	—	1	2	1	1
	Smoke	—	—	—	1	—
	Light	—	—	—	1	1
	Time	—	—	—	1	—
Data capture points	Mobile	—	—	—	1	1
	Fix	—	—	2	3	—
Depth of identification	Item level	—	1	2	2	—
	Case level	—	—	—	2	1
	Pallet level	—	—	1	2	—
	Shelf	—	—	—	—	—

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<tr><td rowspan="4"></td><td>Forklift</td><td>__</td><td>__</td><td>__</td><td>1</td><td>__</td></tr>
<tr><td>Vehicle</td><td>__</td><td>__</td><td>__</td><td>1</td><td>__</td></tr>
<tr><td>Staff</td><td>__</td><td>__</td><td>__</td><td>1</td><td>__</td></tr>
<tr><td>Warehouse</td><td>__</td><td>__</td><td>__</td><td>__</td><td>__</td></tr>
<tr><td rowspan="3">Type of RFID tags</td><td>Passive</td><td colspan="5">4</td></tr>
<tr><td>Semi-passive</td><td colspan="5">1</td></tr>
<tr><td>Active</td><td colspan="5">__</td></tr>
<tr><td rowspan="3">Indoor positioning system</td><td>WSN based IPS</td><td colspan="5">__</td></tr>
<tr><td>Active RFID based IPS</td><td colspan="5">—</td></tr>
<tr><td>Passive RFID based IPS</td><td colspan="5">—</td></tr>
<tr><td rowspan="5">RFID and WSN integration forms</td><td>Integrating RFID tags with sensors</td><td colspan="5">3</td></tr>
<tr><td>Integrating RFID tags with WSN nodes</td><td colspan="5">—</td></tr>
<tr><td>Integrating RFID readers with sensors</td><td colspan="5">—</td></tr>
<tr><td>Integrating RFID reader with WSN nodes</td><td colspan="5">2</td></tr>
<tr><td>Software integration</td><td colspan="5">2</td></tr>
<tr><td rowspan="2">Where the product information is stored</td><td>Product</td><td colspan="5">6</td></tr>
<tr><td>Backend system</td><td colspan="5">2</td></tr>
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Conclusion

In this paper, a novel and up to date framework for classifying use cases of ICT deployments in supply chain management was presented. The paper starts with an introduction on the supply chain ICT requirements, it presents then the parameters of our classification framework, to this extent we carried out an extensive review of the literature, reviewing several use cases of supply chain ICT deployments.

Each use case was thoroughly analyzed and used to elaborate this new framework and give a notation that classifies the different ICT deployments to distinguish between the most and less referenced ones. It then presents a critical analysis of the reviewed use cases accordingly to the ICT deployments factors.

We believe our work can be relevant both for practitioners and academics. Practitioners, in fact, can find in our framework a support tool to validate their business purposes. Academics, on the other hand, could derive from this framework important information about new research areas for supply chain ICT deployments.

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