H2020-MG-2014-2015

MOBILITY FOR GROWTH 2014-2015

H2020-MG-2014_TwoStages

Sustainable **U**rban **C**onsolidation **C**entr**ES** for con**S**truction

List of ICT tools transferable to construction logistics management

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 633338.

Dissemination level	***Public Report***
Workpackage and task	***WP3 T3.1***
Author(s)	***LIST***
Contributor(s)	***EN&TECH, Vinci, VPF, AFT***
Due date of deliverable	**30/04/2016**
Submission date of deliverable	**29/04/2016**
Status (F: final, D: draft)	**F**

Document Control Sheet

Project number	**633338**		
Project Acronym	**SUCCESS**		
Work Package	**WP**		
Version	V4.0		
Issue	**Version**	**Dates**	**Content**
	1.0	09/11/2015	Initial version
	2.0	25/03/2016	Revision with pilot perspective
	3.0	08/04/2016	Revision with partners comments (TRALUX-VCF-CMB-AFT-VPF)
	4.0	27/04/2016	Final version

Classification of this report:

Draft	
Final	**X**
Confidential	
Restricted	
Public	**X**

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Executive summary

SUCCESS has chosen to target the construction industry as major impacting sector on city logistics which has un-exploited potentials of improvement of the efficiency of goods, waste and service trips in EU cities, by answering the challenges pinpointed by the European Commission and in particular by improving urban freight understanding and by introducing more resource-efficient, more environmental-friendly, safer and seamless supply chain innovations.

The ***D3.1 List of ICT tools transferable to construction logistics management*** is part of WP3 of the project, which provides the tools and methodologies needed to design innovative solutions for construction logistics in urban areas. This deliverable aims to identify reusable ICT existing tools for the collaboration and coordination of the various activities between the Construction Logistics Supply Chain partners.

The report is divided into three chapters. The first chapter introduces the opportunity that ICT tools can offer to the construction industry. The second chapter presents the methodology used to identify the main categories of ICT tools dedicated to the construction industry. The last chapter details the different ICT categories identified on a research and market perspectives before exploring the opportunity for each pilot to use the kind of ICT tool.

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1 Introduction

The construction industry is one of the oldest industries, still even recent researches show its low productivity (Fulford and Standing, 2014).

One of the main causes, has been identified in poorly run procurement, handling and material storage processes (Young et al., 2011) and the lack of collaborative relationships with suppliers (Bygballe et al., 2010).

As a response to this issue, supply chain management has been identified as a key area for increasing productivity in this industry. Vrijhoef and Koskela (2000) identify four roles of supply chain management in the construction industry, namely:

1) Improving the interface between site activities and the supply chain

2) Improving the supply chain

3) Transferring activities from the site to the supply chain

4) Integration of site and supply chain.

In this deliverable, we focus on ICT who is a key enabler for efficient supply chain processes as well as to enhance for visibility and integration in the supply chain (Hadaya and Pellerin, 2010). Especially with the advent of web-based technologies, ICT solutions for supply chain have become increasingly viable even to smaller companies in a broad range of industries (Caniato et al., 2009). Still, the construction industry has very peculiar characteristics that make the application of traditional supply chain practices and the related ICT tools complicated. Among these characteristics, we can highlight: temporariness and fragmentation of the supply network, variability due to the large number of stakeholders, traditional low orientation towards collaboration, change inertia (Behera et al., 2015).

As a consequence, the construction industry displays very limited adoption of ICT technologies especially in supply chain and logistics applications and, thus, missing the opportunities of digitalization (Hosseini et al., 2013; Mui et al., 2002) (Figure 1 and 2). Moreover, the lack of adoption affects especially smaller enterprises (Hadaya and Pellerin, 2010).

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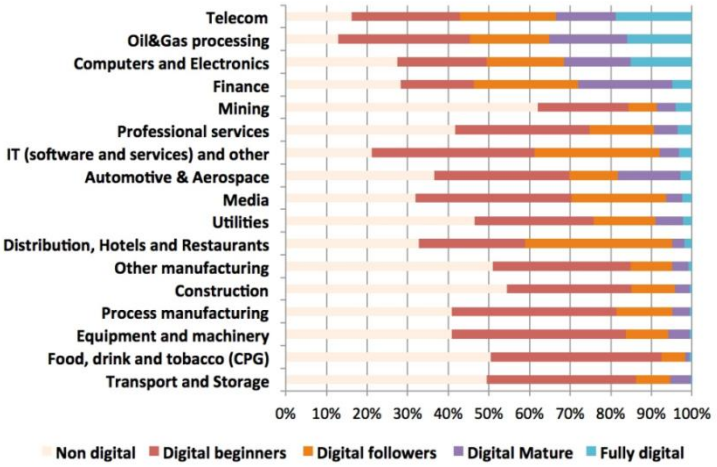

Figure 1: Digital adoption by business in different industries (source: European Commission)

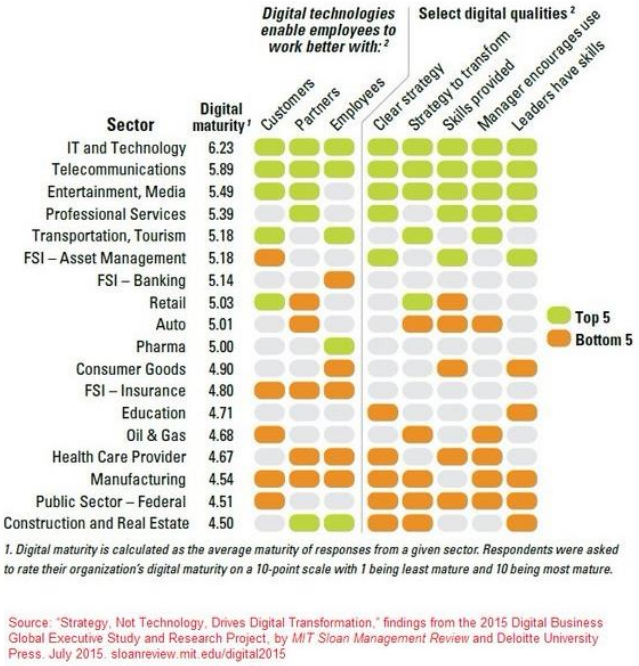

Figure 2: Strategy drives digital transformation (Source: MIT)

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Nevertheless, the scientific literature has broadly discussed the importance of ICT in the construction industry. Moreover, over time, several technology providers have developed these solutions into commercially viable products.

The aim of this deliverable is therefore to identify the main ICT solutions for construction supply chain management and to present for each of them the scientific and market perspectives. After that, we analyse and discuss how the different technologies can support the relevant processes identified in task 3.2. Last, in the conclusions, we present our final remarks.

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2 Methodology

The report describes the main ICT solutions identified in the literature and on the market. The ICT solutions are described from scientific and market perspectives. Analysis and recommendations for each pilot site complete the ICT tool review.

The main ICT solutions described in this report are the following ones:

- ERP systems
- Last planner
- BIM
- E-Business and web-based applications
- Tracking systems
- Mobile Device

2.1 Scientific review

In order to identify the main ICT applications, first we have run an automated search on SCOPUS (using "ICT", "supply chain/logistics" and "construction" as search keywords) and extracted 200 papers. Next, we went through all the papers by title, abstract and keywords and text (where necessary) and identified the different solutions. Several papers only presented general surveys or case studies and were therefore excluded from the analysis.

Finally, for each solution we have scouted online for the main technology providers and checked with actual solutions used on pilot's site.

In conclusion, we have identified which technologies can support the different processes analysed in task 3.2.

2.2 Market review

First, we have asked the 4 pilot sites for the tools they currently use.

In a second time we have searched on internet business documentations from software companies to identify existing tools, their features and their advantages.

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3 ICT applications for construction supply chain management

3.1 ERP systems (Enterprise Resource Planning)

Enterprise Resource Planning (ERP) is an ICT system designed to integrate all the information flowing through the company such as finances, accounting, human resources, supply chain, and customer information. Despite the great benefits that an integrated information system can provide, its diffusion in the construction sector is quite limited (Voordijk et al., 2003; Yang et al., 2007) mainly because of high cost, inflexibility to change, and lack of system extensibility (Cheng et al., 2010).

3.1.1 Global View of an ERP

3.1.1.1 Scientific review

The ERP functionalities needed in a supply chain context have been described by Hadaya and Pellerin (2010) as:

- Tools to support transactions with key suppliers
- Tools to exchange technical documents and drawings
- Tools to share inventory information with key suppliers

However, due to the aforementioned issues related to traditional ERP systems, Cheng et al. (2010) propose a secure, modular, and flexible system for Supply Chain collaboration called "SC collaborator" which includes the following functionalities:

- For suppliers: "*manage and respond received purchase orders, and share production and delivery information with customers*"
- For subcontractors and general contractors: "*submit and manage purchase orders, monitor product production and delivery information, and update the information of project tasks. Master monitoring and control on all the project tasks are also allowed for general contractors*"

3.1.1.2 Market review

The ERP system is a global tool for enterprise. Each company can find and use one or several modules in accordance with their needs (fig. 3)

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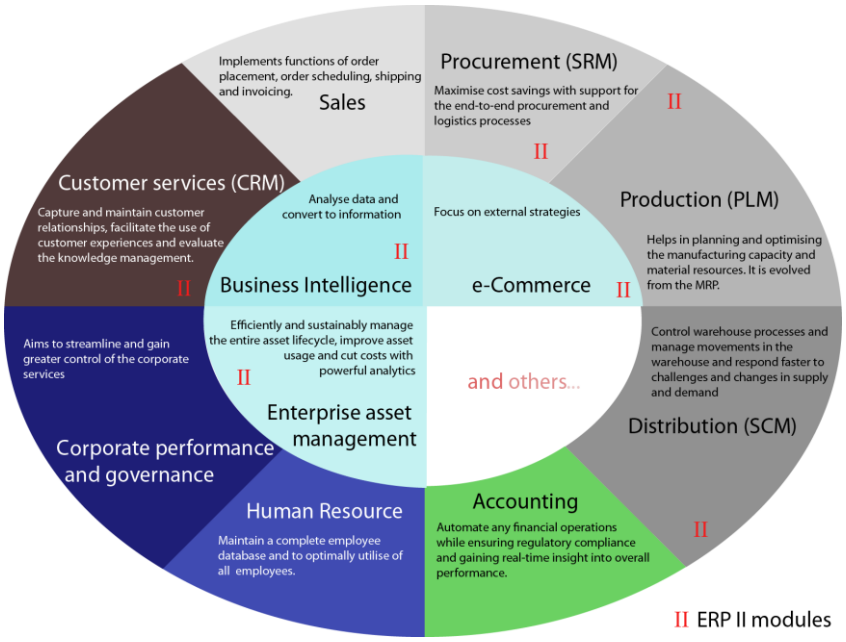

Figure 3: Main ERP modules (Source: Wikipedia)

3.1.1.2.1 Advantages:

- Improve the quality and efficiency of the business (data stored and shared)
- Improve the data quality (no multi entry for the same data)
- Standardize business processes

3.1.1.2.2 Disadvantages:

- Sometimes it's necessary to redefine processes in order to be compliant with the selected ERP
- High costs for the main system, the maintenance and upgrades
- Using a tool requires trainings, abilities and time

3.1.1.2.3 List of the most well-known ERPs on the market:

- CGI Group (CGI Advantage, Momentum)
- IBM (Maximo (MRO))
- Infor Global Solutions (Lawson, Infor ERP BPCS/LX, Barcode, Discrete iEnterprise (XA), Infor10 Distribution Business (aka SX.Enterprise), Infor10 Distribution Express (aka FACTS), Infor10 ERP Business (aka SyteLine), Infor10 ERP Ln, Infor VISUAL, Infor10 ERP Process Business, ERP Blending)
- Microsoft (Microsoft Dynamics AX (formerly Axapta), Microsoft Dynamics GP (formerly Great Plains), Microsoft Dynamics NAV (formerly Navision), Microsoft Dynamics SL(formerly Solomon), NAV-X)

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- Oracle (JD Edwards EnterpriseOne, JD Edwards World, Oracle E-Business Suite, Oracle Fusion, PeopleSoft)
- Sage Group (PFW ERP, Pro ERP, 100 ERP (formerly Sage ERP MAS 90 and 200), 300 ERP (formerly Accpac), 500 ERP, ERP X3)
- SAP (mySAP, SAP Business All-in-One, SAP Business ByDesign, SAP Business One, SAP Business Suite)
- Tata Consultancy Services (iON)

3.1.1.3 Review from pilots perspectives

3.1.1.3.1 Luxembourg site

Tralux does not use a global ERP system.

3.1.1.3.2 Paris site

VINCI Construction France does not use a global ERP system.

3.1.1.3.3 Valencia site

The joint venture composed by the companies Pavasal and Dragados does not use a global ERP system in Parque Central.

3.1.1.3.4 Verona site

CMB does not use a global ERP system.

Those companies are at this stage not mature enough to implement a global ERP system however some of them have already some modules (see below).

3.1.2 ERP - WMS (Warehouse Management System)

The WMS tracks products data before and after the production process. Depending on the size of the organization, it can be a simple spreadsheet, a standalone system or a module of an ERP system.

Warehouse Management includes the reception, the storage and handling of products and raw materials.

WMS uses more often automatic identification and data capture technology, such as barcode scanners, mobile computers, wireless LANs and potentially radio-frequency identification (RFID) to efficiently monitor the flow of products. Once data have been collected, there is either batch synchronization with, or a real-time wireless transmission to a central database. The database can then provide useful reports about the status of goods in the warehouse.

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3.1.2.1 Review from pilots perspectives

3.1.2.1.1 Luxembourg site

Tralux does not use a Warehouse Management System but could be interested in. The total absence of inventory record implies inaccurate levels of inventory and results in overstock or shortages of materials. The integrated information flow that allows ERP, would help to disseminate inventory information. Regarding the storage issue, workers find difficult and time-consuming to search for materials and equipment, inside the construction site. So a WMS with a tracking system would help to identify the exact location of materials and equipments.

3.1.2.1.2 Paris site

VINCI Construction France does not use a Warehouse Management System but could be interested in. One of the opportunities of improvement on the construction site is the storage management: estimate the stock level by storage areas would improve efficiency on site.

3.1.2.1.3 Valencia site

The joint venture composed by the companies Pavasal and Dragados uses their own software for the warehouse management. However, this software only records data about the inventory and the stock of the different material that are used on the construction site. This software does not provide any information regarding the location of the materials inside the construction site, therefore this information would be valuable in order to reduce wasting times in material location and storage management.

3.1.2.1.4 Verona site

CMB keeps track of inventory on the construction site by using Excel files and, sometimes, paper documents.

CMB also has a central warehouse shared between many construction sites and where a set of materials is stored. This central warehouse is managed with the management system edited by Oracle.

3.1.3 ERP – SRM (Supplier Relationship Management)

Like for the CRM (Customer Relationship management), the objective of this type of tools is to manage relations with others partners of a project. The primary goal of SRM is to integrate and automate sales, marketing, supplier and customer support and information.

It provides a method to coordinate business processes with the suppliers. It permits to work with suppliers in real time and to develop long-term relationships between partners.

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It's possible with this tool to select suppliers during all the process (RFQ – Request for quotation, RFP – Request for proposal, RFI – request for information, reverse auctions, negotiating)

3.1.3.1 Review from pilots perspectives

3.1.3.1.1 Luxembourg site

SRM solutions could support Tralux to increase internal transparency and improve communication, eliminating the lack of lateral dissemination of information due to functional organisation structure. Besides, data availability among employees would help to reach better and more equal understanding of the ordering process.

Another important aspect concerning Tralux is transactions with suppliers which, currently, are slow due to the heavy and complex method for validating orders/deliveries and submitting payments. SRM could improve also their selection process in capitalising relations history with their suppliers. Today, Tralux does not have all the information when they select the suppliers.

SRM solutions could also support Tralux in order to have a better tracking of their suppliers and select them faster during the consultation phase. SRM gathers all the aspects of the past contractual relations between suppliers and Tralux (prices, quality of deliveries, etc…).

3.1.3.1.2 Paris site

VINCI Construction France has developed two internal SRM software:

- "V-HA": the goal of this internal tool is to manage the supply. It proposes various catalogues of suppliers and automates the ordering process for the framework agreements.
- "V-FAC": this second tool helps to manage the internal validation workflow of invoices. It allows to dematerialise exchanges between construction site and accounting service.

3.1.3.1.3 Valencia site

The companies involved in the supplier management of the pilot use their own software including a database with all the suppliers they worked before. However, this system does not include the possibility to submit request for quotation, proposal or negotiation.

3.1.3.1.4 Verona site

All construction sites managed by CMB use a centralised system called GEA. GEA covers many aspects of supplier relationship management such as sourcing, ordering (providing all the specifications), acquiring and renting material and equipment, etc.

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3.1.4 ERP – TMS (Transporting Management System)

A TMS (Transporting Management System) is usually used between an ERP-SRM (or an order processing tool) and a Warehouse Management System. It is used mainly by transport companies to:

- Define the most efficient transport scheme (transport costs efficiency, lead time optimisation, number of stops allowed, etc.)
- Determine the transport execution plan (carrier rate acceptance, best path/route, etc.)
- Follow up trips (GPS traceability, sending alerts in case of delay, accident, etc.)
- Calculate measures (KPI calculation in order to improve the system)

3.1.4.1 Review from pilots perspectives

3.1.4.1.1 Luxembourg site

Tralux does not use a TMS software. Such a tool can benefit the staff in charge of material reception since they don't have any information on the status delivery (at the supplier's, at the carrier's…).

3.1.4.1.2 Paris site

VINCI Construction France does not use a TMS software. However such a tool is interesting to be informed of the position of delivery truck or alerted in case of accident to anticipate a delivery delay and readjust the delivery planning. It could be helpful for the construction site.

3.1.4.1.3 Valencia site

The joint venture does not use a TMS software. The construction companies in charge of the pilot site agree the approximate delivery time in advance with the suppliers and the transport companies. Besides, sub-contractors facilitate information of the deliveries regarding the material, unloading characteristics, time window for the delivery, vehicle characteristics, etc. The Project Manager calculates the transport costs without any specific tool. The construction company could take advantages of a specific tool in order to automate this estimation.

3.1.4.1.4 Verona site

On Verona site, CMB manages just a small fleet of vehicles internally equipped with GPS. However they do not normally use it to retrieve the vehicles position, for understanding delay, accidents, etc., it is used instead as a safety tool. The majority of the vehicles related to the construction sites are the subcontractors ones, thus CMB is not extremely interested if they use the optimal routes to get to the site.

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3.1.5 ERP - SCP (Supply Chain Planning)

Supply Chain Planning system is mainly used by a company in order to manage all aspects of the supply chain:

- Follow the flow of orders
- Take account of production constraints
- Take into account the constraints of suppliers
- Manage flows with subsidiaries, with warehouses, etc…

The main objective of this ICT tool is to obtain Indicators for quick decision making.

3.1.5.1 Review from pilots' perspectives

3.1.5.1.1 Luxembourg site

Many problems facing Tralux's construction site are linked to the non-availability of resources (over-allocated resources), such as equipment (mainly, the crane), workforce and no space free for storage or delivery. This means, the non-global integrated scheduling of the planning is the main weakness. By the use of the ERP-SCP tool, much of this would be solved.

3.1.5.1.2 Paris site

Sub-contractors use the delivery booking system *Lsoft Logistique* to book a delivery slot as well as the human and material resources to handle the material. The delivery request includes the following information:

- Day and time period of the delivery
- Delivery zone (Estrees or Saxe delivery zone)
- Handling equipment (lift, forklift truck, or tower crane)
- Specific storage zone
- Nature of material
- Type of delivery vehicles (utility vehicle, 19 T truck, trailer truck or arm truck)

3.1.5.1.3 Valencia site

The joint venture does not use a SCP software. The project manager agrees with the subcontractors the approximate delivery time, which are in charge of facilitating information regarding the delivery characteristics: materials, unloading characteristics, time window for the delivery, vehicle characteristics, etc.

3.1.5.1.4 Verona site

CMB manages the deliveries by using Excel sheets and phone the suppliers to organize the arrivals on site. CMB doesn't book before the delivery the unloading area and handling equipments.

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3.2 LPS (Last Planner System)

The Last Planner System is a project execution system ideated in the beginning of the 90's (Ballard and Howell, 2004). The basic idea is that starting from the master plan, the project is reviewed typically on a weekly basis by the project team to ensure that all the tasks expected to be initiated in the following period have all the necessary inputs (materials, resources, etc.) to be executed on time and, in case, take the necessary actions. In doing so, it is important to involve and give decisional power to staff in contact with the field operations; they are named the last planners.

3.2.1 Scientific review

The LPS is a technique not typical of the supply chain literature developed by the Lean Construction Institute, however, it is important to remind that defective material deliveries account for 8–25% of the non-completed tasks in a last planner context (Ala-Risku and Kärkkäinen, 2006). As a consequence, the literature has focused on the importance to use ICT to track material deliveries and coordinate procurement activities so to provide last planners with reliable and timely information. This ICT solution typically entails tracking and tracing systems and inventory management (Ala-Risku and Kärkkäinen, 2006).

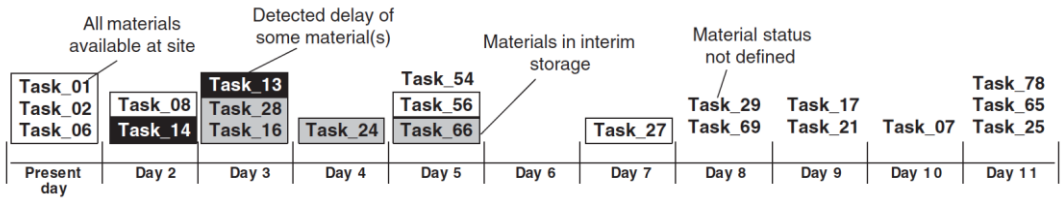

Figure 4: Illustration of the results of materials constraint analysis (Ala-Risku and Kärkkäinen, 2006)

3.2.2 Market review

LPS is a system of inter-related elements and full benefits come when all are implemented together. It is based on a collaborative scheduling with a personal engagement of each actor. Each person involved before his engagement takes in account all prerequisite and analyses all interfaces with other stakeholders.

3.2.2.1 Advantages:

- Improve the planning reliability
- Improve the communication between all actors
- Avoid misunderstanding and interface problems

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3.2.2.2 *Disadvantages:*

- Need time to prepare before the beginning of the construction
- Need the presence of all actors during the meeting
- Need training before using it

3.2.3 Review from pilots' perspectives

3.2.3.1 *Luxembourg site*

A master plan exists but Tralux doesn't put in place the LPS system on this site.

3.2.3.2 *Paris site*

The pilot site is using the LPS since the beginning of the activity. It has required specific courses for each sub-contractor. Weekly meetings occur on site in a dedicated room.

3.2.3.3 *Valencia site*

The project manager and the production manager review weekly the master plan to monitor the correct progress of the construction. In addition, a meeting between the project team, the site manager and the promotors takes place every two weeks with an updated plan of the construction site in order to check its progress.

The ICT tools used for the site planning are MS Project and Presto. As mentioned before, the site planning is updated on a weekly basis.

3.2.3.4 *Verona site*

CMB makes use of a global plan and of a work plan, but they do not use the LSP system.

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3.3 BIM (Building Information Model)

The BIM is used to manage all aspects on the site (as you can see below) but it doesn't take into account the part outside the construction site (like logistics, warehouse management or raw material factory management)

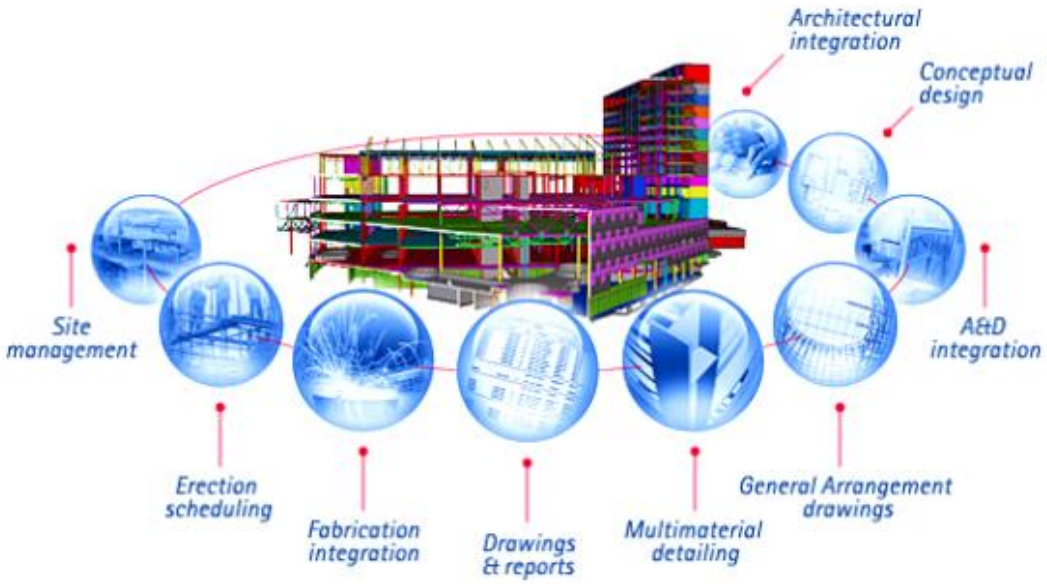

Figure 5: Graphical overview of BIM (Source: TEKLA)

3.3.1 Scientific review

By consequence even if it is not acknowledged as supply chain tool, still it provides fundamental inputs for procurement and logistic processes in a construction project and becomes the missing link between the internal ERP, the project, the suppliers and customers (Babič et al., 2010). However, in order to make BIM a collaboration platform, several technical and architectural adjustments are necessary to take into account the multi-disciplinary nature and organizational complexity of construction projects. (Papadonikolaki et al., 2015; Singh et al., 2011). Moreover, BIM interoperability with other systems (e.g., suppliers' ERPs) needs common frameworks and standards (Jardim-Goncalves and Grilo, 2010). From the practical point of view, to deploy BIM as a supply chain tool, four modules are necessary: "*4 modules: (1) construction progress monitoring module, (2) construction site space estimating module, (3) material delivery coordination module, and (4) material storage optimization module*" (Cheng and Kumar, 2015).

(Irizarry et al., 2013) have integrated BIM and GIS in order to locate suppliers of specific components on a map and estimate the procurement costs based also on transportation costs.

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3.3.2 Market review

BIM is a new technology in construction industry. Currently, not often used, BIM has a big potential to grow because it contains big data to manage all the life of a building and optimise all performances (maintenance, energy, etc…).

3.3.2.1 Advantages:

- Improve visualization
- Improve productivity due to easy retrieval of information
- Increase coordination of construction documents / enterprises
- Increase speed of delivery
- Reduce costs

3.3.2.2 Disadvantages:

- High performance computer needed
- Large bandwidth necessary for all documents
- Interoperability between all the stockholders
- Time necessity to define all components

3.3.2.3 List of the most well-known BIM software on the market:

- Bentley AECOsim Building Designer
- ArchiCAD
- Tekla Structures
- Autodesk Revit
- Synchro PRO
- VectorWorks
- Plangrid
- Fieldwire
- Procore

3.3.3 Review from pilots' perspectives

3.3.3.1 Luxembourg site

The BIM technology isn't used on the site.

3.3.3.2 Paris site

The construction site used Autodesk Revit to make a BIM of the project. For that, the construction site won a "BIM d'or 2015 award" in the category Renovating project more than 40 000 square meter.

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3.3.3.3 *Valencia site*

The BIM technology is not used in the pilot of Valencia. This technology is not widespread enough in small and medium size constructions in Spain.

3.3.3.4 *Verona site*

In the construction site of Verona, CMB is using the BIM technology, in particular Autodesk Revit. The use of BIM is at the beginning and not all its potential have been exploited yet, however they could appreciate its advantages, especially when it comes to the design phase or when used as renderings to retrieve information hard to detect with the normal plans and sections. This last feature can be used also to increase safety on the construction site.

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3.4 eBusiness and web-based applications

Internet and the development of web-based applications brought in the early years 2000 a new wave of development of ICT applications (Cagliano et al., 2003). Internet has been seen as standard communication protocol accessible even to small and medium enterprises.

3.4.1 Scientific review

By merging different papers (Grilo and Jardim-Goncalves, 2011; Laryea and Ibem, 2014; Nitithamyong and Skibniewski, 2004; Ronchi et al., 2010; Vitkauskaite and Gatautis, 2008) it is possible to identify the eBusiness functionalities in the table below.

Sourcing / Ordering process	**EBusiness functionalities**	**Tools and solutions**
Pre-order	• Scout and qualified suppliers	Supplier network Supplier portals
	• Request of information • Call for competition/Call for tenders • Submission / receipt of tenders	eRfX (request for information/proposal/bid) eTendering
	• Negotiation • Awarding	eAuction eAwarding
	• Contract management (e.g., maintenance services)	Repository and contract management
Ordering	• Select product and send the order to the supplier	eCatalogue eOrdering
	• Production and shipment	Production and delivery tracking
	• Administrative tasks	eInvoicing ePayment
Post-ordering	• Vendor rating	Specific tools, usually integrated in the ERP system
	• Reporting	
	• Complaint	

Traditionally, eBusiness software were hosted either by the buyers or the suppliers (Caniato et al., 2010). However, more recently, the spread of high-

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speed Internet created the opportunity for software-as-a-service (or Cloud) solutions. In this case, the software is created and managed by a third-part provider and accessed via Internet by the suppliers and customers that usually pay a fixed fee or pay per use. The opportunities of cloud solutions have been investigated also for the construction industry (Abedi et al., 2014) (Kumar et al., 2010), with particular reference to the SMEs (Hore et al., 2010). Finally, it is important to remind that business solutions deploy the highest potential when combined with BIM (Aguiar Costa and Grilo, 2015; Grilo and Jardim-Goncalves, 2011) and ERP systems. Also the combination with GIS has been experimented (Li et al., 2003).

3.4.2 Market review

On the market, several web-based ICT solutions (eBusiness solutions) have been developed to support companies in their business. In particular, ePurchasing solutions help companies in all the phases of the purchasing process. There are several economic advantages in adopting ePurchasing solutions, (due to automation in the purchasing workflow, or the use of eAuction) and also qualitative ones (transparency and control).

3.4.3 Review from pilots perspectives

3.4.3.1 Luxembourg site

Considering TRALUX case (LU), different tools addressing identified problems are listed below:

- E-Tendering and e-Auction applications could support the construction company in selecting the supplier in a more transparent, faster and more efficient way
- the e-Invoicing and e-Payment applications can ease and accelerate the cumbersome task of validating and matching the orders with their invoice, and the payment which is time consuming because these activities are done today manually at different levels of control
- For TRALUX, a registration point linked to a data base and a security access registration (for trucks, and people) could be implemented, in order to avoid safety and legal problems

3.4.3.2 Paris site

Furthermore the two softwares developed by VINCI Construction France, "V-HA" and "V-FAC", the company develop others internals tools for sales department. For example, they have a specific software where they can find all the previous projects and show the references of the company to a potential client.

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3.4.3.3 *Valencia site*

The e-Business software and apps are not used in the pilot of Valencia. The communications between the construction company and the suppliers is made by mail or telephone. The company has a system to generate the invoices but the use of eInvocing and ePayment could help to improve the management of the administrative task of the site.

3.4.3.4 *Verona site*

In CMB, for the pre-order phase, especially for scouting and qualifying suppliers, for repository and contract management, and for selecting order and send it to suppliers, they use the internal software GEA that is accessible as a web based application. For the administrative tasks and accounting they use Oracle software.

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3.5 Tracking systems

Tracking systems have been advocated as a fundamental enabler for ICT applications related to material handling and inventory management. Knowing where the goods are, allows efficient project control (see for instance the Last Planner) and timely triggering of procurement processes. Their use in the field of construction is relatively new.

3.5.1 Scientific review

While tracking systems (mainly bar codes and RFID) are quite widespread in the other industry the application to the construction sector presents some issues: presence of non-discrete products (e.g., concrete) that make tagging very difficult or even impossible, various and variable storage areas (e.g., warehouse, open spaces, inside/outside the building), need to locate goods in 3D (height is a relevant variable in multi-floor buildings), need to locate goods indoor (where GPS signals may not arrive).

Other systems have been identified, but present strong limitations in terms of accuracy and resilience to different conditions (e.g., obstacles). Such systems include ultrasound and infrared. Theoretically, other technologies could be employed (e.g., Bluetooth, magnetic signals and audible sounds) there is no evidence of studies analysing them (Li et al., 2016).

It is also important to remind that tracking systems can also be applied to vehicles (to track entrance and exit for instance), movable equipment (e.g., drills) and people. For instance, Riaz et al. (2006) developed a GPS based system to prevent collisions between workers and equipment. Vahdatikhaki and Hammad (2014) use UWB technology placed on an excavator to estimate its working cycles. Yang et al. (2012) use a vision based system to track the position of tower cranes and track ongoing activity.

One solution was developed by the EKAHAU company (www.EKAHAU.COM)

3.5.2 Market review

Driven by the market, different tracking technologies have been adopted over time. The main ones are:

- RFID: beside the identification of freight, active RFID allow to locate goods and are employed especially in indoor environments where GPS signal is not available
- GPS: Used for outdoor environment and usually in combination with RFID to identification (Torrent and Caldas, 2009)
- UWB (Ultra-wideband): similar to RFID, but uses passive tags that respond to a short pulse and it is used especially for indoor applications. It can be

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used outdoor as well, but its accuracy is lower in large areas as it is sensitive to obstacles, distance between tags and number of tags. Moreover, UWB requires the connection of a local area network (LAN) to the receivers

- Vision analysis: using this technology, the target object does not need to carry any device, but is recognized by vision algorithms
- WLAN (Wireless local area network): locates objects connected to the WLAN based on the strength of the signal. Usually used in indoor applications, its accuracy and efficacy to provide 3D positioning is limited (Bahl and Padmanabhan, 2000)

3.5.3 Review from pilots' perspectives

3.5.3.1 Luxembourg site

Tralux does not use a Tracking System but could be interested in.

Tracking system on vehicles:

It would be suitable to solve the communication and data-recording problems with hauliers and suppliers about the delivery and material reception status: a notification to inform a late or early arrival, or a not planned delivery. This real-time notification would help the staff on construction site to make last minute changes in reallocating resources (crane, workers, storage space…). A mobile device could be useful as a support to the tracking system to communicate directly with the haulier and give instructions to park and unload.

Tracking system on equipments:

There is an opportunity to equip the handling equipments with a tracking system to find them easily on site. Material can be left anywhere and be damaged because the workers don't know where the equipments are.

Tracking system on material:

A tracking system on material (like RFID tag) could help the construction company to better manage their material like identifying non-conformity (incorrect quantity, incorrect reference, damaged products…) and report immediately the problem to the supplier. Today, the workers who are in charge of the material reception don't have access to the related order.

3.5.3.2 Paris site

Vinci does not use a Tracking System but could be interested in to improve the site management. It would make easier to find material and equipment for the

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workforce, and it would help the site manager to take decision faster (accept a delivery, move storage…) if he identifies quickly where the elements are.

3.5.3.3 Valencia site

The joint venture does not use a Tracking System. The foreman and the project manager check the materials at their arrival on the construction site. Once the materials are checked, the project manager signs the delivery note. If a quality control is needed, there is a specific process previously defined for each material that required the quality check.

3.5.3.4 Verona site

CMB does not use a proper Tracking System however they can report the following:

- The grinding machines, the drills, etc. have an identification code number and a bar code. This is due to the fact that CMB rent these equipment to its construction site, and they need do track them.
- The workforce is tracked with a badge.
- The forklifts and others handling equipment are tracked with an ICT system.
- The internal trucks have a GPS.
- The company cars are tracked by using the plate.

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Conclusion

Only 37 % of industrial companies are equipped with EDI (Electronic Data Interchange) and only 15 % with SCM (Supply Chain Management) tools. In the construction sector, less than 15% are equipped with EDI and result in a bigger challenge for this industry to develop the digital spirit. One reason is the number of SMEs whose managers are not familiar with the new tools. Nevertheless software editors and big companies have realised the interest to use the new technologies to develop their business (e-business), to save time (ERP, Collaborative planning like LPS) and to prevent construction site problems (BIM or LPS).

If you can find a lot of tools on the market, it is difficult to find an integrated tool that all stakeholders can use. Because the stakeholders don't use the same tool, problems arise from the lack of interoperability of the ICT tools. If big construction companies are not leaders on the way to develop ICT tools, it is feared that the construction sector will continue to lag behind other sectors in this domain.

The table below summarises the potential coverage of the ICT solutions explored in this report on the construction logistics processes identified in the SUCCESS project. Most of the ICT solutions apply to one or more processes, specifically ERP solution.

			ICT TOOLS					
			3.1 ERP Systems	3.2 LPS	3.3 BIM	3.4 E-business	3.5 Web based applications	3.5 Tracking systems
BUSINESS PROCESSES	1	SOURCING	X (SRM)			X		
	2	ORDERING	X		X	X		
	3	DELIVERY	X (TMS)					X
	4	MATERIAL RECEPTION AND EXPEDITION	X (WMS)					X
	5	INVENTORY & STORAGE Management	X (WMS)		X			X
	6	MATERIAL HANDLING & EQUIPEMENT Management						X
	7	HOUSEKEEPING						
	8	WASTE Management						
	9	RETURNS Management						X
	10	PLANNING AND SCHEDULING RESSOURCES	X(SCP)	X	X		X	
	11	COMPLAINT Management				X		
	12	ENTRANCE AND EXIT Management					X	

Table 1: ICT solutions coverage

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