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RFID-Integrated Software Platform for Construction Materials Management

Safa Dardouri[1], Zakaria Dakhli[2], Andry Zaid Rabenantoandro[3], and Zoubeir Lafhaj[4]

[1] Design Engineer, Department of Civil Engineering, Centrale Lille
[2] Research Engineer, Department of Civil Engineering, Centrale Lille
[3] PhD student, Department of Civil Engineering, Centrale Lille
[4] Full Professor, Department of Civil Engineering, Centrale Lille
[*]Corresponding author's e-mail: zoubeir.lafhaj@centralelille.fr

ABSTRACT

The intensity and rate of construction operations require logistics and transportation that can adapt to the changing nature of activities on a day-to-day basis of construction and that enable rapid decision-making. This paper aims to design an integrated RFID technology system for managing construction materials onsite. The integration includes managing materials during the front-end and the execution phases, managing the inventory, locating materials on site with Global Positioning System GPS, and developing Kanban systems for managing different stakeholders' inputs onsite. The research also sheds the light into the effect of using RFID on leveraging valuable data. RFID systems can gather large amount of tag data via wireless connections.

KEYWORDS

Materials management, Software platform, RFID, Construction site, Data, Materials supplier

INTRODUCTION

One of the most extended and promising wireless non-contact systems is Radio-Frequency Identification (RFID) (Shen et al. 2008). This system can connect objects to the Internet or databases (ERABUILD 2006) and transmits information via radio waves of a specific frequency (Mehami et al. 2018). The basic architecture of RFID systems consists of an RFID reader that queries the RFID tags and responses to the reader (Alvarez-Narciandi et al. 2018). Tags usually have two parts: a small chip and an antenna. Information is stored and processed by the chip while the antenna is used to receive and transmit information (Zhu et al. 2012).

Since the 1990s, RFID has been applied in the field of construction (Valero et al. 2015). Nowadays RFID technology represents a major and important innovation that enables efficient materials management. This technology leaves its mark at the level of production control along with the supply chain. **Erreur ! Source du renvoi introuvable.** presents the four steps for digital transformation that construction should follow. The construction industry is in the process of embracing the era of digitalization and following the rapid changes of this decade.

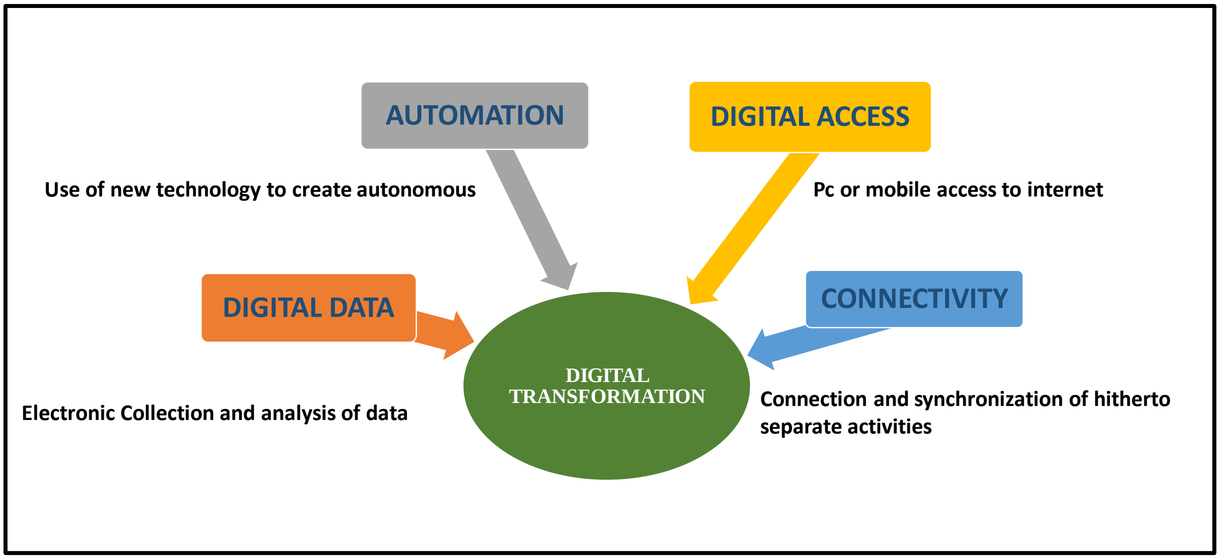

Figure 1. The four steps for Digital Transfotmation

Existing RFID solutions in equipment management

The use of RFID for tracking supply chains has increased over the past 15 years (Hinkka and Tätilä 2013). Mapping, system development, scenarios and recommendations are proposed by (Jaselskis et al. 1995) during their review in 1995. They recommended RFID technology at the construction site to ensure the quality and security of logistics operations. It is also important to trace and identify the history and the localization of products in the construction site.

In this context, many authors investigated the impact of deploying RFID in several industries. Mennecke and Townsend have shown that RFID technology is used in the meat product industry to determine product provenance (Mennecke and Townsend 2005). Q. Yan, 2015 discusses the application of RFID in cold logistics chains of fresh products according to the phases of production, processing, storage, transportation, and sales (Yan 2015). He proposed an RFID-based fresh cold chain traceability system from the view of food safety by combining the development of fresh produce cold chain logistics. Similarly, a proximity-based method was proposed by Song and al. (Song et al. 2007) to locate RFID tagged objects on construction sites. Materials on site were uniquely attached to RFID tags, which are deployed as reference points at known and fixed locations in the construction site, as discussed by Saiedeh N. Razavi and Carl T. Haas (Razavi and Haas 2011). In the same context, Lung-Chuang Wang and Yu-Cheng Lin (Wang et al. 2007) developed mobile construction RFID-based dynamic supply chain management.

The construction industry is complex and often takes place in an uncontrolled, unprepared and dynamic environment where each project is repeated several times (Majrouhi Sardroud 2012). The supply chain process in the construction industry is thus dynamic due to frequent changes in the design and planning of construction projects. However, materials are stored in areas that are fixed by the Site Layout plan (SLP), which is highlighted in Figure 2, in order to properly organize and position the various tasks performed.

Figure 2. Example Site Layout planning (SLP)

The SLP manual remains limited since it does not provide all the necessary information about stock management. Traditional processes on construction site often requires human intervention to verify and to track the presence of materials.

The limitations of the construction sector and specifically the management of material stocks, justifies the proposition of an embedded, real-time stock management and control system for the construction site. This system is proposed in this article and is based on RFID technology to ensure better visibility with accurate and reliable information in real time. It aims at improving the traceability of a wide range of materials for multiple stakeholders (site manager, engineers, work manager, workers).

Goal of the current study

Construction projects require rigorous organization, supervision and control of the building site, agreement on the respect of deadlines, a fixed financial envelope, and a timely supply. This paper suggests a stock management for a construction site on a real platform to:

- Ensure stock tracking and management through an RFID identification and remote monitoring system based on a network of interconnected sensors linked to a DBMS layout system.
- Facilitate construction management by identifying and tracking construction materials.
- Install RFID tags on pallets or boxes in order to improve storage, inventory and security controls.
- Collect data related to the movements of materials in the construction site.
- Optimize orders to properly plan deliveries of materials and equipment.
- Meet budget targets and construction deadlines.
- Design the control system of the electronic prototype for stock management using a device connected to the web server (PC, smart phone).

MATERIALS AND METHODS

The choice of equipment is based on existing solutions proposed by suppliers with quality and optimal efficiency for construction environment. The hardware used was a reader, an antenna, and 10 tags to test the functioning of the prototype. The choice of these materials was based on the range factor, which ensures a favorable use on a construction site as this reader can detect tags within more than 100m. The main software system for communication and implementation was based on an open source software system “the Arduino Ide”. The database was handled by PhpMyAdmin database. Finally, we used LabVIEW interface to visualize and control the construction site in real time. Figure 3 shows the interaction between the different software.

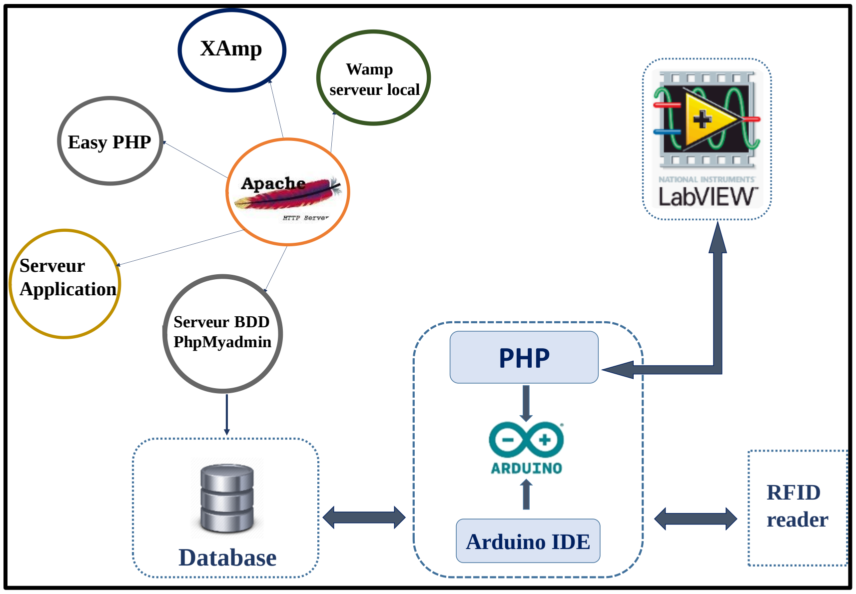

Figure 3. Software interactions

RFID Framework

Figure 4 presents the framework for the tracking of supplies by a real-time system. The identification and localization activities described in the current process have been replaced by semi-automated or automated activities.

In the RFID-based process, RFID tags, containing the ID, place, quantity and the date related to the materials, are attached to each cement bag after production. The RFID reader collects data from this ID and sends them to a database of system.

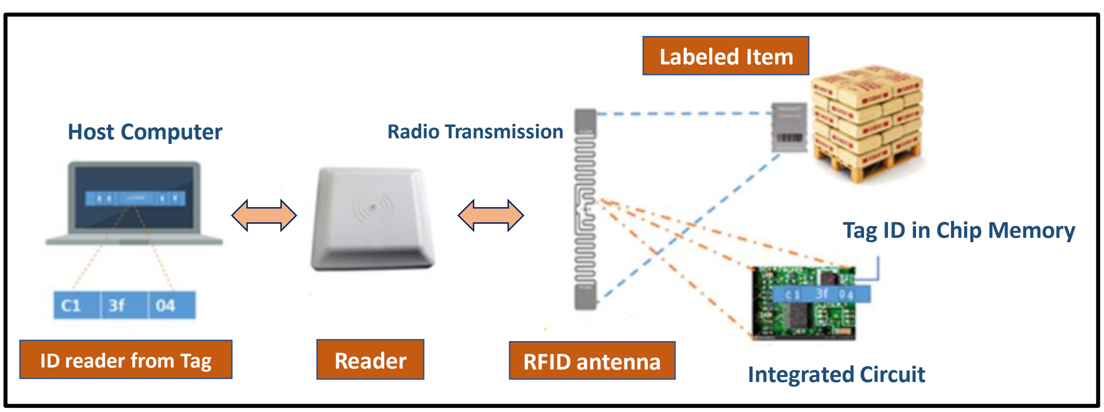

Figure 4. Real time material tracking by RFID system

Experimental procedure of the RFID system

During the construction process, materials are permanently changing their position onsite. The state-machine in Figure 5 shows the hardware localization process, which begins with the site supervisor through the software application. The first criterion is fulfilled by a good coordination of the administrator guaranteeing easy and fast access via the database and verified by a login and password.

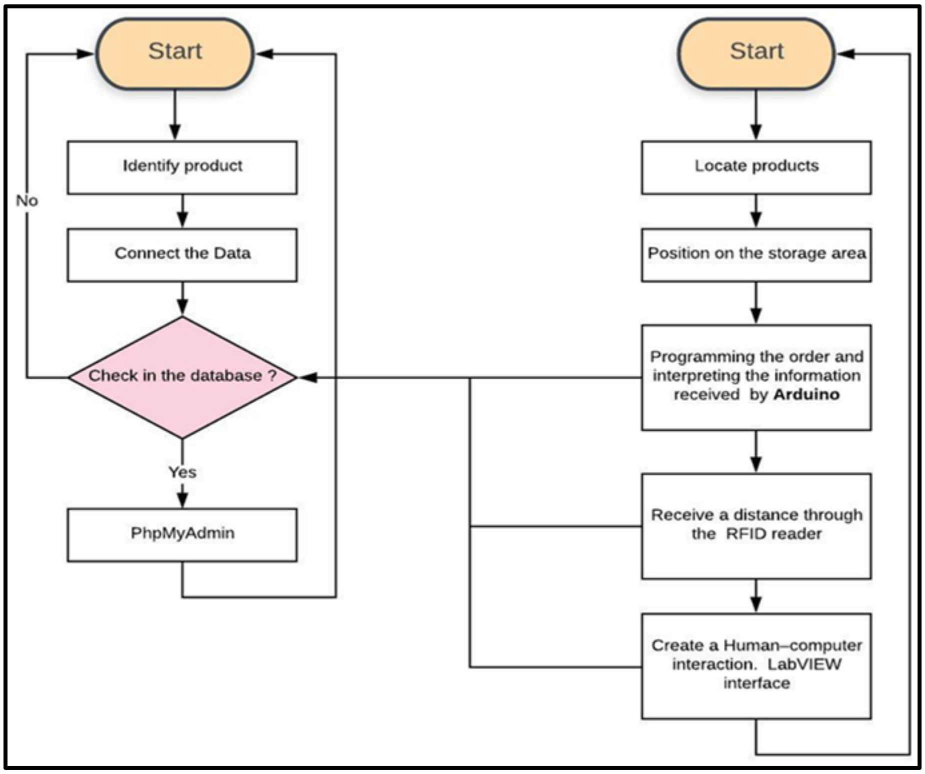

Figure 5. Expectation flow chart of the data system and RFID procedure

RFID system prototype

A prototype of an on-site inventory tracking and management has been developed. As presented in figure 6, the software application was based on the four following steps to locate and identify materials on the construction site by the RFID technology coupled with LabVIEW-Arduino interface.

Step 1) Integrate a label on each bag of cements.

Step 2) The label is detected by the reader that emits the Energy necessary for its activation via the antenna.

Step 3) The recovery of these IDs is done through the Arduino platform, which will be connected, to a Database to store them.

Steps 4) Finally, Cement stock tracking is visualized through the LabVIEW interface.

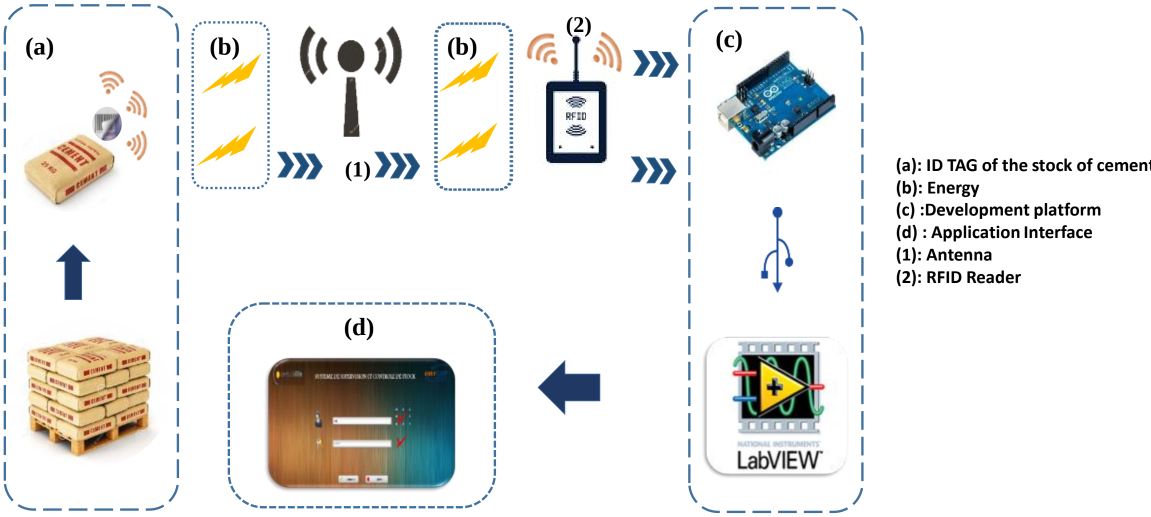

Figure 6. RFID system prototype

RESULTS AND DISCUSSION

The prototype ensures the monitoring and controlling of the availability of construction materials in the storage area. To improve the interaction between construction stakeholders, we introduced alerts to indicate the state of the stock when the quantity is lower than the threshold.

Admin Interface

To be able to access to the application's functionalities, an identification system has been set up to authenticate a user. After that, a message appears to select the next action either product management or supervisor management. Figure 7 shows the message displayed for the product management action for the administrator.

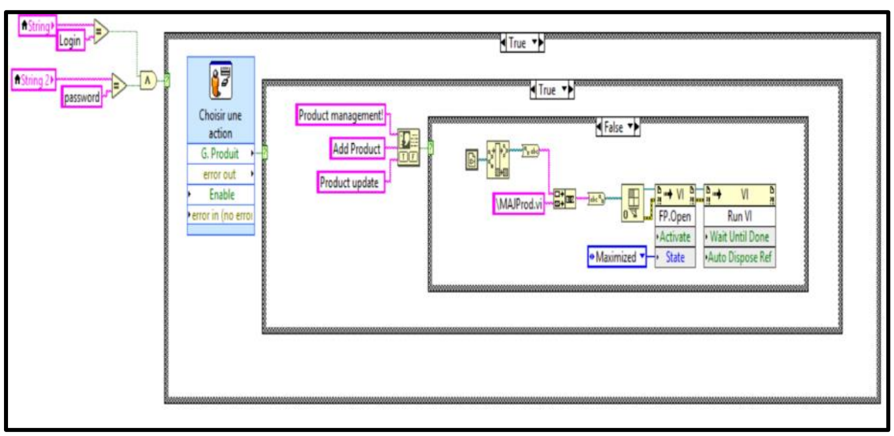

Figure 7. Interface of the Product Management Action

Supervisor Management

An administrator can manage the list of supervisors registered in the database. Figure 9 show the block diagram of this interface.

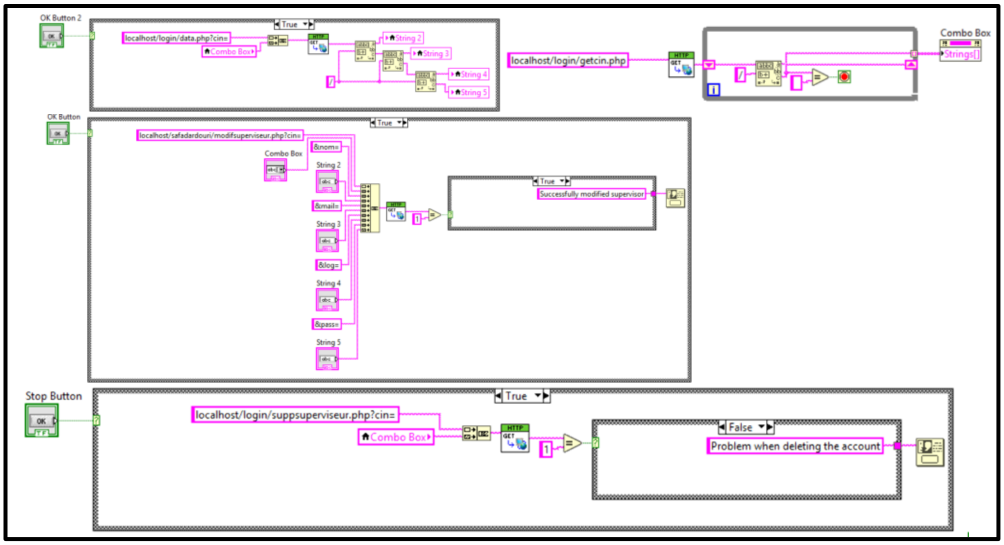

Figure 8. Block diagram of supervisor management

Product management

The supervisor can manage the list of products registered in the database by either the action of adding, modifying or deleting. Figure 10 below illustrates the different interfaces of the block diagram of product management.

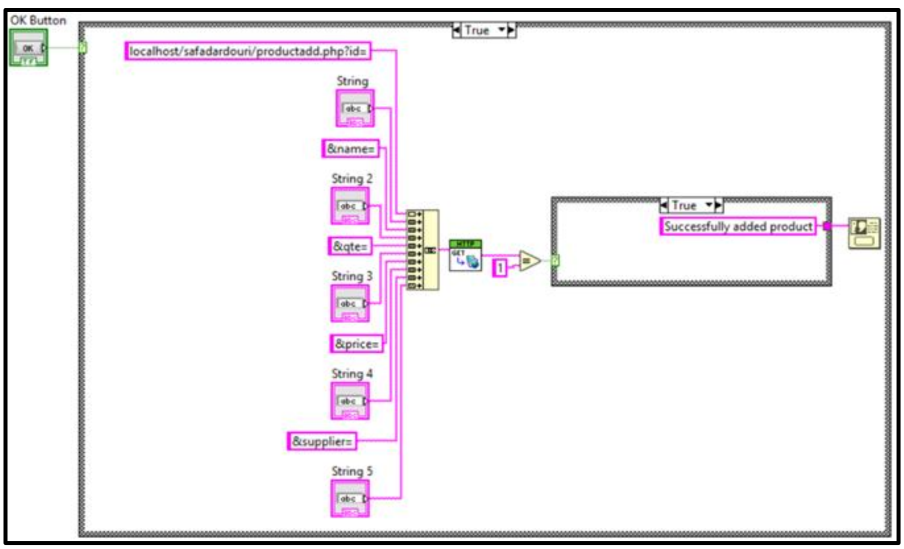

Figure 9. Block diagram of product management

Product control

This interface allows you to display the different products, which are less than five in quantity. An alert indicates the stock status, and a warning message will be sent inform supervisors of the product shortage. Figure 11 below reveals the front panel of the control interface.

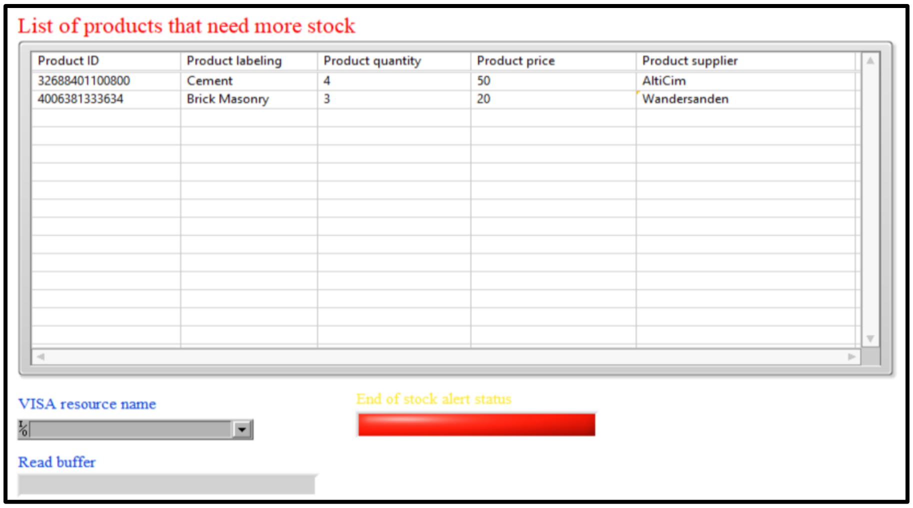

Figure 10. Front panel of control interface

To send and receive data through the serial communication port, an infinite loop should be used to control product typologies. First, port identifies the ID through the VISA serial port, and then the product quantity is decreased from the database.

Observation

Table 1 illustrates the Strengths -Weaknesses -Opportunities and Threats of using the RFID technology in the construction site.

Table 1. SWOT analysis of tracking application

STRENGTHS "S"	WEAKNESSES "W"
✓ Productivity Gain: manage the flow of equipment ✓ Tracking: routing of RFID tags in the site. ✓ Error rate Reduction: Optimize the stock management. ✓ Tracking and controlling inventory (stock) on the construction site in real time.	✓ Metal and water can affect chip frequency ✓ High implementation cost ✓ Limited scope
OPPORTUNITIES "O"	**THREATS "T"**
✓ Anticipate the future evolution of the construction site ✓ Adapt the system to the whole logistics chain	✓ Security/ Safety (Hackers) ✓ Confidentiality problems ✓ Reduce the number of employees

CONCLUSION

In this study, an RFID-system for construction site on a real platform is presented. The proposed method is based on a Human Machine Interface (HMI) with electronic card. A choice of the hardware and software was done during the design phase of this research work. An open source solution was chosen for the software. The hardware was chosen based on its capacity to ensure a suitable use for the construction site. The Human Machine Interface (HMI) is composed by an admin interface that controls the system and that allocates rights for the supervisors and stakeholders. The supervisor is then capable to follow and manage products and storage. A dedicated interface is used for monitoring product flows of input and output.

A SWOT analysis was realized to show the strength, weakness, opportunities and threat of this system. The analysis has shown that the system and technology can enable automation, real-time monitoring, error-free tracking and inventory of unique materials through the supply chain. Future studies should launch a series of tests in a large-scale construction site and generalize the use with a mobile app and an autonomous tagging system.

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