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Monitoring Materials with GIS and RFIDs During a Construction Project

Maria C. Kirkinezou
Civil Engineer, Doctoral Candidate, Department of Civil Engineering,
Aristotle University of Thessaloniki, Greece

Demos C. Angelides
Professor of Marine Structures, Chairman, Department of Civil Engineering,
Aristotle University of Thessaloniki, Greece

Abstract

One of the important factors to a construction project is the ability to monitor and trace the materials during construction. This paper is concerned with the determination and development of a system for monitoring and tracing the materials during construction as well as in a project, after the end of the construction phase and during its use. Furthermore, this system deals with monitoring the equipment which transports the materials. The technology that will be used for recording and tracing the materials is a system of Radio Frequency Identification - (RFID) technology. The RFID system uses tags and readers, which read the tags. The position of the equipment will be monitored with the help of Global Positioning System (GPS). All the data that will be collected will be analyzed with Geographic Information Systems (GIS). A suitable database will be used in order to locate and record, at any time, the materials and their history as well as the equipment that transports them. The information will be transferred to the central software system with the help of Global System for Mobile Communication - GSM technology.

Keywords

GIS, RFID, GPS, GSM, Construction Industry

1. Introduction

The delivery and availability of materials at the right time and at the right place is very critical for the success of a construction project. Therefore, information concerning materials is a major issue. Bad or incomplete information can create serious problems in a construction project. It is necessary to monitor all the materials in a construction site in order to collect all the appropriate data and information needed. The purpose of this paper is to present an approach and a supporting system for monitoring and tracing the materials of a construction project.

This monitoring and tracing includes both the construction phase and the use of the built project. Potential failure during use will be examined along with the history and origin of the material to locate the reasons of the failure and finally to attribute responsibilities.

Radio Frequency Identification technology will be used for monitoring the materials in a construction site. Global Positioning System technology will monitor the equipment that transports the materials. These technologies will provide the GIS tool with all the information needed to analyze and help historical tracing of the materials in a constructed project.

Previous research studies on the utilization of RFID evaluate how the specific technology improves facility management processes and technological feasibility within a facility repetitively on a daily basis (Ergen et al., 2007). A research effort tested active RFID technology focused on the delivery of materials from production to construction, evaluating the performance of RFID in tracing (Aksoy et al., 2004). RFID technology was also used to facilitate the information flow processes from a job site to a field office to measure existing deficiencies and demonstrate the effect of using automated reality capture technologies (Akinci et al., 2006). As far as the GPS technology is concerned, recent study focused on the deployment of GPS to the materials- locating processes on industrial projects, in order to evaluate the technical feasibility and quantify the benefits derived from the integration of GPS devices within pipe-locating processes (Caldas et al., 2006).

The above studies have used the RFID and GPS technology, but none of the above dealt with the application of these technologies in a construction site. The application of the above technologies to a construction site presents a distinct uniqness; this is the open environment compared to the in-door environment of the previous applications. The application to an open environment like a construction site is still unproven. Several factors have to be dealt with such an environment as climatic impacts and geometric scale of the construction sites. A pilot application is necessary to face these problems, to adapt the technology in the most suitable way and to prove the system practicality.

2. Overall Frame of the Proposed System

2.1 Materials

The system includes two parts: a) monitoring the materials during the construction and b) recording the history of materials in the finished built project during its use.

During the construction phase of a project there should be:

- complete registration and monitoring of all materials to be used in a given project
- knowledge of which material and in which quantity will be used
- allocation of the right materials to the right space and at the right time.

Regarding the recording of history of materials, the objective is to identify the elements and materials of the built project that have failed due to a hazard event. In particular, this requires:

- to know its origin and history
- to explain the reason of failure in order to prevent a similar situation
- to determine legal implications.

2.2 Equipment

The system will also monitor the equipment that transports the materials. Monitoring the equipment is necessary to ensure that the materials will be transported to the right place and at the right time. Figure 1 depicts the highlights of the system.

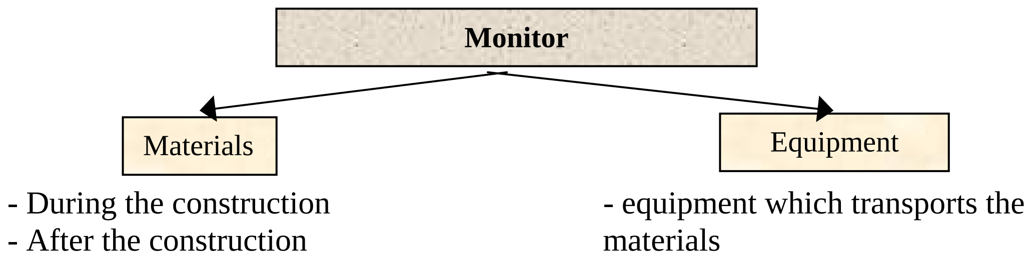

Figure 1: Highlights of the system

3. Components of the System

3.1 Monitor the Materials with RFID technology

The system that will be used for recording and tracing the materials is based on Radio Frequency Identification - (RFID) technology.

Radio frequency identification (RFID) is one of the most promising and anticipated technologies. RFID, wirelessly, exchanges information between a tagged object and a reader/writer. An RFID system comprises the following components (Figure 2):

• One or more tags (also called transponders), which includes a chip and antenna,
• One or more read/write devices (readers) with an antenna on each reader,
• Application software and a host computer system.

Radio waves are used to transfer data between the RFID tag and the reader, which are tuned to the same frequency. The reader sends out a signal, which is received by all tags tuned to that frequency that are present in the RF field. Tags receive the signal with their antennas, and selected tags respond by transmitting their stored data. The tag can hold many types of data about a material item, such as its serial numbers, what time the item traveled through a certain zone, even temperature and other data provided by sensors.

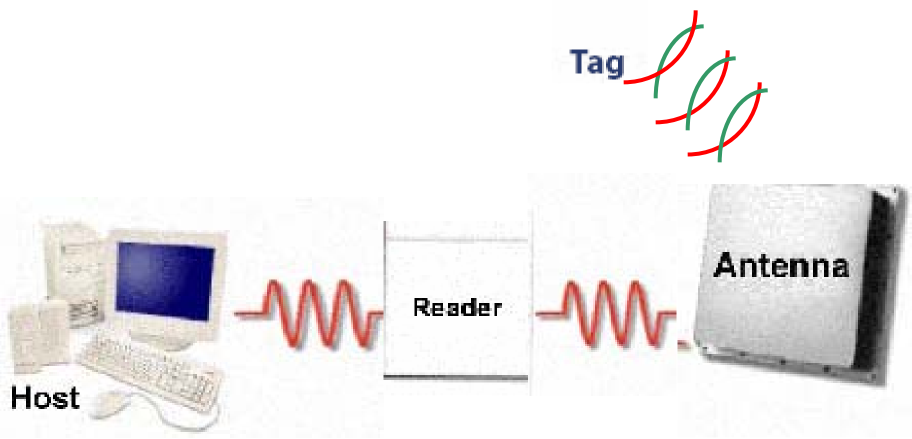

Figure 2: RFID System Components

Depending on the desirable reading range, the system uses three types of tags: passive, active or battery assisted. Passive tags receive their power to exchange data from the signal sent by the reader. Active tags have a battery to power their own transmissions. Passive tags are less expensive and smaller than active versions because they do not require a battery. Active tags are the best selection when the most important consideration is to be able to read the tags at the longest possible distance. (Harrington, 2000, 2001), (Turner, 1999).

The steps that will be followed to monitor the materials are as follows:

- Placement of tags in all packed materials before they are placed in the warehouses.
- Placement of readers in the entrance/exit of the warehouses.

The number of the readers that will be used mainly depends on the size (dimensions) of the entrance/exit of the warehouse. The tags that will be used will be passive. The active tags are avoided because of their high cost.

After the materials are loaded on the equipment, GPS is responsible for monitoring that equipment. In order to ensure that the quantity of materials unloaded at the construction site is the same with the quantity loaded in the warehouse location, a worker with the help of a portable reader will record the materials quantity in both locations (Figure 3).

With regard to the recording of the materials, three are the basic points of interest:

- knowledge of their origin (suppliers).
- knowledge of the point of storage (conditions of storage and preservation).
- knowledge of their destination.

In this phase, distinction between the above materials should be made:
a) the packed materials that are incorporated directly into the under construction project (not stored) and
b) the non packed materials, e.g. sand.
For both cases, it is obvious that it is not possible to place tags, because in the first case, the materials are incorporated directly in the project (and we do not want also to incorporate the tags), in the second case it is impossible to place the tags on the surface of

the non packed materials. In this case, Personal Digital Assistant (PDA) will be used; all the essential information (transport/incorporation of materials) will be stored and transmitted automatically to the central system of process.

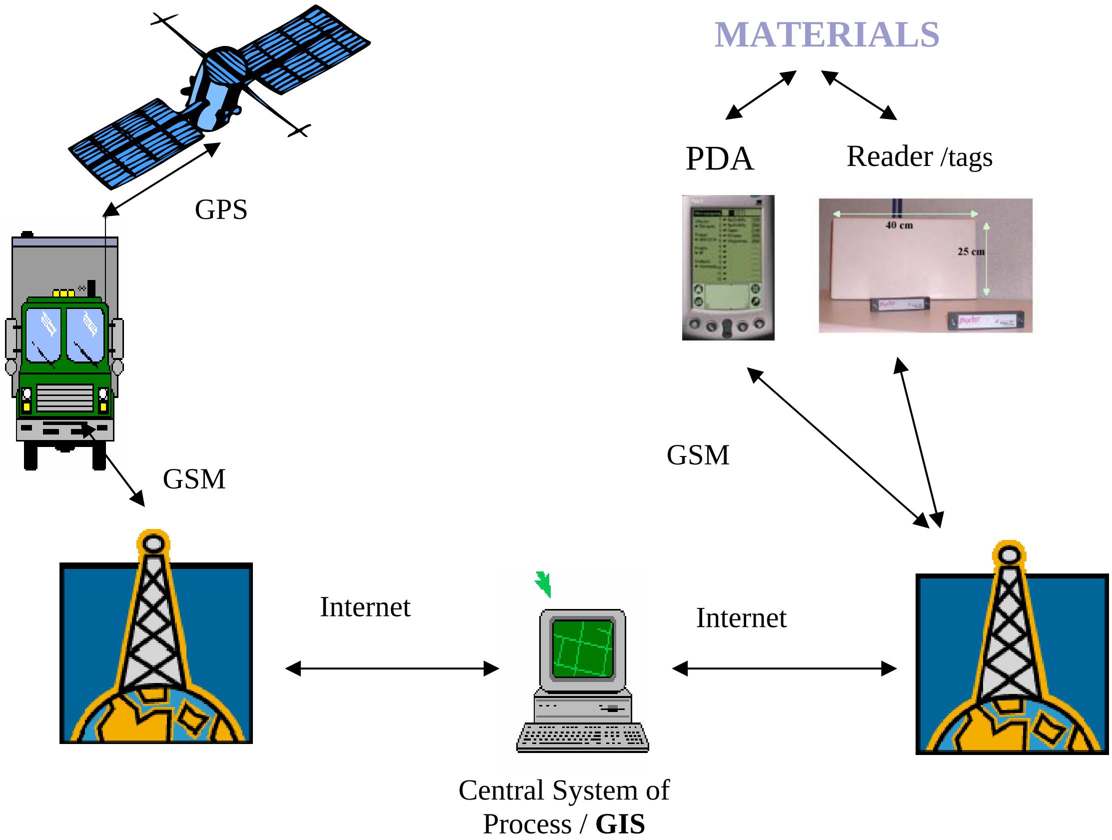

Figure 3: Components of the System

3.2 Monitor the Equipment Transporting not Packed Materials

As far as the equipment is concerned, its position will be monitored with the help of GPS (Global Positioning System) and in certain cases of Differential -GPS (where extreme precision is required) (Figure 3). The system requires GPS antennas to be placed on all equipment. The antennas are placed at the higher point of the equipment and they receive the radio messages, which are emitted by the satellites (Bajaj et al., 2002). The system is focused on tracing the equipment from the loading area to its final destination, i.e. the construction site, where the material will be unloaded. The not packed materials are considered, which can not be traced and registered with any tracking mechanism.

3.3 Recording the History of Materials

The data that are collected with the help of the specific system will be analyzed with Geographic Information Systems (GIS). This represents a substantial part of the system. Specifically, it includes a suitable database and the adaptation of a computational software that will be used by a construction company in order to locate and record, at any time, the materials and their history as well as the equipment that transports them. The analysis of the information will be performed in a central system, which will be installed in the headquarters of the company (Figure 3).

The appropriate GIS software has the following capabilities:
- modeling of the geometry of the construction project
- identification of the materials that have been used and record their precise location in the construction artefact (origin, place of previous storage, conditions of storage etc.).

In case of a potential failure of the built project during its use, knowing the component that suffered a failure will assist to:
- open the specific file and see the history of the material and its origin
- explain the reason of failure and determine legal implications
- take the essential measures and precautions in order to avoid a similar situation in a future construction project
- have the capability to select the suppliers of the materials.

3.4 Transmission of Data

The transmission of data from the readers and from the GPS antennas to the central software system will be carried out with the help of mobile and wireless technology (Global System for Mobile Communication - GSM and Wireless Local Area Network-WLAN supported by mobile telephones, laptop, terminals) (Figure 3). The main advantages of this technology are as follows:
- easy, fast and effective communication between the individuals that participate in the process
- faster transmission of information and data
- transmission of the results to the Internet, or directly to the customers.

3.5 Analysis of Data

The data that are received from:
- the readers in the entrance/ exit of the warehouse
- the deposit of materials in the worksite
- the PDA
- the GPS antennas,

are transferred to the central software system and, with the help of GIS, are analyzed. The system will produce reports, maps and diagrams using all the appropriate data. GIS facilitates the complete control and management of the system for monitoring the materials and equipment.

3.6 Methodology of Implementation

The methodology that will be followed for the implementation of the system includes the steps below:

(a) Identification and integration of the most suitable technologies addressing also cost – benefit analysis
(b) Development of the system
(c) Collection of real data and system validation
(d) Pilot implementation of the system and lessons learned for further improvement.

4. Conclusions

The construction companies can benefit significantly from this system. The main benefits could be summarised as follows:

- Monitoring the materials ensures the disposal of materials at the right time and place
- Monitoring the materials mobilizes quick reaction and handling of potential wrong transport of materials
- Recording the history and characteristics of materials, facilitates the detection of causes, the assessment of legal consequences in a potential failure of the construction and the improvement of the processes of suppliers as well as the improvement of future projects.

The combination of the above issues leads to the benefits below for a construction company:

- Reduction of the total cost of the construction projects and cost of maintainance.
- Reduction of time of construction.
- Improvement of quality of the final product /service.

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The above profits will lead to the qualitative upgrade of the construction projects, with direct result in the further economic and technological development of the construction projects and in the improvement of the quality of provided product/services.

It is believed that the application of this system will lead to important changes in the management and in the concept of operations of construction sites as well as in the processes of construction.

5. References

Akinci, B., Kiziltas, S., Ergen, E., Karaesmen, Z. I. and Keceli, F. (2006). 'Modeling and Analyzing the Impact of Technology on Data Capture and Transfer Processes at Construction Sites: A Case Study'. *Journal of Construction Enginering and Management.* Vol. 132, No. 11, pp 1148-1157.

Aksoy, Y., Chan, I., Guidry, K., Jones, J., and Wood, C.`(2004). "Materials and asset tracking using RFID: A preparatory field pilot study." *Fully Integrated and Automated Technology (FIATECH) Report*, Houston.

Bajaj, R. and Ranaweera, S. and Agrawal, D. (2002). "*GPS: Location –Tracking Technology*", Computer, pp 92-94.

Caldas, H. C., Torrent, G. D. and Haas, T. C. (2006). ‘Using Global Positioning System to Improve Materials-Locating Processes on Industrial Projects’. *Journal of Construction Enginering and Management*, Vol. 132, No. 7, pp 741-749.

Ergen, E, Akinci, B, East, B. and Kirby, J. (2007). ‘Tracking Components and Maintenance History within a facility Utilizing Radio Frequency Identification Technology’. *Journal of Computing in Civil Enginering.* Vol. 21, No. 1, pp11-20.

Harrington, T. (2001). “*How multi-tech RF systems can provide complete tracking*”, www.wherenet.com webpage.

Turner, T. (1999), “*Real Locating Systems*” from the www.wherenet.com webpage.

‘ *Supply Chain RFID: How Works and Why it Pays’*, White Paper, www.intermec.com.