# REAL TIME LOCATING SYSTEM FOR CONSTRUCTION SITE MANAGEMENT

**Farnaz Sadeghpour**[1]

## ABSTRACT

One of the essential tasks in the management of construction sites is tracking portable and moving objects such as material and equipment which is currently carried out with brute force. Leading research and practice is rapidly adopting automated tracking techniques to change the traditional tracking processes and achieve measurable improvements in operations. Despite their success, the application of automated tracking tools is not fully explored in construction research and industry. This paper proposes the applications of automated tracking technology in construction sites by integrating Real Time Locating Systems (RTLS) with 4D graphical representation from a previously developed model called CASL. CASL consists of an object library, which is dynamically linked to a Computer Aided Design (CAD) system. The proposed RTLS employs radio frequency identification (RFID) technology and global positioning system (GPS) to automatically identify the actual location of a facility in real time. The system can track thousands of objects on construction site, simultaneously, and generate a real time 4D representation for the actual layout of the site. It will inform on a real-time basis of movements and changes to objects. Such representation will aid project team members to have an actual perception of the site, leading their interaction and intervention in an effective direction. Further, the product of this system can be utilized in *monitoring* and *control* of facilities on construction sites. As a result it can dramatically increase operational efficiency by supplying up-to-the-minute information on object status and material delivery dates.

## KEY WORDS

Construction site management, Automation in construction, Real Time Locating System (RTLS), Radio Frequency Identification (RFID), 4D visualization, Computer-Aided Design (CAD).

## INTRODUCTION

One of the essential tasks in the management of construction sites is tracking portable and moving objects such as material and equipment. It is importance to know where each object is located and that the critical assets do not get misplaced or lost. Construction site managers have always faced the challenge of locating and tracking inventory and facilities with brute force. Leading research and practice is rapidly adopting automated tracking techniques to change the traditional tracking processes and achieve measurable improvements in

[1] Assistant Professor, Department of Architectural Science, Ryerson University, 350 Victoria St., Toronto, M5B 2K3, Canada, Phone 416/979-5000 Ext. 6480, FAX 416/979-5353, Farnaz@ryerson.ca

distribution and logistics. Facility Real Time Locating System (RTLS) is one of the most common implementation of RTLS within a site or campus, which has a compelling return on investment. Yard management and container tracking are other examples of RTLS applications. Despite their success in inventory management, the application of automated tracking tools is not fully explored in construction research and industry. Instead, tracking of construction objects on sites has typically relied on human memory, which could result in time and productivity losses.

A number of researches in recent years have suggested the use of locating systems in construction process. These researches focus mainly on applications of Radio Frequency Identification (RFID) for material handling. RFID is used for identifying physical objects using computer chips with wireless communications capabilities. The use of RFID as automated tracking system on construction sites was first suggested by Jaselskis et al. (1995) to track material delivery and equipment handling. At the time, the research identified the main barriers to adoption of RFID in construction as psychological and cost of hardware. Current advances in the technology and decrease of hardware price has made the use of automated tracking systems more viable in the construction industry. A more recent cost benefit analysis showed that RFID is cost efficient for material tracking systems on construction sites (Akinci at al 2002). Later, through pilot tests it was demonstrated that use of RFID can reduce required work pertaining to data acquisition for material tracking systems (Jaselskis and Misalami 2003). In another effort RFID was suggested for locating and tracking precast concrete components (Akini at al 2002). Furlani and Pfeffer (2000) experimented the integration of a bar code, RFID and 3D visualization for structural steel components. However, the use of barcode technology has not shown great success in construction industry due to weather-related problems such as deteriorating and sun glare.

This paper investigates the applications of automated tracking technology in the management of construction sites. It proposes an system that integrates RTLS technology with a 4D site representation model. The system will visually represent, on a real-time basis, movements and changes to objects on construction sites. Such representation will provide project team members an actual perception of the site, leading their interaction and intervention in an effective direction.

## REAL TIME TRACKING SYSTEMS

Automated tracking systems can be divided into positioning and locating systems. In positioning systems object tags calculated their own locations, while in locating systems tagged objects is being located by the infrastructure (Song et al. 2005). On one hand, positioning systems require considerable computations on RFID tags. On the other hand, locating tracking systems have limited coverage area and hence requires costly infrastructure for a scalable location. To overcome the disadvantages of both techniques, a combination of RFID and GPS technology has been identified as a viable tracking tool when locating hundreds of materials on construction site is considered (Song et al. 2005).

The tracking system utilized in this research is GPS-enhance RFID, and as such, takes advantage of the best of two worlds. RFID is a remote sensing technology that keeps track of objects using cellular radio technology and low radio signal software analysis algorithms. It utilizes radio frequency and a cellular reader system to detect the presence and location of objects in real time. A typical GPS-enhanced RFID is comprised of tags, readers, locator

tags, antennas and middleware. A tag is a portable memory device on a chip that can be embedded in any object and store dynamic information. Active tags, as opposed to passive tags, allow the stored data to be modified. This is specifically important for the proposed application since the location of facilities is constantly updated in real time. Using readers the information stored in tag microchips can be read and modified. RTLS employs radio frequency communications to exchange data between the memory chip and a host computer. Locator tags are equipped with Global Positioning System (GPS) and allow the identification of exact location for each facility. The antennas communicate with tags through radio frequency and readers interrogate and manipulate the data stored on the tags. Middleware is the software which allows readers to communicate with tags. One advantage of RTLS is that it can be easily expanded by adding new tags to new designated objects. The marginal cost to expand the system is the cost of purchasing and affixing tags to the designated construction objects. In practice, an RTLS can deliver a complete return on investment within a short period by reducing operational costs and increasing workforce productivity (Akinci et al. 2002).

## INTEGRATED REAL TIME LOCATING AND CAD SYSTEM

The proposed system will integrate the 4D graphical representation of construction sites with remote sensing techniques to provide an automated real time tracking system for facilities on construction sites. For 4D representation, the object model of a previously developed site layout model called CASL will be utilized (Sadeghpour et al. 2004 and 2006). Site representation in CASL is carried out using an open architecture supported by object-based concepts. The model offers three tiers of objects: i) site objects, ii) construction objects, and iii) constraint objects. Site objects are those that exist on the site at the commencement of construction. Construction objects enter - and exit - the site through the course of project. Constraints are rules that define the physical relationship among site and construction objects. This classification assists in formalizing the representation of site layout problems. A formal structure for each tier of object is proposed. The model has an open architecture, which supports the development of new objects and updating existing ones. Using the formal structure, new objects can be created and added to the model for future use. As such the developed model provides a flexible support of a wide range of objects for site planning. This feature permits the set up of different construction projects via selecting objects from their respective libraries. This allows for the gradual expansion and enrichment of the supporting libraries. The first two tiers of objects, i.e. site and construction objects, are of interest for the purpose of graphical representation of construction site in the system presented in this paper.

The object model of CASL consists of an object library, which is dynamically linked to a Computer Aided Design (CAD) system. CASL has a relational database to store non-geometrical attributes of objects. The geometrical and graphical attributes of objects are stored in the built-in database of the CAD system. The interconnectivity between the two databases is maintained by a unique ID that is the overlap between two databases. The existing databases can be connected to the RFID database which will connect objects on construction sites to their respective computer representation objects. Once the required resources for a specific project are identified, the computer objects representing these resources, along with their attributes, are retrieved from the database. Upon being selected

from the library, a graphical representation of each object will be generated by the CAD system.

RTLS creates a real time database of asset tag locations that can be used to retrieve real time location based on real time information. In the proposed system, the this database will be integrated with the CASL library to enable the automated generation of actual site, as well as tracking of facilities on construction site in real time. Upon the entrance of a tagged facility to the site, it will be identified and interrogated by readers and antennas. Once the facility is identified, the computer object associated with this facility will be provoked from the object library. Subsequently, a graphical representation of the object will be generated by the CAD system (Figure 1). As all the objects are modeled in the simulation, a dynamic graphical representation of the objects on construction site will be generated. The RTLS continually updates the database with current tag locations as frequently as every several seconds or only every few hours for items that seldom move. Accordingly the location of objects in the computer representation is updated. The proposed system can track thousands of tags on construction site, simultaneously. Consequently, a real time graphical representation of the entire construction site will be automatically generated on computer. As such, the system is able to graphically represent the changes that occur on construction site through the course of construction, and therefore, provides a robust 4D perception of what will happen on construction site.

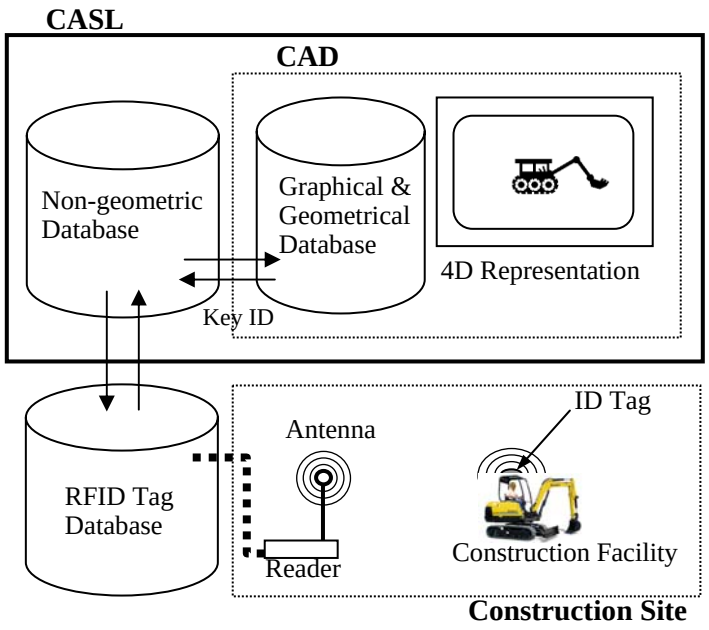


Figure 1: Real time representation of construction site using RTLS.

## RTLS FOR THE MANAGEMENT OF CONSTRUCTION SITES

The proposed system can have several applications in the management of construction sites such as: i) generating 4D visualization of the actual site, ii) monitoring and iii) control of site schedule/activities. As described in the previous section, using the radio frequency identification (RFID) technology and through a set of locating tags, the proposed RTLS *automatically* identifies the *actual* location of construction facilities on site. Through the proposed RTLS, all objects (i.e. moving, portable and stationary) in the computer representation will be virtually connected to actual facilities on construction site. In monitoring construction sites, movements or status changes of facilities can be automatically reflected and traced on computer screen in real time. In addition, the proposed system gives the ability to set alarms that will notify if an object moves when it is not suppose to, or does not move when it should. Using this information, a four-dimensional (three physical dimensions + time) visualization of the *actual* layout of construction site can be generated.

The proposed system will be subsequently utilized to enhance the management of construction sites in planning, monitoring, and control tasks. At monitoring level, by comparing the planned versus the actual layouts of the construction site at different points of time, the model can identify the differences between the two. According to the circumstances a decision can be made to rectify this difference; e.g. changing the location of facilities on site, or updating the planned site layout. The system can be used to control the movements of objects on construction site. For instance, a tag on a high value asset could be set to signal an alert if the asset starts to move so that it could be located and stopped before it is removed from the site. Or a tag on a construction truck could be set to create an alert if the truck did not move to the next process within a specified period of time. Further, the 4D representation of the construction site can aid in identifying the time-space conflicts, which are main sources of delays in construction, before they actually occur. Once a conflict is identified, it can be rectified at the early planning phase by modifying either the site plan, or the construction schedule. The aforementioned process will be presented graphically in a CAD system, and as a result the system provides a better visualization and comprehension of the process and consequently directs the intervention of project management team in an efficient direction.

## SUMMARY AND CONCLUDING REMARKS

This paper presented the applications of real time locating technologies in the management of construction sites. A hybrid system was proposed by integrating a previously developed CAD-based object model with RTLS to track and represent objects on construction sites in real time. The proposed system provides seamless form of data management from construction sites to computer model. It enables complete automation of the tracking process in which the need for human force for physical scanning of an object is eliminated. The proposed system automatically generates a 4D graphical representation of the construction site. This representation provides an actual perception of the entire site as one entity, leading the interaction and intervention of project team in an effective direction. As a result, it can dramatically increase operations efficiency by supplying up-to-the-minute information on facility status and delivery dates. Further, the proposed system can be utilized for space

conflict identification as well as monitoring and control processes for construction projects. The system can be used to monitor objects of high value or mobile equipment that need to be utilized in time-critical activities. It informs on a real time basis when an object moves and gives the ability to set alarms that will notify if an object moves when it is not suppose to or does not move when it should. As such, it will provide an efficient tool for site management, which can aid to avoid cost overruns and schedule delays caused by chaotic sites and time loss due to inability to locate objects.

## REFERENCES

Akinci, B., Patton, M., and Ergen E. (2002) "Utilizing Radio Frequency Identification on Precast Concrete Components – Supplier's Perspective", Proceedings of 19th International Symposium of Automation and Robotics in Construction, IAARC, Washington D.C.

Furlani, K.M. and Pfeffer L.E. (2000) "Automated Tracking of Structural Steel Members at the Construction Site", Proceedings of 17th International Symposium of Automation and Robotics in Construction, IAARC, Krakow, Poland.

Jaselskis, E.J. and El-Misalami T. (2003) "Implementing Radio Frequency Identification in the Construction Process" J. Constr. Engrg. and Mgmt., ASCE, 129 (6), pp. 680-688.

Jaselskis, E.J. Anderson, M.R., Jahren C.T., Rodriguez Y., and Njos S. (1995) "Radio Frequency Identification Applications in Construction Industry" J. Constr. Engrg. and Mgmt., ASCE, 121 (2), pp. 189-196.

Sadeghpour, F., Moselhi, O., and Alkass, S. (2004) "A CAD-Based Model for Site Planning", Journal of Automation in Construction, Elsevier, 13(6), 701-715.

Sadeghpour, F., Moselhi, O., and Alkass, S. (2006) "Computer-Aided Site Layout Planning", Journal of Construction Engineering and Management, ASCE, 132(2), 143-151.

Song, J. Hass, C., Caldas, C., and Liapi, K. (2005) "Locating Materials on Construction Site Using Proximity Techniques", Proceedings of Construction Research Congress, ASCE, San Diego, CA.