

Utilization of Advanced Data Storage Technology to Conduct Construction Industry on Clear Environment

Javad Majrouhi Sardroud, Mukesh C. Limbachiya

Abstract— Construction projects generally take place in uncontrolled and dynamic environments where construction waste is a serious environmental problem in many large cities. The total amount of waste and carbon dioxide emissions from transportation vehicles are still out of control due to increasing construction projects, massive urban development projects and the lack of effective tools for minimizing adverse environmental impacts in construction. This research is about utilization of the integrated applications of automated advanced tracking and data storage technologies in the area of environmental management to monitor and control adverse environmental impacts such as construction waste and carbon dioxide emissions. Radio Frequency Identification (RFID) integrated with the Global Position System (GPS) provides an opportunity to uniquely identify materials, components, and equipments and to locate and track them using minimal or no worker input. The transmission of data to the central database will be carried out with the help of Global System for Mobile Communications (GSM).

Keywords— Clear environment, Construction industry, RFID.

I. INTRODUCTION

THE interest of protection of environment has been rising as global warming problem and reduction of construction waste and carbon dioxide emissions from transportation vehicles related to the strategy of construction industry are one of the important problems [1]. This is the time to be heard the voice of clear environment and it will be possible to conduct construction industry on clear environment by effective managing of construction resources which leads to minimizing carbon dioxide emissions from transportation vehicles and reducing any avoidable construction waste. The first step in understanding and reducing wastage onsite is to know what materials and equipment have been delivered [2].

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In other words, failure to locate a piece has a more significant impact in terms of adverse environmental impacts such as construction waste and carbon dioxide emissions since that piece has to be manufactured again. The delivery and availability of construction resource at the right time and at the right place is very critical to obtain a successful construction project and poor control on construction phase result in wasted materials where double handling can damage the materials and increases waste. Automated approach can deliver continuous results in real-time and thereby overcome much of the inconvenience and inefficiency associated with traditional tracking practices[3], [4]. Given the mentioned monitoring and tracking problems above, the most benefit of using intelligent system could be defined; faster location and accurate identification and reducing wasted materials through loss, damage or oversupply. In construction project accurate data is needed not only to control current projects, but also to update the historic database. Such updates will enable better planning of future projects in terms of resource.

Taking these situations into consideration, the construction industry can benefit from the advantages of combining RF-based technologies with Geographical Information System (GIS) and portal system where Radio Frequency Identification (RFID) can be applied to collect the information by identifying resource automatically and the position of their external and internal transport vehicles (equipments) can be monitored with the help of Global Positioning System (GPS). This paper investigates an RFID-based mobile, pervasive, ubiquitous system (MPU) integrated with GIS and portal system to improve construction management activities. This approach involves the use of RFID, GPS, GSM, GIS, and portal technology to obtain real-time information and information sharing among the involved participants of the construction project, such as materials manufacturers, suppliers, contractors, and construction site offices. Most of the technologies which are used in this research are inexpensive and commercially available. This paper first reviews previous research and work that has been done by others followed by an overview of the enabling technologies which are used in this research. Then it reveals the

architecture of our integrated system for improving construction management and controlling adverse environmental impacts such as construction waste and carbon dioxide emissions. Conclusions are given in the end of paper.

II. BACKGROUND REVIEW

Locating tagged items effectively in construction projects can potentially facilitate great increases in productivity through efficiencies in coordination and allocation of resources. Many researchers reported that RFID can be used for tracking, locating, and identifying materials, vehicles and equipment that lead to important changes in the construction industry.

In earlier research, RFID technology and its potential applications in the construction industry including concrete processing and handling, cost coding of labor and equipment, and material control have summarized and discussed by Jaselskis et al. [5]. Another related research to using RFID technology for discrete point positioning in tracking construction vehicles with the help of GPS was conducted by Naresh and Jahren [6]. Automated tracking of structural steel members with the aid of RFID technology at the construction job site studied by Furlani [7]. In a study implemented by Jaselskis and El-Misalami [8] RFID technology has been used to receive and keep tracking of pipe spool and hangers in a power plant project and a refinery project. Navon and Berkovich [9] studied the use of RFID application in collecting data related to material arrivals and dispatches without information about tracking the status of goods on transit. Li et al. [10] investigated the use of integrated GPS and GIS technology to the reduction of construction waste. In another study, Caldas et al. [11] investigated the use of GPS to track the position of fabricated pipe spools on lay down yards of an industrial construction project in order to improve the process and reduce the number of lost items. Song et al. [12], [13] developed an RFID based method to automate the task of tracking, delivery, and receipt of fabricated pipe spools in lay down yards and under shipping portals. Ergen et al. [14] conceptualized and applied the use of RFID and GPS combined with GIS technology in order to locate precast concrete components with minimal worker input in the storage yard, the position of a gantry crane was tracked by a GPS receiver while GPS data were written into RFID tags attached on the precast units being lifted. Kaneko et al. [15] have developed a construction logistics system using RFID technology for finely controlling several construction sites in order to improve the transportation and handling of construction materials. The authors found that carbon dioxide emissions were reduced by using RFID technology. Jang and Skibniewski [16] developed an Automated Material Tracking system based on ZigBee localization technology with two different types of query and response pulses. Song et al. [17] developed a system that can identify logistics flow and location of construction materials with better performance by using RFID and wireless sensor networks such as ZigBee technologies. Although, the aforesaid research has clearly

proven the value and potential of using new technologies, studies focusing on detailed application of full automatic systems to conduct construction industry on clear environment are still scarce.

III. A BRIEF REVIEW OF TECHNOLOGY

Advancements in field data capture technologies, such as RFID enable collecting, storing and reusing field data accurately (i.e., without inaccurate recording of manual process), completely (i.e., without missing data), and timely (i.e., whenever needed). Some application of advanced tracking and data storage technologies in construction industry have been investigated previously e.g., [18], [19].

A. RFID Technology

RFID is a method of remotely storing and retrieving data by utilizing radio frequency in identifying, tracking, and detecting various objects that streamlines data acquisition and identification and can help improve the effectiveness and convenience of information flow in construction supply chain systems [20]. An early, if not the first, work exploring RFID is the landmark paper by Harry Stockman, "Communication by Means of Reflected Power", Proceedings of the IRE, pp1196-1204, October 1948 [21]. A RFID system consists of tags (transponder) with an antenna, a reader (transceiver) with an antenna, and a host terminal. A typical RFID system is shown in Figure 1.

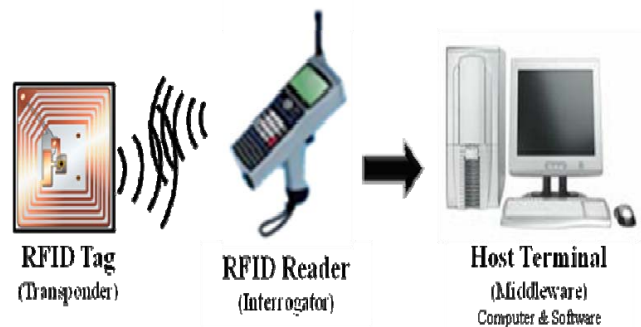


Fig. 1 A typical RFID system

The RFID reader acts as a transmitter/receiver and transmits an electromagnetic field that "wakes-up" the tag and provides the power required for the tag to operate[22]. Figure 2 shows how RFID works, step by step.

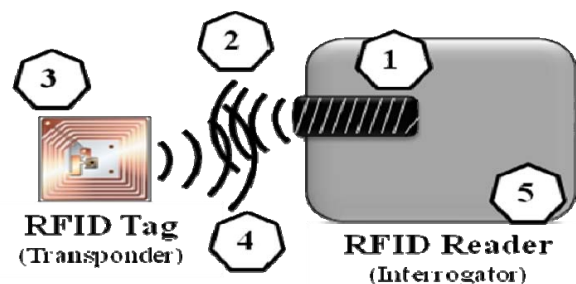


Fig. 2 RFID works, step by step

An RFID tag is a portable memory device on a chip that is encapsulated in a protective shell and can be embedded in any object and store dynamic information about the object. Tags which consist of a small integrated circuit chip coupled with an antenna to enable them to receive and respond to radio frequency queries from a reader. Tags can be categorized as read-only (RO), write once, read many (WORM), and read-write (RW) in which the volume capacity of their built-in memories varies from a few bits to thousands of bits. RFID tags can be classified into active tags (battery powered) and passive tags, which powered solely by the magnetic field emanated from the reader and hence have an unlimited lifetime. Reading and writing ranges depend on the operation frequency (low, high, ultra high, and microwave). Low frequency systems generally operate at 124 KHz, 125 KHz or 135 KHz. High frequency systems operates at 13.56 MHz and ultra high frequency (UHF) use a band anywhere from 400 MHz to 960 MHz [23]. Tags operating at ultra high frequency (UHF) typically have longer reading ranges than tags operating at other frequencies. Similarly, active tags have typically longer reading ranges than passive tags. Tags also vary by the amount of information they can hold, life expectancy, recycle ability, attachment method, usability, and cost. Communication distance between RFID tags and readers may decrease significantly due to interferences by steel objects and moisture in the vicinity, which is commonplace to a construction site. Active tags have internal battery source and therefore have shorter lifetime of approximately three to ten years [8]. The reader, combined with an external antenna, reads/writes data from/to a tag via radio frequency and transfers data to a host computer. The reader can be configured either as a handheld or a fixed mount device. The host and software system is an all-encompassing term for the hardware and software component that is separate from the RFID hardware (i.e., reader and tag); the system is composed of the following four main components: Edge interface/system, Middleware, Enterprise back-end interface, and Enterprise back end [24]. RFID tags are more durable and suitable for a construction site environment in comparison with Barcodes which are easily peeled off and may be illegible when they become dirty. RFID tags are not damaged as easily, does not require line-of sight for reading and writing, can be read in direct sunlight and survive harsh conditions, reusable, and permit remote.

B. GPS Technology

The GPS (space-based positioning system) can provide three-dimensional position data anywhere on the earth, all weather and 24-hour to those with the proper receivers where a pair of receivers can be used in differential mode to avoid transmission interference and to get sub metric accuracy. Locations can be translated into the building's local Cartesian coordinate system for any particular area, such as a construction site [25], [26]. To calculate locations, the readings from at least four satellites are necessary, because there are four parameters to calculate: three location variables

and the receiver's time. The principle of differential GPS can be applied in two ways: using range measurements, called DGPS, and using phase measurements, called "kinematic GPS". In DGPS two receivers are used. One receiver measures the coordinates of a stationary point, called the base, whose position is perfectly known in the reference geodetic system used by GPS. The 3-D deviation between the measured and actual position of the base, which is roughly equal to the measurement error at a second receiver at an unknown point (called "rover"), is used to correct the position computed by the latter [26]. The RTK GPS can further enhance the positioning accuracy to centimetre (even millimetre) levels by combining the measurements of the signal carrier phases from both base and rover receivers with special algorithms.

A. GSM Technology

GSM is a digital cellular technology and the world's leading standard in digital wireless communications that is used worldwide. Short Messaging Service (SMS) is one of the non-voice data and messaging application in GSM and General Packet Radio Services (GPRS) is a GSM service for end-to-end packet switching. SMS is an older, simple and convenient way of sending information so long as they are text based where each message is limited to 160 characters. GPRS is a non-voice value added service that allows data (text, pictures, and sound) to be sent and received across a mobile telephone network. GPRS is a packet switched "always on" technology supporting Internet Protocols (IP) with a theoretical maximum speed of up to 114 kbps which dial-up modem connection is not necessary[27]. Typically, in GPRS based transmission, system can send more data and quicker.

B. GIS Technology

Geographic Information System (GIS) is a computer-based system (a collection of computer hardware, software, and geographic data) to collect, store, integrate, manipulate, analyze, and display data in a spatially referenced environment. GIS allows us to view, understand, question, interpret, and visualize data from a variety of sources in many ways that reveal relationships, patterns, and trends in the form of maps, globes, reports, and charts. Spatial information of resource can be displayed on an electronic geographical map using Web-based GIS (WebGIS) technology. The employment of WebGIS facilitates the dynamic visual representation of the spatial information of the resource distribution on an electronic map. WebGIS is a new technology that combines the Internet and GIS. End users can search and analyze the GIS data intuitively on the Internet using browsers. Luo et al. [28] propose a framework to provide a new model for WebGIS services in a network environment.

C. Portal System

Electronic exchange of information leads to reduction of errors and increased efficiency of the operation processes. When all participants can analyze their projects based on the

information sharing from related-participants in the supply chain, the negative effects of uncertainty can be mitigated in theory [29]. A web-based portal is an ideal platform for sharing information in a supply chain system which leads to produce and distribute construction materials in the appropriate quantities, to the right locations, and at the right times. When a portal is used, all project-related information that is centralized in a project database can be obtained only via a web interface. The portal also provides authentication and access control mechanisms to allow project participants to access information based on user privileges and activity-related units. However, in practice the exchange of information among participants is more difficult than it seems. Portals represent a solution to these problems. An e-Hub construction supply chain management system is needed for information sharing and analysis among project participants [22], [29]. The portal provides an organization with a single, unified database, linked across all functional systems, both within the organization and between the organization and its major supply chain partners. The portal uses middleware technology to integrate disparate sources of information from participants. Also, the portal provides a secure intelligent online gateway with access to multimedia collaboration functions. With the portal and its associated tools, managers and engineers of each participant can conduct effective monitor and controlling activities for the project [29].

IV. PROPOSED SYSTEM

The RFID-based mobile, pervasive, and ubiquitous (MPU) system which is developed in this research could be divided into two parts, the system and central station. This system mainly consists of three types of hardware components; namely, (i) RFID technology (RFID readers, antenna), passive Ultra-High Frequency (UHF) band RFID tags will be used for identifying and monitoring the objects by the help of RFID reader which is connected to the system. To minimize the performance reduction of selected technology under harsh conditions (e.g., in contact with metal and concrete) RFID tags need to be encapsulated or insulated.; (ii) GPS technology (GPS receiver), GPS technology will be used for locating and positioning the equipment that transports the materials and the current location of objects; and (iii) GSM communication technology, the system is then synchronized over GSM, and the information (ID, date, location etc.) retrieved from RFID readers and GPS is transferred to the server in the form of GPRS or SMS. Therefore, data collection is done continuously, autonomously, and it is not influenced by the conditions on-site, such as line of site and weather. The central station consists of two servers, application server and database server.

In this research, collecting data begins when an order for the supply of materials or equipment is being placed. The materials and their transport equipment need to be equipped with RFID tags that contain unique ID. This RFID tags can be placed on any object (engineered-to-order/ materials) and all of the related information such as item and supplier specific information or instructions will be stored in databases which

will be indexed with the same unique ID of objects. Construction commodity will be tagged active or passive dependent upon how they are costly and valuable. At the times of moving or picking up of any pieces, the information on the RFID tag of the piece is captured and deciphered by the RFID reader and the location of the piece is read from a GPS receiver. The ID and location information of the piece is then sent to a database via GSM technology. Any moving probes, such as materials handling equipment (top-slewing and bottom-slewing tower cranes, truck-mounted mobile cranes, and crawler), hoists, internal and external delivery vehicle, the gates, and some key workers should be equipped with a MPU system. A schematic model of this intelligent system (mobile, pervasive, and ubiquitous – MPU) is shown in figure 3.

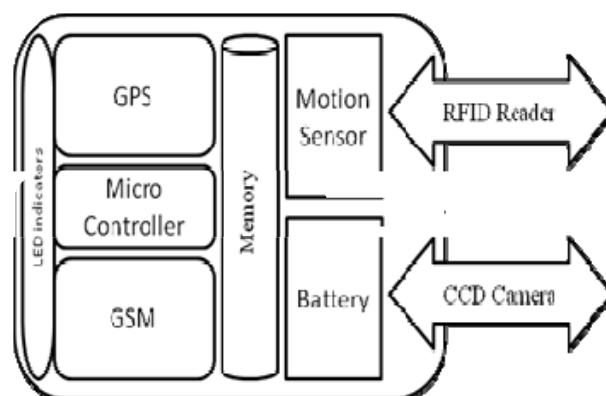


Fig. 3 A schematic model of the intelligent system

This intelligent system could be programmed to send back information via SMS when RFID reader or user defined sensors which are connected to the system receive new data, for example from uploaded component to the truck or detected data by sensors. Extremely heavy foliage or underground places like tunnels would cause the signal to fade to an extent when it can no longer be heard by the GPS or GSM antenna. When this happen, the receiver will no longer know its location and the in the case of an intelligent system application, the vehicle is technically lost and central office won't receive information from this system. In this case to locate vehicles inside GPS blind areas, intelligent system will use RFID reader to save tag-IDs in the way through the tunnel or parking - each tag-id shows a unique location - the device will store all information inside internal memory as a current position, and the system will send unsent data to central office when network re-established. In this approach, materials related activities are grouped into three major categories. These three categories include:

- 1) Production activities;
- 2) Delivery activities; and
- 3) On-site activities.

Each category also further divided into more detailed subcategories. For example, the group of on-site activities (on-site status) contains the following six subcategories:

- 1) Receiving , Handling , Storage
- 2) Recalling and Flagging
- 3) Assembling and Manufacturing
- 4) Picking up and Loading
- 5) Installation (Erection)
- 6) Inspection (Final check)

Product identity code is usually the base of reports which contain tracking information for a particular product, EPCglobal have developed a UHF Electronic Product Code (EPC) to provide a degree of compatibility with a global technical standard code in different industries [23].

Figure 4 illustrates the simple architecture of the integrated technologies for an intelligent management system in construction industry to reduce negative environmental impacts such as construction waste and carbon dioxide emissions from transportation vehicles. By using this intelligent system ordering process for the material will start when the construction site is ready, therefore will avoid deliveries being processed too early or too late.

Collected data will be used in the application side by the help of web-based portal system and GIS technology for information sharing among participants to assist managers in controlling and monitoring progress in construction projects.

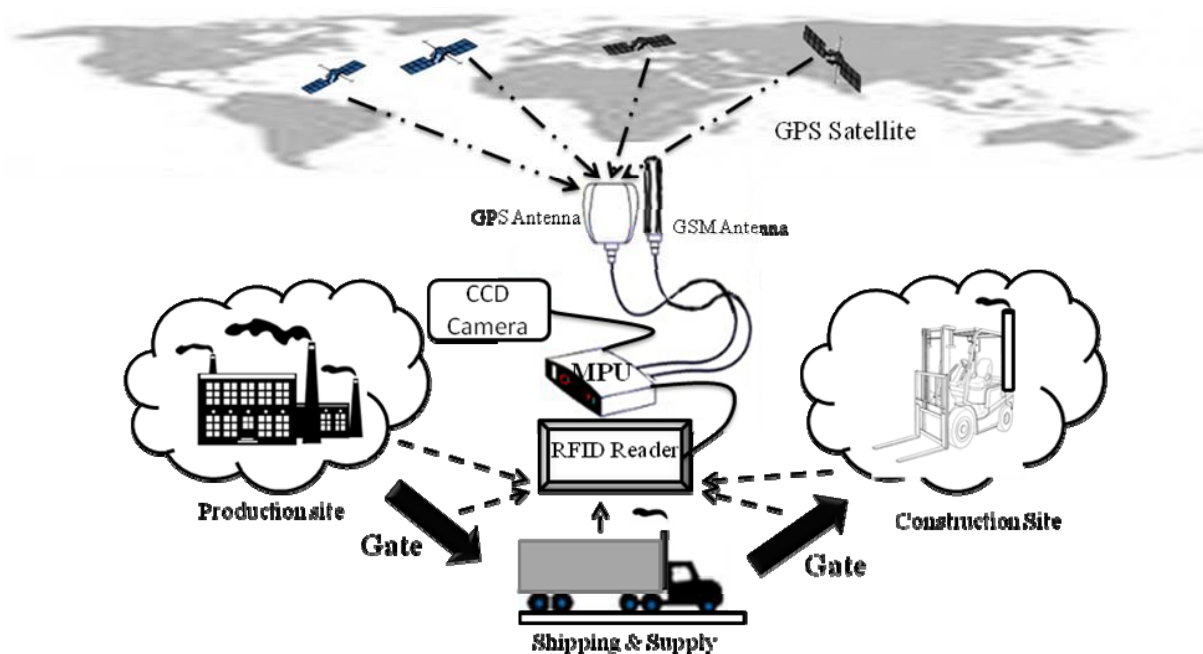


Fig. 4 The architecture of the integrated technologies for an intelligent management system

Information update and announce is synchronously via the portal and system will effectively increase the accuracy and speed of data entry by providing suppliers with information regarding the inventory levels of other portal users and etc. The central station can get the current location of a materials and estimate the travel time of them before it arrives at a predetermined construction site by using functions in a GIS system. The application server defines various applications for collecting, sharing, and managing information.

RFID, GPS, and GSM technologies can provide the GIS tool with all the information needed to analyze and help historical tracing of the materials and equipments in construction phase. An electronic geographical map will be used for presenting spatial information of equipments using Web-based GIS technology (WebGIS). WebGIS will facilitate the dynamic visual representation of the spatial information of the equipments distribution on an electronic map. As a result, the mileage of all vehicles will be reduced by the higher efficiency of distribution which will lead to increase loading ratio of transportation vehicles and reduction of carbon

dioxide emissions from transportation vehicles. As an example, the intelligent system can be used by the on-site crew for discovering and communicating about errors to support real-time collaboration or problem solving by embedding RFID tags in the elements enabling them to be identified wirelessly and associated with information in a data system, the system will be used to collect and transferring defect information to the design office and react automatically, notifying people responsible of faults without any coming to the job site.

V. CONCLUSION

This research is development of advanced tracking and data storage technologies integrated with GIS and portal technologies in order to monitoring and controlling adverse environmental impacts such as construction waste and carbon dioxide emissions from transportation vehicles. The system is consists of GPS combination with RFID and in conjunction with GSM technologies and server side. In this research

application server and database server based on GIS and portal system are Server side or central office that enables related information to be shared among the involved participants of the construction phase via the Internet. Approached system can provide low-cost, timely, and faster information flow with greater accuracy by using RFID technology and portal system which lead to reduce waste and carbon dioxide emissions. It is clear that using intelligent system such MPU system will help to keep waste and carbon dioxide emissions from transportation vehicles under control in construction phase by improving inventory accuracy and resource visibility and reducing or eliminating lost materials or equipments. The authors believe that full automation of the operation in construction industry and effective management of construction resource can dramatically improve the construction management activities and lead to reductions in negative environmental impacts such as construction waste and carbon dioxide emissions from transportation vehicles.

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