TRACKING AND POSITIONING TECHNOLOGY AND ITS APPLICATIONS FOR SUPPLY CHAIN MATERIALS FOR SMALL AND MEDIUM ENTERPRISES (SMES) ON CONSTRUCTION SITES

Sohrab Donyavi[1] and Roger Flanagan

School of Construction Management and Engineering University of Reading, RG6 6AW, UK.

Small and medium enterprises (SMEs) are the core of construction industry. SMEs are recognised as the backbone of economy. Materials form major parts of the total cost of construction project which make control of this resource significant. Despite the importance of materials, not enough attention has been given by researchers to materials control and management. Effective and efficient material management has the capability to reduce cost and increase productivity on construction projects for SMEs. Tracking and positioning technology has the potential to increase productivity and the application of construction material management. Affordability, reliability and ease of use are the capabilities of GPS, GIS, RFID and Bluetooth which make them suitable for SMEs. These technologies are widely available yet rarely applied for SMEs in construction. The aim of this research is to find out the applications of the tracking technology for SMEs on supply chain materials on construction site and to investigate SMEs' attitude and behaviour to the technology. The chosen research method is case study. Observation, interviews and document review have been undertaken. Tracking and positioning technology has the ability to help SMEs to monitor and track their materials movement. Tracking technology is capable for tracking and identification of materials, employees, documents, equipment and safety procedures. It is also capable to transfer data and voice between two different devices. A simulation study has been undertaken to understand how better information flow for supplying materials is possible trough tracking and positioning technology. Interviews have been undertaken with the SMEs owner/mangers to investigate their reflection to the acceptance and adoption of the technology.

Keywords: materials management, productivity, SME, supply chain, tracking technology.

INTRODUCTION

Information is increasingly recognised as a key resource of the organisation comparable in importance to capital and human resources. Some experts believe that just as labour was probably, the most critical resource in the agricultural age, and capital was the most critical resource in the industrial age; information will be the most critical resource in the post- industrial age.

The construction industry is characterized by its fragmentation and poor coordination, which is result of the temporary multiple organisation (TMO) structure and maximization of self interest; this has become more significant over the past few years

[1] s.donyavi@reading.ac.uk

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(Cherns and Bryant 1984; Newcomb 1996; Walker 1996). This fragmentation has led to problems with communication and information processing and has contributed to the proliferation of adversarial relationships between different parties which involve in a project. By increasing the number of projects or complexity of a project for the SMEs, situations also are getting more complicated. Technology provides the opportunity for the members of the project team to work efficiently towards better control and immediate information.

Communication between different parties is one of the critical issues on construction projects for SMEs; it involves many parties such as contractor, consultant, designer, supplier, and client. Information technology (IT) is a great opportunity for communication between different parties and different functionality. IT has the capability to remove lots of human error.

Some technologies have been recognised capable for SMEs; new and low cost technology such as GPS (Global Positioning System), GIS (Geographic Information System), RFID (Radio Frequency Identification) and Bluetooth are available and capable to be used by SMEs. SMEs need to be aware of capabilities of the technology towards better productivity. SMEs need to know how to use the technology since they have not taken full advantages of technology. SMEs want to use affordable, reliable and available technologies to improve performance that are straight forward to use; towards this goals there are capable technologies, for SMEs such as GPS, GIS, RFID and Bluetooth which in this research introduce and their roles and applications on construction for SMEs discuss for supply chain of materials.

This study considers three major sections. Section A, the role of technology, section B, the family of technology and their applications in construction for SMEs and this divides into 3 parts; part 1 communication technologies consists of GIS, GPS and Bluetooth; part 2 Auto-ID technology consist of RFID and could be barcode, tags or chips and part 3 called Electronic Digital Assistance (EDA) including PDA, Ranger, Recon, Due touch, laptop and all mobile computers, section C discusses how to implement and test the system technology into the on going construction project for supply of materials. Three SMEs in the UK were chosen for the case studies. All the SMEs are multi projects, government and private sectors are the clients. The SMEs are basically construction and building companies, operate as civil engineering, construction hard and soft architectural landscape, building construction and refurbishment.

ROLE OF TECHNOLOGY AND ITS ESSENTIAL IN CONSTRUCTION FOR SMES

Technology is the development and application of tools, machines, materials and processes that helps to solve human problems. As human activity, technology predates both science and engineering. It embodies the human knowledge of solving real problems in the design of standard tools, machines, materials or the process.

The materials on construction projects represent 30% to 70% cost of the work (Agapiou *et al.*, 1998), but the reality is the current material management and control procedure are insufficient; they are labour intensive, time consuming, not well planned and not accurate enough and this result in delays, less productivity and outdated information. IT has the capability for changing cultural structure with an objective to reduce the barriers between different functionality. A reliable and precise

materials-locating process has the potential to improve the overall project schedule (Caldas *et al.*, 2006).

In the construction sector information is generally not immediately available for future use due to organisational obstacles and deficiencies in creating structured and formal information (Scott and Harris 1998, Knauseder *et al.*,, 2007, Schindler and Eppler, 2003); so there is a need for research to find the ways to improve the communication channels, thus enabling better information exchange and collaboration innovation in construction sector.

GIS, GPS and Bluetooth as communication technologies and RFID as Auto-ID technology are widely available to enable machines yet are rarely applied for SMEs in construction. Because an enterprise is small, it does not mean they are not forward thinking. In the interviews with SMEs some enterprises were making extensive use of IT, however there was gap between good intent and application; many enterprises failed to use the IT system properly mainly because of pressure of work, although they wanted to use it. The bigger gap was where IT was used for office tasks and accounting, but not used on sites in the production phase. None of the companies interviewed were not using software to track the supply of materials and the status of orders, despite recognising that this was an important area; therefore this study introduce the technologies and their application on construction for SMEs.

TECHNOLOGY, ITS APPLICATIONS AND CAPABILITIES

A review was undertaken and GPS, GIS, Bluetooth as communication technology, RFID as Auto- ID technology were selected; Electronic Digital Assistance (EDA) such as PDA, Ranger, Recon, Due touch and laptop also as mobile computers have been chosen; these are valuable technologies with high capability on construction site.

Communication technologies (GIS, GPS, Bluetooth)

GIS (Geographic Information System) and its applications
Geographic Information System (GIS) is a system which includes mapping software and its application to remote sensing, land surveying, mathematic, geography and all tools that can be implemented with GIS software and capturing, storing, analysing, managing and presents data, link to the location (Behzadan *et al.*, 2008).

There are many applications for GIS in construction. Creation and management data, integration of information and tracking by displaying the position are some examples. Construction industry already has started using information technology which GIS is a new tool in this case for construction and has the ability to improve the construction planning and design efficiently by integrating location and thematic information in a single environment; also GIS has the capability to store large database which can be utilized to keep construction data digital form (Bansal and Pal 2006). Use of GIS may also satisfy the need of spatial and descriptive information requires in different construction process (Jeljeli *et al.*, 1993). However in spite of widespread applications of GIS in construction industry, visualization using of GIS has not yet been used to its maximum potential.

GPS (Global Positioning System) and its applications
GPS is an earth-orbiting-satellite based navigation system. GPS is an operational system, providing users worldwide with twenty four hours a day precise position in three dimensions and precise time traceable to global time standards.

It has the capability of tracking, managing and controlling earth moving and mining operation which accrue in relatively open areas. GPS uses satellite to show current position, navigating and also timing service; it is one of the few modern innovations which are now ubiquitous (Skeen 2008).

GPS technology describes in terms of three segments: 1. Space segment consists of twenty four satellites orbiting 11000 nautical miles above the earth. 2. Control segment consist of 5 ground stations around the globe that manage the operational health of the satellites by transmitting orbital corrections and clock updates. 3. User segment consists of various types of GPS receivers that can vary in complexity and sophistication. This segment is what most people are familiar with, such as navigation system in a car or GPS device in a cell phone (Brown *et al.*, 2007).

GPS has the capability for location tracking. GPS can display an indication of speed and direction of movement based on the difference in position between successive signals; it also can provide a basis for more accurate and more graphically clear displays of the movement path in a mapping display, especially with respect to an individuals' location within a building, so it can determine that an individual is on a particular floor of a building at a particular position so there is a capability to control the track of all materials which are delivered to the site (Lu *et al.*, 2007).

Bluetooth and its applications
Bluetooth is a networking technology with low power, low cost and short range (10-100m) communication technology which is aimed at supporting wireless connectivity among mobile device, such as cellular phones, headsets, PDA, digital camera, laptop and computers.

Bluetooth, exchange data over short distances from fixed and mobile devices, creates personal area networks (PANs). It can connect several devices to overcome problems of synchronization. The Bluetooth radio operates on license-free, globally available 2.400-2.4835 GHZ Industrial, Scientific and Medical (ISM) band, which is divided into 79 channels (Yu *et al.*, 2008).

Bluetooth is a great value to network administrators as it eliminates the need for the incredible mass of cabling to connect the office to the internet. This is a key that makes Bluetooth an ideal solution for portable wireless devices such as Personal Data Assistant (PDA), headset, etc. Flanagan

Auto-ID technology

RFID (Radio Frequencydd Identification) and its applications
RFID is the use of an object (RFID tag) applied to or incorporates into a product or person or animal for the purpose of identification and tracking and it uses radio waves; thus RFID technology is a wireless technology for communication between objects and readers. RFID involves the use of tags or transponders that collect data and manage it in a portable and changeable database. Unlike barcodes, RFID has the ability to identify and track materials and equipment in real time without contact or line-of-sight and the tags can withstand harsh, rugged environment (Song *et al.*, 2006).

There are three types of RFID. Active tags, contain of a battery and transmit signals autonomously; passive tags which have no battery and require an external source to provoke signal transmission and finally semi passive or battery assists passive (BAP) which require an external source to wake up but significant higher forward link capability provides great read range (Ngai *et al.*, 2008).

RFID technology systems have the potential to increase the application of material management by tracking and identification of materials, employees, document, equipments and safety. RFID tags, unlike bar codes offer the possibility of reading, writing, transmitting, storing and updating information. These tags are very useful in the delivery of construction materials when large quantity with different variety of items can be read without having to be separated or scanned individually, so the information can be transferred via radio waves with an inexpensive and non labour intensive of identifying and tracking materials. The chips (RFID tags) have the capability of performing under rug conditions and in rang of temperature from -40^{0}c to 200^{0}c or when it is dirty; it is also capable to overcome of metal interface.

In construction there are variety of applications for RFID such as equipment identification, security (access for the authorized persons also for rental or to detect stolen or misplaced items), access control, equipment and tools monitoring, guided controls of equipment, keeping and updating information such as amount of materials, name of suppliers, time of arriving, quality and other information on site (Yin *et al.*, 2009).

Barcode labels also can be used for identification of the materials; however in contrast with the barcode which have been widely utilized for material tracking, RFID tags are more durable and suitable for a construction site environment because they are reusable and permit remote.

Figure1: Mobile Bar Code Printer (Suitable to use on site)

Electronic Digital Assistant (EDA)

Portable communication devices towards integration IT technology
Portable communication devices are developing these days towards some key elements such as size, and utilization of device, compatibility and ease of data transfer with onsite or headquarter computers, PC compatibility, communication options, barcode or RFID tag readability and positioning (Kimoto *et al.*, 2005). These can be employed by GIS, GPS, RFID and Bluetooth towards practical operability on construction site with SMEs. Some important factors should be considered in terms of mobile computing in construction. Physical comfort of the device such as size and weight, the usability of the device which is basically combination of hardware and software which uses in a device are some important aspects for a suitable device on construction site. Mobile phone, laptop, Recon, Ranger, Due touch are some of these portable devices.

TESTING AND IMPLEMENTATION THE SYSTEM TECHNOLOGY

Testing and using the format of technology

To satisfy the needs for implementing technology a simulation-based study has been proceeded. Technology implementation has been tested within 3 stages in an ongoing construction project towards a successful tracking and purchasing of materials.

Stage 1
A list of materials which should be ordered by SME, has been embedded into a PDA, this schedule consists of type of materials, quantity of materials and quality of materials. Microsoft office program (Information path, Access, Excell, Outlook) was downloaded to the PDA then the format of the material order list was uploaded in a table. For each time of ordering, supply, use and dispatch of material the data enter into the PDA. Then materials ordered according to the ordering list. In this stage the material which should be send to the contractor has been coded by supplier for tracking system then this material can be identified when it arrives to the site by SMEs by the same code with RFID reader.

Stage 2
Tracking materials from supplier to the site has been proceeding in this stage. When an object needs to be tracked outdoors and also within site, then a combined RFID and GPS tagging system can be used; as GPS alone does not provide indoor positioning for the site. The tracking company can provide complete tracking system including any object and material, asset and vehicle and a unique flexible web based application software system. Tracking information is available to multiple end users over the internet from a dedicated password protected web server.

Figure 2: Tracking devices

The GPS software can rapidly configured to represent the key information associated with any object class that SME wishes to track – so it can literally 'track anything' through one consolidated system. An alternative is bar-code scanning; as in this case the tracking company provide a web based barcode system available for each of the suppliers which SME needs to buy materials from them; they can print and apply a pallet barcode entirely to the requirements so the SME can then scan the barcode, upon it receipt at site; so it is possible for SME to get a better handle on what, when, where materials were delivered to their sites. The tracking company also provide barcode systems and / or mixed manual data entry, RFID and barcode systems as required.

Stage 3
In this stage the arrival materials checked according to the order. Materials should be checked manually when arrive to the site by bar-code scanning. It is anticipated to integrate usage of PDA and the application of RFID. Using RFID tag and reader to collect the information and then transmit the multi-faceted, mobilized information such as quantity of material, quality control inspection and transportation management information to the manager office or the site worker via the PDA and wireless internet.

Using PDA associated with RFID; make it possible to know the current situation at the site from inside the plant, allows production to follow up with site progress. After the production and storage of each component, it is easy to quickly locate the target product and when it is needed use the RFID tag.

Through integration of PDA with wireless internet or Bluetooth, information of the components produce at the plant everyday are transmitted to the data base or mobile server at the office; these information are switched into management statistics and announced in the announcement system.

Figure 3: PDA with RFID reader Source (Yin et al., 2009)

However to monitor the material, the object should be tracked and it requires a small RFID or GPS electronic tag device which attached to the object. The hardware devices and the associated software are available through the tracking company and then it is possible to view the status and location of mobile resources from anywhere over the internet. In addition business rule can be applied within the system, then if an object passes into or out of a predefined area then this action can tiger other events, process, email alerts, SMS alert or notification to occur automatically. There are different system and tag types each suited to different objects and environments, for example if the object needs to be tracked inside a large building, or outdoors in a yard, or through UK or across several of these environments then the appropriate system can be configured.

SMEs response behaviour and their attitude to the technology

In preference to questioners, SMEs are reluctant to spend time completing questionnaires because of pressure of work and lack of spare capacity in a small business however it is flexible and adaptable approach to explore the topic by means of conversation, which can reveal people think and feel in different situation, then semi structured interview were conducted for this study. 3 SMEs across civil and building construction projects were chosen in the UK. SMEs are multi project. Government and private sectors are the clients. SMEs' mangers and owners are the main interviewers as the final decision makers. So their reflection, responds, contribution and involvement for using the technology, mention by the following:

SMEs are project oriented more than process oriented; they prefer their routing and their tactical behaviour instead of strategic attitude. They prefer to focus on their operational job and their traditional way of marketing and purchasing, however they are keen to know how this technology can help and bring them benefits. SMEs identified the technology as a need for themselves; however they do not consider the technology as their main problem, they are not willing to take risk for investment on the technology but very keen for the beneficial and managerial point of view of the technology. However, according to the above description, if the technology is affordable and easy to use then SMEs are quite keen to use it. SMEs need to be supported in terms of training for using the technology. The technology is quite affordable and easy to use however psychologically SMEs need support to use the technology. SMEs tend to communicate vertically (focused within discipline) however they are very keen for horizontally communication (focuses across disciplines).

SMEs prefer personal contact, for example they use to picking up the phone and doing things the way they used to, so for SMEs if there is something that has worked for them in the past, it is very hard to get them to stop using it. Since the managers and owners of SMEs mostly are involved in all aspects of managing the projects and their personality completely influence all aspects of the company then accepting and adoption to the technology depends on the owner's character.

CONCLUSION

The research has reviewed the role of technology and its capabilities in construction for SMEs. GIS, GPS, RFID, and Bluetooth have proposed. Based on these technologies the applications of each technology introduced on construction industry. GIS has the capability to capture, store, manipulate and analyse the data. GPS is capable to display an indication of speed and direction of the movement path in a mapping display so it can determine exactly that an individual is on a particular position and it has the capability to control the track of all materials which deliver to the site. An integration of GIS and GPS has the ability to provide real time information to control all the movement of materials' cargo on the road to the sites. RFID involves tags or transporters to collect data in a portable and changeable database. RFID has the capability to identify and track materials and equipment in real time without contact in rug and harsh environment, also barcode labels can be used for identification of the materials; however RFID tags are more durable and suitable on construction site. Bluetooth also as a wireless technology with low power, low cost and short range communication technology design for wireless communication for small range communication device such as mobile and laptop to transfer data and voice between two different devices. Better information flow is possible through IT and large amount of time and money can be saved when materials properly identify, monitor, control and locate. Tracking and positioning technologies integrated into portable communication devices such as PDA towards better supply management of materials. The technology has been implemented into an ongoing project then attitude and response of the 3 SMEs has been considered.

However the research identified the limitation of applying tracking technology for construction project from SMEs perspective. The research has been undertaken to understand the tracking and positioning technology for materials management towards better information flow. The research illustrated that, an integration of GIS, GPS and RFID has the capability to track the materials by availability of data and information moving across different teams and parties towards better materials management.

REFERENCES

Agapiou, A., Flanagan, R., Norman, G. and Notman, D. (1998), "The changing role of builder's merchant in the construction supply chain", *Construction Management and Economics*, **16**, 351-361.

Bansal, V. K. and Pal, M. (2006), "Geographic information systems for construction industry: amethodology to genrerate 3-D view of building", *Enero-Junio*, **11**, 7-28.

Behzadan, A. H., Aziz, Z., Anumba, C., and Kamat, V. R. (2008), "*Ubiquitous Location Tracking for Context Specific Information Delivery on Construction Site*, *Automation in Construction*, **17**(6), 737-748.

Brown, T.M.L., McCabe, S.A. and Wellford, C. (2007), *Global positioning system (GPS) technology for community supervision*, Noblis technical report, NTR -012.

Caldas, C., Torrent, D. and Haas, C. (2006), "Using global positioning system to improve materials-locating processes on industrial projects", *Construction engineering and management*, **741**, 132-137.

Cherns, A. B. and Bryant, D. T. (1984), "Stuyding the client's role in construction management", *Construction Management and Economics*, **2**, 177-184.

Jeljeli, M.N., Russell, J. S., Meyer, H.W.G and Vonderohe, A. P. (1993), "Potential applications of geographic information systems to construction industry", *Construction engineering and management*, **119**(1), 72-86.

Kimoto, K., Endo, K., Iwashita, S. and Fujiwara, M. (2005), "The application of PDA as mobile computing system on construction management", *Automation in construction*, **14**, 500-511.

Knauseder, I, Josephson, P. E. and Styhre, A. (2007), "Learning approaches for housing, service and infrastructure project organisations", *Construction Management and Economics*, **25**, 857-867.

Lu, M., Chen,W., Shen, X., Lam, H. and Liu, J. (2007), "Positioning and tracking construction vehicles in highly dense urban areas and building construction", *Journal of Automation in Construction*, **16**, 647-656.

Newcomb, N. (2008), *The trouble in ward*, Linford, London, UK.

Ngai, E.W.T., Moon, K.L., Riggins, F.J, and Yi, C.Y. (2008), "RFID research: an academic literature review (1995-2005) and future research directions", *Int.J.Production Economics*, **112**, 510-520.

Schindler, M. and Eppler, M. J. (2003), "Harvesting project knowledge a review of project learning methods and success factors", *International Journal of Project Management*, **21**, 219-228.

Scott, S. and Harris, R. (1998), "A methodology for generating feedback in the construction industry", *The Learning Organisation*, **5**, 121-7.

Song,J., Haas, C.T. and Caldas, C.H. (2006), "Tracking the location of materials on construction job sites", *Journal of Construction Engineering and Management*, **132**,911-918.

Skeen, M. E. (2008), "The global positioning system, a case study in the challenges of transformation", ndupress.ndu.edu.

Walker, A. (1966) ,*Project management in construction*, 3rd Edition, Blackwell Science, Oxford, UK.

Yin, S., Tserng, H. Wang, J. and Tsai, S. (2009), "Development a precast production management system using RFID technology", *Journal of Automation in Construction*, **18**, 677-691.

Yu, G. and Chang, C. (2008), "Congestion control of Bluetooth radio system by piconet restrucring", *Journal of network and computer applications*, **31**, 201-223.