www.irmbrjournal.com June 2014
International Review of Management and Business Research Vol. 3 Issue.2

Mobile Computing: Opportunities for Improving Civil Constructions Productivity

LUIS ARRUDA
M.Sc. in Systems Management from the Universidade Federal Fluminense.
Student of the Graduate Program in Civil Engineering UFF
Email: luisarruda@id.uff.br

SERGIO FRANÇA
D.Sc. in Civil Engineering from Universidade Federal Fluminense.
Professor, Laboratory of Technology and Management of UFF

OSVALDO QUELHAS
Ph.D. in Production Engineering from the Federal University of Rio de Janeiro.
Professor at Universidade Federal Fluminense

Abstract

The actual paradigm of competitiveness in enterprises has been its ability to innovate. Researches on the topic Mobile Computing in Construction has gained importance in the international academic literature and this fact is justified because that construction projects occur in various locations, and the professionals who work in them, have more difficulties of access to information systems conventional. Thus, ineffective communication can lead to neglect of important issues that require quick decisions. This study identifies applications of mobile technologies in the construction industry, from reading the international academic production. The method used is qualitative, went applied bibliometric techniques to identify the relevance of journals, articles and authors to the study. The results indicate opportunities for productivity improvements in construction due to the dynamic flows and amounts of information that can be managed by mobile technologies among professionals dealing with the construction of the projects. This study are also related points of attention in the introduction of these originated in implementation costs, ease of access and speed of data transmission technologies.

Key Words: *Mobile Computing, Mobile Devices, Civil Construction, Information Technology, Management of construction.*

Introduction

Despite its history that an enterprise's competitiveness has been determined by production capacity, in the last few decades this factor has been substituted by continuous innovative capacity, which stems from information and knowledge.

In the United States, the subject of mobile computing has gained respect through academic research on applying an IT sector into Civil Construction. Mobile computing allows for users to have access to independent servers from their location using wireless communication. This eliminates the need for the user to connect to a fixed infrastructure.

Enterprises of different economic sectors, such as those from civil construction's traditional sector, have benefited from the advances in mobile computing (CHEN, 2008; SHAN, 2010; CHEN and KAMARA, 2011). The same authors state that the benefits are the easier access to mobile devices, a faster Wifi speed and the development of mobile application devices.

Construction projects are executed in the field, which makes it difficult for builders to access these conventional information systems when information is needed or when support is needed during the decision-making process. Managers, engineers and other key-professionals in civil construction are often moving between work sites and the office. Carrying paper documents or drawings between these locations often becomes a nuisance. This type of inefficient communication can lead to negligence of important questions that should be dealt with immediately. Therefore, the emergence of mobile computing has great potential for guaranteeing communication of data in real time (CHEN and KAMARA, 2011).

Based on the presented information, this study's objective was to identify in scientific and international research studies the application of mobile technologies in the civil construction industry, with aims to provide a theoretical reference for this subject in question.

The sector of Civil Construction was chosen due to its important role in the global economy. Despite such importance, the average productivity in this industry has not shown positive results making the search for innovative technologies like Information and Communication Technologies (ICT) a necessity. The mobile computing area was chosen due to recent evolution and for its key role in organizations during the 21st century. It is widely accepted at all levels of company management that strategic values of ICT in general along with Mobile Computing, provide a competitive advantage.

The relevance of this study is based on the fact that scientific research of mobile computing in civil construction in the United State, in Europe, and in Asian countries is optimizing the communication process between office and work sites. This is different from Brazil, where it is more common to find studies of corporate mobility produced by the telecommunication sector, thus emphasizing an analysis with a critical outlook (DOS SANTOS, 2011).

Research Methods

This quantitative study used Bibliometric analysis in order to identify the papers, periodicals, and relevant authors concerning the area in question (RICHARDSON, 1999; GIL, 2008). Concerning the objectives, a descriptive study was done since it identified the existing characteristics and relationships between Mobile Computing and the Civil Construction industry (GIL, 2008).

Papers were selected in accordance to their relevancy using the *ProKnow-C* method (*Knowledge Development Process Constructivist*), which proposes a systematic search and selective process and uses bibliometric analysis techniques (VILELA, 2012). The *ProKnow-C* method was created by Ensslin, and presents a structured process that collects the necessary information to start a study (ENSSLIN, 2010; ENSSLIN et al., 2012; VAZ and SELIG, 2012).

Access to the data bases was provided by the CAPES Periodicals site (also known as *Coordenação de Aperfeiçoamento de Pessoal de Nível Superior*), a virtual scientific library made up of approximately 33 thousand referenced periodicals in 130 scientific, national and international databases. This study was performed between 7/14/2013 and 3/30/2014.

Results

This section comprises the procedures and results obtained from the *ProKnow-C* scientific method and identify the portfolio of research papers. Reviews of scientific papers on Mobile Computing in Civil Construction are included, and selected in accordance with relevancy in the academic community.

Bibliographic Portfolio Selection Process

This stage required searching for scientific material on the CAPES Periodical website, using key words from the research topic. As proposed in the *ProKnow-C* methods, the words are separated along the two axes (Table 1):

Table 1: Axes and Keywords

AXIS 1: MOBILE		AXIS 2: CONSTRUCTION
Mobile computing	and	Civil Construction
Mobile computing	and	Construction sites
Mobile computing	and	Management
Mobile devices	and	Civil Construction
Mobile devices	and	Construction sites
Mobile devices	and	Management

Using a combination of six-keywords, 8 databases were selected from the CAPES site relating to the research topic (Table 2).

Table 2: Number of articles in the databases of the CAPES Portal

	COLLECTION: ARTICLES; PEER REVIEWED; AFTER 2011	MOBILE COMPUTING			MOBILE DEVICE			TOTAL	
		Construction Civil	Construction site	Management	Construction Civil	Construction site	Management		
1	Scopus (Elsevier)	2	5	78	0	0	6	91	40%
2	Science Citation Index Expanded (Web of Science)	0	3	49	0	0	0	52	23%
3	OneFile (GALE)	1	4	28	0	0	5	38	17%
4	IEEE (CrossRef)	0	0	21	0	0	0	21	9%
5	SpringerLink Open Access	0	0	19	0	0	2	21	9%
6	SciVerse ScienceDirect (Elsevier)	1	2	0	0	0	0	3	1%
7	MEDLINE (NLM)	0	0	0	0	0	2	2	1%
8	American Society of Civil Engineers (CrossRef)	0	1	0	0	0	0	1	0%
9	Directory of Open Access Journals (DOAJ)	0	0	0	0	0	1	1	0%

As shown in Table 2, 230 papers were detected in 9 periodicals. Of these 9, three databases comprised 181 papers, or 79% of the scientific production respectively. The following were: *Scopus (Elsevier), Science Citation Index Expanded (Thomas Reuters) and OneFile (Gale Ceneage Learning).* In Table 2, there are 155 papers with the key word combination *Mobile Computing* and *Management*, indicating, *a priori*, a concentration of interest in mobile computing technology directed towards the administration and management sectors.

The gross paper databank of was built comprising of 230 publications.

Using the gross paper databank, an adherence test was applied after random selection. Twenty-three papers were selected, equivalent to 10% of the gross paper data bank, and consisted of the correct key words. When papers without the key words were found, the gross data bank had to be selected again. This test contained papers with atleast one key word, thus approving the gross data bank.

To obtain a Bibliographic Portfolio, criteria were adopted to decrease the quantity of papers in the gross data bank until an appropriate number was achieved. Therefore, of the 230 papers, 111 were excluded relating to chapters in books, reviews and annals. The 119 papers remaining were imported from the bibliographic management software (RefWork), and repetitions were identified. Using this procedure, another 33 items were excluded and the data bank was completed with a total of 86 papers.
Titles and abstracts of the 86 papers were evaluated based on their relevancy for mobile computing in civil construction. Next, 78 papers without the appropriate titles were removed. Therefore, a total of 8 non-repeating papers with appropriate titles remained.

Bibliographic Portfolio Relevancy

The following step was to verify the relevancy of the papers, and was done using *Google Scholar* and the original database that provides the number of citations. These results are presented in Table 3.

Table 3: Articles of the final portfolio bibliographic

	AUTHOR	YEAR	ARTICLE	QUOTE
1	LUO, XIAOWEI; O'BRIEN, WILLIAM J.; JULIEN, CHRISTINE L.	2010	Comparative evaluation of Received Signal-Strength Index (RSSI) based indoor localization techniques for construction jobsites. (Advanced Engineering Informatics - Elsevier)	45 in Google 21 in sciencedirect
2	CHEN, YUAN.; KAMARA, JOHN M.	2011	A framework for using mobile computing for information management on construction sites (Automation in Construction - Elsevier)	23 in Google 13 in sciencedirect
3	CHEN, YUAN.; KAMARA, J. M.	2008	Using mobile computing for construction site information management. (Engineering, Construction and Architectural Management - Emerald Insight)	14 in Google Not located at the base
4	HEGAZY, TAREK; ABDEL-MONEM, MOHAMED.	2012	Email-based system for documenting construction as-built details (Automation in Construction - Elsevier)	5 in Google 0 in sciencedirect
5	BAE, HYOJOON; GOLPARVAR-FARD, MANI; WHITE, JULES.	2013	High-precision vision-based mobile augmented reality system for context-aware architectural, engineering, construction and facility management (AEC/FM) applications (Visualization in Engineering - Springer)	4 in Google Not located at the base

6	SHEN, XUESONG; LU, MING.	2012	A framework for indoor construction resources tracking by applying wireless sensor networks (Canadian Journal of Civil Engineering)	3 in Google 1 in Canadian Journal
7	KIM, CHANGYOON et al.	2013	On-site construction management using mobile computing technology (Automation in Construction - Elsevier)	1 no Google 0 in sciencedirect
8	ANUMBA, CHIMAY J.; WANG, XIANGYU.	2012	Mobile and Pervasive Computing in Construction: An Introduction (Wiley-Blackwell Online library)	0 in Google Not located at the base

Interesting observations are noted when analyzing Table 3. Five papers (45%) originated from *Sciencedirect*, of Elsevier Editor, and three of these are from the *Automation in Construction* periodical. This suggests an appropriate level of this periodical's relevancy. The most cited papers on *Google Scholar* and their original databases are by LUO et al. (2010) and CHEN and KAMARA (2011). CHEN and KAMARA are the pioneers of Mobile Computing and Civil Construction research, which was published in Emerald Insight back in 2008.

Analysis of papers in the Final Bibliographic Portfolio

The papers listed in Table 3 were read and reviewed in order to highlight important research, such as technological aspects that can stimulate research findings. The reviews of selected papers for the final portfolio are described below.

Luo et al. (2011) assessed precision of location technologies based on RSSI (*Receive Signal Strength Indicator*). This is a measurement that indicates the potential of the received signal. The author compared the RSSI at a work site with one from a functioning building and concluded that the signal intensity is lower at work sites. He also noted that the GPS *(Global Position System)* is uncommon in civil construction, due to the low implementation costs of equipment, tools, batches of material, low precision of cheap devices (between 10 and 20 m) and the mal-functioning of these devices in closed environments. In order to overcome these limitations, the authors suggest that RFID (*Radio-Frequency IDentification*) technologies and laser scanners should be incorporated in vehicles for location detection and collision prevention. Research on low cost solutions for combining such technologies (RSSI, GPS, RFID) at work sites can be beneficial for the civil construction sector.

Chen and Kamara (2008, 2011) identified a structure that implements mobile computing at work sites, and includes an application model (it considers the resources, people and information specific to the civil construction sector) and a technological model (Using a technical perspective, it indicates a structure for mobile computing system design). During their study, Chen and Kamara found that the wireless network protocol IEEE 802.11 was the most adequate for this sector's mobile applications. This protocol was developed by the IEEE (*Institute of Electrical and Electronics Engineers*) and is also known as the Wifi or Wireless Networks. Chen and Kamara chose this protocol since it is widely used in the commercial market and many commercialized wireless products support it. Moreover, this protocol was chosen because the information files that needed to be transferred through the wireless network are instant and latency-free. Secondly, the IEEE 802.11 can provide a band with up to 11 Mbps, a sufficient amount to transfer big files such as drawings, photographs and voice messages. The third important point the authors make about the IEEE 802.11 protocol is that it can attain transmission between 30 and 100 m and can be extended across wireless antennas installed in determined locations at the work site.

Hegazy and Abdel-Monem (2012) stated that in the civil construction sector, *As-built* contains detailed information about the construction progress and permits monitoring and implementation of corrective actions. However, this document was put together manually and consisted of lost time and many errors. Hegazy and Abdel propose a structure that uses *e-mail* as a tool to control bidirectional communication between participants of the enterprise. This proposed structure integrates automated activities to request e-mails so that *As-built* can gather information using forms and provide the upcoming event list. This enables the supervisors to attach documents and notes. On a daily basis, the system reads e-mails and updates the timeline with the entrepreneurial supervisor's notes. This communication system suggested by the authors demonstrates the role and importance of mobile computing substituting the earlier manual processes that were slow and subject to error.

Bae et al. (2013) shared his opinion about context-aware technologies applied to mobile devices in civil construction. The author introduced the increasing arguments that the construction staff on-site can consult and have access to information in 3D, from pictures created in standard mobile devices. The proposed system by Bae takes the user's location and compares the images obtained from mobile devices stored in a memory cloud, which has pre-collected photos of the site. The use of 3D models permits access to the project's details that were once non-viewable, such as electrical and hydraulic installations. Despite this advantage, results show that its application directly affects the speed and location precision of the work site images, as well as the user's technological relationships. Such limitations reflect opportunities to investigate Context-aware methods for projecting and re-projecting the use of cybernetic objects in work sites, speed of transmission technologies and receipt of real and virtual images, and the user's interface elements of context-aware technology.

Shen and Lu (2012) have developed a low-cost method to automatically and continuously track construction resources, which consist of a group of fixed and mobile sensors that communicate between one another. They work in real time and use technology based on geometric triangulation and an indicator of the received intensity signal (RSSI).

Kin et al. (2013) state that smartphones provide room for improvement when considering managing construction processes at the work site. The system proposed by Kin focused on three basic management functions: monitoring of work sites, management of jobs and sharing of information at real time. To develop his proposal, Kin used different components such as; wireless communication, augmented reality and a client-server database to manage, transfer and view project information from a mobile computing platform. The developed system is made up of two main modules: one for managing information of jobs, locations and corresponding resources and the other module is for interactive communication between engineers sharing drawings and plans along with arguments for augmented reality. The system showed potential for implementing intelligent construction processes, improving the level of information sharing and communication in the civil construction industry.

Anumba and Wang (2012) highlight in their book that "Pervasive Computing" or Ubiquitous Computing in the industry of civil construction will represent the new era for professionals in engineering and architecture, such that it will enable integrating diverse computational elements like desktops, sensors, mobile devices, applications, electronic equipment in our homes and work places. With this technology, the construction industry could benefit significantly in the areas of resource management, project management, collaboration, sharing of information and knowledge, all contributing to a greater productivity for this sector.

Conclusions and Suggestions for Future Research

Efficient communication systems are important allies for increasing Civil Construction's productivity. Traditional systems of telecommunication do not offer the necessary coverage for communicative flow

between offices and work sites. Therefore, the IP (Internet Protocol) combined with all types of contact such as voice, data, and video in one single network, is the most viable in terms of cost, implementation speed and process efficiency.

Systems for equipment and material location at work sites require further development to find low-cost solutions because the presently most location-accurate devices are costly and unviable to adopt such a system on a large scale. A possible solution for this situation could be to combine RFID elements and geometric triangulation of sensors that measure signal intensity on the work site grounds.

Development of solutions for mobile computing should consider the Wireless IEEE protocol 802.11, available in most commercialized mobile devices. As well, it is compatible with the fastest and informational transmission devices capable of sending big files that are often required in the civil construction industry.
Communication between participants of the enterprise may consider applications based on *e-mail* exchange through standardized event procedures for monitoring construction's evolution and progress.

Context-aware technology can be used in civil construction. An example of its use comes from the augmented reality arguments that prove to be great resources for managing enterprises, since they provide a viewing of details that were once hidden; such as plans and drawings of electric and hydraulic networks.

Ubiquity is increasingly making it possible to access any information at any time. For the civil construction sector, this represents a revolution in terms of the quantity of possible information generated in an entrepreneurial project. The benefits are many and range from material and project management to the quickness of communication and increasing levels of collaboration.

References

ANUMBA, Chimay J.; WANG, Xiangyu. Mobile and Pervasive Computing in Construction: An Introduction. Mobile and Pervasive Computing in Construction, p. 1, 2012.

BAE, Hyojoon; GOLPARVAR-FARD, Mani; WHITE, Jules. High-precision vision-based mobile augmented reality system for context-aware architectural, engineering, construction and facility management (AEC/FM) applications. Visualization in Engineering, v. 1, n. 1, p. 1-13, 2013.

CHEN, Yuan. Use mobile computing for construction site information management. PhD Thesis. Newcastle University. Newcastle, 2008.

CHEN, Yuan; KAMARA, John M. The use of mobile computing in construction information management. In: Proceedings of the 21st Annual Conference of the Association of Researchers in Construction Management (ARCOM) SOAS, London. 2005.

CHEN, Yuan; KAMARA, John M. A framework for using mobile computing for information management on construction sites. Automation in Construction, v. 20, n. 7, p. 776-788, 2011.

DOS SANTOS, Andrea Pinheiro; BARBOSA, Ricardo Rodrigues. Desafios da mobilidade corporativa para a Gestão da Informação e do Conhecimento. Informação & Sociedade: Estudos, v. 21, n. 2, 2011.

ENSSLIN, L. et al. *ProKnow-C*, Knowledge Development Process – Constructivist: processo técnico com patente de registro pendente junto ao INPI. Brasil: [s.n.], 2010

ENSSLIN, Leonardo; ENSSLIN, Sandra Rolim; PACHECO, Giovanni Cardoso. Um estudo sobre segurança em estádios de futebol baseado na análise bibliométrica da literatura internacional. Perspect. ciênc. inf., Belo Horizonte , v. 17, n. 2, June 2012 .

GIL, Antonio Carlos. Como elaborar projetos de pesquisa. 4. ed. São Paulo: Atlas, 2008.

HEGAZY, Tarek; ABDEL-MONEM, Mohamed. Email-based system for documenting construction as-built details. Automation in Construction, v. 24, p. 130-137, 2012.

KIM, Changyoon et al. Developing a technology roadmap for construction R&D through interdisciplinary research efforts. Automation in Construction, v. 18, n. 3, p. 330-337, 2009.

KIM, Changyoon; LIM, Hyunsu; KIM, Hyoungkwan. Mobile computing platform for construction site management. In: Proceedings of 28th International Symposium on Automation and Robotics in Construction, Seoul, Korea. 2011.

KIM, Changyoon et al. On-site construction management using mobile computing technology. Automation in Construction, 2013.

LUO, Xiaowei; O'BRIEN, William J.; JULIEN, Christine L. Comparative evaluation of Received Signal-Strength Index (RSSI) based indoor localization techniques for construction jobsites. Advanced Engineering Informatics, v. 25, n. 2, p. 355-363, 2011.

SHEN, Xuesong; LU, Ming. A framework for indoor construction resources tracking by applying wireless sensor networks. Special Issue on Construction Engineering and Management. Canadian Journal of Civil Engineering, v. 39, n. 9, p. 1083-1088, 2012.

SHEN, Weiming; HAO Q.; MAK, H.; NEELAMKAVIL, J.; XIE, H.; DICKINSON, J.; XUE, H. Systems integration and collaboration in architecture, engineering, construction, and facilities management: A review. Advanced Engineering Informatics, v. 24, n. 2, 2010.

VAZ, C. R. ; SELIG, P. M. Logistica reversa de aeronaves sob a ótica da produção mais limpa e indicadores de desempenho: seleção de um referencial teórico de pesquisa e análise bibliométrica e sistêmica. In: Congresso Nacional de Excelencia e Gestão, 2012, Niterói. CNEG, 2012.

VILELA, Lílian de Oliveira. Aplicação do ProKnow-C para seleção de um portfólio bibliográfico e análise bibliométrica sobre avaliação de desempenho da gestão do conhecimento. Revista Gestão Industrial, Paraná, v. 8, n. 1, p.76-92, 2012.