Geospatial Embedded Technology for On-Site Tracking and Monitoring

N.A. Wahap[1], N. M. Nor[1], N. Ahmad[1], N. M. Yusoff[2], M. Z. M. Noor[2], N. M. Ismail[2]
[1]*Malaysia National Space Agency, National Space Centre, 42700 Banting, Selangor, Malaysia.*
[2]*Spatial Synergy Consultant Sdn. Bhd., 216B, Jalan Negara 2, Taman Melawati, 53100 Kuala Lumpur, Malaysia.*
azawani@angkasa.gov.my

***Abstract*—Geospatial technology is a term used to describe the range of modern tools contributing to the geographic mapping and analyses which typically involve Global Navigation Satellite Systems (GNSS), Remote Sensing (RS), and Geographic Information Systems (GIS). By manipulating these tools, users can easily plan ahead, scrutinize each data, improve service delivery, and optimize operation management. Field/on-site workers is defined as those who work most of their time away from their main office and get connected via mobile and wireless devices. This paper will demonstrate a methodology to integrate geospatial technology with selected sensors to increase the on-site operations and management using mobile platform and optimize the workflows allowing real-time tracking and monitoring.**

***Index Terms*—Geospatial; On-site Workers; Real-Time; Tracking and Monitoring.**

I. Introduction

Most workforces will often have at least one mobile or field worker such as in fleet management field, services and maintenance, health and pharmaceuticals and also logistics and transportation business. These workers is defined as those who work at least 10 hours per week away from home and from their main place of work, e.g. on business trips, in the field, travelling or on customers' premises, and use online computer connections when doing so (Electronic Commerce and Telework Trends, 2000). Mobile workforce system provides ways to understand and manage the location and history of mobile workforce and assets, beginning with who, what, why, where and when – in multiple function (Driscol and Sheldrick, 2006).

The terms mobile and wireless are often used synonymously, but represent two different technologies. Mobile means the technology can travel with the user, but it is not necessarily in real-time. Wireless gives users a live (Internet) connection via satellite or radio transmitters (connection without wires - cordless). While both have different meanings, wireless is considered as one of the technology required for the workers to be mobile. State government agencies, such as transportation departments, use wireless devices to collect field information, tracking inventory, reporting times, monitoring logistics, and completing forms — all from a mobile environment. The transportation industry is using wireless devices to help determine current locations and alternate driving routes.

From before, most mobile workforces use cellular phone as a device to provide connectivity and mobile applications. Cellular telephones (cell phones) work by using radio waves to communicate with radio antennas (or towers) placed within adjacent geographic areas called cells. A telephone message is transmitted to the local cell by the cellular telephone and then is passed from antenna to antenna, or cell to cell. The trends in cell phones reflect a convergence of voice, video and data communications. This platform is foreseen to be an obsolete as more and more advancement in mobile phone technology but still widely use in data transmission in most applications. Personal digital assistants (PDA) and smart phones have slowly making queue to replace cellular phone role which offers much smaller with the capability of a small computers. They have more integrated system and hardware and capable of entirely digital communications transmission.

The concept of integrating mobile and wireless platform which allows workers to be in touch with the office is still new in certain industry in Malaysia and the readiness is still in debate in term of cost, efficiency and monitoring. In Malaysia, majority of the local authority has applied mobile workforce concept in the past few years where they hire mobile workforce to do field works. For instance, there is a process in the Building Department in each local authority to do verification at the site area for any new building development applied by a contractor before approval. From another aspect, mobile workforce from Technical Department will conduct inspection at the site as well. Hasmi et al. (2011) studied on the readiness of mobile workforce concept in Penang, has addressed several equipment used for mobile workforce to conduct business and type of communication media used.

The study focuses on exploration of several factors towards telecommuting or mobile workforce in the industry emphasizing on work from home concept. Figure 1 shows an effective mobile worker management requires some elements which are:

i) Mobile services — wireless internet, broadband, bluetooth, infrared, communication link;
ii) Location-based services – satellite, INS;
iii) Tracing services – RFID, barcode;
iv) Devices — smartphones, personal digital assistants (PDAs), notebooks, wireless cards, GPS receiver, RFID and barcode reader, data storage;
v) Service control — system integration, management centre allowing real-time connectivity.

II. TRACKING & TRACING MODULE INTEGRATION

Track and trace or tracking and tracing, is a process of determining the current and past locations and other information of a unique item or property. In response to a growing number of recall incidents such as food, pharmaceutical, toys and laboratory, a lot of software, hardware, consulting and systems vendors have emerged over the last few years to offer a range of traceability solutions and tools for industry. Radio-frequency identification (RFID) and barcodes are two common technology methods used to deliver traceability.

A. Tracing Technology

Radio-frequency identification (RFID) is synonymous with track-and-trace solutions, and has a critical role to play in supply chains (Sarac et al., 2009). RFID is a code-carrying technology, and can be used in place of a barcode to enable non-line of sight-reading. Deployment of RFID was earlier inhibited by cost limitations but the usage is now increasing.

Barcoding is a common and cost effective method used to implement traceability at both the item and case-level. Variable data in a barcode or a numeric or alphanumeric code format can be applied to the packaging or label. The secure data can be used as a pointer to traceability information and can also correlate with production data such as time to market and product quality. There are several barcode symbologies available which are linear and 2D. Figure 2 and 3 shows example of various barcode symbologies available.

QR codes were originally designed to track assets during manufacturing process. A QR code is ultimately a two dimensional barcode that stores data both horizontally and vertically. When compared with barcodes, QR codes can hold much more information. In fact, a complex QR code can store over a page of plain text. Since QR codes are much smaller than barcodes, they are also easier to scan using smartphones (Eicher, 2012). Additionally, unlike barcodes they can be scanned at any angle making mobile data collection much faster than before.

B. Tracking Technology

Global Navigation Satellite Systems (GNSS) technology has become vital to many applications and is expanding from the established Global Positioning System (GPS), the Russian Global Navigation Satellite System (Glonass) and the coming Galileo, Beidou and QZSS. Few studies have been presented in the literature regarding the various applications of satellite systems in tracking and tracing. Politecnico di Milano (2007) presented interesting examples of projects and applications which include GPS integrated with other technologies (e.g. RFID, weighing system, sensor systems, General Packet Radio Service (GPRS)).

Ursa et al. (2006) has worked on the monitoring and tracking through GPRS/Universal Mobile Telecommunications System (UMTS). GNSS systems can bridge the gap and enable global monitoring of products/system. By using the function related, for instance to GNSS, RFID device and other communication systems such as Universal Mobile Telecommunications System (GSM), some added value services can be assured.

Figure 1: General concept of Mobile Workforce Management (Source: AT & T Mobility Network)

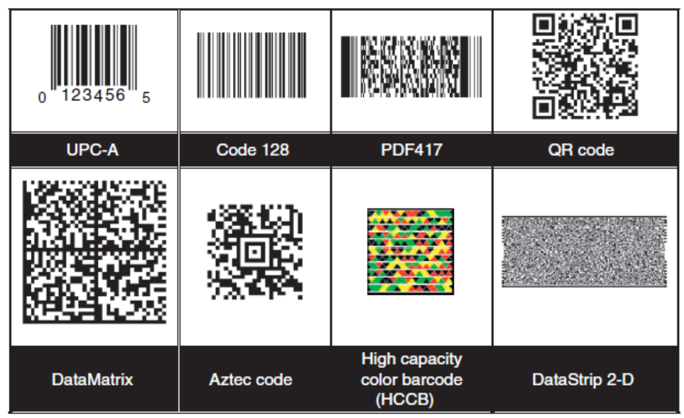

Figure 2: Barcode Sample (Source: Grover, et al., 2010)

Figure 3: QR Code used in Shopping Complex (Source: Nurulain, 2013)

ISSN: 2180 – 1843 e-ISSN: 2289-8131 Vol. 8 No. 4

Table 1
Way Device Classification (Nielson, 2012)

Mobile Phone Class	Smartphones		Non-Smartphones	
	Touchscreen Smartphones	Non-Touchscreen Smartphones	Multimedia Phones	Features Phones
Definition	Open OS* allow installation of applications. Features touchscreen *Open OS include :iOS, Android, Blackberry, Symbian, Maemo, Windows, Linux (Web OS), Bada	Open OS* allows installation of applications. No touchscreen. (Only device with QWERTY or alpha-numeric keypads are include)	Touchscreen and/or QWERTY, but not an open OS. Must be able to acces internet by WIFI or 2.5G upwards, and has HTML browser.	All other phones. (No touchscreen, no QWERTY keypad, no open OS)

C. *Mobile Platform*

Mobile phones can be classified by smartphones and non-smartphones. The smartphone can be categorized into several classifications which are Touchscreen Smartphones and Non Touchscreen Smartphones. As described in Nielson website, the following Table 1 summarizes the 4-way mobile devices classification.

Finding from iPass study on mobile trend for mobile workforce in 2011, showed that younger workers appeared to lean towards the Android as their next smartphone, and older mobile workers wanted to stick with their BlackBerrys. While the BlackBerry appears less slick and sexy than Android-based smartphones – the BlackBerry is familiar to older workers with its physical buttons. iPhone remains the most popular smartphone across all age groups.

III. System Prototype And Evaluation

The proposed overall system architecture starts with the mobile workforce as user access the mobile workforce management system using mobile application and any web browser. The application server and database will be providing the interface and data required by the user. Overall, this system will be equipped with firewall to ensure the security, reliability, and integrity of the system. However, as for prototype development, the focus concentrates on the second layer, the mobile application.

The selection of the users are based on:

i) Their current system which might lacking on the tracking or tracing capability to monitor the whole process
ii) No real-time scheduling, dispatching and reporting in the current mobile workforce management.

The objective of the system were to enable the management to monitor the assets and the on-site workers with the embedded geospatial system while at the same time decreases manual pre and post processes.

A. *Identification of User and Application*

The prototype development started by reviewing the current flow practice in the selected industry (PLUS Highway Maintenance), followed by the workflow of the mobile workforce utilizing the developed prototype, the conceptual design of the tagging and tracing module and tracing and tracking module, the overall system architecture of prototype developed, hardware and software requirement as well as the development tool used for this project. Finally, a general database design development for the prototype system. Figure 4 shows the current process workflow for PLUS.

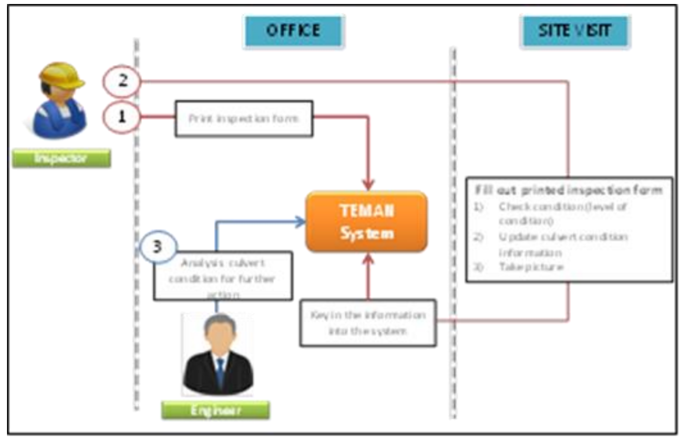

Figure 4: PLUS Culvert Maintenance Workflow

The proposed workflow comprises prototype with integration of the Trimble Yuma, applications and e-form. For the process, the following assumptions are made:

i) Contractors received notification about their maintenance tasks.
ii) Contractors know the location of the slope that they have been assigned.

B. *Prototype Design and Development*

The system prototype comprises the following components: applicants, mobile workforce, GPS service, operation, GSM/GPRS, SQL database, application server, and, Google map server.

i) Assignment Module (yellow)
ii) The general practice for assignment in PLUS was the tasks for monitoring culvert have been pre-planned on a yearly basis. For this practice, a simulation was created to help the Maintenance Managers or supervisors to do tasks assignment to the contractors involved.
iii) Mobile Workforce (red)
iv) Contractors went to the maintenance site (culvert). The contractors scanned the tag on the culvert to get the ID of the culvert and pass it to TEMAN system. The details are queried from the TEMAN Database. All the related details will be retrieved by the maintenance e-form. The contractors will perform the maintenance and filled out the form. The form was updated and saved in TEMAN database.
v) Monitoring & Reporting Module (green)
vi) All reporting and monitoring activities for the maintenance can be accessed by managers and supervisors which can also view the maintenance and

culvert status monthly. The locations of the contractors and the culverts can be verified by the manager and supervisor. These activities involved are depicted in the following Figure 5.

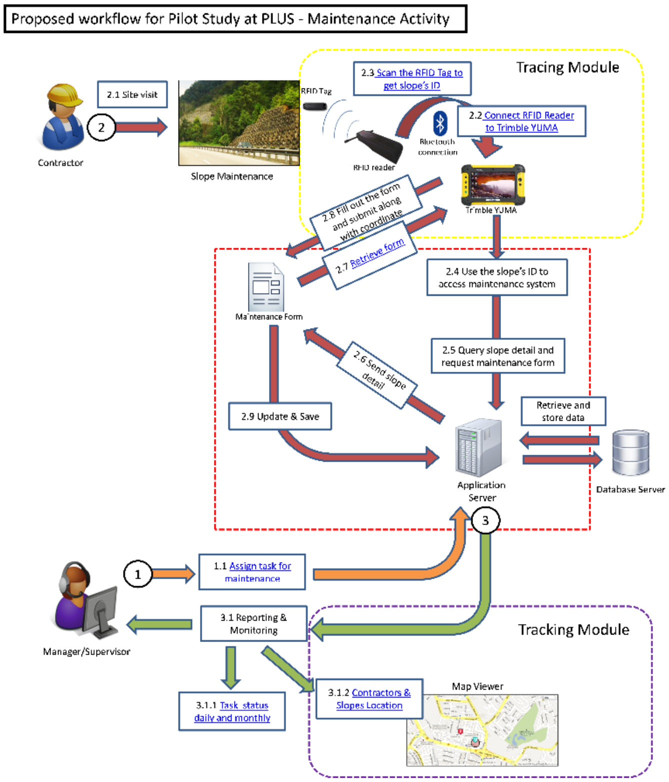

Figure 5: System Prototype of Mobile Maintenance (PLUS Highway Culvert Maintenance)

IV. Results And Discussions

The most prominent and important achievements of the project were the integration of the tracking with tracing capability and the output of the whole system was being presented in a comprehensible spatial representation of the map viewing via the web-based application for all three major components of the mobile workforce management systems which were not being emphasized by other developers as observed in this study.

GNSS has been chosen as a technique for locating the mobile workforce during fieldwork. QR Code and RFID tag have been identified as mechanisms to store assets' ID. By knowing the location of an asset, the mobile workforce must be within the visibility range or buffer or radius of inspection to scan the QR Code and tag dedicated for maintenance purpose thus verifying the presence of the mobile workforce during inspection.

The idea of developing the prototype for this mobile workforce application was mainly to improve manual processes in monitoring mobile workforce activity by utilizing satellite related technology and exploring various technologies of the mobile platform, experimenting from pilot case study of asset maintenance and adding some features that can be enhanced in future. The prototypes were expected to provide a total wireless solution that allows mobile worker to capture and transfer data efficiently and economically.

V. Conclusions

The outcome of the project benefits the three major components in a mobile workforce management system consisting of the mobile workforce, the administrator/supervisor and manager. The prototype benefits the following:

i) Ensure accuracy via a user-friendly mobile device and web tools.
ii) Monitor errors and data collection time.
iii) Help to improve productivity of real-time tracking and tracing data of asset information.
iv) Help to reduce operating costs in the organization.
v) Fast monitoring action and delegating new assignment to the mobile workforce by the management.
vi) Finding directions to any working site made easy.
vii) The application is user-friendly and convenient as people are at ease of using smartphone and other mobile platforms for various purposes.

Acknowledgment

The authors would like to thank to Ministry of Science, Technology, and Innovation Malaysia (MOSTI) for funding the project through eScience Fund and PLUS Malaysia Berhad for the support given in providing information of the existing mobile workforce management systems and platform to conduct the integration of modules and verification for the prototype system incorporating satellite tracking module integrated with data tracing and decoding technologies.

References

[1] M. A . Bayir. "Enabling Location Aware Smartphone Applications via Mobility Profiling," Ubiquitous Computing Laboratory Department of Computer Science and Engineering, University at Buffalo, 2010.

[2] M. B. Becker, "Interoperability Case Study The Bar Code/UPC," *The Berkman Center for Internet & Society Research Publication Series*. 2012. Retrieved March 2012 from http://papers.ssrn.com/sol3/papers.cfm?abstract_id=2031107

[3] S. Benjamin, *The Android mobile platform*. Eastern Michigan University, 2008.

[4] S. M. Catherine, B. Yehuda, P. Eric, N. T. Janan, P. N. Andrew, and C. F. Scott, "DNA Barcoding.Limitations of mitochondrial gene barcoding in Octocorallia," *Molecular Ecology Resources*, 2010.

[5] S. Collado, and A. Moreno, "Integration and Verification of Mobile Meteorological Measurements," Department of Electrical and Information Technology, Faculty of Engineering, LTH, Lund University, Lund Sweden, 2011

[6] CoreRFID Ltd. Maintenance and Engineering: Case Study of The London Underground Escalator Maintenance Project. Warrington: Author, 2008.

[7] "Economic Performance and Prospects", 2012. Retrieved from http://www.treasury.gov.my/bajet2011/data/er/chap3.pdf

[8] H. Edith, "Integration of JPF into Jboss.Component-based Web Development," 2007 Retrieved May 2007 from http://genome.tugraz.at/Theses/Hofer2007.pdf

[9] M. Emiliano, *Smartphone Sensing* (Dartmouth College,Hanover New Hampshire), 2011 Retrieved June 2011 from http://sensorlab.cs.dartmouth.edu/pubs/miluzzo-phd-dissertation.pdf

[10] "Guess How Many Android Devices Have Now Been Activated (Google

I/O)". WebProNews, 27 June 2012. Retrieved 9 Dec 2012 from http://www.webpronews.com/guess-how-many-android-devices-have-now-been-activated-google-io-2012-06.

[11] A. Grover, P. Braeckel, K. Lindgren, H. Berghel, & D. Cobb, "Parameters Effecting 2D Barcode Scanning Reliability," In M. Zelkowitz, (Eds.): *Advances in Computers*, vol. 80, pp. 209-235, Burlington: Academic Press, 2010.

[12] Intelligent Mobility Agents, Advanced Positioning and Mapping Technologies Integration Interoperable Multimodal location-based services, 2005, IM@GINE IT.

[13] iPass. Mobile Workforce Survey Report. Redwood Shore, California: Author. 2011 Retrieved from www.ipass.com

[14] John, W. "Attendance Tracking. CodeREadr," 2012.Retrieved from https://www.codereadr.com/

[15] C. Kaiser, "How to Develop Mobile Applications with Web-Technologies." 2011. Retrieved May 2011 from http://diuf.unifr.ch/main/is/sites/diuf.unifr.ch.main.is/files/documents/student-projects/eBiz_2011_Christian_Kaiser.pdf

[16] A. Klimaszewski-Patterson, "Smartphones in the field: Preliminary study comparing GPS capabilities between a smartphone and dedicated GPS device," *Papers of the Applied Geography Conferences*, 2010, vol. 33, pp. 270-279.

[17] Kronos Incorporated. Workforce Management. When and Where You Want It. Chelmsford, MA: Author, 2011

[18] Liu, K.H. *A Taxonomy and Business Analysis for Mobile Web Applications*, 2009. (Massachusetts Institute of Technology Cambridge, MA 02142).

[19] T. Lagvankar, Mobile Application Development with Android (UMBC), 2009 .[PowerPoint Slide].

[20] X. Ma, B. Yan, G. Chen, C. Zhang, K. Huang, and J. Drury, *A Toolkit for Usability Testing of Mobile Applications*, University of Massachusetts Lowell and University Avenue, Lowell Massachusetts, 2011.

[21] P. G. Maropoulos, and D. Ceglarek, "Design verification and validation in product lifecycle," *CIRP Annals - Manufacturing Technology*, vol. 59, no. 2, pp. 740-759, 2010.

[22] S. Mokhlis, and A.Y. Yaakop, "Consumer choice criteria in Mobile Phone Selection: An Investigation of Malaysian University Students," *International Review of Sciences and Humanities*. Vol. 2, no. 2, pp.203-212, 2012.

[23] L. Naismith, P. Lonsdale, G. Vavoula, and M. Sharples, "Literature Review in Mobile Technologies and Learning," 2004.

[24] Nielsen Company. Know what they do with just a touch of a finger, Nielsen Smartphone Insights 2012.

[25] E. Nordborg, *A Theoretical and Practical Analysis of the iPhone SDK 3.0. The next Generation of Mobile Applications.* University of Technology, Lulea, 2010.

[26] L.E. Nugroho, *A Context-Based Approach for Mobile Application Development*. Monash University. 2001.

[27] M. I. Nurulain, "Development of Mobile Workforce Monitoring (MWM) System Prototype Utilizing Satellite Related Technology," *Dissertation for the Master of Science (information Technology)*, Universiti Teknologi Mara, 2013.

[28] A. Osman, Z. Talib, Z. Abidin, T. Shiang-yen, and A. S. Alwi, " A Study of the Trend of Smartphone and its usage behavior in Malaysia," *International Journal on New Computer Architectures and Their Applications (IJNCAA)* vol. 2, no. 1, pp. 274-285, 2012.

[29] M. Pannevis, *Location Based Systems for Mobile Phones.* University of Amsterdam, 2007.

[30] RFID Solution Center Dayton, Preventative Maintenance & Trouble Shooting for Passive RFID Technology, 2007.

[31] A. Ramalingam, P. Dorairaj, and S. Ramamoorthy, "Personal Safety Triggering System On Android Mobile Platform," Department of Electrical Engineering, Blekinge Institute of Technology, Karlskrona Sweden, 2012.

[32] A. Sarac, N. Absi, and S. Dauzere-peres, "A Literature review on the impact of RFID technologies on supply chain management," *Working paper ENSM-SE CMP WP* 2009/2.

[33] Satellite Mobile System Architecture, The R&D Group of the Advanced Satellite Mobile System Task Force, 2002.

[34] C. E. Schultz, *INS and GPS Integration*. Technical University of Denmark Informatics and Mathematical Modelling, 2006.

[35] F. Schultman, and N. Sunke, Life Cycle Information of Buildings Supported by RFID Technologies, 2008 [Power Point Slide]. Germany: University of Siegen.

[36] S. Shampain, GPS Phone An Integrated GPS/Cellular Handset. NAVSYS Corporation.

[37] Smart Phone Time Management for CA Clarity Project and Portfolio Management. Retrieved from http://www.ca.com/

[38] S. N. M. Said, *Smart Complaint System(SCS) Maintanance System Using RFID*. Universiti Teknikal Malaysia, 2011.

[39] E. Thompson, *Integration PDA,GPS and GIS technologies for Mobile Traffic Data Acquisition and Traffic Data Analysis*. IT University of Goteborg and Chalmers University Of Technology, Goteborg, Sweden. 2003.

[40] S. Wahab, *Mobile Navigation System Using GPS.* Faculty of Informative Technology and Quantitative Science,University Technology Mara, 2006.