Exploring Context-Awareness in the construction logistics services delivery

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ABSTRACT: Managing a construction project supply chain effectively and efficiently is extremely difficult due to involvement of numerous sectors that are supported by ineffective communication system. An efficient construction supply chain system ensures the delivery of materials and other services to construction site while minimising costs and rewarding all sectors based on value added to the supply chain. The advancement of information, communication and wireless technologies is driving construction companies to deploy supply chain management strategies to seek better outputs. As part of the emerging wireless technologies, context-aware computing capability represents the next generation of ICT to the construction services. Conceptually, context-awareness could be integrated with Web Services in order to ensure the delivery of pertinent information to construction site and enhance construction supply chain collaboration. An initial study has indicated that this integrated system has the potential of serving and improving the construction services delivery through access to context-specific data, information and services on as-needed basis.

1 INTRODUCTION

Context-aware computing involves the use of environmental characteristics such as the user's location, time, identity, profile and activity to inform the computing device so that it may provide information to the user that is relevant to the current context (Burrell et al., 2001). Awareness of user context can enhance communications and collaboration in the construction industry by providing a mechanism to determine information relevant to a particular context.

This paper reports a part of an on-going research study on the proposed development of context-aware services delivery for construction project supply chain. This small part is an initial study that investigates the potential of improving the supply chain interactions in the construction delivery process through an effective integration of context-aware, wireless networking and web services technologies. The main research addresses one of the key limitations of existing supply chain interactions, i.e. the lack of context-specificity in the distribution of information, services and other project resources which results in both information overload (where some sectors of the supply chain are provided with more information than they need) and information starvation (where other sectors are not provided with the information that they do need).

2 LITERATURE REVIEW

2.1 *ICT in construction supply chain*

Fast development in information and communication technology (ICT) has emerged as a key driver and thus provided the opportunity for construction companies to be more sensitive towards their business strategy and productivity (Ahuja & Yang 2005, Ribeiro & Lopes 2001). The amount of project data and information generated during construction periods are enormous and uncontrolled due to the fragmented nature of the construction processes. The traditional paper intensive method of processing and transferring data and information is still being practised due to high investment capital cost on ICT facilities, lack of supporting interoperability between hardware-software within organisations and culture of most construction organisations. However, the emergence of interconnectivity between different information and communication systems over the internet coupled with ICT-construction researches that are being actively and widely explored to overcome these critical problems has encouraged construction organisations to seek ICT method of processing and transferring data (Leung et al. 2008, Zhou & Benton 2007, Lu et al. 2006 and Aziz et al. 2006, 2005). The use of Information Technology (IT) and learning from other industries were part of the recommendation and action plans suggested by the Strategic Forum (2005) committee for better logistics processes. Jang et al. (2003) and Rebolj et al. (2008) also suggested that a great deal of improving the construction logistics must be focused on the materials and information delivery in order to achieve better productivity, avoiding delays and reducing waste.

The Internet is bringing a major contribution to the evolving field of supply chain management. The primary benefits of e-commerce especially in logistics activities are reduced 'clerical' transaction costs, such as those involving contracting, ordering, confirming, invoicing and settlement. Information moved via the Internet has a number of characteristics that can change the way in which construction logistics supply chains are configured and managed. It is therefore, a great challenge to identify which ICT package is capable of addressing such issues in order to deliver various jobs or tasks within the context (Egan 1998). In addition, Aziz et al. (2006) had revealed that the current state-of-the-art in mobile communications in the construction industry has some underlined limitations due to lack of cohesion with the existing ICT infrastructure, little work towards developing automation technologies and the heterogeneous distribution of communication networks systems. In supporting and boosting the construction information sharing and communication flow, the powerful wireless web technologies show a great challenge to be used to enable project team members to access in real-time different corporate back-end systems and multiple inter-enterprise data resources collaboration and integration. Nevertheless, the growth in number and sophistication of web services means that, increasingly, useful applications will be available on the Internet that can be invoked directly from the construction supply chain management systems. These invocations can be triggered by changes in the context of the users or the project, and can significantly enhance the effectiveness of construction supply chain interactions. This provides enhanced capabilities for interoperation between a variety of logistics services and applications that are essential for intelligent collaboration and information exchange within the supply chain management network. Context-aware services delivery adds an additional application on top of such real-time wireless connectivity by providing the ability to intelligently interpret the user context and delivering data and services to a project team member based on the user's context.

2.2 *Wireless web services and context-aware technologies*

The integration of context-awareness and web services offers considerable potential for enhancing construction logistics collaboration activities by providing access to context-specific data, information and services. The incorporated context parameters can be defined based on the project tasks requirements. These include user context parameters (e.g. role, discipline, interests, preferences, etc.) as well as project parameters (e.g. project stage, client requirements, project location, procurement/contract type, etc.). Wireless sensor technologies such as active WiFi tags can be imbedded within the environment to capture the context parameters.

The semantic web, web services and software agents can be integrated with a wireless system network to form complete Intelligent Wireless Web building blocks (Aziz et al. 2006). The semantic web is an extension of the current web in which information is given well-defined meaning, better enabling computers and people to work in co-operation. It is based on the idea of having data on the web defined and linked such that it can be used for more effective discovery, automation, integration and reuse across various applications (Hendler et al. 2002). Semantic web technologies offer considerable benefits in terms of project management, content and document management, knowledge management, supply chain management, integration of distributed applications and services and improved efficiency of construction project delivery (Anumba et al. 2003).

Web services are self-contained, self-describing, modular applications that can be published, located and invoked across the web. Once a web service is deployed, other applications (and other web services) can discover and invoke the deployed service regardless of operating system or programming language (Kreger 2001). The key to web services is on-the-fly software creation through the use of loosely coupled, reusable software components (Fensel & Bussler 2002). Typical Web Services architecture consists of three entities; service providers, service requestors (or clients) and service registries. Service providers publish their services through brokers who maintain registries that clients can look up. The API (Application Programming Interface) for registering services is called Universal Discovery and Description Interface (UDDI). This API enables an enterprise to describe its businesses, its services and how they wish to undertake transactions, search for other businesses that provide desired services and integrate with these businesses to undertake a transaction, if desired. Service requestors (Human users or agents) search services in registries and invoke these services using a Web Interface (WSDL). With the help of information taken from the registries, users invoke the required service, through a Web interface. Simple Object Access Protocol (SOAP) is used to pass object information between applications. Web services loosely coupled approach suits the construction industry because of the temporary, multi-organisation structure of many construction projects, where companies work together for a short period of time.

Context-awareness system has been applied and established in many sectors including tourism, museums, libraries and medical. It is found that the researches in the application of context-awareness in the tourism industry, which is highly distributed activities based, are among the most intensive to date, and worth emulating due to the fact that the development of works in tourism is quite similar to construction, as both are based on the same factors, i.e. taking into account the aspects of engineering and technology, information services delivery and business strategy. The application adapts services to the interpreted context, thereby ensuring that the busy user gets highly specific data and services (Schilit 1995). Examples of successful related works include GUIDE (Cheverst et al. 2000) and CATIS (Pashtan et al. 2003).

Context is defined by Dey (2000) as "*any information that can be used to characterize the situation of an entity. An entity is a person, place, or object that is considered relevant to the interaction between a user and an application, including the user and application themselves*", meanwhile for Context-Aware Computing, Dey (2000) established the following definition: "*A system that uses context to provide relevant information and/or services to the user, where relevancy depends on the user's task*". Context-Aware computing enables a mobile application to leverage knowledge about various context parameters. Pashtan (2005) described four key partitions of context parameters, including user static context (includes user profile, user interests, user preferences), user dynamic context (includes user location, user current task and vicinity to other people or objects), network connectivity (includes network characteristics, mobile terminal capabilities, available bandwidth and quality of service) and environmental context (includes time of day, noise, weather, etc.).

2.2 *Wireless technology*

The advancement in wireless technology has dramatically changed the society's way of interaction, including most industries' management of communication and information. The concept of *anywhere, anyplace and anytime* for people to access information is becoming a reality through rapid emergence of wireless technologies (DELL White Paper 2005). Increased mobility and collaboration, improved responsiveness, better access to information, easier network expansion and enhanced customer access are among the reasons that encourage enterprises to go for wireless technology (CISCO White Paper 2008). The opportunities to boost productivity can also be benefited by encouraging information sharing in the construction supply chain services through the emerging high-speed wireless data transmission technologies, incorporating broadband, multi-media support and wireless sensors development. The use of standard 802.11 wireless networks assisted by wireless sensor technology such as active WiFi tag is capable of tracking and providing useful information feedback to end-user in real-time basis (Ekahau White Paper 2008). This application tracks and monitors assets and personnel within wireless network areas. The advancement of portable devices, such as PDAs, mobile phones, Tablet PC and other wearable equipment, supports W-WAN (wireless wide area network), W-LAN (wireless local area network) and PAN (personal area network) capabilities. However, even though a variety of mobile and context-aware applications already exist, there are still major shortcomings. The big challenge in applying this technology in practice is due to heterogeneous network consisting of local and wide area, and wired and wireless communication system operated by different authorities. (Neumann 2007)

3 METHODS

The aim of the initial study was to gather construction experts' views on whether the proposed system had the potential of improving the current construction project logistics activities. The specific objectives were to:

- Discover the actual current construction logistics practices
- Investigate the industry's readiness to adopt new technology.
- Identify and validate context-aware parameters
- Generate and validate real project scenarios

A number of different methods were used to carry out this initial study. First, a literature review was carried out to identify the possible context-dimensions to be addressed in the research project. Then, real project scenarios were generated, where these context dimensions were incorporated into the scenarios. A survey consisting of questionnaire and semi-structured interview was then conducted. The questionnaire survey was carried out to investigate the industry's readiness to adopt new technology. The interview was performed to learn the actual current construction logistics practices, to validate the context dimensions identified from literature review and also to validate the scenarios that had been developed.

3.1 *Context-aware system*

This part of the study focuses on identifying the context dimensions such as user, environmental and project contexts.

In generating the real project scenarios, context dimensions and context parameters to be addressed need to be identified concurrently. It is crucial to understand the range of construction logistics services in order to plan for the relevant project scenarios. Some of the construction logistics services include material supply, material and equipment storage, manpower supply, schedule control, infrastructure and equipment locations, etc. These services are proposed to be monitored by the integrated Wireless Web Services-Enterprise Resource Planning (ERP) Software Application as illustrated by Omar & Ballal (2009).

Table 1 shows the context parameters deployment which will be drawn from WiFi link (context location), user device (e.g. Pocket PC) via W3C CC/PP standards to allow description of capabilities and preferences with mobile devices, user identity (e.g. logistics engineer) via the unique IP address of the mobile device and user's current activity (e.g. tracking materials location) via integration with project management software application.

Table 1. Context dimensions, context parameters and context-aware services identified.

Context dimension	Context parameter	Context-aware services
User's static context	Profile	Deliver information based on user occupation or preferences
User's dynamic context	Location Current task	Inform and display tasks
Network connectivity	Network characteristics Mobile terminal capabilities	Inform WiFi signal strength Inform device power level
Environmental context	Weather Time	Inform/display location weather forecast Display time
Object's static context	Specifications Transport	Deliver object information details e.g. manufacturing date, volume, delivery date, etc.
Object's dynamic context	Location	Inform/display current location

The concept of context-aware services delivery centres on the need to provide the project team members with specific information and services as needed in a real-time basis within the construction logistics environment. It is pertinent that contexts are captured as efficiently as possible. Contexts are proposed to be captured from the following sources:

- Current location (project team members) – via WLAN real time positioning system (from Ekahau 2009 or Airetrak 2009). A client application running on a user's mobile device or WiFi tag sends constant position updates to the position engine over a wireless link
- Current location (material or machinery) – via WLAN for outdoor and indoor tracking services. A client application running on a user's mobile device or WiFi tag sends constant position updates to the position engine over wireless link
- User Device – via Microsoft.NET framework application
- Component Device – active WiFi tag
- User Profile – associated with mobile device's unique IP address
- Component Profile – associated with WiFi ID code
- Time via computer clock.

Changes in the context prompt the context broker to trigger the pre-programmed events. Events may include delivery of push-based messages to the user or an exchange of information with other applications, to make them aware of the events on the site. As the user context changes (e.g. change of location, tasks), the context broker recalculates the available services to user in real-time. In the prototype implementation, RDFS (RDF 2004) will be used to provide vocabulary and structure to express the gathered contextual information. Previously, many researchers had also used RDFS for representing and delivering the context information (Ferscha et al. 2002, Chen et al. 2004, Toivonen et al. 2003). Being XML-based, RDF also ensures provision of context information in an application and platform-independent way. Using RDFS, the context broker maps, captures and delivers contextual information to available data and services.

3.2 *Scenario Generation*

This research uses the scenario-planning method as a basis for understanding user-needs for the context-aware system design. This method is chosen for a number of reasons, one of which is the simple fact that it is easier to communicate visual descriptions of technology implementation scenarios in real construction situations.

Based on literature review case studies and assumptions made based on previous work experiences, possible scenarios of smart construction site had been generated. The main objective of developing these scenarios was to gather some useful feedbacks from construction experts during semi-structured face-to-face interviews to validate the conceptual scenarios and to enhance the potential of the proposed system in the construction logistics supply chain.

Figure 1 shows an example of one of the generated context-aware services delivery implementation scenario. This implementation describes the processes by which the key persons, e.g. project manager, logistics manager and client, based on his/her profile would be contextually aware of the logistics services/activities at site. The following illustrates the chronology of a crane hire from third party.

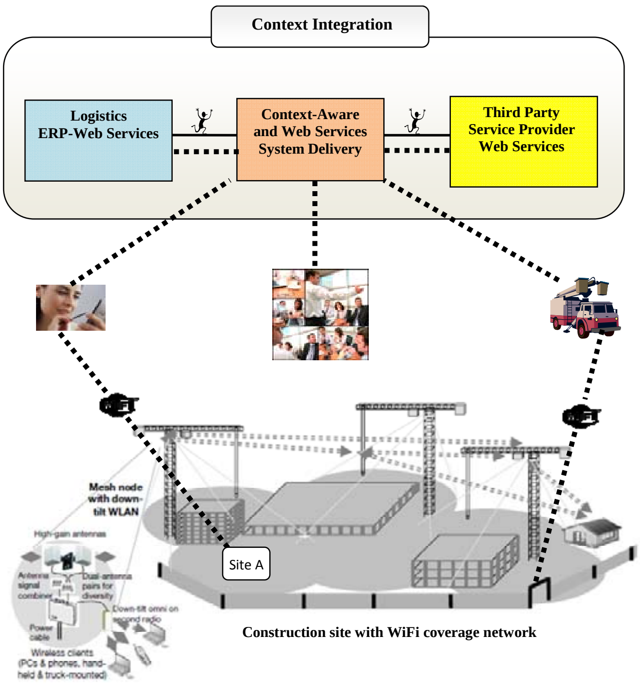

Figure 1. Scenario for logistics supply chain service delivery.

- By using a mobile device (i.e. PDA), the site supervisor makes a request for the deployment of a crane to lift steel beams at site A (Figure 1) for 10.00am on the next day. The technical detail of the project activity is automatically sent and updated by the context-aware system based on the site supervisor's current location.
- The request is processed by the logistics Enterprise Resource Planning (ERP)-Web Service system in order to source out the required crane from the nominated list of crane suppliers.
- Logistics agent through the web services makes request to supplier via supplier (third party) web services.
- Supplier agent confirms the delivery of crane as per requested. All the negotiation processes are done virtually by both agents. Logistics manager is alerted of the event and approves of the arrangements being made. Information is sent to the ERP-Web Services agent in order to notify the supplier agent.
- Upon agreement of the arrangements, the supplier agent processes and delivers crane delivery context parameters (supplier profile, machinery profile, machinery device, operator profile, operator device, delivery time) to logistics agent. All context parameters are stored in the crane's WiFi tags and operator's mobile device. ERP-Web Services agent then updates all the information in the context-aware integrated system.
- Delivery progress is wirelessly tracked through the crane operator's mobile device IP via mobile telecommunication network. The crane location can also be tracked via WiFi tag attached to the crane.
- Upon arrival at site gate, the on-site WiFi network scans the crane operator's device and WiFi tag, and updates the crane arrival information into the context-aware integrated system. At the same time, the logistics management/personnel, project manager/site supervisor and the supplier automatically receive this information on their mobile devices. All the information is updated in real-time on ERP-Web Services and Third Party web services.
- At the gate, the crane operator automatically receives information about the route to the exact site location on his mobile device. He is directed and assisted to the location through VoIP and site map.

3.3 *Survey*

A survey was conducted to validate the conceptual scenarios developed by interviewing several construction industry practitioners. The survey consisted of both questionnaire and semi-structured interview. The questionnaire was carried out to learn the magnitude of which technology is being used at construction sites and to investigate the industry's readiness to adopt new technology. The interview was performed to validate the scenarios that had been developed and the context dimensions identified earlier from literature review. The scenarios were explained to construction experts during the in-depth semi-structured interviews to get their opinions and recommendations. The current construction logistics practices were discovered through both the questionnaire and interview.

Eight respondents identified from people who have knowledge in construction as well as in dealing with logistics as their main scope of works, and therefore, deemed as experts, were selected. They were selected based their expertise, also the size and location of the construction project under their management. They include a construction manager for a multi-storey building project in a busy traffic area, a logistics project manager for an airport project (high security area), a logistics technical director for a project on a university campus and a project manager for a museum in city centre. Other respondents include a senior project manager, facilities manager, contracts manager and senior quantity surveyor of various construction projects of various sizes in different locations.

During the early stage, the selected respondents were contacted and notified through email and phone in asking for their favours to co-operate in supplying the information needed. They were told that their personal information would be kept confidential to ensure the fidelity of the data. They were asked to answer the questionnaire questions first before being interviewed.

3.3.1 *Questionnaire*

The questionnaire was designed objectively to investigate the level of acceptance of using wireless communication network technology in improving logistics services within the construction supply chain network as a whole. Since it was also pertinent to learn the magnitude of which technology was being used at construction sites, relevant questions relating to the use of communication and information tools, construction logistics services and digital technologies were developed.

The researcher-administered questionnaire survey was conducted in each of the respondent's respected site office. They were briefed on the overall scenario of the designated questionnaire before starting to fill in their answers. This had been done in order to ensure the validity and reliability of the survey data. In addition, their answers were discussed for clarification or to collect additional information, and hence eliminate misunderstandings. This questionnaire provided the basis for the ensuing face-to-face in-depth interview.

3.3.2 *Semi-structured interview*

For the final part of the survey, the pre-generated visual scenario (Figure 1) that incorporated context-aware parameters identified from literature review were presented and a brief description of the conceptual intelligent work environment and its potential were given. The scenarios were explained to the respondents, and they in return gave their opinions whether the scenario was valid and system was practical to be implemented, also whether it could solve issues such as information flow, communication, and other matters being raised in the first part of the survey, i.e. the questionnaire. Their suggestions to improve the proposed system were also asked. These feedbacks were used to evaluate the scenarios. Positive evaluations would indicate that the scenario was valid, and that the proposed system was practical to be implemented.

Each interview took between one to three hours to complete.

4 RESULTS AND DISCUSSION

This section provides the summary and discussion of the initial study results. Due to the small number of respondents, it is deemed meaningless to quantify the results of the survey. Still, the questionnaire data were analysed just to observe initial patterns, but is not presented in this paper.

4.1 *Readiness to adopt new technology*

The questionnaire listed some common communication and information tools such as face-to-face meeting, video conferencing, e-mail, text messaging, multimedia messaging, telephone and facsimile, and respondents were asked to identify which of these tools were normally observed to be used at site. In addition, they were also asked for their opinions which of these tools they would recommend or would not recommend to be used. It is observed that face-to-face meetings and communication through telephone are not only the most common tools used by the construction workers in their daily works or activities, but respondents highly recommended the use of these tools for communication and information delivery at the construction site. The main concerns that stand out when using the tools listed include information not readily available, slow retrieval and lack of information storage.

With regards to construction logistics services, respondents were asked to identify the activities that were commonly observed under work planning, work implementation and tracking/monitoring system practiced or used by the construction industry in their works related activities. It is observed that material flow, materials order and delivery, material handling and traffic flow are the main activities that are seriously taken into account by logistics personnel or construction management during the planning and design stages. In terms of work implementation at site, it shows that material delivery is given the highest priority compared to other items but the work safety and health rules are equally observed. Whilst tracking/monitoring system in logistics services is seldom observed and deemed unnecessary at the construction site. It is also agreed by all respondents that almost all of the problems listed in the survey, e.g. delays, double handling of materials, material delivery not always as scheduled, limited site storage, etc. are encountered in the logistics services.

In addressing the use of digital technologies at site, the questionnaire also listed some of the technologies and devices available, and respondents were asked to identify which items were observed to be used in their organizations, and which items they considered to be effective or ineffective. For communication technology, the items include internet, W-WAN, W-LAN/WiFi, W-PAN/Bluetooth and global positioning system (GPS). Listed for communication device were smartphone, personal digital assistant (PDA), tablet PC, laptop, personal computer and walkie-talkie. Respondents identified that the use of internet as the most effective way for communication compared to other wireless system network. Therefore, the use of personal computer (PC) is the most preferred tool compared to smartphone, PDA, laptop etc. This is not surprising because PC and internet are the most common items the respondents identified as being used by their organisations. In order to track the material flow, equipment location, personnel activities etc., among the proposed sensor technology such barcode, RFID, WiFi tags, CCTV and webcam, only CCTV and webcam are given a high regard. Interestingly, the others are classified as ineffective. It is observed that there are two main concerns in the application of digital technologies, i.e. lack of automation and lack of robustness.

The survey result indicates that the construction industry is not ready to adopt a new technology. Even the existing technology has been underutilised, and opportunities have not been explored. Respondents felt that it was not really necessary for information to travel in real-time. It stands to reason that they felt that the technology and device that they were not familiar with were ineffective or unnecessary.

4.2 *Construction logistics practice*

From the initial study survey, it is found that the current logistics practice in many construction projects is as illustrated in Figure 2. Project manager appointed by the owner to manage a project acts either as a consultant or the main contractor to the project. The project manager plans the execution of the project and appoints contractors to carry out the works. In terms of site logistics, the project manager designs for and provides facilities for storage and handling of materials or component. It is seldom for specialised personnel, e.g. logistics manager, to be in charge of the site logistics and everything else related to construction logistics, but some organisations do appoint consultants (third party) to deal with these. Nevertheless, 'managed' logistics are usually reserved for large projects. Contractors and sub-contractors order their own materials, components, equipment and machinery. Generally, on a construction site, there is at least a sort of a booking system for the contractors to book the time for their suppliers to deliver construction materials. On some sites the security guard or gate keeper keeps a log book to record the material delivery schedule. Suppliers that are not pre-booked on the system or are late are turned away and asked to pre-book another delivery times as not to disrupt the delivery schedule for the day. Web-based booking systems are also becoming common on construction sites. Suppliers from all around the region can book themselves the delivery times without the contractors having had to do it for them provided that they are registered with the system and have access to it. However, as far as construction logistics are concerned, the material delivery is about the only thing that project managers design for. Other aspects of construction logistics are usually left to common sense and chance, resulting in double handling of materials, material damage and misplacement; creating waste.

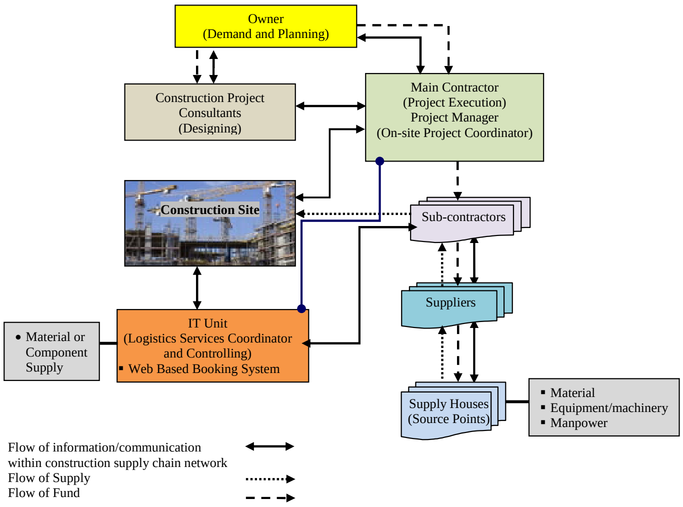

Figure 2. Logistics supply chain model based on the survey conducted.

It is seen from the model in Figure 2 that only low level IT capability is used at construction sites, and this does not cover all of the logistics services within off-site and on-site. The IT unit is fully under the project manager's responsibility where all the material supply to the on-site is arranged by the contractors or sub-contractors through their nominated suppliers. The logistics IT activity is limited to controlling the material supply to on-site through the limited capability booking system. From the study, it is observed that the system fails to respond to any delay/inconvenience that could occur during material delivery by suppliers. The consequences from this would indirectly affect the on-site activities.

4.3 *Validation of construction logistics scenario*

The information gathered from the respondents via the in-depth semi-structured interviews gives a positive indication that the proposed system has a promising potential. Generally, logistics means different things to different people, but all respondents liked the idea of the smart construction site scenarios. They all agreed that the proposed system has the potential of improving project logistics services delivery by improving the on-site and off-site communication, thus improving the supply chain communication. However, not unexpectedly, there were some reservations. Two of the respondents, however, felt that the implementation of such system would be more suitable for large or repetitive projects, and one or two of the respondents had some concerns about how the system would affect the works and the workers. According to the survey, one of the key barriers to the implementation of the proposed system is work culture. Workers are reluctant to change their way of doing things without any promise of personal gains. Also, most construction organisations are technologically conservative organisations. They are unwilling to invest in new, costly technology, due to the lack of belief of its potential benefits. They are not easily persuaded to try something that has not been proven of its cost-effectiveness and demonstrated its practical application benefits unless their client is willing to invest and force them to use under certain technical and management reasons.

Basically, to introduce a new technology involves cost, time, manpower and training, which are not necessarily in that order. An organisation needs funds to develop/purchase and implement the new system. Workers are required to develop or use the system, and they need training to become knowledge workers. To implement the system and train the workers all involve time and cost, which most organisations would rather spend trying to complete a construction project. Due to this, client and top management commitment are crucial in the adoption of the proposed system. Without motivation and client enforcement to adopt the technology, organisations would not bother testing the proposed system. Therefore, top management awareness and commitment in this matter are crucial for the system to be successful.

Another concern regarding the implementation of the proposed system is the use of mobile device on construction site to disseminate information and to track workers. Some projects have already banned the use of mobile phones on site as they pose as a hazard to health and safety. Also, most workers will resent being monitored at all times as in 'Big Brother'. The tagging of materials and equipment causes concern for the need to change the whole of the construction industry operation.

It is not the intention of the context-aware services delivery system to change the way the whole of the construction industry operates. The practice and processes will mainly remain the same, but the introduction of the system to the construction business model is to enable enhanced, more effective and efficient communication mechanism. The proposed system is to be updated on real-time basis where any information required can be pushed or pulled to the relevant user as appropriate. Through this model, all the logistics services will be controlled by IT manager/unit under the main contractor's responsibility. The IT unit could either be appointed through third party logistics (3PL) or under the full responsibility of main contractor.

By proposing a new logistics supply chain network information/communication model, the activities/services within the supply chain could be improved through the concept of pull-push that is fully controlled by context-aware and wireless technology capability. This new model provides the facility for information to be accessed by all parties at anytime, anywhere and anyplace with most updated information services.

5 CONCLUSION

Based on the literature review, the contextual requirements have been identified but the survey has confirmed and established them. The following context parameters are now established: user profile, components profile, location, time, user device and component device.

The study has indicated that the proposed system has the potential of improving project logistics services delivery by improving the on-site and off-site communication, thus improving the supply chain communication. However, with regards to the system's implementation, the issue of health and safety needs to be seriously considered to comply with construction site's regulations.

The study also validated the scenarios generated, but they need further enhancement to match the current construction practice which seems to favour Project Management Consultant (PMC) procurement route, where very minimal material ordering is involved on the part of the main contractor.

The process of integrating context-aware computing and web services to facilitate the creation of intelligent collaboration environment for managing construction supply chain takes into account all the critical parameters such as materials, information and finance flow. The project scenario generated has illustrated that conceptually context-awareness could be integrated with web services in order to ensure the delivery of pertinent information and enhance construction supply chain collaboration. It postulates that parallel developments in web services, which provide the ability to dynamically discover and invoke services regardless of operating system or programming language, can be leveraged to enable construction project team members to access, in real-time, different corporate back-end systems and multiple inter-enterprise project resources. The integration of context-awareness and wireless web services could offer considerable potential for enhancing construction services and ensuring that each service is provided with access to context-specific data, information and services.

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