# Performance and Impacts of Web-based Project Management Systems in Construction Projects

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## Abstract

**While web-based project management systems are widely being implemented in most construction projects, there is a clear lack of understanding among the industry professional in relation to any quantified benefit and achieving success in projects. The aim of this research is to unfold the understanding of the key factors affecting the implementation decisions and aided benefits of such web-based systems in projects empirically. Adopting the partial least square structural equation modelling (PLS-SEM) approach, the relational links between the six latent factors associated with the functionalities of web-bases PM systems have been assessed. The effect of six latent variables on the performance of web-based project management systems has been analysed using the data from a questionnaire survey of 77 respondents comprising the stakeholders within construction industry. The results of the data analysis suggest that project complexity (PC) and information streamline (IS) are the two key factors supporting the implementation of web-based systems (PWB) in projects. The general perception of increased users' satisfaction (US) and transparency and accountability (TA) has no strong empirical basis for rationalising the use of web-based systems across projects. Effective monitoring and control (EMC) during project delivery can only be marginally enhanced by implementing web-based project management systems. With a clear understanding of the significance of these factors in the context of implementation of web-based project management systems, these findings could potentially contribute to the development of company's procedures or to enhance existing knowledge within the construction industry.**

**Keywords: IT application, web-based systems, project management, project performance, structural model**

## 1 Introduction

Increased complexity of modern construction projects with involvement of scattered stakeholders present enormous challenges for achieving seamless collaboration within the organisations. While the implementation of web-based project management systems has been significant over past years, the current literature lacks any clear consensus on rationalizing such decisions across the industry. The research proposes a PLS-SEM based model for investigating the impacts of the key factors on the performance of the web-based systems being implemented in construction projects. The resulting structural model is used to test ten underlying hypotheses as postulated in the study.

The basic rationale behind the implementation of web-based PM systems is communication and information handling in most projects. Increased practices of concurrent design, frequent change of scopes, budget constraints, design novation etc. demand centralized access with reliable means of transmitting and storing the project information. As such, the web-based centralized system offers a level of access to project information that supersedes the traditional means of communication using telephones, faxes, hard copy ring binders or emails (O'Brian, 2000). In the advent of technological advancements and rapid launches of competitive products in the marketplace, the idea that web-based project management is the only way to achieve success in modern projects among the industry professionals remains obscure. In fact, research shows that hastily introduction of web-based project management systems across organizations are showing the sign of dissatisfactions and reduced productivity in projects (Alshawi and Ingirige, 2003).

## 2 Literature Review

The implementation of web-based PM systems generally helps to achieve better communication practices, speed of construction and greater collaboration amongst the project team members (Alshawi and Ingirige, 2003). The need for increasing the efficiency of these processes via exchanging massive volumes of information at high speed and relative at a low cost has been long recognised by the industry (Dong *et al*, 2001). As suggested by Baldwin *et al.* (1999), the key reasons for implementing the web-based PM systems are combination of poor-coordination, inaccuracy and inconsistency in information sharing in most projects. The study by Thomas *et al.* (2004) asserted that project size was the single most important factor in determining the degree of IT use on a project. One of the primary reasons for implementation of web-based PM systems in most projects is the enhance communication between the project participants above and beyond traditional paper-

based poor communication which is believed to impact projects significantly by causing delays and inefficiencies (Williams, 2007). However, Thorpe and Mead (2001) suggested that web-based system has the ability for generating information overload, which potentially limits its effectiveness (Thorpe and Mead, 2001). Mitropoulous and Tatum (2004) argue that the four main forces that drive the adoptation of new technology by construction companies are *competitive advantage*, *technological opportunity*, *improving construction processes* and *external requirements*. However, these findings do not provide any understanding on the main forces contributing to the overall success on implementing a web-based PM system in the project. As asserted by Wayte *et al.* (2002), successful implementation of IT requires not only strategic decision making at a top management level, but also technical managers input. Anecdotally, there have been numerous examples where the implementation of IT has been unsuccessful or did not meet the expectations of the end users in the organization. For this reason, it is important to understand the key drivers associated with the decision making of such implementations and communicate the tangible benefits among the project teams (Williams, 2007).

### 2.1 Hypothetical model

The aforementioned studies provide the theoretical basis to construct the model for this study. It is assumed that information streamline (IS), Transparency and accountability (TA), effective monitoring and control (EMC), users' satisfaction (US), increased competition (IC) and project complexity (PC) collectively determine benefits of web-based project management system (PWB) being implemented in projects. All these technical factors are important in terms of rationalising the decisions for implementation of web-based PM systems and thereby exhausting the benefits in the project. Thus, a series of hypotheses can be drawn to verify the relational linkages and underlying effects between these technical factors and the performance of web-based systems being implemented in projects.

In order to analyze the PLS-SEM model, the initial path diagram was developed based on a total of 10 hypotheses as follows:

- The benefit of web-based project management system in projects is exhausted by the six key factors namely high *Users' Satisfaction* (hypothesis 1), high degree of *Transparency and Accountability* (hypothesis 2), *Increased Competition* (hypothesis 3), *Information Streamlining* (hypothesis 4), *Project Complexity* (hypothesis 5) and *Effective Monitoring and Control* (hypothesis 6);
- Web-based systems implementation is driven by high degree of *Transparency and Accountability* (hypothesis 7) in projects;
- The high degree of *Transparency and Accountability* is due to high degree of *Information Streamline* (hypothesis 8), which enhances *Effectiveness in Monitoring and Controlling* (hypothesis 9) of projects;
- *Project Complexity* is easily managed with increased *Effectiveness in Monitoring and Controlling* in projects (hypothesis 10).

### 2.2 Research Method

As mentioned earlier, the survey method was adopted to test the hypotheses proposed in this study. A questionnaire survey was designed for respondents to assess the performance of web-based systems implemented in relation to the perceived influences of users' satisfaction, transparency and accountability, information streamline, increased competition, project complexity and effective monitoring and control on those projects. The questions were phrased to ask the respondents an affirmative response on the relevant variables or indicators impacting the overall performance of the web-based systems in their projects. Respondents' profile and the project information were also collected in the survey.

Before undertaking an industry-wide survey, a pilot study was conducted among a six member focus group explaining the research intents and the questions in order to validate the contents for accurate translation of the overall model construct. Based on the feedback received, the questionnaire was refined and the ethics clearance was obtained from the University Ethics Committee for conducting the industry-wide survey. The preliminary data was collected from a total of 15 medium to large construction firms in Australia. The target population of the survey in this study was clients, contractors, designers or consultants, project managers, site managers and site coordinators involved mostly in residential and commercials projects. In total 150 survey questionnaires were distributed amongst the identified organizations with an expectation that there would be a rate of return somewhere between 25-50% of the total number of questionnaires issued. This range of rate of return would be considered applicable and consistent with other reported mail surveys in the literature reviewed (Fellows & Liu, 1997; Stevens, 2002). The overall aim was to distribute the survey questionnaire to as many applicable organizations and to receive at minimum five questionnaires back from any one firm. Studies have shown that as low as two people completing a research questionnaire can provide a general consensus on how the remainder of the organizations employees may also perceive the data content under question (Cheung *et al* 2004). In total 77 completed questionnaires were returned, constituting a 48% response rate. Eight additional questionnaires were received incomplete and thus excluded from the sample in the analysis. Such a response rate was primarily due to the selection of the sample and the interaction between the researchers and the respondents in confirming willingness and participation in the study.

While 23% of the respondents have been in the industry for less than 5 years, 51% have been in the industry with the

experience bracket of 6-15 years. The remaining 26% respondents had the experience over 15 years and considered fairly senior among the participants. As uptake of the web-based systems in most construction firms are spaned over past 5-7 years, over 73% of the respondents were able to provide with informed judgements based on their experiences from pre- and post- web-based systems implementation periods. Of the 77 respondents, over half of them (55.6%) noted that their current project was worth between 300-599 million dollars which is considered quite significant in the context of deriving benefits from the implementation of the web-based PM systems. The remaining projects were worth between 100-300 million in the sample.

The valid dataset was then analysed on Structural Equation Methodology (SEM) using the PLS-Graph 2.0 software.

## 3 PLS-SEM Model

Partial least square structural equation modelling (PLS-SEM) is selected over the covariance-based SEM (CB-SEM) due to the fact that PLS-SEM is based on a series of ordinary least square (OLS) regressions which does not demand a high sample size, yet without compromising the high levels of statistical power (Reinartz et al. 2009). Conversely, CB-SEM involves constraints regarding the number of observations and small sample sizes, often leading to biased outcomes with reduced statistical power and inadmissible solutions especially in complex model set-up. Thus, PLS-SEM, which is a distribution-free soft modelling approach, is highly suitable for applications without having to make any strong assumptions which often cannot be fully met in most models (Hair et al., 2011).

The outputs from the PLS-SEM models require two step interpretations, validity and reliability testing and assessment of the relationships based on the path coefficients. The validity and reliability of the measurement model is first evaluated by examining the individual loadings of latent factors for internal composite reliability and discriminant validity (Chin, 1998). After making adjustments of the items in the model and acceptance of the final model, the relationships between the independent latent variables and dependent variables are assessed based on "standardised beta estimates" as the path coefficients. These path coefficients are then used to prove or disprove the hypotheses in the research (Aibinu and Al-lawati, 2010).

## 4 Model analysis and validation

The initial structural model hypothesised (Figure 1) was analysed using PLS-Graph 2.0 software and the results of the measurement model are discussed in the following sections.

Before accepting the final model for testing the hypotheses, the adequacy of the structural model was tested using individual variable reliability analysis, convergent validity measures of the latent factors and discriminant validity of the measurement model. Individual variable reliability measures are mostly the standardized loading or simple correlations of the measured variables with their respective latent variables relative to the errors (Hulland, 1999). As a rule of thumb, the standardized loadings of the measured variables should be 0.7 or more which implies that about 50% of the variance in the observed variables (i.e. the square of the loadings) is due to the latent variables. There are numerous suggestions on the threshold values of the standardised loading below which the measured variables should be dropped in the final model. While Hulland (1999) suggests the threshold as 0.4, the recommended values by Fornell and Larcker (1981) and Chin (1998) are 0.7 and 0.707 respectively. With the view of these suggestions and adopting a threshold of 0.7 in the outputs from PLS-Graph 2.0, six measured variables were dropped before accepting the final structural model. The standardized loadings of the measurement variables as shown in Figure 1 demonstrate satisfactory level of individual variable reliability in the final structural model.

## 5 Model Development and Validation

The paths of the structural model that corresponds to the underlying hypotheses have assessed using the PLS-Graph 2.0. Table 1 depicts the summary of the path results and corresponding significance (p-values), standard errors (SE) and the t-values associated with each structural path. As seen, all these indicators can be used to prove or disprove the hypotheses by careful interpretations of their sizes, signs and significance levels (significant at $p<0.05$).

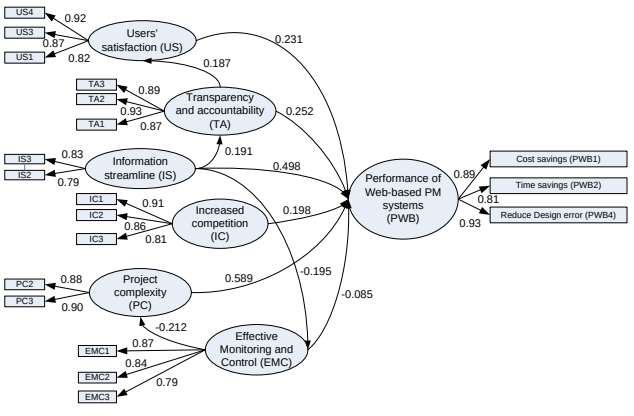


Figure 1: Structural Model of the factors affecting the implementation of Web-Based project management systems

Table 1: Path Coefficient Estimates of the PLS-Graph

| Path | Standardised Coefficient estimate[1] | Sig. (p) | S.E. | t-value |
|---|---|---|---|---|
| H1: PWB <--- US | **0.231** | 0.052 | 0.102 | 1.98 |
| H2: PWB <--- TA | **0.252** | 0.057 | 0.117 | 0.66 |
| H3: PWB <--- IS | **0.498** | 0.008 | 0.098 | 0.56 |
| H4: PWB <--- IC | 0.198 | 0.073 | 0.104 | 1.08 |
| H5: PWB <--- PC | **0.589** | 0.004 | 0.097 | 1.17 |
| H6: PWB <--- EMC | -0.085 | 0.050 | 0.142 | 0.51 |
| H7: US <--- TA | **0.187** | 0.009 | 0.091 | 0.43 |
| H8: TA <--- IS | **0.191** | 0.038 | 0.192 | 2.65 |
| H9: EMC <---IS | -0.195 | 0.089 | 0.131 | 0.55 |
| H10: PC <--- EMC | -0.112 | 0.049 | 0.271 | 1.22 |

[1]All standardised coefficient estimates are significant at $p<0.05$

The final PLS-SEM results supported only two primary hypotheses (H3 and H5) with an acceptable level of p being less than 0.05 with reasonably strong path coefficients. These results suggests that project complexity (PC) and information streamline (IS) are the two most influencing factors with highest positive correlations (with a standardise coefficient = 0.589 and 0.498 respectively) with the implementation and performance of web-based PM systems in projects. The path between increased competition (IC) and performance of web-based PM systems (PWB) with statistical insignificant (p=0.073) coefficient of 0.198 does not support the hypothesis H4. Similarly the path between information streamline (IS) and effective monitoring and control (EMC) with a statistically insignificant (p=0.089) coefficient of -0.195 does not support any direct and meaningful linkages as postulated in hypothesis H9. The reverse influence depicting the influence of effective monitoring and control on information streamline is rather insignificant with a smaller path coefficient and hence hypothesis H9 can be dismissed.

The influence of the factors, users satisfaction (US) and transparency and accuracy (TA) on performance of web-based PM systems (PWB) with part coefficients of 0.231 and 0.252 at their respective acceptable borderline significances (p=0.052 and p=0.057) depict that Hypotheses 1 are 2 are marginally supported. The hypothetical paths between transparency and accuracy (TA) and users satisfaction (US) and information streamline (IS) and transparency and accuracy (TA) with relatively smaller path coefficients of 0.187 and 0.191 and with acceptable significance levels (p=0.009 and p=0.038 respectively) support hypotheses 7 and 8 partly. The structural paths linking effective monitoring and control (EMC) to performance of web-based PM systems (PWB) and project complexity (PC) with their respective acceptable borderline significances (p=0.050 and p=0.049) depict that hypotheses 6 are 10 are marginally supported but in reverse orders with their negative path coefficients of -0.085 and -0.212 respectively.

## 6 Results and Discussions

As depicted in Table 1, the test results generally support the relationships between project complexity, information streamline and implementation of web-based project management systems which validate both hypotheses 3 and 5 reasonably well. A significant and positive relationship (with standardise coefficient = 0.187) was found between transparency and accuracy and users satisfaction. Similarly, a significant and positive relationship (with standardise coefficient = 0.191) suggests that information streamline potentially influence in achieving the transparency and accuracy in projects. Due to the relatively smaller path coefficients between the respective two factors (with standardise coefficients of 0.187 and 0.191 respectively), these findings support hypotheses 7 and 8 partially. The path coefficients between users satisfaction and performance of web-based PM systems (with standardise coefficient = 0.231) and transparency and accuracy with performance of web-based PM systems (with standardise coefficient = 0.252) with borderline significances suggest that hypotheses 1 and 2 are marginally supported respectively. The existence of marginal negative standardised coefficients of -0.085 between the factors EMC and PWB and -0.112 between the EMC and PC with borderline significances clearly make the hypotheses 6 and 10 only marginally supported in reverse orders. The influence of effective monitoring and controlling of projects on the implementation of web-based PM systems is found to be marginal which contradicts the findings reported by Lee et al. (2005). The assertion that the demand for effective monitoring and controlling increases with the increase in project complexity is also found to be marginally supported in this research. While the increased competition is believed to have a direct influence in implementation of web-based PM systems within construction organisations, the finding of an insignificant standardised coefficient (= 0.198) between the two factors does not support this hypothesis (H4). Similarly, information streamline resulted from the implementation of web-based PM systems does not contribute in effective monitoring of the controlling of project due to an insignificant standardised coefficient (-0.195) between the factors and hence hypothesis 9 is rejected.

This study has proved the hypothesis that the project complexity and information streamlining are the two most influencing factors for exhausting full benefits of the web-based PM systems implementation in projects. The assertions by El-Gohary and El-Diraby (2010) that increased necessity of the seamless integration of knowledge-carrying processes required in complex projects is significantly facilitated by the implementation of online collaborative platform are clearly validated in this research. It has been revealed that transparency and accuracy in information communication and satisfaction of users with added confidence significantly contribute to effectiveness of the web-based PM systems in projects and hence improving the rate of success. Therefore the

blanket rule that web-based PM systems is an absolute necessity and key driver for such implementation is due to increased market competition and technological advancement eventually undermine the objective decision making in projects (Nitithamyong and Skibniewski, 2004). This finding is in the line of the previous findings that the necessity of web-based PM systems increases with the increased complexity of modern projects. Implementation of web-based PM systems should be based on objective analysis of functionalities, discussions among project team members and clear support of the senior management in projects (Ryoo et al, 2010; Chan and Leung, 2004; Forcada et al., 2010). Furthermore, while the PLS-SEM model shows some contrast to the to the results published by Lee et al. (2004) and Cheung et al. (2004) contending that onsite decision making, information sharing in the context of planning and control and enhanced are some of the key factors impacting implementation and performance of web-based PM systems in projects, the findings however support the research by Mohamed and Stewart (2003) asserting that enhanced coordination and reduced response time supplemented by web-based systems implementation cannot be considered as a clear industry practice.

## 7 Conclusions

The model suggested that overall success of the implementation of web-based PM system significantly relies on degree of project complexity and need for information streamlining across the contracting parties in project. Underestimation of project scope and lack of in-depth understanding of information sharing and data exchange requirements across the diverse project stakeholders potentially undermines the true performance of web-based systems implementation. However, the there is no any significant evidence of effective monitoring and controlling being supported by the web-based systems implementation in projects. The findings of the PLS-SEM suggest that the factors such as users' satisfactions, market competitions, increased transparency and accuracy, real time communication barely have any impact on objective benefits of web-based systems being implemented and overall project success. However, the implementation of the web-based PM systems for exhausting the necessary benefit have been supported by the factors associated with the complexity and necessity of the seamless integration of knowledge among the users in the project.

## References

[1] Adriaanse A., Voordijk, H. & Dewulf, G. 2010. The use of interorganisational ICT in United States construction projects. *Automation in Construction,* 19, 73-83.

[2] Ahuja, V., Yang, J. & Shankar, R. 2009. Study of ICT adoption for building project management in the Indian construction industry. *Automation in Construction,* 18, 415-423.

[3] Aibinu, A. & Al-lawati, A. M. 2010. Using PLS-SEM technique to model construction organizations' willingness to participate in e-bidding. *Automation in Construction,* 19, 714-724.

[4] AJAM, M., ALSHAWI, M. & MEZHER, T. 2010. Augmented process model for e-tendering: Towards integrating object models with document management systems. *Automation in Construction,* 19, 762-778.

[5] ALBERT, P. C. C., DANNY, C. K. H. & TAM, C. M. 2001. Design and Build Project Success Factors: Multivariate Analysis. *Journal of Construction Engineering and Management,* 127, 93-100.

[6] ALSHAWI, M. & INGIRIGE, B. 2003. Web-enabled project management: an emerging paradigm in construction. *Automation in Construction,* 12, 349-364.

[7] ARSLAN, G., KIVRAK, S., BIRGONUL, M. T. & DIKMEN, I. 2008. Improving sub-contractor selection process in construction projects: Web-based sub-contractor evaluation system (WEBSES). *Automation in Construction,* 17, 480-488.

[8] BARIMA, O. K. B. 2009. Crucial tactical variables for value delivery in virtual projects. *Automation in Construction,* 18, 875-880.

[9] C MCCARTHY, S. & L K TIONG, R. 1991. Financial and contractual aspects of build-operate-transfer projects. *International Journal of Project Management,* 9, 222.

[10] CARMINES, E. & ZELLER, R.A. (1979), Reliability and Validity Assessment, Sage University Paper Series on Quantitative Applications in the Social Sciences, No.07-017. Sage, Beverly Hills, CA.

[11] CHAN, E. H. W. & YU, A. T. W. 2005. Contract strategy for design management in the design and build system. *International Journal of Project Management,* 23, 630.

[12] CHENG, J. C. P., LAW, K. H., BJORNSSON, H., JONES, A. & SRIRAM, R. 2010. A service oriented framework for construction supply chain integration. *Automation in Construction,* 19, 245-260.

[13] CHENG, M.-Y., TSAI, H.-C. & HSIEH, W.-S. 2009. Web-based conceptual cost estimates for construction projects using Evolutionary Fuzzy Neural Inference Model. *Automation in Construction,* 18, 164-172.

[14] CHEUNG, S. O., SUEN, H. C. H. & CHEUNG, K. K. W. 2004. PPMS: a Web-based construction Project Performance Monitoring System. *Automation in Construction,* 13, 361-376.

[15] CHIN, W. W. (1998). The partial least square approach to structural equation modelling, in: G.A. Marcoulides (Ed.), Modern Methods for Business Research, Erlbaum, Mahwah, NJ, pp.295-336.

[16] CHOU, J.-S. & O'CONNOR, J. T. 2007. Internet-based preliminary highway construction cost estimating database. *Automation in Construction,* 17, 65-74.

[17] DAVE, B. & KOSKELA, L. 2009. Collaborative knowledge management--A construction case study. *Automation in Construction,* 18, 894-902.

[18] DENG, Z. M., LI, H., TAM, C. M., SHEN, Q. P. & LOVE, P. E. D. 2001. An application of the Internet-based project management system. *Automation in Construction,* 10, 239-246.

[19] DOSSICK AND SAKAGAMI (2008), Implementing web-based project management systems in the United States and Japan, J of Construction Engineering and Management, Vol.134(3), pp.189-196.

[20] El-Gohary, N.M. and El-Diraby, T.E. (2010). Dynamic Knowledge-Based Process Integration Portal for Collaborative Construction, J. of Construction Engineering and Management, Vol.136(3), pp.316-328.

[21] FORCADA, N., CASALS, M., FUERTES, A., GANGOLELLS, M. & ROCA, X. 2010. A web-based system for sharing and disseminating research results: The underground construction case study. *Automation in Construction,* 19, 458-474.

[22] FORNELL, C. and LARCKER. D.F. (1981), Evaluating Structural Equation Models with Unobservable Variables and Measurement Errors, Journal of Marketing Research, Vol.18, pp.39-50.

[23] HAN, S. H., KIM, D. Y., KIM, H. & JANG, W.-S. 2008. A web-based integrated system for international project risk management. Automation in Construction, 17, 342-356.

[24] Mohamed, S and Stewart, R.A. (2003). An empirical investigation of users' perceptions of web-based communication of a construction project. Automation in Construction, Vol.12, pp.43-53.

[25] HULLAND, J. (1999). Use of Partial Least Square (PLS) in Strategic Management Research: a review of four recent studies, Strategic Management Journal, Vol.20, pp.195-204.

[26] LAM, K. C. & NG, S. T. 2006. A cooperative Internet-facilitated quality management environment for construction. *Automation in Construction,* 15**,** 1-11.

[27] LIN, Y.-C. 2008. Developing construction assistant experience management system using people-based maps. *Automation in Construction,* 17**,** 975-982.

[28] MENA, Á., LÓPEZ, F., FRAMIÑAN, J. M., FLORES, F. & GALLEGO, J. M. 2010. XPDRL project: Improving the project documentation quality in the Spanish architectural, engineering and construction sector. *Automation in Construction,* 19**,** 270-282.

[29] MOHAMED, S. & STEWART, R. A. 2003. An empirical investigation of users' perceptions of web-based communication on a construction project. *Automation in Construction,* 12**,** 43-53.

[30] NITITHAMYONG, P. & SKIBNIEWSKI, M. J. 2004. Web-based construction project management systems: how to make them successful? *Automation in Construction,* 13**,** 491-506.

[31] NUNNALLY, J.C. (1976), Psychometric Theory, McGraw Hill New York, 1976.

[32] STEWART, R. A. & MOHAMED, S. 2003. Evaluating the value IT adds to the process of project information management in construction. *Automation in Construction,* 12**,** 407-417.

[33] O'BRIAN, JW. (2000), Implementation Issues in Project Web Sites: A Practitioner's Viewpoint, J of Management in Engineering, May/June, Vol.16, pp.34-39

[34] STEWART, R. A. & MOHAMED, S. 2004. Evaluating web-based project information management in construction: capturing the long-term value creation process. *Automation in Construction,* 13**,** 469-479.

[35] UDEAJA, C. E., KAMARA, J. M., CARRILLO, P. M., ANUMBA, C. J., BOUCHLAGHEM, N. & TAN, H. C. 2008. A web-based prototype for live capture and reuse of construction project knowledge. *Automation in Construction,* 17**,** 839-851.

[36] WILKINS, B. & BARRETT, J. 2000. The virtual construction site: a web-based teaching/learning environment in construction technology. *Automation in Construction,* 10**,** 169-179.