Study on a Web-based Project Integrated Management Information System in A/E/C Industry

LIU Yong
School of Architecture and Civil Engineering, Zhejiang Sci-Tech University, Hangzhou, P. R. China
Email: super_liu2001@126.com

CHEN Chunlai
Faculty of engineering, Zhejiang University City College, Hangzhou, P. R. China
Email: cclzju@163.com

CUI Caiyun
Department of Civil Engineering, North China Institute of Science and Technology, Langfang, P. R. China
Email: cuicaiyun@163.com

***Abstract*—The author tries to develop and implement a Web-based Project Integrated Management Information System (PIMIS) in Architecture/engineering/construction (A/E/C) industry. The targets, the functional planning, the framework and the technical index of the PIMIS were presented firstly. Then, experimental implement of this developed system were put forward in 3 A/E/C project. Finally, an empirical interview survey targeting the project managers of the studied 3 cases was carried to estimate its implement performance. Results show that the acceptance and implement of the PIMIS can significantly improve the performance of the project cost control, and successful implementation of the PIMIS, in terms of leading to better outcomes for the A/E/C project, Coordination improvement among participators and Reduction of contract disputes, etc, is not simple a matter of introducing the system into an project organization. Instead, it must be associated with overall project management approaches such as a suitable organization mode, an appropriate system, the standard workflows, adequate personal trainings and even a coordinated project management philosophy.**

***Index Terms*—project, web-based PIMIS, implement performance, A/E/C industry**

I. INTRODUCTION

Your goal is to simulate the usual appearance of papers in a Journal of the Academy Publisher. We are requesting that you follow these guidelines as closely as possible.

The Architecture/engineering/construction (A/E/C) industry is fragmented due to the many stakeholders and phases involved. That has led to well documented problems with communication and information processing and has contributed to the proliferation of adversarial relationships between the parties to a project. This fragmentation is also often seen as one of the major contributors to low productivity in construction [1]. According to the statistical data collected by the Bricsnet.com Corporation in American, approximately 3% to 5% of the total cost are caused by project changes and mistakes resulted by the bad information communication in A/E/C project, especially in the large-scale construction project. And there is no project stakeholder who can access construction information at a level of 65% [2]. With the development of project management both in theory and practice, project management in A/E/C industry tends to be transformed from extensive to intensive. It makes Communication and information processing among project stakeholders becomes the key influencing factor which interfere the development of the construction industry directly.

The use of IT can promote coordination and collaboration between organizations participating in a A/E/C project which is led to better communication practices, and can improve the project management performance, including project cost and schedule reductions, team productivity promotion, project stakeholder success, etc[3-8]. Some researchers argued that the usage of IT in A/E/C industry has become an international trend in building and construction research [9, 10]. Meanwhile, according to the data surveyed by the Engineering News Record (ENR), IT spending in A/E/C firms has increased 16% within the past two years, and will still increase twice in the following 6 months [11], which indicated that A/E/C firms are increasing their interests in IT application to facilitate the construction project.

Among all IT applied in A/E/C industry, the Internet is the technology that best facilitates a collaborative working environment in an A/E/C project. Its use as a

Manuscript received Sep. 10, 2011; revised Oct. 18, 2011; accepted Oct. 28, 2011.
Project number. 2011-R3-15

doi:10.4304/jsw.7.8.1713-1720

communication medium which can help information transfer occur faster and more effectively and enable new opportunities for the development of distributed systems that can cross organization boundaries and provide a unique opportunity for teamwork and workflow automation. Thus, Internet will impact professions, education, collaboration, and the construction business structure, and will be the key to a change in global construction business in the near future [8, 12]. The Web can also overcome the incompatibilities of data formats through smart browsers and servers. Therefore, independent project participants using different hardware platforms can share the same system over the Web [7]. As described in some literatures [1, 13-15], the practical advantages of Web technologies in construction include an increase in the quality and timeliness of documentation, an increase in speed of work, better financial controls and communications, simpler and faster access to common data, and a decrease in documentation errors, and can be broadly categorized into three areas: the support of relevant information services, communication between project participants, and engineering and management computing.

Web-based construction project management system has grown rapidly in some developed countries, including America, the EU, etc. There are Project Collaboration Network (PCN), such as Buzzsaw™ and e-Builder™, to facilitate the current construction project management; Project Information Portal (PIP), such as Building.com and HomePro.com, to deal with the information processing and communication among project stakeholders; and Project Procurement Exchange (PPE), such as BidHost™, to streamline the procurement cycle of construction materials and services. And there are also some project management application service provider (PM-ASP) can provide software products to solve all of 3 problems talked above in A/E/C project, for example, the Bricnets®. But in China, though there are some advertisements made by ASPs that their products are the only solutions to the problems currently faced by project participators, such as LinkProject (http://www.bjmr.com), PowerPIP and PowerOn (http://www.p3china.com), etc, the Internet application in the A/E/C industry is still in early stage. Factors which may lead to the low application performance of the Web-based project management information systems in China can broadly categorized into four areas: its bad applicability and functionality, its unsuitable business models and services provided [16], the lagged system building by the Ministry of Construction [17] and the shortage of skilled information management practitioner in A/E/C industry.

"Mechanisms to ensure all parties are informed and coordinated via information and communication technology" has been identified one of the four "engines of change" in A/E/C industry [7]. In 2007, the total investment in fixed assets of China reached to ￥13724 billion, with an annual increase of 25.8% within the past five years. Due to the tremendous scale capital construction, it is of great significance theoretically and practically for us to implement the modern project management theories and IT, especially the Internet technology, to improve the performance of the project management in A/E/C industry, and to promote the core competence of A/E/C firms. Hence, we set up a software development project to develop web-based project control information system named the Web-based Project Integrated Management Information System (PIMIS) in A/E/C industry. The PIMIS was firstly used in a campus construction project to test and modify the software prototype. Then, the modified PIMIS was implemented into two A/E/C projects. This paper discusses the results of a case analysis on the development and application performance of the PIMIS.

II. DEVELOPMENT OF THE WEB-BASED PIMIS

A. Objectives

The PIMIS is developed for a common project manager to better the cost control of the A/E/C project in line with stakeholders' requirements and needs for the project. Hence, the main purpose of the PIMIS is to help project managers in controlling the project cost which is usually seen as a key factor of the project success criteria. On the basis of this, the sub-objectives of the PIMIS identified by the development team are:

1) To set up a conventional database to meet requirements of cost data collecting, transmitting, processing, maintaining and storing;

2) To establish a communication platform to promote coordination and collaboration between participators of the project, this is usually fragmented by the organizational ramparts and location restrictions;

3) To provide a standardized flow processor based on the workflow of the project management to satisfy needs of standardization and reutilization;

4) To construct a decision supporting system to aid the project manager with some cost decision-making.

B. Cost breakdown structure and its code system

The Work Breakdown Structure (WBS) organizes and defines the total scope of the project, and subdivides the project work into smaller, more manageable pieces work to fit the requirement of project schedule control [18]. Simultaneously, to control and estimate the cost of a project, another level of work items according to cost accounts is also necessary. This is so-called the Cost Breakdown Structure (CBS). The CBS is a logical breakdown of a project into controllable elements which fundamentally determine the total cost of a project for the purpose of cost control and reporting, and is coded systematically in a logical manner, which provides a consistent organization throughout the life of the project in cost controlling and estimating. The CBS and code system is established early in a project, and used during the constructing cycle to control the costs. As a project progresses, the same CBS and code system is used while the elements of data are updated.

As the promulgation and implementation of the national standard named ***Code of Valuation with Bill Quantity of Construction Works (GB50500-2003)*** in Feb,

13th, 2003, the cost management mode of China transformed from static to dynamic. The CBS regulated by ***GB50500-2003*** which is a hierarchical system divided by type of work, similar to **MasterFormat™** [19], provides a sound basis for us to establish a CBS and code system which can meet the needs of the PIMIS. The CBS and code system of the PIMIS is shown in **Figure 1**:

The Bill of Quantity (BOQ) code shown in **Figure 1** can be got from the ***GB50500-2003***, and be shown in **Figure 2**.

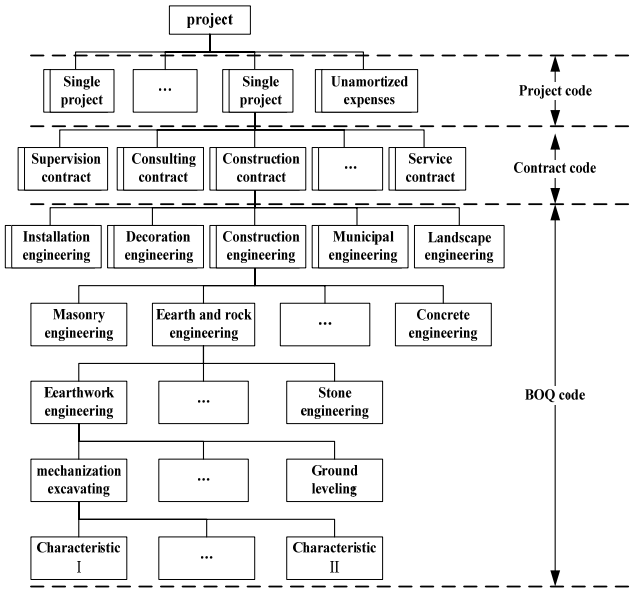

Figure 1. The CBS and code system of the PIMIS

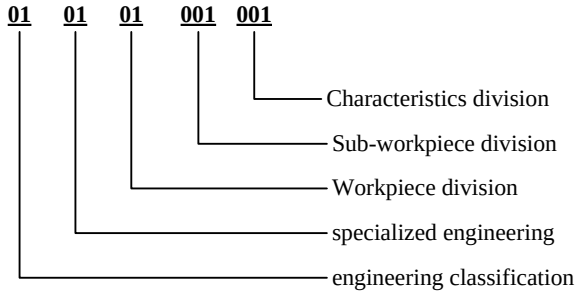

Figure 2. The Bill of Quantity (BOQ) code

C. Function model

To realize the system objectives talked above, a detailed functional planning has been completed by the development team based on a formal requirement analysis originated from some potential users. Due to the difference of the module users, the function of the PIMIS can be broadly categorized into two areas: the basic function and the expanded function.

The basic function means some fundamental abilities which can help sub-managers do some regular cost control tasks, such as Measurement and payment for the monthly installment, Change/claim management on line through workflow technology, etc.

Based on the development of project management theories and IT, some expanded functions of the PIMIS are needed to solve problems appeared with the expansion of the A/E/C project scale. The expanded function can do some cost analysis and prediction based on mathematics models and management models to aid managers of the strategic level in decision making, such as the "earned value" analysis, project cost estimate and forecasting, etc. The function model of the PIMIS is shown in **Figure 1**:

D. Framework

The PIMIS is an electronic project integration management system conducted through the Extranets, which are virtual networks that allow an organization to connect partners, customers and suppliers using the technologies and architectures that best support their business needs [20], and be developed to enhance the A/E/C project cost control and to revolutionize the way in which stakeholders conduct business. It can be basically provides a centralized, commonly accessible, reliable means of transmitting and storing project cost information [21]. With the utilization of the PIMIS, we can make the basic cost control and management works, such as the monthly settlement, easy to accomplish and more prompt, more accurate and more convenient than before firstly. Then, dynamic cost information can be obtained by managers authorized via the PIMIS. Moreover, there are some analysis and forecasting models here to aid project manager do some cost decision-makings using of data collected and processed by the PIMIS.

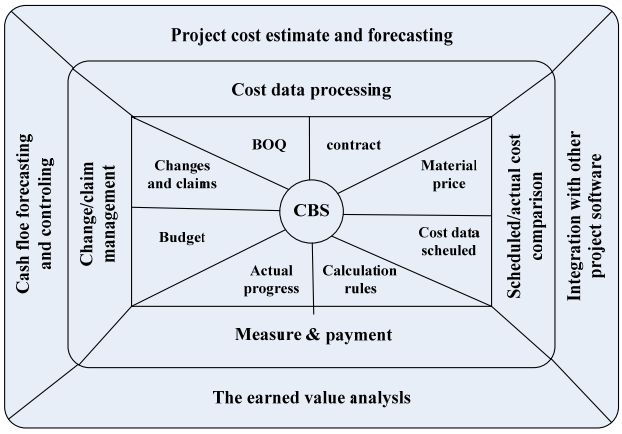

Figure 1. The function model of the PIMIS

To ensure functions talked above and to promote the efficiency of project cost control and management, the Browser/Server model (B/S mode) is selected to construct the framework of the PIMIS, and some working procedures of A/E/C project cost control are identified and authorized by the development team, including:

1) Measure & payment procedure;
2) Change management procedure;
3) Claim procedure;
4) Material/facility purchase and settlement procedure;
5) Users authorizing procedure;
6) Documents management procedure.

In the PIMIS, project information concerns the project cost control, including cost data, material price data, and user data, etc, is stored on the server and a standard Web

browser, such as IE, Maxthon, is used as a gateway to exchange those data, eliminating geographic and boundary hardware platform differences. The framework of the PIMIS is shown in **Figure 2.**

E. Decision supporting models and system

In some decision situations of the project construction, quantitative models embedded in a Decision Supporting System (DSS) can help managers make better decisions [22]. Given the growing complexity and uncertainty in many decision situations in A/E/C project management, helping project managers use quantitative models to support their decision-making and planning is an important research topic. With the development of the PIMIS, and combined some application software, a DSS module related to the project cost control is developed to help project managers improving project management performance. Excel from Microsoft and Grandsoft GBQ 4.0 (http://www.grandsoft.com.cn/) is used to construct quantitative models and prediction models which can be provide a simplified representation of a situation that is understandable to a decision maker, and data which is concerned with project cost control and distilled from the PIMIS and A/E/C industry is put into the models to simulate the decision situation. Models of the DSS module including: the Earned Value management model and the Logistic Curve prediction model. The following sections describe the mathematical models and the detailed algorithms of each model.

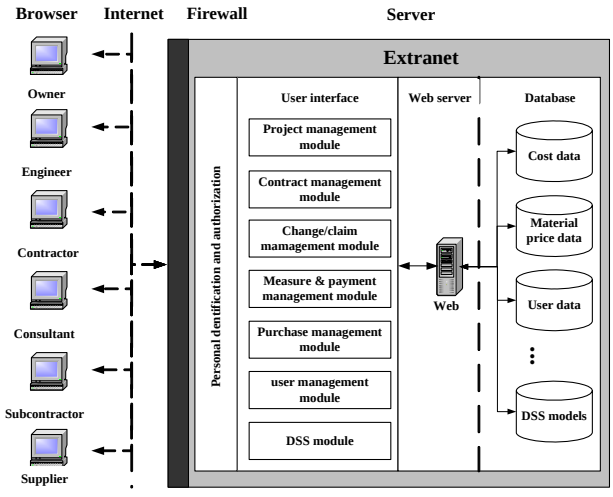

Figure 4. The framework of the PIMIS

1) The Earned Value Management model. The Earned Value Management (EVM) is a well-known management system used to integrate cost, schedule and technical performance, and to measure and communicate the real physical status of a project. It allows the calculation of cost and schedule variances and performance indices and forecasts of project cost and schedule duration to provide early indications of project performance for the purpose of highlighting the need for eventual corrective action, and is proved effective and reliable [23-24].

Based on the Planned Value (PV), the Earned Value (EV) and the Actual Cost (AC) obtained from the PIMIS, four performance indices, the Schedule Variance (SV), the Cost Variance (CV), the Schedule Performance Index (SPI) and the Cost Performance Index (CPI), can be calculated by the EVM model to estimate the project performance, and one prediction index, the Estimate At Completion (EAC), can be simulated to forecast a project's final cost and duration. Data input and output of the EVM module is designed as following:

Inputs:

- Detailed planned cost data and schedule data arranged by the CBS of the project;
- Budget of the project;
- Actual progress and cost data obtained from the measure & payment module;
- Total cost of the project planned;

Outputs:

- SV or SPI;
- CV or CPI;
- EAC (duration and cost of the project predicted).

Then, based on the Outputs of the EVM model which is used to measure the real physical progress and cost control performance of the project, project decision makers in A/E/C project are able to carry out some corrective actions to improve the final performance of the project management.

2) The logistic curve prediction model. The Logistic curve created by a Belgium mathematician named P.F.Verhulst in 1938 is one of the more widely used curves in financial and management prediction. It is an S-shaped curve, symmetric about its point of inflection and the value of the curve finally reached some limit [25-26]. There is some feasibility to forecast the final project cost by the Logistic curve forecasting model for its characteristic which relatively matches the status of project cost increasing.

The Logistic curve forecasting model is shown as following:

$$Y_t = \frac{K}{1 + e^{a - rt}} \quad (1)$$

k, a and r are coefficients

Based the time series of project monthly expenditure originated from the PIMIS, the Logistic curve forecasting model can be transformed into a linear regression model and the extremum parameter **K** can be estimated by the 3-point method [27]. After the establishment of the Logistic curve forecasting model by utilizing the Excel, the final cost of the project, as well as the cash flow during the process of project construction, can be predicted by project managers. Data input and output of the Logistic curve forecasting model is designed as following:

Inputs:

- Time series of project monthly expenditure;

Outputs:

- Total cost of the project forecasted;
- Cash flow forecasted。

F. Technical index of the PIMIS

The main technical index of the PIMIS is shown in **Table 1.**

III. IMPLEMENTATION

TABLE I.
THE MAIN TECHNICAL INDEX OF THE PIMIS

Index	content
Name	PIMIS
Framework	B/S mode
Interface	Browser
Database	Microsoft SQL server 2000
Environment	Microsoft Visual Studio. Net 2003
Development language	C#
Operating system	Windows XP
Network	Extranet
User	Distributed
Server	IBM eServer system X
Development mode	Rapid prototype method

3 experimental application cases are studied by the development team. Prototype and modified prototype of the PIMIS are applied in 3 A/E/C projects and development team members are joining in the project organization as system administrator and training person to conduct the verifying test. 3 A/E/C projects include:

Case 1: A Library in China, total cost of ￥140 mil, and duration of 24 months.

Case 2: A new urban districts construction project, total cost of about ￥1,000 mil, and duration of 48 months.

Case 3: An office building, total cost of about ￥120 mil, and duration of 24 months.

How can the project organization match the use of the PIMIS? What department should we appoint to responsible for it? The PIMIS needs a skilled, real-time team to hold and process all key information relevant to the analysis and control of the project cost. Thus, an information management team should be established to fit this needs. Positions of information management teams in project organizations are different in 3 different application cases, and its Organization modes are also non-unique. The 3 different organization modes are shown as following.

A. The PMO mode

The PMO mode means that the information management team functions as a tactical project management office, which is an organizational entity established to assist project managers, teams and various management levels on strategic and tactical matters and functional entities throughout the organization in implementing PM principles, practices, methodologies, tools and techniques, and was utilized in **Case 1**. The organization structure of the PMO mode is shown in **Figure 3**.

B. The "landscape orientation" mode.

The "landscape orientation" mode (The "L-O" mode) means that the information management team functions as an organizational function entity of the owner, such as planning department, procurement department, etc. The "landscape orientation" mode was utilized in **Case 2**, and its organization structure is shown in **Figure 4**.

C. The "virtual" mode.

As organizations expand their operations geographically and engage in inter-organizational alliances, the formation of work teams with physically distributed, culturally and organizationally diverse members is going to be increasingly prevalent [28]. The "Virtual" mode means that the information management team functions as a virtual organization which is exploiting the diverse capabilities of individuals by teaming up employees from different organization and culture enabled by advances in network technologies. Individuals comes from all participators of the project are teamed up as an information management team by the project manager to collect project cost data and to operate the PIMIS. The "Virtual" mode was utilized in **Case 3**, and its organization structure is shown in **Figure 5**.

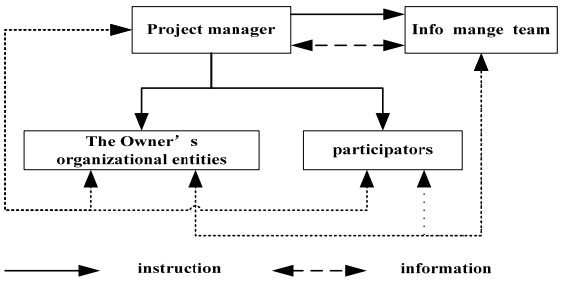

Figure 5. The PMO mode

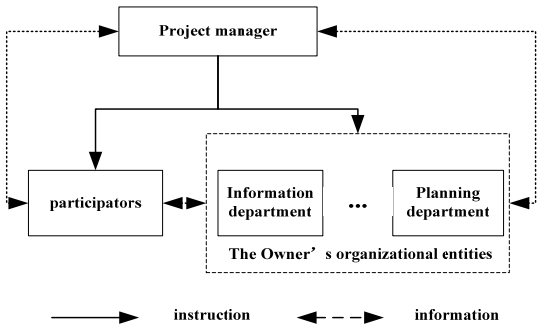

Figure 6. The "L-O" mode

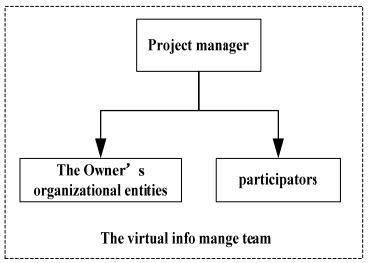

Figure 7. The "virtual" mode

D. Rules and Regulations

After the establishment of the information management teams talked above, some rules and regulations in project organization to support the application of the PIMIS should be presented. Rules and

regulations used in the three application cases which were made by the information management team and authorized by the project manager are unique, and generally include:

1) Communicating and coordination system;
2) Information collecting and transforming system;
3) Information security system;
4) Training system.

E. Workflow

Working procedures in 3 application cases are not unique. To fit the needs of case 2 and case 3, some secondary developments are carried out, and workflows in the PIMIS which are not match the requirement of the project managers in case 2 and case 3 are adjusted by the development team. Meanwhile, some workflows currently existing in 3 application cases are optimized and reengineered by the information management team to meet goals of dynamic cost control and systematic cost decision, such as the measure & payment process between participators of the project. Details of these optimizations and reengineering are shown in literature [17].

F. Application performance

To estimate the application performance of the PIMIS, an empirical interview survey targeting the project managers of the studied 3 cases was carried out by the development team. During the interview, the project managers were first required to answer some general questions about the PIMIS. Then, the interview was divided into two parts: Part Ⅰ— application performance; part Ⅱ— advices for future improvement.

In Part Ⅰ, the project manager was asked to evaluate the performance of the application of the PIMIS empirically. The results indicate that the application performance of the PIMIS is mainly including:

1) Processing efficiency promotion of project cost data;
2) Coordination improvement among participators;
3) Standardization and reutilization of the project cost controlling workflows;
4) Dynamic and reasonable project cost decision-making;
5) Reduction of contract disputes;
6) Team knowledge increasing.

As for part Ⅱ, the project manager was required to give some advices to the future improvement of the PIMIS. Advices presented by the project managers were based on the difference of the existing system function and the needs for project management practice in the A/E/C industry. The results indicate that advices for future improvement of the PIMIS are mainly including:

1) More simple and more applicable;
2) Integrated with other factors such as schedule, quality, etc;
3) Strengthening the DSS module;
4) Improve the reliability and security;
5) More training before application.

IV. Discussion

It is intelligent for us to utilize the web-based PMIS, such as the PIMIS, to improve the performance of the construction project. It provides an information exchange platform which transformed the communicating modes between organizations participators from point-to-point to virtual organization environment, and can be improve coordination and collaboration between organizations participating which is led to better communication practices, and can improve the project management performance, including project cost and schedule reductions, team productivity promotion and project stakeholder success, etc.

While the potential benefits of the PIMIS are beyond doubt, organizational, institutional and educational barriers militate against realizing these. It is not a technical problem but a management problem to establish an information management system. Besides hardware and software, organization and education are also considered as critical successful factors of the implementation of the PIMIS [29]. The utilization of the PIMIS is a task for the entire project management system, including organizations, systems, workflow, education and even management philosophy. Thus, some preparation such as suitable organization, appropriate systems, standard workflow, etc, must be constructed, and personal training must be put forward to participators of the project before application of the PIMIS.

In the 3 cases studied, all 3 organization mode could meet the requirement of the PIMIS, but there are some differences among them. In the “PMO” mode, the information managing team was able to fit the needs of operating the PIMIS and assisting the cost decision-making. But excessive disturbances originated from the information managing team which is considered as an informal PMO of the project participators had broke the balance of the project organization system. In the “landscape orientation” mode, the information managing team was considered as a regular function entity of the project organization. Meanwhile, data collecting and processing efficiencies has reduced by the extra organizational rampart come from the join-in of a new information managing department. There was neither organization unbalance nor efficiencies reduction in the “virtual” mode which has been considered as the development direction of the construction project organization [30] while it needs more personal training of all participators than the two modes talked above.

Considered the development of A/E/C industry and IT in China, there are still some important barriers existing which need to be addressed in order to increase public confidence in adopting the-PIMIS -liking web-based PMIS in construction projects, such as system reliability and security, difficulties in quantifying costs and benefits, prejudice of project senior managers, etc.

V. Conclusion

The construction industry is under pressure to reduce project delivery times and costs despite increase uncertainties, ambiguities, and complexities that surround today’s projects [31]. Web-based PMIS may well hold

the key to success on this front. The author tries to develop and implement a web-based Project Cost Integrated Management System (PIMIS) in China. The targets, the Cost Breakdown Structure (CBS) and its code system, the functional planning, the framework and the technical index of the PIMIS were presented firstly. Then, experimental implement of this developed system were put forward in 3 A/E/C project. Finally, an empirical interview survey targeting the project managers of the studied 3 cases was carried to estimate its implement performance.

This research found that the acceptance and implement of the PIMIS can significantly improve the performance of the project cost control. In addition, a finally and major conclusion arising from this research is that successful implementation of the PIMIS, in terms of leading to better outcomes for the A/E/C project, Coordination improvement among participators and Reduction of contract disputes, etc, is not simply a matter of introducing the system into an project organization. Instead, it must be associated with overall project management approaches such as a suitable organization mode, an appropriate system, the standard workflows, adequate personal trainings and even a coordinated project management philosophy.

ACKNOWLEDGMENT

This work was financially supported by the soft science research Foundation of The Ministry of Housing and Urban-Rural Development, P.R.C (2011-R3-15) and Zhejiang Sci-Tech University Foundation (0914851).

REFERENCES

[1] Nitithamyong P, Skibniewski. M, Web-based construction project management systems: how to make them successful? Automation in construction, 13(2004), pp. 491-506

[2] Bruce Tenkins, Bricsnet will be out in full force for realcomm 2001, http://www.bricsnet.com/, 2001-02-15

[3] W.E. Back, K.A. Moreau, Cost and schedule impacts of information management on EPC process, Journal of management in engineering, 16(2), 2000, pp. 59-70

[4] R.E. Johnson, M.J. Clayton, The impact of information technology in design and construction: the owner's perspective, Automation in construction, 8(1), 1998, pp. 3-14

[5] P.M. Goodrum, C.T. Haas, partial factor productivity and equipment technology change at activity level in U.S. construction industry, Journal of construction engineering and management, 128(6), 2002, pp. 463-472

[6] YANG Li-ren, James T.O'Connor and CHEN Jieh-haur, Assessment of automation and integration technology's impacts on project stakeholder success, Automation in construction, 16(2007), pp. 725-733

[7] E.M. Rojas, A.D. Songer, web-centric systems: a new paradigm for collaboration engineering, Journal of management in engineering, 15(01), ASCE, New York, USA, 1999, pp. 39-45

[8] Gordon Kelly, Ghassan Aouad, Yacine Rezgui and Jonathan Crofts. Information systems developments in the UK construction industry [J]. Automation in construction, 06(1997), pp. 17-22

[9] Bakens W, International trends in building and construction research, Journal of construction engineering and management, 123(02), 1997, pp. 102-104

[10] A. Jaafari, K. Manivong, Towards a smart project management information system, International journal of project management, 16(04), 1998, pp. 249-265

[11] M.C. Hurtado, New survey points to spending growth, Engineering news record, McGraw-Hill, New York, USA 264(21), 2003, pp.21

[12] D. Walker, M. Betts, Information technology foresight: the future application of the world wide web in construction, proceedings of the CIB W78, (http://itc.scix.net/data/works/att/w78-1997-399.content.pdf), IT for construction process reengineering, Cairns, Australia, 1997.07, pp. 399-407

[13] Nitithamyong P, Skibniewski. M, Success/failure factor and performance measures of web-based construction project management systems: professionals' viewpoint, Journal of construction engineering and management, 132(01), ASCE, New York, USA, 2006, pp. 80-87

[14] Skibniewski. M, Abduh. M, Web-based Project Management for Construction: Search for Utility Assessment Tools, Proceedings of International Conference on Construction Information Technology 2000 (INCITE 2000), Hong Kong Polytechnic University, Jan. 2000.01

[15] I. Ahmad, S. Azhar, and SM. Ahmed, Web-based Construction Project Management: Scope, Potential and Trends, Proceedings of CIB-W65/W55 International Conference "Construction Innovation and Global Competitiveness", Cincinnati, Ohio, 2002.09, pp. 599-610

[16] ZHOU Qi, R. Krawczyk, A survey of the Internet application in the A/E/C industry, Journal of Southeast University(English edition), 19(03), 2003, pp. 225-230

[17] LIU Yong, WANG Jian-ping, The optimization design of measure & payment process in construction by using the business process reengineering technology, Proceedings of 2007 international conference on management science & engineering(14th), Harbin, China, 2007.08, IEEE, Piscataway, NJ, USA, pp. 2344-2350

[18] Project management Institute, A guide to the project management body of knowledge, third edition, 2004, Four campus boulevard, Newtown square, PA19073-3299, USA, pp. 112

[19] CSI/CSC（Construction Specification Institute/construction Specification Canada）, MasterFormat™- Numbers & Titles, 2004 Edition, http://www.csinet.org/s-csi/docs/9400/9361.pdf, 2003.12

[20] David Morgan, Deploying extranets? Network security, 12(2004), pp. 12-14

[21] W. J. O' Brien, Implementation issues in project web-sites: a practitioner's viewpoint, Journal of management in engineering, 16(03), ASCE, New York, USA, 2000, pp. 34-39

[22] D. J. Power, R. Sharda, model-drive decision support systems: concepts and research directions, Decision support systems, 43(2007), 1044-1061

[23] S. Vandevoorde, M. Vanhoucke, A comparison of different project duration forecasting methods using earned value metrics, International journal of project management, 24(2006), pp. 289-302

[24] W. Lipke, O. Zwikael, K. Henderson and F. Anbari, Prediction of project outcome, the application of statistical methods to earned value management and earned schedule performance indexes, International journal of project management (2008), doi:10.1016/j.ijproman. 2008.02.009, pp. 289-302

[25] N. Meade, T. Islam, Forecasting with growth curves: an empirical comparison, International journal of forecasting, 11(1995), pp. 199-215
[26] HUANG Ru-bao, LI Bin, Logistic model and positive research for investment in fixed assets, Journal of Tongji University (nature science), 33(02), 2005, pp.251-254
[27] YIN Zuo-yun, Study on the fitting methods of logistic curve, Application of statistics and management, 21(01), 2002, pp. 41-46
[28] Sze-Sze Wong, R. M. Burton, Virtual teams: what are their characteristics, and impact on team performance? Computational & Mathematical organization theory, 06(04), 2000, Springer Netherlands, pp.339-360
[29] DAI Bin, Analysis of concept and implementation of project information portal, Journal of Tongji University (Nature science), 33(07), 2005, pp. 990-994
[30] Liz Lee-Kelley, Tim Sankey, Global virtual teams for value creation and project success: A case study, International journal of project management, 26(2008), pp. 51-62
[31] A. Jaafari, concurrent construction and life cycle project management, Journal of construction engineering and management, 12(1997), pp. 427-436

Yong LIU, Zhejiang Province, China. Birthdate: Nov. 5, 1980. is Management Science and Engineering Ph.D., graduated from School of Architecture and Civil Engineering, China University of Mining and Technology, 2009. His major fields were concerned with project management information system in A/E/C industry, and project integrated management.
He is a senior lecturer of School of Architecture and Civil Engineering, Zhejiang Sci-Tech University.

Chunlai CHEN, Zhejiang Province, China. Birthdate: May, 1977. is Civil Engineering Master D., graduated from College of Civil Engineering and Architecture, Zhejiang University, 2002. His major fields were concerned with project management in construction.
He is a associate professor of Faculty of Engineering, Zhejiang University City College.