KEY SUCCESS/FAILURE FACTORS AND THEIR IMPACTS ON SYSTEM PERFORMANCE OF WEB-BASED PROJECT MANAGEMENT SYSTEMS IN CONSTRUCTION

SUBMITTED: May 2006
REVISED: September 2006
PUBLISHED: January 2007 at http://itcon.org/2007/3/
EDITOR: B-C Björk

Pollaphat Nitithamyong, Lecturer
School of the Built and Natural Environment, Glasgow Caledonian University
email: p.nitithamyong@gcal.ac.uk

Mirosław J. Skibniewski, A. James Clark Endowed Chair Professor of Project Management
Department of Civil and Environmental Engineering, University of Maryland
email: mirek@umd.edu

SUMMARY: *The effectiveness and usefulness of Web-based project management system (WPMS) applications in construction projects are still not yet as high as initially expected, mainly because many important factors that can greatly impact system performance are left unknown or misunderstood by most practitioners. Understanding which factors are critical for system success is fundamental for improved WPMS implementations. To this end, an empirical study was conducted to capture the important factors for successful WPMS implementations and their cause-effect relationships with system performance. This paper discusses results from a survey of 82 different construction projects managed with the use of 14 different commercial WPMSs. The results reveal that certain characteristics of the project, the project team, the service provider, and the system have significant correlations with one or more WPMS performance perspectives (strategic, time, cost, quality, risk, and communication), while eleven variables prove to be critical to the success of WPMS implementations. The paper also addresses how practitioners judge the overall performance of WPMSs and reports on the relationships found between system success and project success. Findings presented in this paper can lead to more productive and successful ways of implementing WPMSs and, therefore, benefit companies that are currently using or planning to exploit such systems*

KEYWORDS: *information technology, internet, project management, success factors, web-based project management systems, web.*

1. INTRODUCTION

Web-based project management systems (WPMSs) are one of the latest Internet-based applications in the construction industry. Although the current rate of WPMS implementations is still lower than the projected trend, the systems hold a great promise and are expected to replace traditional project management methods (Becerik 2004; Zou and Roslan 2005). Several reasons supporting this promise include increased competitive pressures, expectations of revenue growth, ability to compete globally, and the desire to reengineer the business to respond to market challenges (Nitithamyong and Skibniewski 2006). Currently, the most popular systems used by A/E/C firms are developed and offered to clients by Application Service Providers (ASPs) who provide all the computing power, storage, security, backup, disaster recovery and network infrastructure needed, as well as the staff to manage the platform. Such systems, hereafter referred to as "project management systems–application service providers (PM-ASPs)," are practical for a small or mid-sized construction firm because the systems require minimal technical, financial, and human resources to develop and operate. Interesting readers are referred to Nitithamyong and Skibniewski (2004), Becerik (2004), and Zou and Roslan (2005) for more detailed information on various types, brands, features, potential benefits and impediments, and future trends of PM-ASPs.

Despite the great promise of PM-ASPs for the construction industry, the current usefulness of most PM-ASPs is still limited, and, all too often, instead of "dramatic improvement," many companies implementing PM-ASPs ended up with a mess. The verity is that the PM-ASP concept is relatively simple, but understanding how it interacts with the complex business processes of the construction industry remains extremely challenging for most practitioners. According to O'Brien (2000), one major reason of unsuccessful PM-ASP implementations is because many factors that can significantly impact the effectiveness of using PM-ASPs in construction projects are still not clearly defined, and factors such as sociological and personnel issues have not gained sufficient consideration even though these factors can greatly impact performance of the systems. Practitioners must not only consider factors related to the technology, but also give equal prominence to other factors associated with processes and individuals who are involved in the technology in order to successfully employ PM-ASPs and achieve business benefits (Alshawi and Ingirige 2003; Björk 2002).

While there have been some attempts conducted to suggest important organizational and managerial factors that can cultivate the successful development and usage of PM-ASPs, the majority of them are still based exclusively on either a few practitioners' perceptions on selected systems/projects or subjective indication provided by success stories published in the trade press, so their consistency and reliability remain questionable. The following questions still need to be addressed: 1) what are the common key success/failure factors of PM-ASP implementations across different systems, projects, and organizations; 2) how these key factors affect the different performance perspectives of PM-ASPs; 3) how industry practitioners evaluate the success of PM-ASPs; and 4) how PM-ASP implementation success affects construction project success?

2. CONCEPTUAL PM-ASP SUCCESS/FAILURE MODEL DEVELOPMENT

To provide answers to the aforementioned questions, the study began with a comprehensive review of literatures in relevant areas (i.e., construction IT, IT success/failure appraisals, and management of information systems), followed by semi-structured interviews with a number of industry practitioners from 18 A/E/C firms in the United States with hands-on PM-ASP experience. Based on the knowledge and information acquired from the literature review and the interviews, the conceptual PM-ASP success/failure model was formulated. The model proposed that 42 factors, categorized into four different groups (characteristics of the project, the project team, the service provider, and the system), could potentially affect the performance of PM-ASP implementation in a construction project. It also incorporated 40 measurement criteria that could be used to assess PM-ASP performance in six different perspectives: 1) strategic improvement, 2) time improvement, 3) cost improvement, 4) quality improvement, 5) risk improvement, and 6) communication improvement (Nitithamyong 2003).

The conceptual model was further scrutinized and verified by 39 professionals working in the United States and with international organizations who possess eminent experience in PM-ASP applications. The results of the model verification supported that all 42 factors would influence PM-ASP performance, but only 36 measures were revealed as appropriate PM-ASP performance measures (Nitithamyong and Skibniewski 2006). The 42 potential PM-ASP success/failure factors and 36 performance measures are listed in Tables 1 and 2, respectively. These factors and measures formed the basis for developing the questionnaire to collect data from construction projects implementing PM-ASPs in order to test the model. The questionnaire organization and the data collection process are explained in the next section. A complete description of the factors and measures as well as a sample questionnaire can be found in Nitithamyong (2003).

3. SURVEY ON PM-ASP IMPLEMENTATIONS

3.1 Questionnaire Organization

The questionnaire was separated into three sections. Respondents were asked to answer all the questions on behalf of their project's team members using data from the most recent construction project managed with the use of PM-ASP in which they had participated. Data collected from the most recent project would minimize potential errors in a respondent's memory because the information would still be fresh and the respondent would not be able to select a biased project.

Section 1 consisted of 11 questions to collect general information about respondents. Section 2 consisted of 38 questions asking respondents to provide information about characteristics of their project, project team, PM-ASP's provider, and system. The questions objectively inquired about the success/failure factors identified in the research model that may correlate to PM-ASP implementation success/failure measures. For example, respondents were asked to provide the number of project team members having access to PM-ASP; they were not asked whether more users having access to PM-ASP would have made its implementation more successful. Respondents were also asked to rate the cost and time performance of their project according to a nine-point Likert scale (1 = behind schedule/overrun budget by > 10% and 9 = ahead schedule/underrun budget by > 10%)

and the extent to which the project conformed to the technical specifications, the level of health and safety, and the level of owner satisfaction according to a seven-point Likert scale (1 = unsatisfactory and 7 = better than expected).

Section 3 included six questions about the effectiveness and benefits of PM-ASP. The first question asked respondents to assess the performance of PM-ASP used in their project with regard to six different improvement perspectives as identified in the research model: strategic, time, cost, quality, risk, and communication. Thirty six measures associated with the six perspectives were listed with their positive statements, and respondents were requested to rate the degree to which the performance of each measure was actually achieved using a seven-point Likert scale (1 = strongly disagree and 7 = strongly agree). The second question asked respondents to rate the overall performance of their PM-ASP using a seven-point Likert scale (1 = extremely fail and 7 = extremely success). The subsequent three questions were open-ended questions asking respondents about the most important benefits, barriers, and general opinions about using their PM-ASP, respectively. The last question asked respondents whether they were willing to participate in the research project as a case study. Respondents who answered "yes" to this question were contacted for further information.

TABLE 1: Potential PM-ASP Success/Failure Factors (Nitithamyong and Skibniewski 2006)

Group	Potential factors
Project characteristics	Project location Type of owner Type of contract Type of project Project size Project cost Project duration Complexity related to design and engineering Complexity related to construction tasks Starting stage of PM-ASP development
Project team characteristics	Party deciding for the use of PM-ASP Party paying for the use of PM-ASP Internet access availability Type of Internet service/access Presence of champions Prior experience with PM-ASPs Alignment of PM-ASP objectives to project objectives Users involvement during implementation planning Level of support from top management Team attitudes toward PM-ASPs Team attitudes toward IT Adequacy of training Adequacy of resources Ability of project managers Computer experience Frequency of PM-ASP's features usage
Service provider characteristics	Contact facilities Promptness of responses Attitudes of staff Technical competency of staff Knowledge of construction business
System characteristics	Type of hosting options Number of users Frequency of software/version update Ease of use Output quality System reliability Data quality and reliability Data security Integration among PM-ASP features Integration with external software program Integration with project team's internal systems

TABLE 2: PM-ASP Performance Measures (Nitithamyong and Skibniewski 2006)

Performance perspective	Potential measures
Strategic improvement	Facilitating forecasting and control
	Improving customer/supplier relations
	Improving project team's computer literacy
	Enhancing organization's image
	Increasing capability for global cooperation
	Helping in attracting more sophisticated clients
	Establishing and supporting project alliance
	Enhancing competitive advantage of team
Time improvement	Reducing number of requests for interpretation (RFIs)
	Reducing response time to answer queries
	Facilitating document transfer and handling
	Enabling immediate report & feedback
	Helping in searching for files & documents
	Reducing bottlenecks in communications
	Reducing number of face-to-face meetings
	Helping in preparing correspondence
	Enhancing organization of updated records
	Enabling streamlining of processes
	Helping in tracking project activities
Cost improvement	Enabling realizing cost savings
	Reducing amount of paperwork
	Reducing number of faxes
	Reducing number of postage and shipping
	Reducing travel expense
	Reducing telephone usage and expense
	Facilitating control of cash flow
Quality improvement	Easily identifying errors and inconsistencies
	Improving quality of documents
	Reducing rework
	Reducing number of design errors
Risk improvement	Helping in conforming with contracts
	Reducing number of claims
Communication improvement	Reducing barriers in communications
	Enhancing coordination among team members
	Improving decision making of project team
	Improving integration with other business functions

3.2 Data Collection

The targeted respondents were construction management personnel who had practical experience with the use of PM-ASPs in either completed or ongoing construction projects. To gain access to all targeted respondents, several companies offering PM-ASPs for the construction industry were contacted and invited to participate in the study. Finally, thirteen service providers participated in the study, and nearly all of them opted to circulate the questionnaire to users themselves because of the confidentiality issues. A number of organizations also helped in publicizing or circulating the questionnaire, including the Associated General Contractors (AGC), the Association for the Advancement of Cost Engineering (AACE) International, the Project Management Institute (PMI), the ExtranetNews.com, the ConstructionWeblinks.com, the LaiserinLetter.com, the UpFront.eZine.com, etc. The questionnaire was also advertised in several newsgroups related to construction, such as CNBR-L, PM-Talk, and ProC-E-Com. It should be noted that there was a possibility for bias in sampling because the participating service providers could choose to only reveal clients/projects that had positive experiences with their products or services. Yet, there are two countervailing reasons that helped to protect the randomness of the sample. First, most service providers wish to get honest feedback from their customers in order to improve their products; therefore, they would circulate the questionnaire to all clients and take good news with the bad. Secondly, the shear diversity and near random quality of the composition of every construction project protects the sample from bias.

The survey was conducted between 15th July and 30th September 2003, and 114 questionnaires were returned. Of this number, 13 were received in paper-based versions and 101 were received online. Twenty-three respondents did not have any experience with the use of PM-ASPs and could not complete the questionnaire. A total of 91 respondents indicated that they had experience with PM-ASP applications in construction projects and completed the questionnaire. Of the respondents who completed the questionnaire, nine completed the questionnaire incorrectly and 82 provided valid responses, representing a total of 82 construction projects that were managed utilizing 14 different PM-ASPs. The 82 valid responses were from general contractors (36.59%), architecture firms (18.29%), engineering firms (14.63%), construction consulting firms (10.98%), owners/owner representatives (8.54%), engineering contractors (7.32%), sub-contractors (2.44%), and suppliers (1.22%). The average number of projects utilizing PM-ASPs in which the respondents had experience was approximately four projects. The majority of the respondents (58.5%) had experience with PM-ASP implementation in one to three projects, and approximately 26% of them indicated more than five projects utilizing PM-ASPs. As shown in Table 3, approximately 62% of the respondents held a position at the project management level, which was excellent for the study since the targeted respondents were practitioners who had used PM-ASPs for project management and could therefore answer all questions on behalf of their team members.

The total dollar volume of the surveyed projects was approximately US$ 7.5 billion, with the smallest project valued at US$0.1 million and the largest valued at US$1.2 billion. Table 4 summarizes several important characteristics of the surveyed projects, whereas Fig. 1 illustrates the distribution of PM-ASPs utilized. The wide variety of project types, values, and PM-ASPs utilized speaks well to the diversity of the sample.

TABLE 3: Classification of Respondents by Roles and Proficiencies

Group	Positions/titles	Owner	Architecture and engineering firms	Contractor	Others	Total
Top management	President, vice president, senior vice president, executive vice president, CEO	0.0%	3.4%	13.9%	9.1%	8.5%
Middle management	Managers, directors, chief engineers, consultants	50.0%	13.8%	11.1%	18.2%	15.9%
Project management	Project managers, project leaders, project administrators, construction manager	50.0%	65.5%	63.9%	54.5%	62.2%
Supporting staff	Resident engineers, estimators, architects, CAD staff	0.0%	17.2%	11.1%	18.2%	13.4%
Total		100%	100%	100%	100%	100%

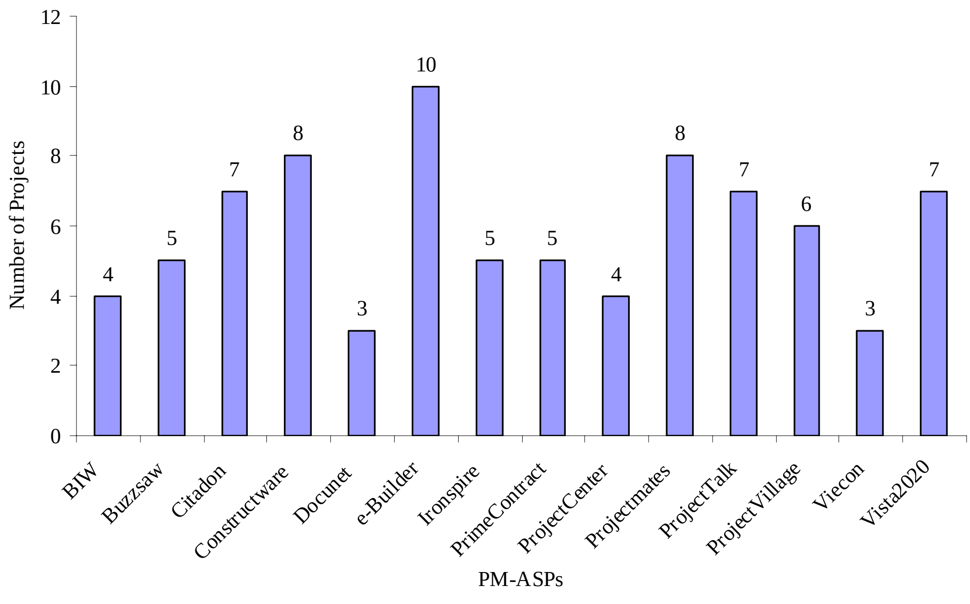

FIG. 1: PM-ASPs Employed in the Surveyed Projects

TABLE 4: Characteristics of the Surveyed Projects

Project characteristics	Number of projects	Percentage
Project location		
U.S.	62	75.61
International	20	24.39
Type of owner		
Public	29	35.37
Private	53	64.63
Type of contract		
Design-build	20	24.39
Design-bid-build	22	26.83
Construction management	10	12.20
Guaranteed maximum price	25	30.49
Others	5	6.10
Type of project		
Residential	18	21.95
Commercial	31	37.80
Heavy engineering	16	19.51
Industrial	17	20.73
Project value		
<$1 million	3	3.66
$1-$2 million	4	4.88
$2-$5 million	6	7.32
$5-$10 million	15	18.29
$10-$20 million	8	9.76
$20-$50 million	12	14.63
$50-$100 million	15	18.29
>$100 million	19	23.17
Project status		
Completed	38	46.34
Ongoing	44	53.66

Note: A construction project was considered to be "U.S." only if the respondent's company location and the project location were both in the U.S. Otherwise, it was considered "international."

4. DATA ANALYSES AND RESULTS

4.1 Analysis of PM-ASP Performance Measures

The responses received on the performance of PM-ASPs were first analyzed using two analytical methods, factor analysis and mean. Factor analysis was used to reduce the 36 performance measures into a smaller number of "underlying" measures, thereby facilitating further analyses of the data. It also helped to confirm the performance perspectives previously identified in the model and to check whether the measures were grouped appropriately. The mean was used to investigate the respondents' perceptions on the current usefulness and benefits of PM-ASPs.

Principal components analysis with a Varimax rotation was performed through the SPSS program on the 36 measures. The SPSS program was selected because it provides a comprehensive range of statistical programs suitable for manipulating the work of analysis. The results obtained from factor analysis confirmed that the 36 measures assessed PM-ASP performance from six different perspectives, which had eigenvalues greater than one. These six perspectives explained 77.51% of the variance in responses. However, the interpretability of the extracted perspectives was rendered problematic because of three complex measures, which loaded on more than one perspective. The three measures were "enabling streamlining of processes," "enabling realizing cost savings," and "facilitating control of cash flow." Due to the problematic nature of these three measures, they were removed from further analyses, and a subsequent run was performed on the remaining 33 measures. The results of the second run still suggested six perspectives for evaluating PM-ASP performance. These six extracted perspectives altogether explained 78.89% of the variance in responses, and each measure loaded heavily on only one perspective. A higher cumulative percentage of the explained variance indicated that the second run was superior to the first. All measures had factor loadings greater than 0.5, indicating that the extracted perspectives and the measures associated with them were consistent and reliable. Cronbach's alpha values for the six perspectives ranged from 0.855 to 0.947, which were above the lower acceptable limits of 0.50-0.60 suggested by Kaplan and Saccuzzo (1993), indicating that the perspectives had adequate external consistency.

Table 5 shows the 33 measures that were reorganized into appropriate perspectives according to the factor analysis results. The table also exhibits factor loadings of the measures, the Cronbach's alpha values, and the percentage of the explained variance of each perspective. Six perspective scores for each surveyed project were then calculated and used for subsequent analyses as indicators of PM-ASP performance. A perspective score is an average score of performance measures associated with the perspective.

As shown in the fourth column of Table 5, the mean responses received on the 33 performance measures range from 3.5 for "reducing number of design errors," to 5.35 for "enhancing organization of updated records." The top five measures having the highest average scores are: 1) enhancing organization of updated records; 2) facilitating document transfer and handling; 3) enhancing coordination among team members; 4) helping in searching for files and documents; and 5) enabling immediate report and feedback. Obviously, the respondents perceive that the current usefulness of PM-ASPs is limited to the strategic, time, and communication improvements to their projects. For the cost improvement, PM-ASPs only help in reducing the number of faxes and shipping. The amount of paperwork, telephone usage, face-to-face meetings, and travel expenses are still not substantially reduced when PM-ASPs are implemented. In addition, the benefits of PM-ASPs with regard to the quality and risk improvements are still unsatisfied, indicating that many of the existing systems available on the market are not successfully producing these types of benefits. The mean value for all measures is 4.56, signifying that the performance of PM-ASPs, on average, is rated as moderately successful.

TABLE 5: Factor Analysis and Mean Results of PM-ASP Performance Measures

Performance perspective	Measure	Factor loading	Mean	SD
Strategic improvement	Enhancing organization of updated records	0.655	5.35	1.49
Cronbach's alpha = 0.9474	Helping in tracking project activities	0.777	5.07	1.79
Percentage of explained variance = 17.132	Enhancing organization's image	0.701	4.96	1.60
	Establishing and supporting project alliance	0.637	4.95	1.64
	Enhancing competitive advantage	0.601	4.92	1.48
	Improving project team's computer literacy	0.734	4.88	1.40
	Improving customer/supplier relations	0.608	4.61	1.61
	Increasing capability for global corporation	0.671	4.60	1.65
	Helping in attracting more sophisticated clients	0.790	4.35	1.80
	Improving integration with other business functions	0.719	4.28	1.65
Time improvement	Facilitating document transfer and handling	0.708	5.28	1.66
Cronbach's Alpha = 0.8830	Helping in searching for files and documents	0.539	5.18	1.54
Percentage of explained variance = 10.627	Enabling immediate report and feedback	0.715	5.09	1.58
	Reducing response time to answer queries	0.733	4.93	1.69
	Helping in preparing correspondence	0.513	4.42	1.75
Cost improvement	Reducing number of faxes	0.680	5.03	1.66
Cronbach's alpha = 0.9271	Reducing number of postage and shipping	0.728	5.02	1.60
Percentage of explained variance = 13.673	Reducing amount of paperwork	0.692	4.88	1.70
	Reducing telephone usage and expense	0.644	4.46	1.69
	Reducing travel expense	0.699	4.40	1.64
	Reducing number of face-to-face meetings	0.646	4.07	1.67
Quality improvement	Improving quality of document	0.853	4.28	1.65
Cronbach's alpha = 0.9153	Facilitating forecasting and control	0.516	4.10	1.63
Percentage of explained variance = 15.051	Easily identifying errors and inconsistencies	0.809	4.00	1.58
	Reducing rework	0.739	3.96	1.61
	Reducing number of design errors	0.695	3.50	1.66
Risk improvement	Improving decision making of project team	0.569	4.58	1.67
Cronbach's alpha = 0.8552	Helping in conforming with contracts	0.658	4.09	1.40
Percentage of explained variance = 9.502	Reducing number of claims	0.633	4.06	1.53
	Reducing number of RFIs	0.762	3.58	1.69
Communication improvement	Enhancing coordination among team members	0.648	5.21	1.57
Cronbach's alpha = 0.9184	Reducing bottlenecks in communications	0.675	4.99	1.64
Percentage of explained variance = 12.913	Reducing barriers in communications	0.685	4.97	1.62

4.2 Different Performance Perspectives vs. Overall Performance

To investigate how the respondents evaluated the overall success of their PM-ASPs, the relationships between the responses received on the overall PM-ASP performance and the six performance perspectives were examined by bivariate correlations. The most common measure of correlation is called Pearson's correlation, which reflects the degree of linear relationship between two variables. A correlation coefficient (r) varies between +1 and -1. When r=1, there is a perfect positive linear relationship between the variables, whereas r=0 means that there is no linear relationship between the variables. A positive value of r means that as one variable increases, the other increases as well. Conversely, there is a negative value of r if one variable decreases as the other increases.

Table 6 displays the Pearson's correlation coefficients of the six performance perspectives to the overall performance. At the 99% confidence level, every performance perspective has a strong and positively significant relationship with the overall performance. This finding suggests that practitioners do not focus on a single performance aspect to judge the overall success or failure of a PM-ASP; rather, all six performance perspectives identified in this study are considered. They may put more emphasis, however, on the time, strategic, communication, and cost performance, proving that the use of PM-ASPs is not only important for them in terms of short-term benefits but also for long-term benefits.

In addition, a stepwise regression modelling was performed using the overall score on PM-ASP performance as the dependent variable and the six performance perspectives' scores as the independent variables. The objective was to identify the performance perspectives that best statistically predict the success or failure of PM-ASP implementation. Table 7 shows the regression model which is the best statistical fit for the collected data. The strategic, time, and cost performance perspectives are revealed as the important predictors of a system's overall performance. All three perspectives have positive coefficients with the overall performance, demonstrating that an increase in each of these performance perspectives correlate to an increase in the overall PM-ASP performance. Interestingly, the strategic performance appears as the best predictor of the overall performance, as displayed by its highest standardized regression coefficient (b^*=0.360). This finding is consistent with the correlation results and confirms that practitioners weigh the importance of strategic performance relatively high when judging the overall PM-ASP performance.

TABLE 6: Correlations of Performance Perspectives and the Overall Performance

	Overall PM-ASP performance	
PM-ASP performance perspective	*r*	*p*-value (two-tailed)
Strategic improvement	**0.788	0.000
Time improvement	**0.792	0.000
Cost improvement	**0.773	0.000
Quality improvement	**0.629	0.000
Risk improvement	**0.625	0.000
Communication improvement	**0.776	0.000

*Note: Correlations noted with ** are significant at the 99% confidence level (two-tailed test)*

TABLE 7: Overall PM-ASP Performance Regression Model Results

Variable description	*β*	Std. error	*b**	*t*	*p*-value
Constant	-0.087	0.351	N/A	-0.248	0.805
Strategic improvement	0.407	0.112	0.360	3.639	0.000
Time improvement	0.363	0.114	0.343	3.191	0.002
Cost improvement	0.238	0.118	0.221	2.018	0.047

4.3 PM-ASP Success vs. Construction Project Success

The relationship between PM-ASP success and construction project success was examined by Pearson's correlation. Table 8 exhibits the Pearson's correlation coefficients of the overall PM-ASP performance to five measurement criteria of project success (cost performance, schedule performance, conformance to technical specifications, health and safety performance, and owner satisfaction).

At the 99% confidence level, there are strong and positively significant relationships between the overall PM-ASP success and the cost and time performance of a project, while there are no statistically significant correlations between the overall PM-ASP performance and the project success in terms of conforming to technical specifications, health and safety, and owner satisfaction. These correlations suggest that the current features of PM-ASPs help in increasing the time and cost performance of construction projects, which is consistent with the expectation since the most common major objective for using PM-ASPs is to save time and cost. Yet PM-ASP implementation success or failure does not have any significant impact on the potential for a project to conform to the user's expectations (quality of a project) and to have a high level of safety and client's satisfaction. Therefore, it would not be recommended to implement PM-ASPs just to impress clients since there is no guarantee that the level of a client's satisfaction will be higher even when a PM-ASP is considered successful. PM-ASP providers should also strive for developing new features or improving the existing features to facilitate the realization of benefits of using PM-ASPs besides time and cost performance.

TABLE 8: Correlations of PM-ASP Overall Performance and Project Success

	Overall PM-ASP performance	
Project success criteria	*r*	*p*-value (two-tailed)
Cost performance	**0.540	0.000
Schedule performance	**0.481	0.000
Conformance to technical specifications	0.083	0.549
Health and safety performance	0.223	0.090
Owner satisfaction	0.140	0.290

4.4 What Are the Common Factors Affecting PM-ASP Performance?

To depict how the 42 potential success/failure factors included in the research model independently affect PM-ASP performance, an individual variable analysis was performed through Pearson's correlation. This section discusses primary findings found in each of the four major characteristic categories (project, project team, service provider, and system).

4.4.1 Project Characteristics

Five factors display strong correlations with PM-ASP performance: owner type, project type, project cost, project duration, and starting stage of PM-ASP development. Project location, contract type, project size, and project complexity do not have any significant correlations with PM-ASP performance. Table 9 shows the Pearson's correlation coefficients of the project characteristics to the six PM-ASP performance perspectives.

At the 95% confidence level, private projects gain lower time and risk improvement benefits of using PM-ASPs than public projects. One explanation might be because public projects are usually larger, more complex, and involve more parties than private projects; therefore time and risk improvements when PM-ASPs are utilized can be easily realized. The results also indicate that the strategic and cost benefits are significantly reduced when the systems are applied in residential projects. This might be because residential projects are usually less complicated than the other project types (i.e., commercial building, heavy engineering, and industrial projects), and therefore it is possible that PM-ASPs are only helpful to simplify and expedite daily construction tasks rather than to enhance strategic purposes. Another reason might be that residential projects tend to have a smaller number of team members and less communication barriers than the other project types, so the communication cost savings such as fax and telephone expenses, resulting from the use of PM-ASPs may not be significant. Residential projects also have a significantly negative correlation with the frequency of PM-ASP's communication feature usage (r=-0.219 at the 95% confidence level), which implies that project teams of residential projects do not heavily utilize the communication feature of PM-ASPs (i.e., instant messaging and a web board). This supports why residential projects may not gain a very high level of communication cost benefits through the use of PM-ASPs.

There is also a significantly positive correlation between heavy engineering projects and the time performance, implying that PM-ASPs tend to have better time performance when they are used to manage heavy engineering projects, such as infrastructure projects. This finding is consistent with an original expectation that heavy engineering projects are more complex, have a relatively high budget, and usually generate a large amount of project documents, so PM-ASPs may help in reducing the time required to manage these documents more than when they are applied to the other project types.

Regarding the project cost, PM-ASPs perform better in several perspectives when they are utilized in projects with higher budget amounts. One explanation is that high-budget projects usually involve many parties and require more robust communications and data sharing capabilities. These projects generally take longer to design and construct, allowing more time for gaining experience with PM-ASP. They also offer the opportunity to take advantage of a learning curve by transferring experience gained on one part of the project to a later one. In contrary, a project with a smaller or tighter budget can experience cost constraints that will impact the level of personnel required to keep a PM-ASP operating and the time required to populate the database with updated information regularly.

At the 95% confidence level, PM-ASPs applied in projects with a longer duration tend to gain higher strategic and cost performance. This is rational because a PM-ASP implementation usually requires a great deal of change to business processes, so it is relatively difficult to implement a PM-ASP effectively on a shorter project. It generally takes a considerable amount of time before the strategic and cost benefits of using IT systems can be realized. Thus, a PM-ASP implemented in a short-term project might not generate these benefits as much as when the system is implemented in a longer project.

The last factor affecting PM-ASP performance is the starting stage of PM-ASP development. The results show that both the time and cost performance of PM-ASPs are substantially reduced when the systems are introduced during the construction phase. Although there are no significant correlations to substantiate that PM-ASP performance is better when the systems are introduced early in the projects, it is clear that introducing PM-ASPs in a later phase of construction projects yields lower performance overall. Starting a PM-ASP at the earliest possible stage of a project will reduce the level of adjustment required during the transition from one stage of project development to the next and will facilitate all team members becoming familiar with the system.

TABLE 9: Correlations of Project Characteristics and PM-ASP Performance

Variable	Strategic improvement	Time improvement	Cost improvement	Quality improvement	Risk improvement	Communication improvement
Project location	-0.023	0.072	0.055	-0.158	-0.037	-0.042
Owner type	-0.153	*-0.262	-0.141	-0.147	*-0.218	-0.216
Contract type 1 (design build)	0.094	-0.003	-0.080	0.079	0.054	0.016
Contract type 2 (design-bid-build)	-0.076	-0.030	-0.063	-0.038	-0.107	-0.066
Contract type 3 (construction management)	-0.112	-0.037	0.029	0.019	0.079	-0.022
Contract type 4 (guaranteed maximum price)	0.066	0.018	0.119	-0.016	-0.051	0.010
Contract type 5 (others)	-0.003	0.076	-0.008	-0.068	0.094	0.104
Project type 1 (residential)	*-0.221	-0.205	*-0.243	-0.094	-0.205	-0.150
Project type 2 (commercial)	0.021	0.016	0.142	-0.131	0.112	-0.049
Project type 3 (heavy engineering)	0.181	*0.220	0.054	0.145	0.122	0.152
Project type 4 (industrial)	-0.017	-0.062	-0.043	0.120	-0.100	0.046
Project size	0.099	0.038	-0.057	0.061	0.015	0.026
Project cost	*0.262	**0.297	0.164	*0.249	0.158	*0.269
Project duration	*0.222	0.213	*0.173	0.211	0.185	0.191
Complexity related to design and engineering	0.215	0.081	0.025	0.172	0.066	0.148
Complexity related to construction tasks	0.202	0.085	0.033	0.081	-0.011	0.052
Starting stage of PM-ASP 1 (pre-project planning)	-0.018	0.180	0.120	0.058	-0.015	0.087
Starting stage of PM-ASP 2 (design)	0.002	0.048	0.052	0.062	0.132	0.085
Starting stage of PM-ASP 3 (procurement)	0.120	0.042	0.084	-0.114	-0.019	0.008
Starting stage of PM-ASP 4 (construction)	-0.057	*-0.257	*-0.226	-0.051	-0.108	-0.179

*Note: Correlations noted with * are significant at 95% confidence level (two-tailed test), where as correlations noted with ** are significant at the 99% confidence level (two-tailed test).*

4.4.2 Project Team Characteristics

Table 10 displays the Pearson's correlation coefficients of the project team characteristics to the six PM-ASP performance perspectives. All factors except the party paying for use of PM-ASP are found to affect PM-ASP performance.

The performance of PM-ASPs is significantly reduced when their uses are decided or mandated by project owners. Yet projects having champions who motivate and support team members for the use of PM-ASPs gain significantly higher PM-ASP performance in all perspectives. There is also a significant negative correlation between projects having owners mandated the use of PM-ASPs and the existence of champions (r=-0.375 at the 99% confidence level), which strongly supports that champions usually do not exist when PM-ASPs are mandated by owners. It also implies that a champion usually does not reside in an owner organization but rather is more likely to be another project party. The presence of project champions also positively correlates with the willingness of team members to use PM-ASPs (r=0.282 at the 95% confidence level), indicating that team members tend to have a higher acceptance on PM-ASP usage when there is a project champion who can motivate and assist them in the use of the system. According to these findings, it is recommended that the use of a PM-ASP should not be solely decided or mandated by an owner or the system will tend to lack a champion and will potentially result in failure. Project teams should identify a champion (or even assign a member to act as a champion) who can encourage team members to use PM-ASP prior to its actual implementation in order to ensure its success.

TABLE 10: Correlations of Project Team Characteristics and PM-ASP Performance

Variable	Strategic improvement	Time improvement	Cost improvement	Quality improvement	Risk improvement	Communication improvement
Party deciding for the use of PM-ASP 1 (owner)	**-0.361	*-0.249	*-0.206	**-0.372	**-0.328	*-0.269
Party deciding for the use of PM-ASP 2 (designer)	0.167	0.119	0.171	0.126	0.106	0.136
Party deciding for the use of PM-ASP 3 (consultant)	*0.226	0.185	0.211	0.102	0.135	0.192
Party deciding for the use of PM-ASP 4 (engineer)	0.167	0.163	0.109	0.125	0.144	0.149
Party deciding for the use of PM-ASP 5 (contractor)	0.021	-0.034	-0.113	0.170	0.108	-0.023
Party paying for the use of PM-ASP 1 (owner)	0.019	0.164	0.216	-0.026	0.108	0.102
Party paying for the use of PM-ASP 2 (contractor)	-0.040	-0.184	-0.206	0.034	-0.173	-0.160
Party paying for the use of PM-ASP 3 (others)	0.029	0.004	-0.052	-0.007	0.083	0.073
Internet access availability	*0.243	**0.401	**0.303	*0.232	*0.209	**0.311
Internet access type 1 (dial-up modem)	**-0.333	**-0.351	**-0.367	*-0.181	*-0.223	**-0.416
Internet access type 2 (cable modem)	*0.278	*0.277	*0.255	*0.275	**0.309	*0.282
Internet access type 3 (DSL/ADSL)	0.040	0.024	0.032	-0.060	-0.096	0.040
Internet access type 4 (T1)	-0.001	0.039	0.068	-0.026	0.026	0.080
Presence of champions	**0.521	**0.475	**0.501	**0.378	**0.377	**0.461
Prior experience with PM-ASPs	0.205	0.145	0.156	**0.310	**0.294	0.126
Alignment of PM-ASP objectives to project objectives	**0.612	**0.651	**0.553	**0.629	**0.573	**0.585
Users involvement during implementation planning	**0.592	**0.507	**0.511	**0.493	**0.475	**0.486
Level of support from top management	**0.422	**0.507	**0.381	**0.406	**0.487	**0.448
Team attitudes toward PM-ASPs	**0.397	**0.388	**0.378	**0.330	**0.332	**0.332
Team attitudes toward IT	**0.292	0.145	0.192	*0.263	0.211	0.151
Adequacy of training	**0.512	**0.412	**0.422	**0.491	**0.489	**0.477
Adequacy of resources	**0.459	**0.311	**0.442	**0.377	*0.263	**0.414
Ability of project managers	**0.325	0.208	**0.296	*0.275	0.179	0.214
Word processing competency	0.106	-0.092	0.050	0.138	0.074	-0.006
Spreadsheet competency	0.196	-0.046	0.063	*0.236	0.074	0.108
Database competency	0.199	0.133	*0.256	0.104	-0.005	0.169
CAD competency	*0.280	*0.272	**0.414	**0.303	*0.228	*0.276
Internet surfing competency	**0.406	0.159	**0.363	0.199	0.193	*0.260
E-mail competency	0.207	0.025	0.207	0.064	-0.010	0.080
Online messaging competency	**0.333	0.064	*0.224	0.166	0.165	0.215
Video conferencing competency	**0.317	*0.229	**0.339	0.302	*0.282	0.203
Newsgroup competency	0.178	0.147	*0.247	0.091	0.148	0.145
E-commerce competency	*0.260	0.078	*0.275	0.112	0.186	0.203
Usage of schedule management feature	**0.360	*0.281	*0.275	**0.396	**0.343	*0.276
Usage of cost management feature	**0.374	**0.447	**0.386	**0.383	**0.350	**0.291
Usage of quality management feature	**0.527	**0.503	**0.528	**0.423	**0.402	**0.422
Usage of contract management feature	**0.390	**0.511	**0.375	**0.339	**0.539	*0.266
Usage of material management feature	**0.322	**0.354	**0.284	**0.432	**0.394	*0.199
Usage of procurement feature	**0.448	**0.477	**0.377	**0.548	**0.505	**0.319
Usage of human resources management feature	0.250	0.160	0.155	0.203	0.291	0.128
Usage of safety feature	0.329	0.226	0.184	0.338	0.405	0.206
Usage of communication feature	**0.541	**0.483	**0.504	**0.328	**0.423	**0.490

The Internet access availability significantly correlates with all PM-ASP performance perspectives. A project having a higher percentage of Internet access available to its team members from their work locations gains higher performance on the use of a PM-ASP, which is consistent with the original expectation. The results also indicate that projects having the most team members accessing PM-ASPs by dial-up connections tend to have lower PM-ASP performance, while projects equipped with cable modem connections yield higher PM-ASP performance in all perspectives. Yet projects using DSL/ADSL, T1 and other connection types such as satellite service, do not prove to yield higher performance. These findings imply that a cable modem connection deems to be the most reliable means of Internet access for PM-ASPs and is recommended to be selected if available, whereas dial-up connections must be avoided.

At the 99% confidence level, a greater PM-ASP experience by team members helps to increase quality and risk performance of PM-ASPs. Prior PM-ASP experience also strongly correlates with the usage level of several PM-ASP's advanced features, such as material/equipment management (r=0.275 at the 95% confidence level), procurement management (r=0.295 at the 99% confidence level), human resources management (r=0.349 at the 99% confidence level), and safety management modules (r=0.343 at the 99% confidence level). Word processing and e-mail experience of team members has no significant impact on PM-ASP performance, but experience with some computer applications (i.e., spreadsheets, databases, newsgroups, online messaging, e-commerce, internet surfing, and online video/audio conference) has significant impacts on different performance perspectives. An interesting finding is that all PM-ASP performance perspectives are high when CAD experience of team members is high, implying that CAD experience is probably the most important computer experience that team members should have when a PM-ASP is utilized. This result might be because most drawings used in a project utilizing a PM-ASP are probably in CAD format rather than paper format. Therefore, team members must know how to access and read these drawings and to occasionally download or edit them online. Without a good CAD background, they definitely cannot perform these functions. The usage of certain PM-ASP's features, such as the schedule, cost, quality, contract, material and equipment, procurement, and communication management features also strongly correlates with all PM-ASP performance perspectives. When team members intensively use these features, the performance tends to be high.

Regarding the team attitudes toward PM-ASPs, it is found that when team members have a high level of positive attitudes toward PM-ASPs, PM-ASP performance in all perspectives significantly grows. Unlike their attitudes toward PM-ASPs, there are only two significant positive correlations between team members' IT attitudes and PM-ASP performance in terms of the strategic and quality improvements. This is somewhat surprising and is not truly consistent with the original expectation. Yet it may be conclude that the positive attitudes of team members toward IT in general do not guarantee that a PM-ASP implementation will be successful; rather it is the positive attitudes of members toward PM-ASPs that would warrant the success and should not be ignored.

Training also proved to be statically significant to PM-ASP implementation success. As expected, projects providing more training to team members gain higher PM-ASP performance in all perspectives. At a minimum, everyone who will be using PM-ASP in a project needs to be trained on how the system works and how it relates to the team's business processes early in its implementation. Although a consultant or a service provider may be used to help during the implementation process, it is important to ensure that knowledge is really transferred to team members. It is strongly recommended that continuing training opportunities should be provided to team members in order for them to enhance their skills to meet the changing needs of business processes. In addition to training, the results show that when more resources in terms of money, time, and personnel are provided, PM-ASP performance tends to be higher. This is rational since the presence of adequate resources can lead to a better chance of overcoming organizational obstacles and communicating high levels of organizational commitment.

Consistent with the original expectation, a project with a better alignment of PM-ASP implementation objectives to the project objectives gains a higher PM-ASP performance in all perspectives. A PM-ASP implementation strategy should correspond with and support the project team's strategy and business needs. If the roles of PM-ASP are well defined, many problems related to the appropriate variety of services, the commitment of the organization, and the facilitation of PM-ASP implementation may be avoided. The results also show that the more team members involve in the planning process of PM-ASP implementation, the more likely it is that the system will yield higher performance. The common sense reasoning is that if team members have participated in the development and implementation process, then they will be more likely to develop a better understanding of how the system can assist them in performing their jobs effectively. Therefore, they tend to have a better acceptance of the system.

Lastly, the level of support from top management has significant positive correlations with all PM-ASP performance perspectives, which reinforces the belief that a high level of commitment by top personnel to a PM-ASP implementation is needed in order for the system to be successful. Since an adoption of a PM-ASP always involves significant changes in business processes and individual tasks, determination and commitment from high authority personnel are necessary in order to make these changes possible. Team members are more likely to accept and use a PM-ASP if they perceive the system as having strong support from the top management of their organization. A project manager's performance also shows significant positive correlations with some performance perspectives (i.e., strategic, cost, and quality), signifying that the ability and competency of a project manager would help in raising the chance of having high PM-ASP performance in several important perspectives. Yet it must be noted that there is no warranty for a PM-ASP to be successful in all perspectives even when the performance of a project manager is relatively high. This is because PM-ASP performance is more likely to rely on all team members rather than on the performance of one person.

4.4.3 Service Provider Characteristics

As shown in Table 11, all factors associated with service provider characteristics have statistically significant impacts on PM-ASP performance. At the 99% confidence level, the contact facilities and promptness of responses provided by a service provider significantly correlate with all PM-ASP performance perspectives. The performance of a PM-ASP on every perspective tends to be higher when it is easier for team members to contact a service provider who can promptly respond to queries. The attitude of a service provider's staff also significantly correlates with all PM-ASP performance perspectives at the 95% confidence level or better. When a service provider's staff have an improved attitude in helping their customers (the system's users) to solve problems, all PM-ASP performance perspectives tend to be higher.

TABLE 11: Correlations of Service Provider Characteristics and PM-ASP Performance

Variable	Strategic improvement	Time improvement	Cost improvement	Quality improvement	Risk improvement	Communication improvement
Contact facilities	**0.448	**0.427	**0.423	**0.471	**0.468	**0.448
Promptness of responses	**0.357	**0.429	**0.436	**0.462	**0.454	**0.357
Attitudes of staff	*0.232	**0.211	**0.299	**0.382	*0.251	*0.232
Technical competency of staff	**0.354	**0.386	**0.393	**0.437	**0.410	**0.354
Knowledge of construction business	**0.402	**0.467	**0.521	**0.503	**0.484	**0.402

For the technical competency of a service provider's staff, the results show that PM-ASP performance on every perspective tends to be higher when a service provider's staff have a greater ability to understand technical problems related to the system and to provide solutions to such problems. This finding is consistent with previous findings reported in IT literature (Bergeon et al. 1990; Leitheiser and Wetherbe 1991; Magal 1991), confirming that technical competency of a service provider's staff ensures a high level of quality in the service provided and minimizes the possibility of technical difficulty.

A service provider's construction business knowledge also shows significant positive correlations with all six PM-ASP performance perspectives at the 99% confidence level. When a service provider have a better understanding of construction business and problems, PM-ASP performance on every perspective tends to grow, indicating that the level of a service provider's knowledge of the construction business is an important factor that significantly affects PM-ASP performance. This finding is consistent with previous studies which suggest that a service provider must have a good understanding of an end user's business tasks and problems to ensure the success of system implementations (Leitheiser and Wetherbe 1991; Magal et al. 1988). It must be noted that not all service providers offering PM-ASPs for the construction industry have a background in construction. Although some of them may be financially-backed by well-known construction companies, many are start-up organizations and have little or no background related to the construction industry. Limited knowledge of service providers in construction has also claimed as a major reason of the slow PM-ASP adoption rate in the construction industry (Becerik 2004).

4.4.4 System Characteristics

Table 12 exhibits the Pearson's correlation coefficients of the system characteristics to the six PM-ASP performance perspectives. Nine factors display significant correlations with PM-ASP performance at the 99% confidence level.

The number of users has significant positive correlations with all PM-ASP performance perspectives. According to this result, it is recommended that all associated team members should have access to a PM-ASP, and the access should not be limited to personnel at high authority or management levels. However, it should be noted that a very large number of users may create a chaotic environment and make it difficult to control both access to and the accuracy of project documents. In order to prevent implementation problems, it is important to decide early in a project on an adequate number of project team members who can obtain access to the system.

A system's ease of use shows significant positive impacts on all PM-ASP performance perspectives, proving that a system that is easier to be used yields higher performance. Ease of use generally depends on a number of design issues, including user interface, screen design, page layout, color, icons, help facilities, menus, user documentation, and on-screen prompts (Burch and Grunitski 1989; Alter 1992). In addition to the ease of use, the quality of both on-screen and printed outputs generated by the system also has significant positive impacts on all PM-ASP performance perspectives. It is clear that a PM-ASP having a good quality of screen-based and printed outputs can help in reducing misinterpretation of project data that potentially results in miscommunication and disputes.

A system's reliability and the quality, reliability, and security of data are also important to PM-ASP performance. The reliability of a system encompasses response time, uptime, and availability (Alter 1992). Obviously, a system's downtimes can create a high possibility for project data losses that can result in both time and money losses to a construction project. When a PM-ASP is more reliable and provides data that are more secure and accurate, the system's performance on all perspectives tends to be higher.

TABLE 12: Correlations of System Characteristics and PM-ASP Performance

Variable	Strategic improvement	Time improvement	Cost improvement	Quality improvement	Risk improvement	Communication improvement
Type of hosting options	0.069	-0.038	0.027	0.001	-0.009	0.026
Number of users	**0.311	**0.368	**0.267	**0.394	**0.298	**0.342
Frequency of version update	-0.064	-0.071	-0.151	0.087	0.081	-0.158
Ease of use	**0.667	**0.405	**0.522	**0.480	**0.477	**0.568
Output quality	**0.707	**0.525	**0.513	**0.557	**0.521	**0.620
System reliability	**0.534	**0.450	**0.484	**0.418	**0.385	**0.490
Data quality and reliability	**0.644	**0.485	**0.537	**0.446	**0.450	**0.557
Data security	**0.702	**0.590	**0.546	**0.542	**0.620	**0.589
Integration among PM-ASP features	**0.508	**0.454	**0.372	**0.362	**0.434	**0.460
Integration with external software	**0.483	**0.416	**0.475	**0.350	**0.403	**0.496
Integration with project team's internal systems	**0.409	**0.405	**0.434	**0.337	**0.388	**0.390

Lastly, the results show that the level of system integration has major effects on the performance of a PM-ASP. A system having a greater ability to integrate internally and externally gains significantly higher performance in all perspectives. The integration ability of a PM-ASP enhances the workflow of project information, which in turn will lead to the success of the system and the project. System integration should be considered at three levels: 1) integration among PM-ASP features, 2) integration with external software applications such as Primavera and CAD, and 3) integration with a project team's internal systems, e.g., enterprise resource planning (ERP) and knowledge management system (KMS).

4.5 Key Success/Failure Factors of PM-ASP Implementations

Section 4.4 discusses the bivariate correlations of the 42 factors to PM-ASP performance results. The multiple regression modeling presented in this section extends these correlations by investigating how the factors act together to affect performance of PM-ASP in order to determine the critical PM-ASP implementation success/failure factors. Since multiple regression modeling offers the ability to analyze the effects of numerous variables at once, the variables in the multiple regression equations are not always those which have the highest individual correlations. The independent variables are the 42 factors associated with the characteristics of the project, the project team, the service provider, and the system. The dependent variables are the scores of the six PM-ASP performance perspectives as described in Section 4.1. These perspective scores create the six regression models discussed in this section.

Before multiple regression modeling began, correlations among the 42 factors were checked to protect the multicollinearity problem, which could lead to erroneous models. Highly correlated factors were combined to form a new variable, resulting in a total of 11 new variables produced as shown in Table 13. These new variables were then used as independent variables in the regression modeling in lieu of factors that are highly correlated. The score for each new variable is an average score of its component factors' scores. Yet a score for one new variable, "project scale," could not be calculated since its component factors (project cost, duration, and the number of members having access to PM-ASP) have different units. Therefore, a decision was made to insert each of its component factors into the regression models one at a time and to select the optimal models that best explained the variances. In total, 27 variables constructed the independent variables of the regression models.

Over 100 models created using different combinations of variables were developed and tested. Their predictive powers were judged through statistical measurement of the coefficient of determination (R^2) and standard error, and they were tempered with experimental judgment. The discussion that follows is a presentation of the final or "optimal" models, which represent the best fit for the data collected and yield the most accurate insight into the key success/failure factors of PM-ASP implementations. A summary of the optimum regression models is presented in Table 14. Of the 27 variables, 11 are critical to one or more perspectives of PM-ASP performance.

4.5.1 Project Type

Type of project is critical to the cost performance of PM-ASPs. The regression results show that commercial projects gain significantly higher cost benefits of using PM-ASPs than other project types. This might be due to the fact that although commercial projects usually generate a large amount of drawings, they are generally not as sophisticated as those for heavy and industrial projects so most of the drawings can be uploaded and transferred via PM-ASPs with fewer problems or errors, resulting in a significant reduction of paperwork. Management personnel in most commercial projects can also use PM-ASPs as a sole communication channel to discuss project issues with no need for other communication methods or site visits, as is often required for heavy and industrial projects. Therefore, potentially significant communication and travel cost savings could be realized with the use of PM-ASPs.

Project type is also critical to the success of PM-ASPs in terms of their risk benefits, wherein the risk performance is measured by how the systems help in reducing the number of RFIs and claims, conforming to contracts, and improving decision-making of team members. The positive regression coefficient suggests that commercial projects yield better PM-ASP risk performance than other project types.

According to the findings presented, it can be concluded that the usefulness of PM-ASPs is still limited to some types of projects. Projects that are highly complex, i.e., heavy engineering and industrial constructions, or relatively uncomplicated projects such as residential construction might not benefit as much from the use of PM-ASPs, especially for the cost and risk benefits, as would moderately complicated projects, such as commercial projects.

4.5.2 Project Duration

Project duration is a critical factor affecting the strategic and cost performance of PM-ASPs. The positive regression coefficients mean that a project with a longer duration will gain significantly higher PM-ASP strategic and cost performance. As explained earlier, it generally takes a considerable amount of time before a project's team members accept and use a PM-ASP effectively and the strategic and cost benefits of using the system can be realized. PM-ASP implementation usually requires significant changes to current business processes, and these changes require time to be accomplished and are relatively difficult to achieve in a short project. People are normally resistant to change, so a project with either a short or an accelerated duration tends to experience several additional challenges when trying to alter the work patterns of team members. These challenges usually take time to overcome, and, therefore, it would be much easier to implement a PM-ASP successfully on a project with a longer duration.

TABLE 13: New Variables Produced from Highly Correlated Factors

New variable	Variable components
Project scale	Project cost Project duration Number of users
Project complexity	Complexity related to design and engineering Complexity related to construction tasks
Level of internal support	Alignment of PM-ASP objectives to project objectives Users involvement during implementation planning Level of support from top management Adequacy of training Adequacy of resources
Team attitudes toward changes	Team attitudes toward PM-ASPs Team attitudes toward IT
Basic computer knowledge of team members	Word competency Spreadsheet competency E-mail competency Internet surfing competency
Advanced computer knowledge of team members	CAD competency Database competency Instant messaging competency Online video/audio conference competency Newsgroup competency E-commerce competency
Usage frequency of basic PM-ASP features	Usage of cost management feature Usage of quality management feature Usage of schedule management feature Usage of communication feature
Usage frequency of advanced PM-ASP features	Usage of contract management feature Usage of material management feature Usage of procurement management feature Usage of human resources management feature Usage of safety management feature
Level of support provided by a service provider	Contact facilities Promptness of responses Attitude of staff Technical competency of staff Knowledge of construction business
Functionality and reliability of PM-ASP	Ease of use Output quality System reliability Integration among PM-ASP features
Data security and reliability	Data security Data quality and reliability
Level of external integration of PM-ASP	Integration with external software program Integration with project team's internal systems

TABLE 14: Optimum Regression Model Results

Key success/failure factors	β	Std. error	b^*	t	p-value
(a) Strategic improvement (adjusted R^2 = 0.284, standard error = 0.898)					
Constant	1.532	0.587	N/A	2.609	0.011
Level of internal support	0.293	0.108	0.318	2.707	0.008
Functionality and reliability of PM-ASP	0.207	0.098	0.248	2.115	0.038
Project duration	0.208	0.081	0.243	2.584	0.012
(b) Time improvement (adjusted R^2 = 0.506, standard error = 0.982)					
Constant	-0.355	0.655	N/A	-0.542	0.590
Level of internal support	0.342	0.157	0.275	2.172	0.033
Usage frequency of advanced PM-ASP features	0.335	0.132	0.274	2.542	0.013
Data security and reliability	0.246	0.108	0.238	2.278	0.026
Internet access availability	0.015	0.006	0.235	2.679	0.009
(c) Cost improvement (adjusted R^2 = 0.534, standard error = 0.732)					
Constant	-1.514	0.746	N/A	-2.014	0.048
Level of internal support	0.465	0.115	0.385	4.032	0.000
Functionality and reliability of PM-ASP	0.356	0.105	0.326	3.390	0.001
Project type (commercial projects)	0.828	0.231	0.290	3.589	0.001
Project duration	0.143	0.005	0.212	2.628	0.010
Ability of project managers	0.295	0.117	0.197	2.512	0.014
(d) Quality improvement (adjusted R^2 = 0.455, standard error = 1.013)					
Constant	-1.424	0.848	N/A	-1.679	0.098
Level of internal support	0.359	0.162	0.293	2.209	0.031

Usage frequency of advanced PM-ASP features	0.291	0.113	0.286	2.581	0.012
Data security and reliability	0.269	0.135	0.224	1.995	0.050
Level of external integration of PM-ASP	0.280	0.134	0.190	2.087	0.041
(e) Risk improvement (adjusted R^2 = 0.547, standard error = 0.866)					
Constant	-0.692	0.546	N/A	-1.268	0.209
Usage frequency of advanced PM-ASP features	0.348	0.080	0.355	4.355	0.000
Data security and reliability	0.390	0.109	0.342	3.566	0.001
Level of support provided by ASP	0.240	0.108	0.218	2.223	0.029
Type of Internet connection (cable modem connections)	0.476	0.244	0.151	1.953	0.055
Project type (commercial projects)	0.349	0.205	0.132	1.708	0.092
(f) Communication improvement (adjusted R^2 = 0.511, standard error = 1.050)					
Constant	1.054	0.576	N/A	1.831	0.071
Level of internal support	0.510	0.129	0.391	3.965	0.000
Functionality and reliability of PM-ASP	0.400	0.117	0.334	3.377	0.001
Type of Internet connection (dial-up connections)	-0.620	0.319	-0.164	-1.941	0.056

4.5.3 Internet Access Availability

The regression results show that the Internet access availability is critical to the time performance of PM-ASPs. A higher number of members having direct Internet access from their work sites lead to a higher level of PM-ASP time performance.

Ideally, a successful PM-ASP implementation requires all team members to participate and all of them should be able to access the Internet and the system as needed. Yet the cost of networking infrastructure and concerns regarding security issues usually limit the Internet access provided to team members. Most projects provide limited Internet access to its team members, generally only to those at management level. Such a strategy, however, can be detrimental because not only the personnel at the management level are important for the successful PM-ASP application, but members working in the field, such as superintendents and foremen, are also important. It is highly recommended that Internet connections be made available for every associated member to ensure the success of the system, especially in terms of its time performance. Just one team member not being able to access the Internet to input his/her information can affect the system not working as intended and its time performance can significantly decrease.

4.5.4 Type of Internet Connection

Interestingly, the Internet connection type is one of the key factors influencing the risk performance of PM-ASPs. When cable modem connections are used, the benefits of PM-ASPs related to their risk management tend to be amplified. This finding is somewhat surprising but is consistent with the correlation results presented in Section 4.4.2. The finding confirms that a cable modem connection is the best choice for PM-ASPs, probably because it is simple to be established and does not require a telephone line so it can be installed in a remote site with less effort. Another implication may be that a cable modem connection is more reliable than other connection types so the data transferred via a cable modem experience fewer errors.

The Internet connection type is also critical to the communication performance of PM-ASPs. The negative regression coefficient indicates that if dial-up connections are used, the communication performance of the systems will decrease. This finding is consistent with the original expectation because low-speed Internet connections would not be able to convey large and complex project information or to process requests for large amounts of information online and could create bottlenecks and barriers in communications, thereby hampering coordination among team members.

4.5.5 Level of Internal Support

As shown in Table 13, internal support consists of an ability to align PM-ASP implementation objectives to project objectives, the level of users participation prior to PM-ASP implementation, top management support, training provided to users, and availability of resources (money, time, and personnel). The regression results show that the level of internal support provided for the use of PM-ASPs is the most important variable among the 11 critical factors found since it is critical to almost all PM-ASP performance perspectives. First, it affects the strategic performance and is the best predictor in the equation, as displayed by its highest standardized regression coefficient (b*=0.318). The positive regression coefficient suggests that projects with a higher level of internal support provided to team members would yield a significantly higher level of PM-ASP strategic-related performance. This is reasonable because strategic performance is a long-term benefit that is difficult to achieve without an appropriate level of internal support provided. If a company aims to use PM-ASPs for a strategic purpose, it is highly recommended that the level of internal support be adequate to ensure the success of the systems.

Second, the internal support is the best predictor of the time performance (b^*=0.275). The positive regression coefficient correlates to a significantly higher PM-ASP time performance as the level of internal support increases. Since the major objective of PM-ASP implementations in most projects is to save communication time, it is very important that an implementation strategy is planned and agreed upon by all major users to avoid any conflict of interest, which can result in the system being abandoned. All parties should be allowed to participate during implementation planning in order to have clear expectations of the system's performance as well as team members' reaction to its use. When team members have a better understanding of the system, PM-ASP can become a major communication channel, potentially leading to significant communication time savings. Moreover, training should not only be provided when a new system's features or functions become available but should be provided on a continuous basis to update members' knowledge and to allow members to share experience with others.

Third, the internal support is the best predictor of the cost performance (b^*=0.385). The positive coefficient means that projects with a higher level of internal support yield a higher level of PM-ASP cost performance as well. Without adequate internal management support, most team members will resist the use of a PM-ASP, potentially resulting in its low cost performance. Fourth, the internal support is also one of the best predictors of PM-ASP quality performance (b^*=0.293). When team members perceive a PM-ASP as having strong management support, they are more likely to accept and use it. Therefore, its quality benefits, such as facilitating forecasting and control of processes, identifying errors and inconsistencies, and improving the quality of documents, are higher.

Lastly, the internal support is the best predictor of PM-ASP communication performance (b^*=0.391). The positive coefficient correlates to communication performance increasing as the level of internal support raises. This finding could be due to the fact that team members perceiving a PM-ASP as having strong internal support are more likely to accept and use it as a main communication channel in the project, thereby facilitating the coordination among team members while reducing bottlenecks and barriers in communications.

4.5.6 Ability of Project Managers

Factors related to the skills and characteristics of project managers have been repeatedly proposed in the literature as having strong effects on the successful completion of a construction project (Jeffery 1985; Jaselskis and Ashley 1991; Pinto and Slevin 1989; Chua et al. 1999). This study extends the existing literature by proving that the ability of project managers is also important to the success of using PM-ASPs. The regression results show that when the ability of project managers (i.e., competency, authority, involvement, and commitment) is higher, the cost performance of the systems significantly increases. Obviously, project managers who are in charge of the project must have sufficient authority, skills, and reputation to ensure that everything that needs to be done for the benefit of the project is done. It is therefore suggested that project managers should participate in the PM-ASP implementation planning process in order to have a clear understanding of the system and how it can be integrated into current working practices. Without the support of project managers, team members could become frustrated with the system, resulting in the system being discarded.

4.5.7 Usage Frequency of Advanced PM-ASP Features

This variable considers the usage frequency of PM-ASP's advanced features (i.e., contract, material, procurement, human resources, and safety management) and is one of the best predictors of time, quality, and risk performance of the system. The positive regression coefficients indicate that when the usage level of advanced features increases, the time, quality, and risk performance of the system significantly increases as well. It is suggested, therefore, that a project team aiming to save communication time, to improve the quality of documents, or to increase risk management benefits by using a PM-ASP should search for a system that provides these advanced features, try to integrate them into business processes, and encourage team members to use such features. Using only the basic features does not warrant that the time, quality, and risk benefits resulting from the use of a PM-ASP will be realized; rather it is the usage level of advanced features that can guarantee such benefits.

4.5.8 Level of Support Provided by ASP

The level of support provided by a service provider is critical to the risk performance of a PM-ASP. In this study, the level of an ASP's support is measured by four factors: contact facilities, problem-solving speed, staff's attitudes, staff's technical competency, and knowledge in construction business and problems. The regression results reveal that the risk benefits of using a PM-ASP increases when a service provider is easier to contact, provides faster service, has staff with better attitudes and more technical knowledge, and has a better understanding of construction business processes. Consequently, it is highly recommended that a project team planning to use a PM-ASP notes the importance of these factors and treats them equally to other factors. Using advanced functions offered or advertised by a service provider does not 100% warrant that the system will work as intended. In fact, there will always be new modules and features and better fits to be achieved between a business and a system. Customer support in the form of extended technical assistance, emergency maintenance, updates, and special user training become important to ensure that all features will work as advertised with minimum technical difficulty, and that high performance will actually be realized.

4.5.9 Functionality and Reliability of PM-ASP

PM-ASP's functionality and reliability are combinations of several factors, including ease of use, user interface, output quality, system reliability, and feature integration. They are critical to the three important performance aspects of the system: communication, cost, and strategic. A good explanation is that when a PM-ASP is proven to be easy to use and reliable in a project, team members will be more willing to use it as a central communication channel to coordinate and exchange information with others. This will result in a significant reduction of bottlenecks and barriers in communication, so the communication benefits will rise. The number of paperwork, telephone calls, and the need to travel will be reduced because all major communications can be conducted through PM-ASP, all of which can lead to significant cost savings. Team members will also be impressed by the system and will be willing to use it on future projects, leading to a better chance to achieve long-term or strategic benefits. On the other hand, team members will avoid using the system and will use other communication mediums if they perceive that the system is complex and unreliable. They will probably also resist using any PM-ASP in the future.

4.5.10 Data Security and Reliability

Walker and Rowlinson (1999) points out that data reliability and security are the prime concerns to construction practitioners when deciding whether or not to adopt an IT project. This study further proves that the degree to which the data produced and maintained by a PM-ASP are accurate, current, reliable, and secure is also critical to the success of the system in terms of its time, quality, and risk performance. The regression results show that as a PM-ASP provides a higher level of data security and reliability, these three performance aspects significantly increases. One simple explanation for this finding is that a system providing better levels of data reliability and security will generate fewer project information errors, resulting in more savings in communication time and a better ability to forecast and control construction processes and reduce rework. The number of RFIs will also be reduced, so team members can conceivably make faster and better decisions. In addition, the number of claims will decrease since all the data will be relatively accurate, leaving a smaller chance for disputes.

4.5.11 External Integration Ability of PM-ASP

The degree to which a PM-ASP used in a project can integrate with external software applications (i.e., CAD and Primavera) and the project team's internal management solutions (i.e., ERP and KMS) is a critical factor affecting its quality performance. The positive regression coefficient indicates that the quality performance of a system is significantly higher when the extent to which the system integrates with external applications increases. A PM-ASP that cannot integrate well with external software used frequently by construction practitioners would require users to manually enter the data to it. Manual data entry means rework and can usually generate errors and inconsistencies, resulting therefore in a low level of document quality.

5. CONCLUSIONS

Despite the great promise of PM-ASPs for the construction industry, their current usefulness is still limited to some extent. The results obtained from the survey of 82 construction projects managed with the use of 14 different systems have shown that only the benefits in terms of the strategic, time, and communication improvements are obvious to most practitioners, while the benefits related to cost savings, quality improvement, and risk management still remain unsatisfied. Yet all the six benefit perspectives are considered important to most practitioners when judging the overall system performance, resulting in the average overall performance of all the surveyed systems being rated as moderately successful. The survey has also revealed that PM-ASPs only facilitate the time and cost performance of construction projects but do not have any significant impact on the improvement of project quality, safety, and client's satisfaction.

PM-ASP performance is also greatly affected by certain characteristics of the project, the project team, the service provider, and the system. Among all these characteristics, 11 are critical to the performance of PM-ASP implementation. They include: 1) project type, 2) project duration, 3) Internet access availability, 4) type of Internet connection, 5) level of internal support, 6) ability of project managers, 7) usage frequency of advanced features, 8) level of support provided by a service provider, 9) functionality and reliability of PM-ASP, 10) data security and reliability, and 11) external integration ability of PM-ASP. Yet the level of internal support (ability to align PM-ASP implementation objectives to project objectives, the level of users participation prior to PM-ASP implementation, top management support, training provided to users, and availability of resources) has the most significant impacts on PM-ASP performance, confirming that the effectiveness and efficiency of a PM-ASP mainly depend on the unique characteristics of the firm using the system.

Findings of the study may be used for inference, deviation-cause detection, and improvement of future PM-ASP implementations. The benefits behind changes or improvements in areas of implementation related to the key success factors and the relationships between PM-ASP implementation success and project success can be better comprehended. Altogether, the findings can help increase the likelihoods of successful PM-ASP applications and thereby lead to an improvement of PM-ASP utilization, management, and acceptance in the construction industry.

6. REFERENCES

Alshawi M. and Ingirige B. (2003). Web-enabled project management: an emerging paradigm in construction, Automation in construction, Vol. 12, No. 4, pp. 349-364.

Alter S. (1992). Information systems: a management perspective, Addison-Wesley, Reading, MA.

Bergeron F., Rivard S. and DeSerre L. (1990). Investigating the support role of the information center, MIS quarterly, Vol. 14, No. 3, pp. 247-260.

Becerik B. (2004). A review on past, present and future of Web-based project management and collaboration tools and their adoption by the US AEC Industry, International Journal of IT in Architecture, Engineering and Construction, Volume 2, No. 3, pp. 233-248.

Burch J. G. and Grudnitski G. (1989). Information systems theory and practice, John Wiley and Sons, NY.

Björk B-C. (2002). The impact of electronic document management on construction information management, Proceedings of the CIB W78 workshop on distributing knowledge in building, June 12-14, the Aarhus School of Architecture, Denmark, Vol. 1, pp. 83-92.

Chua D. K. H., Kog Y. C. and Loh P. K. (1999). Critical success factors for different project objectives, ASCE Journal of construction engineering and management, Vol. 125, No. 3, pp. 142-150.

Jaselskis E. and Ashley D. (1991). Optimal allocation of project management resources for achieving project success, ASCE Journal of construction engineering and management, Vol. 117, No. 2, pp. 321-340.

Jeffery P. (1985). Project managers and major projects, Project management journal, Vol. 3, No. 4, pp. 225-230.

Kaplan R. M. and Saccuzzo D. P. (1993). Psychological testing: principles, applications and issues (3rd edition), Brooks/Cole Publishing, Pacific Grove, CA.

Leitheiser R. L. and Wetherbe J. C. (1991). A comparison of perceptions about information center success, Information and management, Vol. 21, No. 1, pp. 7-17.

Magal S. R., Carr H. H. and Watson H. J. (1988). Critical success factors for information center managers, MIS quarterly, Vol. 12, No. 3, pp. 413-425.

Magal S. R. (1991). A model for evaluating information center success, Journal of management information systems, Vol. 8, No. 1, pp. 91-106.

Nitithamyong P. (2003). Analysis of success and failure factors in application of web-based project management systems in construction, PhD dissertation, Purdue University, West Lafayette, Indiana.

Nitithamyong P. and Skibniewski M. (2004). Web-based construction project management systems: how to make them successful?, Automation in construction, Vol. 13, No. 4, pp. 491-506.

Nitithamyong P. and Skibniewski M. (2006). Success/failure factors and performance measures of web-based construction project management systems: professionals' viewpoint, ASCE Journal of construction engineering and management, Vol. 132, No. 1, pp. 80-87.

O'Brien W. J. (2000). Implementing issues in project web sites: a practitioner's viewpoint, ASCE Journal of management in engineering, Vol. 16, No. 3, pp. 34-39.

Pinto J. K. and Slevin D. P. (1989). Critical success factors in R&D projects, Research-technology management, Vol. 32, No. 1, pp. 31-35.

Walker D. and Rowlinson S. (1999). Procurement and the World Wide Web (WWW) - presenting company capabilities for selective tendering, In: Hall, K. (ed.), Customer satisfaction - a focus for research and practice, Proceedings of the CIB W-55 and W-65 Symposium, September 5-10, The University of Cape Town, South Africa, Vol. 1, pp. 436-444.

Zou P. and Roslan B. (2005). Different perspectives towards using web-based project management systems in construction: large enterprises versus small- and medium-sized enterprises, Architectural engineering and design management, Vol. 1, No. 2, pp. 127-143.

7. ACKNOWLEDGEMENTS

The writers would like to thank all individuals and organizations who helped distribute the questionnaire. Special gratitude goes to those individuals who responded and contributed their valuable input in completing the survey and the Purdue Statistical Consulting Services for their support on the questionnaire design and data analysis.