Project Management Practices and Information Technology Research

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Abstract: Corporations of varying sizes and operations within the construction industry acclaim the contribution of project management applications that assist in business and operational practices. An integrated intelligent construction management application that enables process modeling and algorithmic analysis of construction process planning, interacts with a mainframe-based automated relational database system, and drives the project sequencing, scheduling, decision making and change management processes can introduce dramatic speed, simplicity, accuracy, and collaboration into existing project planning practices. Several research organizations and academic fraternities in concert with industry participation are focusing on the development of such futuristic tools as described above. However, evidence of such computing applications being used by the industry is minimal and a number of reasons have been cited by researchers for this. This study, through a review of the genesis, evolution, and future of computing applications in construction followed by an industry-wide survey, aims to study whether or not concurrent research agendas in construction information technology are truly sustainable from the industry’s perspective.

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Introduction

Computing, electronic, and communication tools have been experimented and used extensively by the construction industry in the last few decades. For the most part, however, such tools were used for the conceptual drawing, design, and preconstruction planning aspects of the project. The use of such applications to plan, schedule, manage, and optimize construction projects is believed to be minimal (Ding 2002). In the last two decades, many new software applications have been developed to aid planning and control of projects and are also being implemented. The capability of these applications to be compliant with the latest research innovations is, however, either lacking or unknown.

A number of reasons have been cited by researchers and industry professionals for the inadequate penetration of advanced IT and computing tools into the construction industry. Commercially available off-the-shelf project management software is very expensive and can be afforded only by large project management (PM) and construction firms. Smaller software is cheaper but is unable to address important aspects of project controls that are demanded by specific companies (Gidado 1996) and is also not amenable to customization. It is cumbersome and costly to procure a software and experiment with it in order to optimize it for a given firm or project (Becerik 2005). Introducing a new technology is cited as being more difficult in the construction industry than in other industries (Allmon 2000). Off-the-shelf software tools are not seen as a source of competitive edge, since others can procure it as well (FIATECH 2004). The fragmented nature of structure and operations of firms within the construction industry also make it difficult for software vendors to gauge a common set of features or tools to incorporate in their existing software applications (Molenaar and Songer 2001). It has been noted by Nitithamyong et al. that technology push is only one of the critical success factors for effective implementation (Nitithamyong 2004). There is a preference for established conventional methods and the industry seems disinterested in IT research and development. Surveys of IT expenditures in US construction companies have highlighted that the construction industry is one of the lowest spenders among major industries (Cutter 1999). An implementation centric study by Becerik states that little has been done to analyze what has happened in the past and the current situation of the construction project extranet (CPE) market as well as reasons for slow adoption of CPE technology by the AEC industry (Becerik 2004).

Background

Advanced computing technologies have the potential to empower project managers and construction engineers to make quick decisions based on accurate information that can be visualized, studied, optimized, and quantified with greater accuracy. Research institutions such as the Construction Industry Institute, National Institute of Standards and Technology, Center for Integrated Lifecycle Facility at the Stanford University, National Research Council Canada, Center for Construction Industry Studies at the University of Texas at Austin, Project Management Institute,
Fully Integrated and Automated Technologies (FIATECH), etc., along with industry participation, are working toward the development of such tools.

Research efforts are also being made to introduce technological innovations such as process simulations, database management systems, 4D or timebound-3D computer aided design (CAD), data migration through wireless networks, and software applications integration (FIATECH 2004).

Some of the outlined targets that these tools of the future need to achieve include:

• Supporting accurate and complete planning and analysis of all important aspects of the project.
• Analyzing activities, recognition, and evaluation of conflicts, analyzing risks, and recommending actions based on situational analysis.
• Learning and continually building the enterprise knowledge base.
• Adapting to needs of individual companies.
• Ensuring seamless data access that is available through reliable and secure search mechanisms.
• Enabling information sharing and online capabilities.
• Interoperating with all systems related to construction project management and services.
• Automatically extracting and interpreting data.
• Optimizing across the enterprise, considering interactions between and among projects for highest business value.

For current PM applications to achieve the goals listed above, it is essential to investigate the capabilities and limitations of commercially available project management software tools and analyze problem areas that seem to be a barrier in their implementation.

Various researchers have identified numerous capabilities and qualities that are desirable in construction project management applications (FIATECH 2004). The following include some of the common issues with commercially available project management applications.

• The use of tools for visualization and fit is quite widespread in the industry, but mathematical or statistical-based toolsets for process optimization and selection are not used as widely.
• There is no standard method to evaluate cost/benefit value pertaining to acquisition of software and their use (FIATECH 2004; Becerik 2005).
• There is resistance to change from deeply rooted industry traditions (FIATECH 2004; Moselhi et al. 1991).
• The goal of a comprehensive tool as an aid to project managers should not be acquisition of data but the interpretation and processing of such data so as to enable them to make decisions in congruence with all stakeholders (FIATECH 2004).
• Project managers lack informed decision making, especially with many changes happening simultaneously (FIATECH 2004).
• There is a lack of integration of knowledge and information management systems with intelligent control systems (FIATECH 2004).

Considering these, there is a need to focus on the functional capabilities of such advanced tools and their deliverables, while keeping the compatibility and implementation perspectives of current construction management applications in mind.

Hypothesis

As explained above, various processes and phases in construction project planning and execution are being scrutinized and researched in order to cover most gray areas that might result in better project planning, execution, and delivery. Notwithstanding these, the fact that such advanced protocols have not yet penetrated the industry is well acknowledged. Keeping the deliverables of this work in mind, the study was conducted to understand the genesis or reasons that necessitated the use of computing tools, their ramifications, and how they have evolved and have been implemented over time.

The study was based on the hypothesis that many of the problem areas as identified by research organizations and relevant to the nature of the industry and its work force needed substantiation and deeper insight than currently exists.

PM IT Work Environment Survey

The questionnaire for this study was designed in order to quantitatively assess some of the primary influences on IT systems and PM work environments by collecting information to establish some generic trends within the construction management IT area. The survey was designed online in order to facilitate easy dissemination to select participants, easier data collection, interpretation, and analysis as well as ease of use from the participant’s perspective.

The questionnaire was divided into four logical sections including personal information, general information, project management work environment, and project management applications. The personal information section contained questions about the company that the participant works for and his position in the firm. The general information section included questions pertaining to the respondent and his firm. The third section included the participant’s opinion on various PM functions such as collaboration and communication, IT training, and deployment issues and generic information about their existing project management applications setup. The fourth section included questions regarding the opinions of the respondent with respect to the functionality of their PM applications.

Recruitment of Participants

Personal e-mails were sent to request participation after reviewing the credentials of the respondent in order to ensure the reliability of the respondents as well as the responses. This was done by collecting contact and business information of prospective participants from various member lists provided by esteemed academic and industry institutions. E-mails were sent to professionals belonging to companies that varied in size, geographical location, area of operations, and the type of projects they cater to.

Response Rates

The response rate for the questionnaire was close to 18%. Of the total of 372 mails sent, 109 people responded. Of these, 14 were completely empty records and 30 were mostly incomplete. All of these could not be included in the data analysis since it would affect the classification of record sets later. Any response set where the participant had skipped an entire section was not considered. Sixty-five responses were considered for the final data analysis.
Industry Representation

In order to penetrate the depths of the industry, selection of respondents was done keeping in mind that an array of responses would be necessitated to infer conclusively. Industry participation in this study was very diverse and represented all cross sections of the construction industry. Responses were received from more than 20 states covering the spread across North America. Approximately 34% of the establishments were based in the southeast United States, 33% in the western United States, 20% in the southern United States, and 13% in the midwestern United States.

Considering the scope of this study, representing companies were categorized on the basis of their primary area of operations as contracting firms and program management/CM firms. This was owing to the fact that these two segments reflected a difference in their needs from the PM application toolsets purview. Close to 74% of the firms engaged in PM and planning services, 41% in general AEC, 31% in design build, 26% in general contracting, and most establishments were involved in multiple functional areas of construction and affiliated operations.

Some of the other factors that were studied in order to extrapolate conclusions based on the sample to the population included number of employees in the firm, number of cross-functional departments, and geographical spread of their operations. Charts were plotted to observe distributions based on the above-mentioned factors and it was concluded that the data were adequately well distributed to be considered as representative of the industry.

Data Accuracy

Fig. 1 shows the percentage responses based on years of experience that the participants had in project positions. It was seen that most respondents had over 10 years of experience in their respective fields and have used PM applications of various types during their professional career.

Data Analysis

In order to study current trends such that the results could be generalized to various segments of the industry, it was pertinent that the record sets be categorized on the basis of differences in approaches and influencing factors as related to PM applications (Fig. 2).

Initial observation of datasets coupled with common knowledge revealed certain differences in the company reflections toward such applications in two areas:

- Size and spread of the firm.
- Primary operational functions.

Large companies contained the body of responses from firms having over 500 employees and over 10 cross-functional departments catering to management areas such as operations, finance, procurements, etc. They operated or had branches, partners, and/or clients at a global or at least at a nationwide level. It was also discerned from response records that such companies were involved in various aspects of construction from AEC consultancy to general contracting, facilities maintenance and repair, program management/CM, and more. Such companies constituted approximately 41% of all participating firms.

Midsized companies typically employed more than 250 people and the number of cross-functional divisions ranged between 5–10. Their operations, clientele, branches and/or business affiliates were contained yet well spread within the USA, and in some cases localized to a few states. Most of these firms, like large companies, were also active in several areas of construction ranging from contracting and consultancy to construction management. Some of these also catered to specialized services such as dispute avoidance and resolution, land development, homeland security, etc. Such firms made up close to 35% of all respondents.

Small companies exhibited a marked deviation from large and midsize companies and constituted anywhere from 20 to approximately 200 employees. They had very few (1–5) or no cross-functional departments and functioned as affiliates, support services such as HVAC or plumbing services, or special contracting firms in tandem with larger firms. Some of the firms in this category were independent contracting firms too. Their operations are totally localized with branches or business partners in a few cities at most. These are in most cases sole proprietorships or limited liability corporations involved in activities such as AEC consultancy, structural and transportation design, minor construction contracting and maintenance work, etc. These comprised around 24% of the respondents.

Contracting firms were classified as those that invested their own manpower, equipment, and other resources in the construction execution process. In other words, their primary function was that of general contracting on projects of various scales and all the other aspects might be controlled by the firms themselves or del-
egetated to its affiliates or partners. Most of the responses collected from such firms reveal that such firms are active in various aspects of construction projects as well, including construction and program management. Such firms amount to approximately 45% of the respondents.

The other category from the operational standpoint included companies whose primary area of activity embraced program or construction management. These are firms that principally cater to the project and/or construction engineering and management needs as affiliates of contracting companies. Their services range from, for example, exclusively design and architectural services to financial management and move on to encompass everything but actual construction execution. Such firms do not deploy their own resources toward execution. These firms include close to 55% of all respondents.

Descriptive Statistics and Trends

Queries in the survey had been designed to specifically address certain areas of organizational practices and to compare and analyze issues within. Some of these included:
- Internal communications, associated preferences, and barriers.
- Competitiveness and peer evaluation.
- Project management IT environment.
- PM applications, implementation, and preferences.

Cross-Functional and External Collaboration

Interdepartmental communication and collaboration with various stakeholders and partners is one of the key precursors for the recent spate in development and implementation of PM applications. Recent technologies in such applications are known to enable collaboration in all of its forms ranging from simple e-mails and telephonic conferences to real-time video conferencing as well as automated site level audio and video capturing using hand held or preinstalled electronic devices. Studying this aspect at a basic level was necessary to examine how project personnel belonging to different setups feel about it.

Asked to rate various modes of communications within their organizational and project network, respondents assigned the average rankings shown in Table 1.

E-mails were found to be the foremost means of communication followed by telephones and faxes. PDAs and intercoms are the least rated and collaborative software applications are midranked. Only one deviation is observed in the ratings allocated by different categories. This was the assignment of computer-based collaboration as one of the least preferred modes by small companies.

It must be noted that preferences still remain with time-tested conventional methods and the shift to other courses is lacking. Reasons for this could be that project personnel prefer tools that have been used through the years and are commonly accepted forms of communications. Large companies that are known to have invested heavily in PM applications do not rely on them for communication, but only for data storage and centralized information access.

Unexpected results in the midst of such analysis is that even though conventional tools are preferred and have been used through the years, communication has been rated as efficient and timely by only 35% of the respondents. As can be easily noted, between 30–40% respondents from all five categories have described their communication as highly efficient. On the other hand, close to 58% reflect that communications are redundant and inaccurate on occasions with moderate efficiency and that there is a need for improvement. Two percent of respondents (averaging a total 6% representation from small companies and 3% from contracting firms) believe that it is lacking and cumbersome. A comparative plot for these statistics is shown in Fig. 3.

There are two other noticeable aspects here. The first is the ratings from small companies. Generally compared with large and midsized companies, communications in small firms are more efficient and less redundant and inaccurate. This could logically be attributed to the lesser strength and departmentalization in small companies as compared to bigger firms, which justifies their inhibitions from investing in expensive collaborative tools.

Another aspect is the marked deviation of midsize companies in the moderate efficiency category. This could be because midsize companies, while undertaking high volume construction projects, affiliate with a lot more agencies toward integrated project control as compared to large companies that are well

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Fig. 3. Graphical comparison of communication efficiencies
equipped to absorb most task delegations within their parent firms. Comparative evaluation of other parameters in following sections allows us to better explain such discrepancies.

**Competitiveness and Peer Appraisal**

A critical factor that features in justifying the investments on PM applications and various other related issues like data security is the ambition to stay competitive in the market.

An associated aspect is also the implicit demand to match up to the tools, applications, and technologies that are being used by partner firms and affiliates. This is significant from the composite performance efficiency and compliance aspect of project planning, execution, and monitoring. When asked to rate their performance on projects being executed in various different locations relative to those being executed on home sites, most respondents from all categories rated these as equally successful.

Close to 20% of midsize contracting firms, however, rated projects being undertaken at external locations as more successful. A notable deviation is also seen in close to 40% of small companies rating of “not applicable” that is reflective of their operations being completely localized in one place. Then again, in cases where projects undertaken in different locations are concerned, the volume of work might be such that the difference in location does not seem to be affecting their performance efficiencies.

Efficiency assessment from the level and nature of collaboration purview was also done. Consider a large contracting company that is using certain applications that can receive, sort, process, and then retransmit information or data to their affiliates, for example, located on the jobsite toward a given decision.

The affiliates computing setup, however, is unable to receive or compile this information and present it in a comprehensible form. This would result in a bottleneck leading to loss of time and project progress. It is, therefore, mandated or at least recommended by top companies that their applications use applications that are compliant with other applications being used toward integrated management (Fig. 5).

The results show that more than 80% of the respondents from all categories rate the applications being used by their branches and affiliates as being equally good and compliant with their current computing and IT setups. This is indicative of the fact that penetration of PM applications, though unidirectional, is yielding uniform growth within the construction IT area.

Similar observations were also made when the respondents were asked to comment upon how the PM IT setups of their peers or partner firms affected their performance on projects, as shown in Fig. 6.

Close to 75% of large contracting firms seem to agree that PM applications and computing tools employed by their peers have a positive effect on project performance. Similar trends are noted for around 55% of midsize CM firms.

Approximately 34% of small companies, however, did not feel that they were affected by their peer’s PM tools with another 40% responding to “not applicable.” Only one sector, that of 5% midsize program management/CM firms or affiliates, feel that PM applications employed by their partners seem to have a negative effect on their performance. However, this does not stand out as a trend as the said observation has too low an occurrence and is very specific. No other category responded similarly. In general, the trends are indicative of positive affects on project performance.

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**Fig. 4.** Comparative ratings of project performance based on location

**Fig. 5.** Assessment of PM applications in peers and affiliate companies

**Fig. 6.** Impact of IT setup of peers and affiliates on project performance
Project Management and IT Work Environment

A study of the project management and IT work environment is needed since these factors are indicators of a company’s approach toward enhancements in project management practices through computing and technology implementation.

Very favorable responses were elicited when queries regarding the presence of an in-house IT department were made, as shown in Fig. 7. Except small companies, an average of 89% of all firms reported having their own IT divisions. Fifty-three percent of small companies also reported having IT setups. A caveat must be mentioned here. Not all IT departments have qualified professionals who can develop software applications to address the needs of specific projects or specific techniques that are used by their respective firms. It is quite possible that in many of the above cases, the IT departments that the participants refer to are mostly teams of computer installation and maintenance personnel.

It was noted from the questionnaire records that many companies do have IT divisions that create customized software applications for exclusive use by the company. In some cases, they may also be making small packages whose only functional value lies in creating communication protocols between different software packages. Altering a proprietary application cannot be done since it is illegal, and very few companies have the financial resources or the inclination to have customized applications developed for them.

Another critical factor that affects the PM application implementation is the time taken for such deployment. The average duration of such deployment ranges from a couple of months to more than a year, as shown in Fig. 8. This is because companies opt for a phased deployment process so that it does not affect their ongoing project or operations. This is clearly reflected in the fact that 50% of large and midsize contracting companies take nearly a year toward such efforts since deployment is slow and in parts.

Another observation here is the nearly 30% of companies responding to “not applicable.” This does not indicate that such deployment did not occur in their respective organizations, but that the participant in question did not experience such implementation.

Another crucial aspect of PM applications deployment and effective utilization arises from the executive training and development programs that companies practice. Purchase or implementation of such tools is futile if company professionals do not know how to use such applications or are ill at ease with them. The IT training trends of a company are, therefore, indicative of its advancement in this direction.

Responding to the training codes followed by their firms, approximately 30% of respondents reported being up to date and well trained, as shown in Fig. 9. Close to another 40% reported moderate and need-based training, which is also good.

It was also noted that close to 30% of all firms imparted training initially and then expected the employees to cope with further enhancements. Very few firms reported training being delegated to external agencies at personal expense or not being imparted by the hirer at all.

Responding to another query inquiring if they felt that such applications make PM tasks more agile and easy to perform, more than 50% felt positive about it. Varieties of comments were also received toward this query. These are reflective of the mixed feelings that the industry evinces toward advanced computing protocols and IT technologies research in general, with PM applications being an integral part of these.

Project Management Applications

Investigation of PM software applications currently being used by the industry was done to assess preferences and inclinations for different software and to determine the suitability of commercially available applications for various firms.
It is manifest that in most cases the industry deems regular applications inadequate to address PM concerns and demands of computing tools. Close to 85% of all respondents’ firms are noted to have opted for customization, even though the modes have been different. Approximately 50% of small companies are using off-the-shelf applications, the main cause for which can be safely attributed to lack of financial resources toward customizing the applications to meet their individual needs.

Almost half of all customizations are being carried out by the software vendors design team itself, which indicates that vendors are aware of the general preference of the industry toward customized tools. Moreover, this also forms a lucrative prospect for the vendors, since such modifications are done for a fee and are proprietary as well. This makes the vendor a very important participant in the entire computerization process since they contractually bind the construction companies for future upgrades and maintenance of data and hardware.

Noting that most firms opt for customized tools, it was imperative to understand and analyze reasons as to why such customization was done (Fig. 10).

Fig. 10. Types of software application enhancement by industry category

Queried about the levels of automation such tools possess, close to 50% of all participants reported that their tools were capable of automated data transfer and updating facilities. This sheds light on the fact that customization is done with the objective of minimizing data entry and reentry for various ends.

A 20% average response rate for single package integrated modular architecture for such applications is also indicative of the fact that construction companies are acknowledging the need for greater integration in their applications and realizing that it is an effective tool toward avoiding typographical errors and redundant information, thereby increasing efficiency, timeliness, and accuracy.

However, as mentioned earlier, this does not stand true for the entire industry since close to 30% of such applications still necessitate manual data entry and the updating and tracking of information.

**Discussion**

PM software applications, irrespective of the architecture or purpose that they are designed for, are for the most part extremely sophisticated databases with elaborate front-end tools.

A study of the deployment of some of these tools in the industry makes it evident that the reputation of delivering and having precedents of implementation and returns on investment by similar companies contribute largely toward the application selection criteria.

Applications that are relatively generic with lesser features as compared to large customizable tools are favored by the smaller companies. The foremost reason can safely be attributed to limited budgets. Another reason behind this could be that these applications are capable enough to fulfill most requirements demanded by their clients. The limitations of such applications can be overcome by using in-house software departments or hundreds of small software vendors who create packages to add interoperability between software.

Marketing strategies and business development practices employed by software vendors seem to play a decisive role in the considerations toward such selection. Even though all of these applications are networked databases and applications, none of the applications interact with external databases, as proposed by several research institutions, for any reason (such as regulatory compliances or vendor lists). One reason could be that there is very limited knowledge of such databases that are regulated by authorized agencies. In addition, security concerns associated with establishing communication with external sources of data might be barring such initiatives.

In cases of process improvement measures within an enterprise, it is the company’s corporate concerns that dictate the investments. Likewise, in decisions pertaining to the financial corpus that should be dispensed toward IT and software applications, the business needs and goals of the company seem to be the primary movers. Other factors follow and may or may not be related to such business targets.

**Conclusions**

The construction industry, like any other profit making enterprise, looks upon the entire computerization process as it perceives any other advanced technology. It should be sustainable and should yield returns. The approach of the industry does not seem to vary much with the company in question, its size, operations, etc. It is more an issue about whether or not the company can afford the
PM application setup. One probable reason could be that of the hundreds of such available applications, very few are from reliable vendors and of these few, most are extremely expensive to procure and maintain.

As mentioned earlier, most of these applications are high-end relational database management systems and do not have much data processing capabilities. With this view, certain futuristic toolsets (that were incidentally extremely low rated as observed through the survey) based on database features such as equipment management and materials flow and management could be incorporated without much difficulty. However, it is difficult to gauge the complexity of incorporating tools based on algorithmic data processing capabilities such as simulations and optimization. It is all the more difficult to customize such tools, thereby making them very expensive. Before moving into the developmental phases of such modules, it is imperative to understand whether or not these tools shall be sustainable from the business point of view. The industry on its part does not seem to doubt the capabilities of these modules at all.

Considering another aspect of futuristic toolsets for PM applications, such as centrally regulated vendor or subcontractor databases, it was observed that most companies prefer to work with parties that they already have a successful work history with and shift to another party solely for commercial purposes does not reflect business ethics within current construction industry practices. If need be, the companies might try to improve their existing project management protocols with all concerned parties and attempt to bring subsidiaries and affiliates to their performance levels.

Such facilitations or informational databases might, however, be helpful to new companies that are in the process of finding project affiliates or business partners but the likelihood of their affecting the way most established companies do business is quite low. Established companies, at best, might use it to gauge the competition in the industry.

**Recommendation**

The above-mentioned observations make it necessary to look into the business aspects of technological innovations that are being planned. Creating IT environments that are extremely advanced but are not synchronized with the currency of the situation might not be accepted very well by the industry. Technological enhancements that pertain to various industrial sectors should first cater to what is most needed rather than attempting to realize futuristic computing solutions.

**References**