ARCHITECTING PROJECT MANAGEMENT

for Enterprise Agility

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Click and Mortar: Perspectives on Leveraging Technology for Agility in Construction

Leverage of Technology for Enterprise Agility

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ABSTRACT

The architecture, engineering and construction (AEC) industry remains a cornerstone of modern economies, especially in the developing world. Unlike other industries which have seen continuous improvements in productivity, AEC has been relatively stagnant for decades. While there have been significant increases in efficiency in pockets thanks to automation, mechanization and other technological interventions, these benefits have not translated into overall improvement in project delivery.

To resolve this paradox, while technology remains a key enabler, it is necessary to rethink the way in which technology is put to use in project management. The public impression of the average construction project, not surprisingly, is of a somewhat bumbling enterprise that lurches to a delayed conclusion in fits and starts. We propose a framework that seeks to remedy this and enable agility and nimbleness in project delivery.

We discuss the unique industry characteristics from the perspective of project management and highlight the key factors that exacerbate the problem. We describe a framework for thinking about projects in terms of construction information supply chains. While technologies including sensor-based data collection, image recognition, IoT etc. are discussed, we describe a project-centric technological backbone into which stakeholders can plug into. While the immediate tangible benefits in terms of improved visibility and real-time decision-making support for individual stakeholders are enumerated, we elucidate how such a framework would transform project management as a whole.

We conclude with case studies where such frameworks have been undertaken, and discuss the challenges faced and results observed thus far.

INTRODUCTION

The architecture, engineering and construction (AEC) industry forms a significant fraction of economies globally as far as GDP and employment are concerned. Given the infrastructure deficit in large parts of the world, the industry has played and will play a vital role in the growth trajectory of these regions.

Given AEC's significance, it comes as somewhat of a surprise that it has not seen the advances in productivity and output that we associate with other sectors such as manufacturing. Studies have shown that construction productivity has been relatively stagnant. This leads us to surmise that the root cause of the lack of improvement in productivity lies outside the building technology domain and in the domain of project management and delivery.

In this paper, we first outline the paradox in construction productivity. We then discuss the unique characteristics of the AEC industry and identify the key factors which differentiate it. We review how the notion of supply chain management (SCM) may be applied to AEC projects via the concept of construction SCM (CSCM). The characteristics of AEC projects which make them sluggish are described.

Extending this to the realm of information management, we propose a project-centric information and communication technology (ICT) backbone which should be easy to create, easy to configure and easy to dismantle. We discuss the candidate technologies that would be plugged into this backbone, and how such a framework would operate and help enhance agility.

We conclude with case studies where such frameworks have been implemented and the learnings from them.

DETAILS OF THE PAPER

Industry Overview

In the United States (US), construction contributed 4.2% to GDP [3], a number that has been growing steadily since 2010, when the recovery from the global financial crisis of 2008 kicked in [16]. In the United Kingdom (UK), the contribution of construction to the economy in 2014 was GBP 103 billion or 6.5% of the total. It also contributed 6.2% to employment [13]. The scenario is not very different in the developing world. Among the large growing economies, construction constituted 7.2% of China's GDP in the Jan-Mar quarter of 2016 [17] and continues to play a major role in that economy. In India, the sector has contributed about 8% to GDP [7] over the period 2006-07 to 2010-11, with a growth rate of about 8.1%.

The Productivity Paradox

It therefore comes as a surprise that although construction is the bulwark of the modern world, it has not seen significant gains in productivity and output over time. The available data suggests that productivity has remained flat or even decreased with time. This is in contrast to other industries such as manufacturing and software/IT.

One study [15] which reviewed total factor productivity (TFP) growth in the US economy from 1870 across various sectors has illuminating results. The economy is classified into the following sectors: Durables, Transportation, Construction, Finance, Nondurables, Mining, Government, and Other (which includes the service economy). The results (pp 16) show that since 1950, while the "Share of Hours Worked" has reduced across the "old economy" (Durables, Nondurables, Transportation, Mining) and expectedly increased in "newer" sectors (Finance, Others), it has actually held steady and indeed marginally increased in Construction. The next result (pp 16) i.e. "Real Value Added per Hour Worked" is starker. It clearly shows how Construction is the only sector in which value added actually drops and trends continuously downwards since around 1990.

A 2002 article [4] which compares 50 years of labour productivity in US and foreign manufacturing finds that while there are variations between the US and other advanced economies, the overall trend is one of productivity growth in manufacturing in the advanced economies between 1950 and 2000.

When it comes to AEC, the trend and outlook are more problematic. A 2012 paper [5] cites (pp 1) a well-known and oft-quoted study which states that while nonfarm business productivity more than doubled between 1964 and 2004, construction productivity remained almost stagnant.

It should be noted that there are other studies [11] which raise issues with respect to how construction productivity is measured and find that productivity metrics are sensitive to the methodology used. While a complete review of the available literature is not in the scope of this study, it may not be overstatement to say that the preponderance of the available studies find that construction productivity growth remains disappointing.

While on the one hand there is the well attested lack of productivity increases, on the other hand we have evidence of significant improvements in construction technology and methods. In the field this includes better and more specialized equipment, as well as mechanization and automation. At a broader level, workforces are increasingly more skilled and better-educated, and custom ICT tools for the various specializations in the AEC industry are available. These advances undoubtedly make the AEC professional's job in and off the field easier.

The two themes touched upon above therefore beg the question: why are overall productivity and output not keeping pace with the improvements in technology and techniques? This is the paradox of AEC project management.

Industry Characteristics

In today's industrialized and globalized scenario, virtually every industry is characterized by complexity and change. For example, manufacturing and software are both industries which undertake large scale, complicated ventures. However, as we have seen, these sectors seem to be more effective in improving their output over time.

In order to model complex undertakings, the conceptual framework of SCM may be useful. A serviceable definition [10] of the supply chain is as follows (pp 133):

"An association of customers and suppliers who, working together yet in their own best interests, buy, convert, distribute and sell goods and services among themselves resulting in the creation of a specific end product."

This adequately covers all aspects of various major industry categories and captures all the major elements. Figure 1 contains a pictorial representation of a sample construction supply chain.

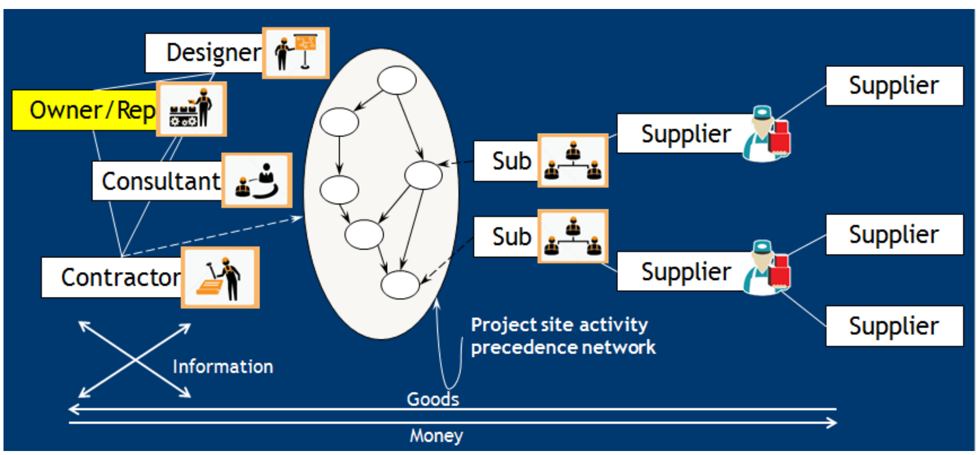

Figure 1: Construction Supply Chain

While SCM in the context of manufacturing has been well studied, the concept of construction SCM has been in vogue since the early 1990s [1]. In a 2009 study, the authors summarize (pp 2-9) the differences between manufacturing and construction supply chains (CSC). The summary is that in manufacturing there is better integration across the supply chain, long term relationships are the norm, and high levels of technology adoption and automation.

The overarching feature of the AEC industry which differentiates it from manufacturing is the "ephemeral" nature of the enterprise. In the case of an AEC project,

- A large number of stakeholders need to come together for a relatively short duration
- Stakeholders need to deal with relatively large uncertainties in terms of each other's performance, as well as in terms of the larger economic and industrial environment (changing prices, statutory changes etc.)
- Stakeholders need to be extremely collaborative in the short term, and yet have to simultaneously prioritize their own needs and interests, being aware that they may not work with the same client or partners in the next project, leading to conflicting objectives
- Levels of automation and technology adoption are comparatively low, and even within a single project the level of technology maturity can vary significantly

These factors lead to the "fragmented" and consequently non-agile nature of AEC projects.

Agile Project Management in AEC

The notion of agile project management (APM) itself came to prominence in the software industry in 2001 via the Agile Manifesto [2], although the possibility of a non-sequential (i.e. "waterfall") approach to project management was first proposed in 1970 [14]. Since then, attempts have been made to study and apply the concept in other domains including in construction. One study [12] finds that APM has significant applicability in predesign and design stages of a project, while it may be of limited use during the construction phase.

APM embraces change as an opportunity for improvement, and enjoins stakeholders to be prepared for a changing and fluctuating environment. The traditional goal of project management in AEC has been the opposite i.e. the minimization of change and fluctuation in any given stage of the project. The reality of project execution on the ground, in all its phases, is one of a constantly changing landscape. In the case of AEC, these changes can happen anywhere in the supply chain. The APM approach for dealing with these inevitable changes include the following:

- Multi-directional information flow between all stakeholders [12 pp 55]
- *"Dense communications to create innovative solutions through swarm intelligence"* [12 pp 55]
- *"APM relies on a flatter, team-based structure rather than traditional close, hierarchical management. The removal of tiered management effectively removes communications protocol overheads, as well as reducing unnecessary systems noise and the probability of compounding errors."* [12 pp 55]

- *"It is advisable to organize through an empowered team any large and complex pre-design effort, with frequent mutual communication. Hierarchical decision making has been found to cause problems"* [12 pp 61]

Agile projects and organizations are both able to *predict* or *forecast* potential issues that may impact the project, and *respond quickly* to the changes in the environment. Such projects are not just *reactive* (conventional behavior) but *real-time reactive* and also *proactive*.

Construction Information Supply Chains

For a CSC to be real-time reactive and proactive, a necessary condition is that all the actors in the eco-system have information at hand that is both accurate in real-time and also predictive. The flow of this information through a supply chain is in some ways analogous to the flow of goods and materials, and in a well-coordinated and smoothly operated supply chain, the information flows seamlessly through. However, thanks to the fragmented nature of the AEC supply chain, the information is also *silo-ed* within and between stakeholders and the flow suffers from barriers, particularly at organizational boundaries. Figure 2 illustrates this fragmentation and silo-ing of information.

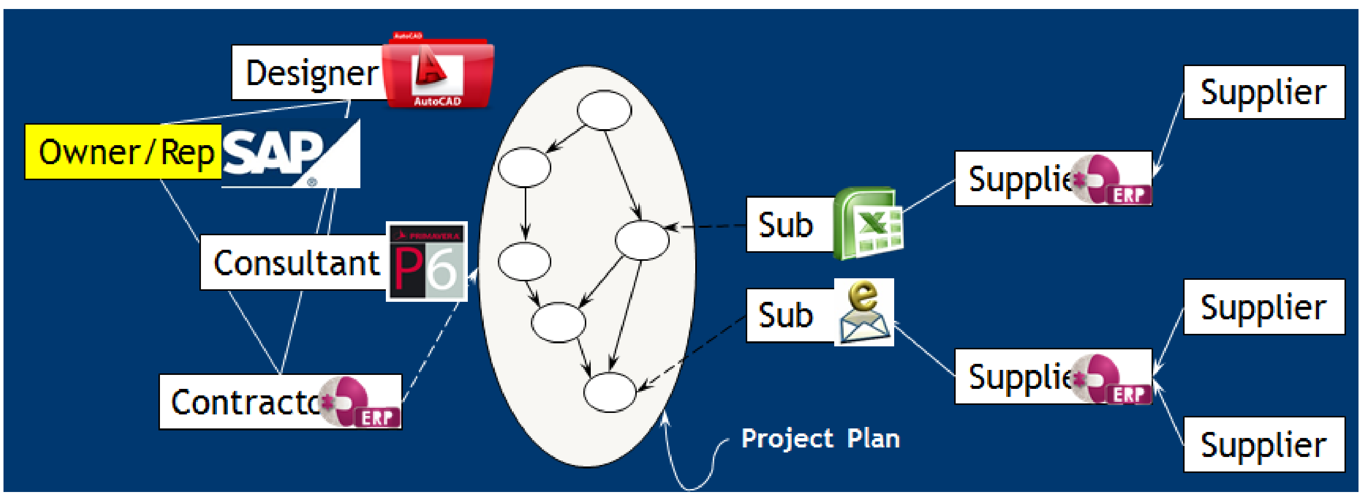

Figure 2: Technology and Information Silos

The need to break from this state of affairs and attain seamless, real-time information flow, without compromising the security and privacy needs is felt not just in academia, but also by industry practitioners:

"The scale and complexity of today's projects call for swift coordination and real-time reporting. A fully integrated PMIS can keep key stakeholders informed of schedule and cost status, and help enable faster decision-making to keep projects on track… 82% of respondents expect greater owner/contractor collaboration over the next 5 years." [6]

"...in-depth interviews with highly collaborative contractors reveal that there is no tool that allows them to share data effectively both internally and externally...Better tools are needed that allow more intensive data-sharing within and beyond individual firms..." [8]

To summarize:

- Construction productivity seems to have remained stagnant in spite of improvements in specific construction. This suggests that there are factors such as project management beyond the trade productivities that impact delivery.
- To bring agility into project management, one pre-requisite is the availability of predictive information and insights in real-time.
- One challenge to achieving this is that AEC projects are ephemeral; a number of stakeholders with competing objectives come together as a virtual organization for a relatively brief period of time to bring the project to fruition. The industry is not very well incentivized for long term collaborative arrangements.
- Projects are also characterized by fragmentation of the stakeholders' data and silo-ing of information, with poor information sharing within organizations and across inter-organizational boundaries.

We propose a technology backbone framework that addresses these concerns and enables collaboration in the AEC industry.

A New Approach to Information Management in AEC

In order to meet these needs and challenges, it is imperative to put in place a technology backbone which has the following characteristics.

Plug and Play

Since the stakeholders use disparate specialized applications, the backbone should support "plug and play" of various third party systems into it without needing customization or software development. For example, it should

- Be able to extract schedule data from and update into various systems such as Microsoft Project
- Support out-of-the-box interaction with enterprise resource planning (ERP) systems
- Be able to read and write from document management systems (DMS) seamlessly
- Serve the needs of the smaller stakeholders who may not have access to sophisticated systems by supporting ubiquitous formats such as Microsoft Excel
- Integrate with building information management (BIM) systems, which are fast becoming the norm, especially in complex projects

Last Mile

The ability to capture the "last mile" data with minimal human intervention for data entry/massaging is critical to achieve true agility. In our experience, adding a layer of human data processing in between the field where all the "action" happens, and the ICT system is one of the major causes of poor ICT adoption in AEC.

By "last mile" data, we refer not only to the construction site itself, but also other "last mile" source points of data. For example, a draughtsman in an architect's office is a small but vital cog in the wheel. His ability to be able to seamlessly communicate his progress on his task and to ask for and receive inputs is vital for downstream activities such as budgeting and execution. Ideally, the system should allow the receiving and sending of inputs when on-the-go via mobile and handheld devices.

The backbone should also be designed such that it leverages the latest advances in field data capture technologies such as biometric scanning, bar/QR code scanning, drone data, and other Internet of Things (IoT) systems. Being able to plug such systems into the backbone greatly enhances the ability to meet the goal of keeping the data current.

Predictive Decision Support and Analytics

While having the latest data at one's fingertips is necessary and desirable, it is not sufficient in three respects:

- Having data about the past is useful, but where it can be taken to the next level is if the data can be used predictively. For example, let us say our draftsman reports that he is going to be delayed by a few days in delivering a set of drawings. While this is useful, its usefulness multiplies manifold if this information can be used to provide insight into what it means for downstream milestones. The system should be able to project the impact into the future, and notify stakeholders and management about potential slippages.
- The data should be analyzed and presented in such a way that management can use it to take decisions based on the data, rather than merely be able to view it. The system should highlight areas where intervention by the decision maker is needed and can have the greatest impact.
- Analytics is increasingly being adopted as a tool to transform business performance. In AEC, data such as punctuality of stakeholders, reliability and quality of their deliverables, productivity of their resources etc. constitute a treasure trove which may be exploited to identify high performers and perhaps prioritize relationships with them in future projects.

Social

The system needs to be a "social" system by which we mean that it should provide a place where different actors in the ecosystem can come together and interact with each other seamlessly. For example, a subcontractor punching progress or lack thereof into his app may result in the data and analyses flowing upstream through the CSC all the way to the client's organization, where someone in management may take some action which further results in processing downstream by other actors. In this way, disparate actors can collaborate on the same framework. Needless to say, this sharing has to respect the boundaries of data confidentiality and security and the system should be designed such that the ownership and modifiability can be controlled via role based access control (RBAC).

Case Studies

In this section we present the findings from implementing a system similar to the one proposed here in two real life projects. The system used [9] is a proprietary technology which integrates various aspects of AEC project management such as schedule tracking, bill of quantities (BOQ), document management, issues and risk management, material management and resource productivity tracking. It comes with a native mobile application.

The two projects in question where the tool has been used for over a year are the following.

Project A

Project A is a large commercial real estate space in an Indian metro. The client has mandated that the contractor, project management consultant (PMC) and other stakeholders use the tool for information management. Each stakeholder accesses and updates their own data, while the client gets an integrated view of the project. The tool has been used since about January 2015. During this time, work has been proceeding at a steady pace, initially under the heading of civil works and lately in interiors and finishing. It should be noted that on this project, almost all the activities fall squarely in the construction phase.

Project B

Project B is a medium sized factory being constructed in the UAE. The client uses the tool for internal collaboration between their team members and uses the reports and intelligence generated by the system to monitor the project's progress. It has been used since about April 2015. This project has gone through a longer lifecycle. During the first few months (April – Oct 2015), the focus was on procurement activities, since it is a factory with dozens of specialized equipment which needs to be ordered from around the world. The focus since then has been on construction, installation and commissioning of equipment.

These particular projects were chosen because of the good adoption of the technology and sustained use over an extended period of time. Within these projects, we have focused on the usage of one module (i.e. issue and risk management) since it is the most heavily used feature and also most used for collaboration.

In both cases, the following data was recorded and calculated.

- *Planned Duration*: The *Planned Duration* of an issue is the duration needed to close out the issue as estimated at the time of issue creation

- *Actual Duration*: The *Actual Duration* of an issue is the actual time taken to close it i.e. the duration elapsed from the time when it was created to the time when it was closed

The technology not only records these temporal data points, but also sends periodic reminders to the assignees about their due dates. Also, when an assignee needs an input from some other stakeholder, they use the system to collaborate in real time. The trends in *Planned Duration* and *Actual Duration* for both projects are presented in Figure 3 below.

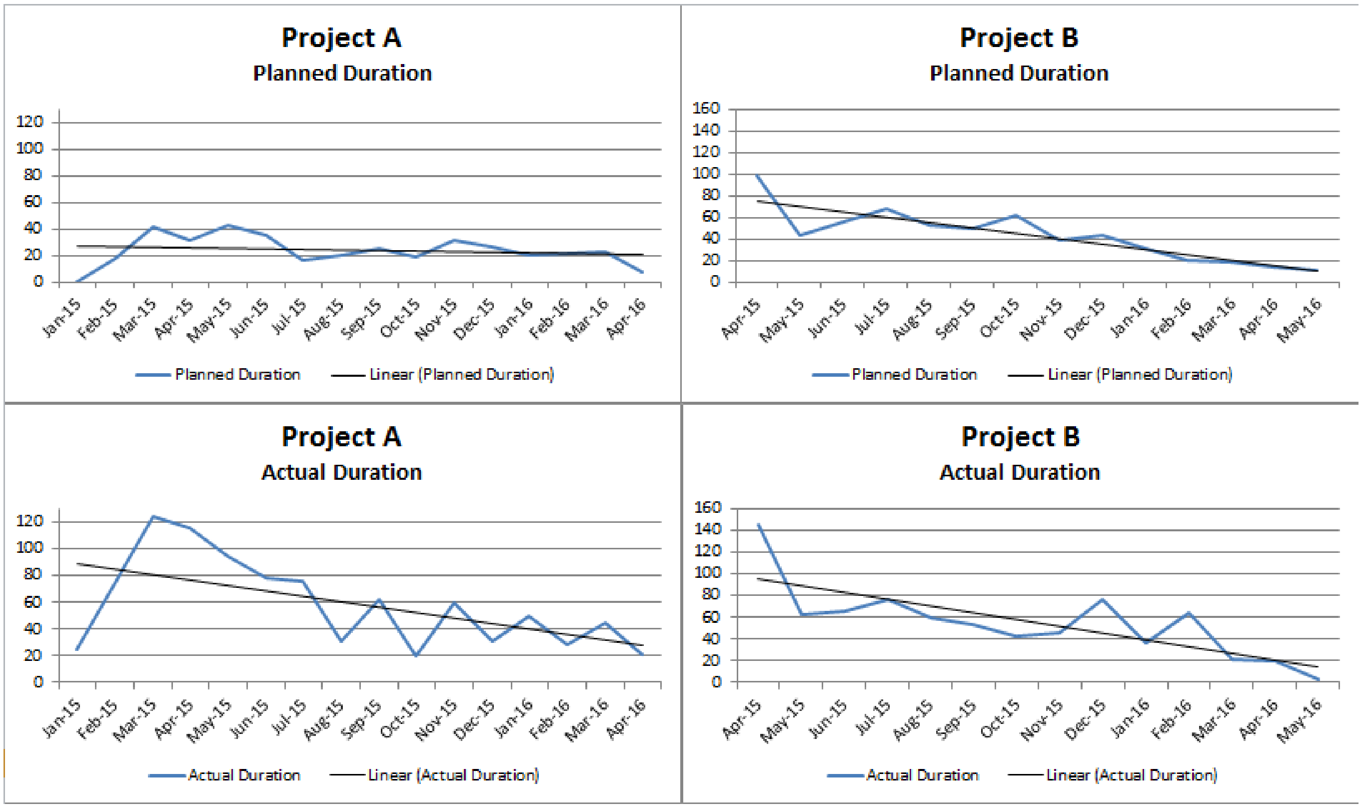

Figure 3: Planned vs Actual Duration for Project A and Project B

In Project A, we observe that the average *Planned Duration* holds relatively steady over time. In contrast, the average *Actual Duration* shows a distinct downward trend. This suggests that as the tool usage and adoption grows, the time to closure and/or punctuality is improving, as one would expect. In Project B, both the *Planned Duration* and *Actual Duration* trends are downward from the beginning, with the improvement in *Actual Duration* outstripping the *Planned Duration* indicating that the same factors may be responsible. The fact that *both* are trending downwards is consistent with the expectation that the procurement phase of the project involved more complex procurement tasks with longer durations, whereas later phases are relatively straightforward execution related. Anecdotal evidence indicates that unlike in India, once the statutory approvals are obtained and the material is on site, the construction/erection phases of projects typically proceeds smoothly without hindrances and this is perhaps reflected in the data.

The tool allows users to classify issues into High, Medium and Low priority issues. High priority issues are typical critical issues which involve complex paths to resolution. We measured the *Planned Duration* and *Actual Duration* metrics for High priority issues as well, and these results are shown below.

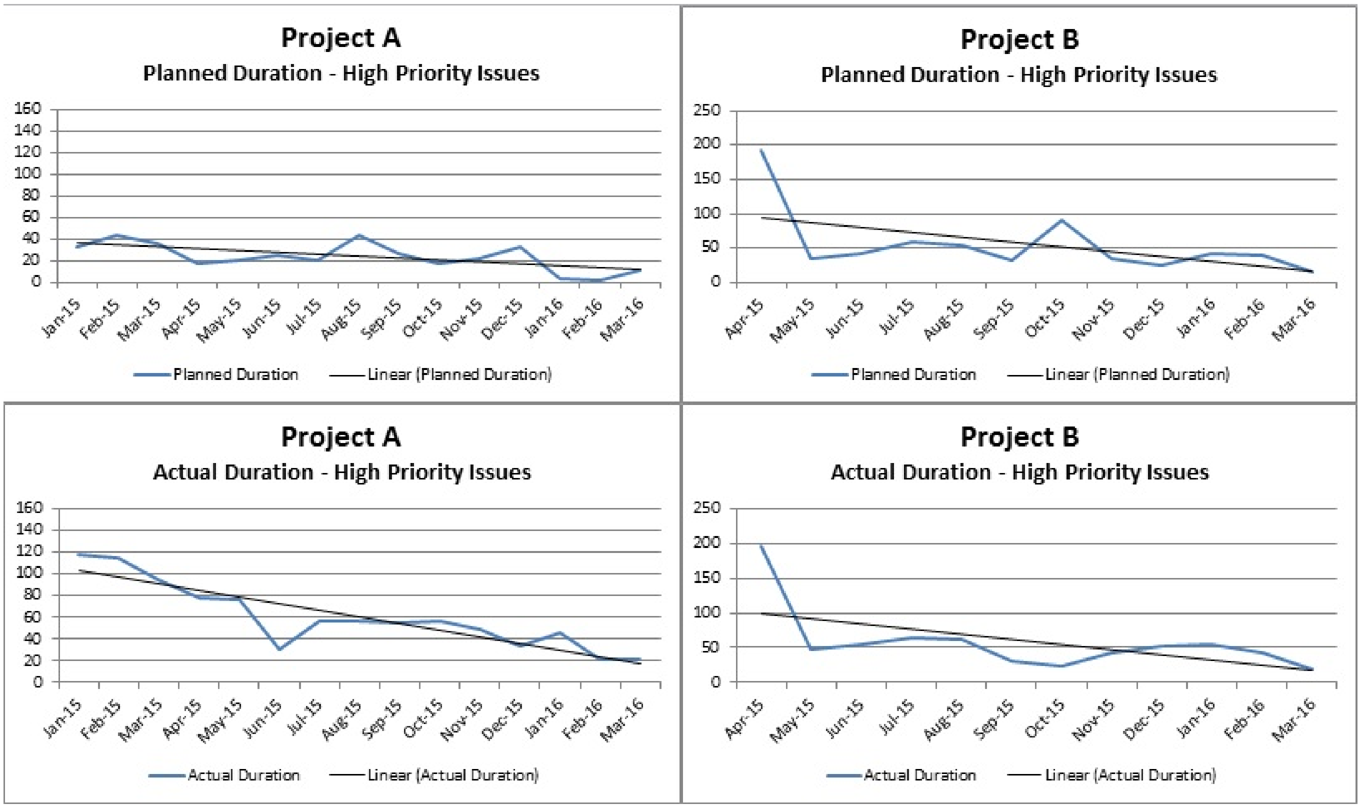

Figure 4: Planned vs Actual Duration for Project A and Project B for High Priority Issues

Here we observe that the gains are in fact greater than in the case of all issues i.e. the drop in *Actual Duration* is perceptibly steeper for Project A, and somewhat less so for Project B. This suggests that the benefits of using an information management similar to the one posited in the previous section may accrue to a greater degree when more critical areas are addressed, which is encouraging.

CONCLUSION

We have examined the unique characteristics of the AEC industry which pose a challenge to achieving agility in project management. Based on the needs of this industry, we then proposed a technology backbone or framework which is flexible and comprehensively addresses the lacunae in this sector. Finally, we examined real-life cases where such a backbone has been implemented in AEC projects in a limited way.

While these preliminary analyses suggest the value of adopting collaborative ICT frameworks and indicates that this is a promising line of enquiry, a more detailed study of the collaborative aspects of these tools may be carried out for better understanding and evaluation of the benefits (if any) realized by adopting the technology framework proposed here.

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