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Review

Web-enabled project management: an emerging paradigm in construction

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Abstract

The paper addresses the emerging paradigm of performing project management over the web. It describes the pitfalls in current project management practices amidst the challenges they have to face due to increasing project complexities.

At present, the government, industry and clients are all seeking to bring about change in the construction industry to improve quality, competitiveness and profitability and increase value to clients. The findings of this report will highlight how web-enabled project management and its associated features are strongly linked at fulfilling the above endeavours of the parties concerned. However, it emphasises that in order to successfully embrace web-enabled project management equal consideration should be given to technology, processes and people.

Keywords: The Internet; Web-enabled project management; Business benefits; Project management

1. Introduction

"Project management" and "projects" are not new concepts. Throughout history, vast projects of different magnitudes have been undertaken successfully across generations. Project management first emerged in the early 1950s on large defence projects [43] and gradually smaller organisations took to adapting the idea, and currently, the smallest construction firms are known to operate project management in some form. A great deal of project management involves avoiding problems, tackling new ground, managing a group of people and trying to achieve very clear objectives quickly and efficiently [44].

Considering a generic project, its status changes from that of an idea or a concept through to feasibility studies, execution and finally completion [43]. But projects today are far more complicated than ever before. They involve larger capital investments, embraces several disciplines, widely dispersed project participants, tighter schedules, stringent quality standards, etc. These factors coupled with high-speed developments in Information and Communication Technology (ICT) have influenced project management practices to take a new turn taking advantage of newly developed management tools and the latest technology.

This paper briefly sets out the evolution of project management, the challenges and problems facing the current project management practices. It then discusses the impact of the latest advances in technology on project management and the emerging paradigm of performing project management over the web. Fur-

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ther, the report presents a number of case studies to demonstrate the merits of using the Internet for project management followed by the analysis and the way forward.

2. Challenges facing project management

The government, industry and clients are all seeking to bring about change in the construction industry to improve quality, competitiveness and profitability and to increase value to clients. Implementation is carried out through initiatives such as the Construction Task Force [9], the Government Construction Clients Panel (GCCP), the activities of the Construction Industry Board (CIB), the Construction Clients Forum (CCF) and other CIB umbrella organisations. These initiatives are seeking to secure a culture of cooperation, teamwork and continuous improvement in the performance of the industry. Where the emphasis has traditionally been on the need to manage the interface between the project and the client's organisation, it is now shifting towards the need to manage the flow of activities through the whole life cycle of the project, concentrating on those activities that actually add value.

The Egan report stresses the need for project managers to integrate projects' phases (from conception to final delivery) leading to performance improvement, and for designers to develop greater understanding of how they can contribute value in the project process and the supply chain. This pace of change is introducing new climate, which have highlighted the limitation of the current project management practices in meeting the new requirements.

The changing construction environment is also influenced by other factors, which are interrelated and interdependent. Examples of such factors are:

1. Globalisation of the marketplace; many industries are facing a lot of pressure due to this factor. Tariff barriers are virtually falling and labour has become more mobile. Further, due to productivity improvements and advantages in economies of scale, some foreign firms are capable of competing with local firms on price, quality and delivery.
2. The economical forces; this factor may significantly affect the client organisation and subsequently can impact the initial objectives of their projects.
3. Increases in project complexity; project complexity has increased due to extent of scope and fragmented parties around the world having to communicate with one another for efficient project execution. The complexity of the projects is reflected by the large number of specialists who contribute to the decision-making process.
4. The need to achieve faster results with the given resources; this factor places severe time pressures on the entire project team.
5. Rapid changes to project scope to expand benefits; some scope changes take place very rapidly before even realising the benefits of the changes [41].
6. New procurement practices; the emergence of new procurement practices changes the way the team members are interrelated. For example, procurement schemes such as Private Finance Initiative (PFI) and partnering have impacted construction project management [10]. Such schemes bring the government and the private sector firms together in large-scale infrastructure projects in which very high quality standards, tight schedules and cost targets are aimed at. With the government's greater involvement in standardising contractual procedures for PFI schemes, the commitments of all parties have become clearer and more visible.
7. Client sophistication; this has become a major driver for productivity improvements in construction. Clients demand higher quality end products and services at lower price. This has created a buyers market whereby firms compete for projects at lower margins and hence demand better project management practices to enforce tighter control on the projects activities.

3. Limitations of the current project management practices

In facing up to the above challenges, the current project management practices have many limitations to efficiently deal with these demands. These lim-

itations can be categorised into the following groups.

3.1. Lack of adequate communication

Current project management practices are often isolated and are concerned with managing problems related to individual stages of the projects. The following examples are caused by such a problem.

3.1.1. Additional expenditure due to reworking

Problems of reworking occur due to conflicting information and information not received in time to the parties concerned. The main cause is the lack of consistency in the flow of information between the different parties involved in the construction project. According to Built Environment and Transport Panel [7], up to 30% of construction rework (an approximate proportion of the total volume of construction activity in UK) is attributable to process-related problems.

For example, architects/clients make changes to designs quite frequently and they do not effectively communicate these changes to the contractors and subcontractors in time for them to be implemented efficiently, resulting in rework. This imposes a lot of strain on the client's budget. Rework in this fashion predominates most of the construction sites.

3.1.2. Lack of integration within the supply chain

The current ordering, purchasing and invoicing practices have a lot of shortcomings in terms of delays in supplies being received, less collaboration with manufacturers and suppliers and low integration of purchasing with accounts software.

For example, many delays result out of implementing current material procurement systems, which do not integrate well with project plans and schedules. The lack of a fully integrated procurement system tends to impact on stock control policies (e.g. carrying a high quantity of stock) of construction firms due to the inability to make accurate predictions of resource requirements for the project. The main reason for this is the poor communication and coordination among the supply chain partners and the overall lack of an integrated system to cater to this need.

3.2. The introduction of automation into management practices

In the 1990s, there have been significant developments in technology, which have resulted in the production of very powerful software packages for the construction industry. The "ad hoc" deployment of such packages have resulted in improvements at their local level of implementation, such as planning, estimating, design, etc, but have added limited benefits at the project level. The following examples are caused by such a problem.

3.2.1. Electronic communication versus culture

Although many construction organisations are using IT to improve specific processes/applications, the construction industry still traditionally holds the view of issuing hard copy documentation as against electronic forms for auditing and record purposes. Deng et al. [8, p. 241] show how communication in the construction industry is complicated by its structural problems.

> When drawings are amended, the revised drawings or instructions need to be in hard copy form confirmed with the architect's chop or signature and the receipt of the drawings be acknowledged by the contractors in writing. Therefore sending these documents electronically cannot complete these endorsement procedures.

The mixing of electronic and hard copies in organisations make it difficult for project managers to process the right information as and when required.

3.2.2. Lack of software integration

A high percentage of the IT system solutions (software) that are available today focus on specific tasks such as project planning and monitoring, estimating, design, etc. These isolated applications have resulted in a broad spread of stand-alone applications packages with no or "fixed" communication links. The industry lacks an integrated comprehensive system, which facilitates the smooth flow of information between the various stages of the project [1,3].

3.2.3. Lack of a standardised platform for information exchange

The incompatibility between hardware and software, mentioned earlier, have raised a serious "technical" problem, which have prevented project managers to easily access and manage project information. These problems are caused by the lack of standardisation of project information that can facilitate the flow of information between incompatible hardware and software. Therefore, IT systems that are available and currently used by the industry do not consider the needs of widely dispersed participants in large construction projects [47].

3.2.4. Lack of proper decision-making tools for project planning

Planning is a lengthy process and needs contributions from the entire project team. It is also context dependent. This process can be significantly improved if appropriate decision-making tools are incorporated into their structure. Comprehensive systems have not yet been developed in this direction.

3.3. Lack of standard processes for project management

Projects are normally managed according to the experience of the project managers who are specifically appointed for this task. Each project manager, even within the same organisation, prefers to follow his/her own experience, which has been developed over a long period of time. These practices lead to large variations in management practices and thus can create a significant impact on the capability of coordinating and controlling project information [39].

4. The influence of the Internet and the business models on project management

The advent of various new technologies, with the potential to address some of the limitations facing current project management practices, has created a major impact on many organisations. Foremost of the new technologies is the Internet, which offers the platform for more effective communication. Many businesses throughout the world use this technology as a channel to communicate or to exchange information. The Internet has also embraced the construction industry that it could be used as an efficient tool for communication to bring together the widely dispersed project participants and multinational project teams. On the other hand, a few are under the impression that the Internet provides an automatic solution to the fractured communication system in construction, in that they adopt a "plug and play" attitude towards the use of the Internet, thus overemphasising the role of technology and ignoring other important processes that need to be taken into consideration in making the overall communication process more effective and efficient. Another reason for the Internet's popularity is driven by its influence on improving measures of business performance. Various business models have also evolved, which draws upon links between the use of the Internet to perform project management and to improving an organisation's internal processes in their road to achieving excellence. The next section addresses these two issues in detail.

4.1. Emphasis on communication and the Internet

4.1.1. Communication

Although new techniques of project management evolved, it took some time before people realised that communication plays a vital role in solving each of these problems. Scanlin [46] points out that communication consumes about 75–90% of a project manager's time and information therefore needs to be current and available on demand. He explains how the "Bell Atlantic project management centre of excellence" communicates standard processes, templates, tools; inform internal clients about training classes, internal video conferences and networking opportunities; share lessons learned and recognise outstanding performance through their website. Biggs [4] also lists communication as the root cause of most project failures. She notes that the latest web-based solutions which can be linked with email or collaborative software can reduce the incidence of people related issues and overall communication problems which lead to project failures. Deng et al. [8] point out that the extensive physical distance between project participants, extending over national boundaries is the main cause leading to delays in decision making. Wide communication problems ranging from delays to distortion of messages impose strains on project

management in construction. Further, the dismissive nature of expenditure on making long distance telephone calls, facsimile transmission, etc, have made the project management community in construction, look for more viable alternatives.

Gartner group [18] has identified that the highest level of interaction across organisations generally occurs between the middle level managers in an organisation. The middle level managers are thus known as "knowledge workers". The interactions between the knowledge workers who will be working with the available collaboration tools generate the highest potential Return on Investment (ROI) for the project. Their argument of the interactions at various levels is denoted in Fig. 1 below.

Although there are limited contacts between the top executives from time to time, it is the knowledge workers who collaborate more regularly on the day-to-day running of the project. Gartner group has found that most of the collaborative IT tools, such as emails and web tools etc., are widely being used by the knowledge workers.

As a result of this emphasis on communication, new technologies have been developed for networking, information sharing, database management systems, etc. However, in contrast to manufacturing and retail industries where most of the new developments have taken place, the overall construction industry has shown a relatively slow uptake of web technologies to improve its practices [5]. The situation is changing; however, as more and more firms in the construction industry started to realise the benefits of improving communications between the projects' participants which can lead to improved cost efficiency, better quality and competitive advantage.

4.1.2. The Internet

It is expected that the Internet will be of a great potential advantage to project managers over the next 5 years. The Internet provides speedy information transfer, so messages not only can reach the recipients more speedily and accurately, but also can be traceable. Besides, it saves money for construction companies in having to communicate with their overseas construction sites because the cost of providing and maintaining the Internet to construction sites costs less compared to couriering and IDD telephone usage. On the other hand, it makes a lot of sense in providing an Internet link between the firms due to the transfer of a very high volume of information across sites and the head office and between other firms. The Internet is a global network, which does not have restrictions on locations, time or different computer-operating systems.

Rapid evolution of communication technologies is making distributed projects increasingly viable [42]. The project participants could be widely dispersed yet coordinated by sophisticated tools. The increasing availability and the usage of the Internet by small to very large-scale construction organisations has enabled project management to be performed over the web.

There are many technological advances, which have enabled companies to adopt project management

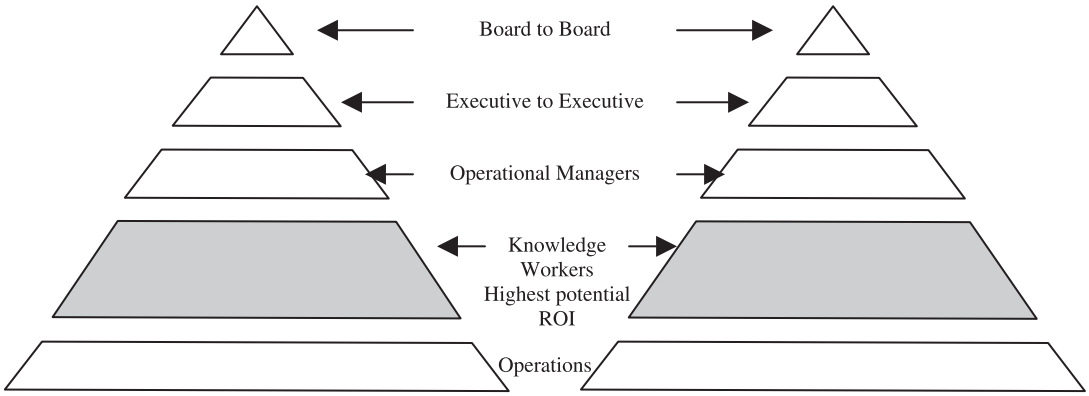

Fig. 1. Human interactions at various levels in two organisations.

over the web. Virtual meetings and tele- and audio-conferencing are such developments, which have been adopted by some of the project management software. Ellis [11] mentions that the technologies for teleconferencing in the past fell short of being fully effective as a result of the dismissive initial costs and transmission charges, but with today's availability of the Internet, higher CPU and modem speeds, it is possible to connect up boardroom to boardroom.

All parts of the project can become one community using teleconferencing and other collaborative tools. Tele- and audio-conferencing bring the widely dispersed project team together. For example, Takaneka of Japan [45] developed a technology that enables every participant of a project, even in distant locations, to work together by using the Internet as an information management platform. The project website (accessible through user ID and password), apart from having access to all project related information such as progress report, photographs, CAD data, minutes of meeting, etc., also had the facility of a virtual conference room where all project information is available.

4.2. Emphasis on business models

Another factor that has influenced project management to be performed over the web has been its link with business models. Scanlin [46] cites the worldwide evolutions of quality management programs such as ISO 9000 and the Malcolm Baldrige program in the United States as the main drivers for the growth of software use for project management. Some of the business excellence models such as the EFQM excellence model [13] explain how project management systems have been influenced.

Through a process of self-assessment against the EFQM excellence model, a project management performance could be measured. Eventually, the project manager can identify clearly its strengths and those areas in which improvements can be made. Performing project management over the web will improve a project's processes, contribute to a more focussed strategy for the project and motivate the project participants due to online collaboration and its benefits such as the ability to track project progress online, fast access to up-to-date information, increased dynamism of the project, etc. These improvements can be measured by a scoring method, which enables an organisation to perform a self-assessment exercise, by comparison with other organisations. At the heart of the EFQM, excellence model is the tool to perform the self-assessment exercise: RADAR, which stands for results, approach, deployment, assessment and review. RADAR achieves the self-assessment of new approaches such as web-based project management by the following stepwise approach [40]. The steps to be followed are:

1. determining the financial, operational and stakeholder perception results the organisation is aiming for with the use of the web-based software;
2. plan and develop a sound approach for achieving the proposed results;
3. deploy the approaches in a systematic way so that full investigation is achieved;
4. assess and review the approaches by undertaking regular measurement, which in turn promotes learning and leads to improvement activities where necessary.

Furthermore, Jackson [40] believes that the scope of the results needs to address the relevant areas of the organisation. This improves the overall score in the self-assessment exercise indicating an excellent organisation; hence, the use of the Internet for project management can become a major driver of performance.

5. Communications over the Internet: types and levels

The Internet's ability, as a technology, to bring the diverse participants of a construction project in an effective collaborative environment is constrained, i.e. the Internet alone cannot create an environment of interoperability among the various participants [2]. This is mainly attributed to the type and format of the exchanged data/documents as well as to the different hardware and software systems in organisations. This section addresses this issue with the aim of clarifying the types and levels of data exchange, which are required for effective project management.

Data exchange can be defined as the process of transferring relevant/common information between

different construction parties in order to meet the project's objectives and to minimise data re-entry and duplication. Data exchange can take place across several organisations, construction applications and/or professionals. Normally, these applications are implemented to improve very specific applications such as design, estimating, planning, etc. Therefore, each department has its own hardware and software and in many cases are incompatible with each other.

5.1. Data exchange across applications/organisations/industry

During the design stage, for example, drawings need to be exchanged between designers to fulfil the client's objectives. Such drawings are either exchanged via printouts, in which case they have to be re-drawn, or via a disk/network if the design applications are compatible or can read a standard data format such as DXF. This type of data exchange we refer to as organisation data exchange. When designers alter the design drawing due to changing client requirements, these alterations might have a direct impact on other members of the team within the same organisation, in which case they have to be informed. If this is not carried out in a professional manner, it might have devastating consequences. This type of data exchange is referred to as application data exchange. At the tender stage, the design practice dispatches the tender to contractors and possibly to the client. This process can be carried out either via disk/networks if the systems are compatible, which is seldom the case, or via special communication standards, such as Electronic Data Interchange (EDI), which enable all applications to be read in any format. This type of data exchange is referred to as industry data exchange.

5.2. Types of data exchange

The type of information, which can be exchanged between applications, can be categorised into two groups; the element/object and the document groups. Information transferred at the element or object level is normally detailed and can impact the outcome of the application. For example, information about a beam or a column can be exchanged between two design packages. Any changes to this type of information will automatically impact the other information, which exist in the other application, while information transferred at a document level is normally considered as an image, which can only be viewed, shared and annotated by users.

Exchanging information at the element or object level is far more difficult to manage compared to exchanging information at the document level. The former needs compatible hardware and software where information can be read and freely transferred between the applications. Or it requires common standards, which enable information to be transferred freely between applications, such as the industry foundation classes (IFC). The document level, on the other hand, can use standards such as the Internet to transfer documents as attachments to a web-based application. All existing web-based project management software is based on exchanging and sharing documents. Information is exchanged as documents, which can be stored in a single database, whereby users can view, track and manipulate as and when required.

Currently, there are many commercially available software to cater for different types of document-based data exchange; they all come under the umbrella of web-based project management. These software cater for the application needs of the different stages of the project life cycle, i.e. the tender stage (where tender documents are exchanged between clients, contractors, subcontractors, etc.), and the design and construction stages, (where drawings and other documents are exchanged between project partners), and the construction stage (where buying and selling of building materials take place over the Internet).

6. The stages in which web-enabled project management software is used

This section briefly explains the main features of the currently available web-based software, which comes under the umbrella of web-enabled project management tools. They are discussed according to their use at different stages of the project life cycle.

6.1. Tender stage

The main functions of this type of software are to advertise and distribute tender documents, select suc-

cessful tenderers and award contracts. Software used in the stage can:

- speed up the distribution of documentation and tenderers' communications;
- register tenderers online and download tenders/work packages electronically;
- provide a simple environment to evaluate the tenderers' responses through standard templates;
- prevent unauthorised access through built in security mechanisms;
- communicate changes in the tender documents, during the tender process, quickly and easily.

6.2. Design and construction stage

Project managers control and manage the exchange of documents between members of the project team so that the overall deadlines of the project are met. It is essential that each team member receives the right documents at the right time such as the latest version of drawings, specifications, requirements, etc. web-enabled software used in this stage can:

- reduce the risk of errors and rework by ensuring that everyone in the project team is working with the most current drawings and other documents;
- save time in the query (request for information, RFI) and approval process, by allowing the design team to mark up and comment on drawings online;
- eliminate the risk of losing important files, by maintaining all current and past versions in one central location;
- improve team communication by enabling team members to raise and respond to queries in a structured way;
- maintain a complete log of all communications for tracking purposes (audit trail facility);
- provide clients and other participants with a view of the project as it is built; as some software have incorporated virtual reality models to denote the status of a project at any point in time (a snap shot view of a project);
- provide a collaborative environment whereby the diverse participants can perform online collaboration via the web.

6.3. Trading (e-commerce)

Purchasing of materials is a lengthy and complex process, which requires the identification of considerable resources and potential suppliers as well as the evaluation of quotes, which are normally received in different formats. web-enabled Software used in this stage can:

- save time in the procurement of materials by automating document distribution and communications (E-procurement);
- reduce the administrative costs of document handling and distribution to multiple parties;
- reduce errors due to effective communication;
- ensure ease of comparison and evaluation of bids.

7. Samples of web-enabled project management software

Over the past few years, the construction industry has witnessed the emergence of a number of powerful web-enabled software to monitor, control, manipulate and store project information and to make them available to all participants. Many of these software cover a wide range of facilities and functionalities, which have made the management process of a construction project cost effective and efficient. Some of the software offer more comprehensive solutions for the entire life cycle of the project than others. For example, "prime contract", project management software, which initially dealt with the feature of project information exchange, has the capability of performing the e-commerce function.

The software available in the market is classified according to the stages identified in Sections 7.1, 7.2 and 7.3: Tender Stage Exchange of Information, Design and Construction Stage Project Information Exchanges and trading (e-commerce). These stages will be codified as stages A, B and C, respectively, for referencing purposes. Samples of web-enabled PM software are tabulated with their corresponding website addresses in Table 1 below.

Detail reviews on each of the above products are available on http://www.nceplus.co.uk/proj_collaboration/.

Table 1
Sample software for web-enabled project management

Project management software	Projects/Clients	Website address	Commonly used stages
ProjectsOnline,	Refer case study No. 3	[12]	B
TenderOnline		[12]	A
TradeOnline		[12]	C
SuppliersOnline		[12]	C
Project Information Channel	Capital One, J. Sainsburies, Boots Chemists, Refer Case study No. 1.	[16]	B
TeamPlay		[15]	B
PrimeContract		[15]	B, C
Open Plan		[17]	B
Project.Net		[21]	A, B, C
4Projects	Microsoft, BAA, Slough estates, Nationwide building Society, Tesco, Taylor Woodrow, Marconi, BASS Leisure retail	[22]	B
Architec.net		[23]	A, B, C
Integration		[24]	A, B
iProNET		[19]	A, B
Viecon		[25]	A, B, C
ProjectCenter	Bank of America, Hilton Hotels, Beacon	[26]	B
ProjectPoint		[27]	A, B, C
Cadweb.net		[28]	B
ProjectLink		[29]	B
Business Collaborator		[30]	B
eProject" Express		[31]	B
ActiveProject		[32]	B
DOCS Fusion	AMEC, John Laing plc, Costain, Skanska, Gleeson	[33]	B
iScraper		[34]	A, B, C
ProjectTalk		[35]	A, B, C
LiveLink	Balfour Beatty, HBG, McNicholas	[36]	B
ProjectVillage		[37]	B
WebWorks" and "eReview		[38]	B

8. Case studies

There have been many success stories where web-enabled project management has been implemented in the Construction Industry. This section reviews a few documented case studies. The references to the acronyms of each case appear in the appendix. However, their identities have not been disclosed.

8.1. INMANCO [29,33]

8.1.1. Background

This case is concerned with an electronic document management system that is capable of facilitating, reviewing and updating of project drawings and specifications over the web using the Project Information Channel (PIC) of the Building Information Warehouse. The cost savings mainly arise from not having to print drawings and specifications from time to time and the capability to track changes electronically.

8.1.2. Benefits

The case study shows a £58,130 saving on a £5 million, 30-week retail construction project, involving an international firm of management and construction consultants (INMANCO). The detail breakdown of the cost saving is as follows:

Printing costs for project drawings	£46,112
Postage costs for project drawings	£1584
Copying costs and project specifications	£10,215
Postage costs and project specifications	£219
	£58,130

These are only the identified direct cost savings. Potentially, much greater savings were achieved through reduction in mistakes and reworks and by avoiding unnecessary project delays. In the same study, the company estimated these additional indirect savings to be in the region of £300,000, which is 6% of the overall project costs. They were able to achieve this saving through the following means:

1. Avoiding delays. Delays are avoided because team members do not have to wait for the arrival of updated drawings. Comments and requests for information are immediately delivered to the headlines page of the relevant team

members, avoiding the delays and mistakes often caused by conventional methods of communication.
2. Reducing visits to site and travelling time to meetings. Visits to site and travelling time to meetings can be reduced because the most up-to-date progress photographs are always available for viewing on the system.
3. Avoid mistakes. Mistakes are avoided because all drawings and documents are always up-to-date and instantly available. There is no longer any risk that team members are acting on information that is out of date, or incomplete.
4. Reducing time and money spent on disputes. Time and money spent on disputes is reduced because the system creates a full audit trail containing all the minutes, actions comments, requests, approvals and notifications that are generated during the project. The database records: who has published what, when it has been viewed and by whom, for auditing purposes.

8.2. ALCOA [27]

8.2.1. Background

The main objective of the project was to make computer connectivity available to every ALCOA location worldwide so that the team could collaborate over the web. The project team consisted of ALCOA (a major aluminium company in the USA), Microsoft and Hewlett Packard (HP) and the suppliers and distributors of ALCOA.

8.2.2. Collaboration via a web server

The project team decided to pursue a web solution although not explicitly stated in their terms of reference. The approach meets the monthly reporting requirements and also attempts to delight users with point and click navigation capabilities. In some respects, it was an over-delivery of client expectations with the intent being to reduce monthly reporting costs and simplify a repetitive process.

8.2.3. Benefits

1. Elimination of paper reports as all the information was sent on electronic form via the web.
2. The team was able to leverage exiting firewall solutions to prevent unauthorised access to the web server.
3. Automate repetitive routine processes.
4. Data sharing among all support entities.
5. Integrated communication process promoting more accurate information transfer.

8.2.4. Problems

1. The need to upgrade the firewall protection from time to time.
2. The need for a project manager with IT infrastructure knowledge.
3. Having to treat the web server as a full scale IT project, entailing:
   - Appropriate funding
   - Appropriate staffing
   - Utilisation of project management knowledge
4. Need to understand the corporate culture to prevent clashes.

8.3. CATHQUARTER [12]

8.3.1. Background

The case study is concerned with the use of a project collaborative tool, ProjectsOnline, which is web-enabled and has the capability to enhance cooperation and coordination of team members across several countries to achieve strict deadlines of projects. The Cathedral Quarter project involved collaboration between a Dublin-based architect and developer, and a Northern Ireland structural engineer, services engineer and quantity surveyor.

As the architect firm issues drawings, they are uploaded onto the project website, members of the project team in Belfast are notified automatically and can retrieve these documents immediately, regardless of their location. Comments can then be posted online, thus reducing the turnaround time on documents and drawings from days to minutes. ProjectsOnline manages the team members' access rights, ensuring that members have access only to the data relevant to their roles so that they cannot do unauthorised alterations. New information that is posted in the website is alerted to all team members. Any member can access or submit drawings, documents, etc., and view all project information on one secure location.

8.3.2. Benefits

1. Substantial increase in the speed of communication, resulting in shorter lead-time on tasks.
2. Increased accuracy of communications and therefore reduced errors and rework costs.
3. Dramatic reductions in travel costs.
4. Reduced cost of hardcopy production, distribution and storage.

8.4. TITS [8]

8.4.1. Background

The objective of TITS is to help information transfer more effectively during the construction process, between head office and its overseas construction sites. TITS uses a Linux (Unix-based) and MS Windows 95 (PC-based) for setting up the information transfer system. Logging to the remote host is achieved through telnet and transfer of files through File Transfer protocol (FTP). Telnet protocol allows an Internet user to log into a remote host from his/her local host computer. Due to its direct connection to the remote system, the system can provide a cheap and efficient method to get information compared to facsimiles, phone or snail mail. FTP is a way of sending files across the Internet. This function enables file transfer from one computer to another irrespective of their operating systems. Security of the server information is provided through password access. Email and Internet chat is enhanced with on-screen images, pictures or drawings that can simulate telephone conversations and meetings. TITS was applied for project monitoring in a small-scale residential project in China.

The main reason for adopting TITS was due to the extensive geographic separation of the head office and the site, which resulted in a very high cost being incurred for the existing project information system. Therefore, an Internet-based project information system was devised for data retrieval and processing by intelligent HTML and Java programming. The project information system focuses on information generation (data input at site), information transfer (web-based communication) and information retrieval (intelligent graphical view on the web). The data is submitted through a standardised form and it is saved in a text format in the head office web server. The Java applets specifically programmed to handle the data in text format refreshes the parameters in the web server. Performance at the project site can be compared with the schedule/estimated performance. The schedule and the actual progress are automatically plotted graphically to get a clear picture of the site progress.

8.4.2. Benefits

1. Improved efficiency brought about by speedy and accurate transfer of information between head office and sites.
2. Better management and decision-making.
3. Savings on communication through the Internet as against traditional methods such as IDD phone calls and courier services.

8.5. "3COM" [6]

8.5.1. Background

The project involves construction of office space/laboratory space for 3 COM, which is an American computer networking company with offices in 45 countries around the world. Design began in July 1996 and the buildings were completed in February 1998. The client emphasised on using a partnering approach within the team to execute the project. The case explains how collaboration was achieved among the team members through electronic means via email.

8.5.2. Collaboration

Drawings were issued electronically as email attachments to each member of the team and requests for approvals and confirmations were also accepted via the same medium. 3COM provided the network file server and group working software (lotus notes) and backup facilities. In addition to the electronic form of collaboration, the client's project manager PPT-Integration insisted on a number of management procedures.

1. Each organisation would check the file server three times a day to collect any new information.
2. There would be only one person responsible within each organisation for the administration of the documentation (the network account holder).

3. One hard copy of the drawings would be sent to each of the members of the project team as a control measure to check for any discrepancies.
4. PPT-Integration would keep a log of all information issued.

Communication was achieved via ordinary telecommunication links with the central file server. Design consultants were only responsible for issuing an electronic drawing file to the file server and for issuing a single printed copy to the other members of the project team. The contractor was responsible for duplicating the drawings at site, which were distributed to the site team and subcontractors.

8.5.3. Benefits

1. The speed of communicating drawings increased (sending drawings by post or courier compared with the email attachment, which takes a few minutes to download).
2. Due to the increased speed, the team was able to agree to an additional one million pounds worth of work without a time overrun on the project (About 6 weeks of time overrun was saved).
3. Traditional, monthly site meetings were converted to ''information-required meetings'' so that all the team members need not participate in them. The contractor produced an electronic report and distributed it to the team members.
4. Reduction of delivery and copying costs that resulted from the contractor being more focussed on the precise requirements for drawing copies resulted in an overall saving for the project (approximately £25,000).
5. Reduction in storage space for paper work as a result of more and more electronic storage.

8.5.4. Problems

1. Costs of overcoming incompatibilities.
2. Team members possessed different degrees of IT sophistication. Therefore, some members had to go back to earlier versions of the software to be in line with the rest of the team. The M & E contractor preferred to use the traditional draughting system, which needed to be input into a CAD based system elsewhere and transferred back to site.
3. Technical issues such as inability to deal with large file sizes and various security issues had to be overcome. Printing of drawings at site was not straight forward as it was reported that backgrounds had to be assembled and some layers were lost in the file transfer.
4. Although the system worked well with the principal members of the team, some subcontractors found it difficult to match the technology.

9. Analysis and discussion

The review of five case studies consisting of four construction projects and a collaborative project between an aluminium company, its distributors and suppliers indicate that the main aim was to improve communication between the team members of the project with the use of the Internet and Internet-related tools. INMANCO and the CATHQUARTER used specific software developed for project management over the web; project information channel and projectsOnline, respectively. 3COM used Lotus Notes software provided by the client to send drawings as email attachments to all project participants and TITS used the File Transfer Protocol as the method to transfer. ALCOA used an unspecified collaboration tool for reporting purposes between the team members.

Due to the fact that communication is a root cause of most project failures as asserted by Biggs [10] has been addressed by all of the above cases. They have also addressed major issues such as enhancing collaboration and increasing speed and accuracy of information transfers. The comparison of the cases' highlights and the main benefits of using web-enabled project management software are given below in Table 2.

Although communication problems have been addressed in all these cases, the current tools for performing project management over the web has other weaknesses. They could be listed out as follows.

9.1. Issue of security of project information

Security is a major issue, which need to be addressed for any online collaboration between project team members. New technological developments

Table 2
Comparisons of case highlights

	INMANCO	ALCOA	CATHQUARTER	TITS	3 COM
Purpose of Collaboration	Reviewing and updating of project drawings over the web using project information channel (PIC)	Share and exchange project information	Share and exchange project information using projectsOnline	Transfer of files using FTP	Collaboration via Email and group working software using Lotus notes
Main Benefits	(1) Cost savings on document management (2) Audit trail	(1) Cost savings on document management (2) Secure access	(1) Reduction in travel costs	(1) Savings on travel costs (2) Increased speed of communication	(1) Increased speed of communication

have taken place in providing security to prevent unauthorised access to sites. But they impose a lot of financial constrains on project teams as the costs need to be incorporated into project feasibility studies.

9.2. Cultural issues

Traditional practices such as "receipt of drawings to be confirmed in writing", "issue of drawings to be under the architect's chop", etc. are still observed in the construction industry. Sending of drawings electronically between participants do not conform to these traditional practices and as such have not been well received in the industry.

9.3. Ownership of drawings

Some designers perceive that holding data centrally (e.g. Design information), and downloading them as and when necessary (e.g. the case of 3COM phase II) from the server and printing at the downloaded destination, infringes their copyrights. Some may also perceive that when designs are held centrally, they could loose control of the project.

9.4. Will telepresence replace face-to-face meetings?

Although buzzwords like "virtual meetings", "teleconferencing" are used frequently in construction, still the stage has not reached whereby the periodic site/project meetings can be totally dispensed.

9.5. Integrated databases

All the cases that have been discussed, addressed the issue of communication by way of document-based exchanges. Taking the document-based exchange tools forward to provide integrated solutions at the object level can provide a better environment for exchanging data.

10. The way forward

The government, industry and clients are all seeking to bring about change in the Construction Industry to improve quality, competitiveness and profitability and to increase value to clients. Implementation is through initiatives such as the Construction Task Force [20], the Government Construction Clients Panel (GCCP), the activities of the Construction Industry Board (CIB), the Construction Clients Forum (CCF) and other CIB umbrella organisations. These initiatives are seeking to secure a culture of cooperation, teamwork and continuous improvement in the performance of the industry. Where the emphasis has traditionally been on the need to manage the interface between the project and the client's organisation, it is now shifting towards the need to manage the flow of activities across the supply chain, concentrating on those activities that actually add value.

In doing that, electronic data exchange, in particular web-enabled project Management and e-commerce, has shown to have tremendous potentials not only in adding value to internal performance of an organisation but also to the whole supply chain and therefore the client. Unlike many IT tools, web-based tools are very much concerned with the exchange of information across the project life cycle. Their successful implementation therefore will not only require a state of readiness within one organisation, but within all those involved in this process. This makes the

successful implementation of such tools difficult to be planned for and managed. Moreover, the implementation of web-based tools have been hampered by the reluctance of participants to practice comprehensive sharing of knowledge and the absence of clear assessments of the business models which are most suited to the adaptation and adoption of web-enabled Project Management software.

Many web-based developments have been led by end-user products, which have been divorced from the true integration with business processes. This lack of a strategically driven implementation approach has resulted in resource wastage and unrewarding investment. Few years ago, the construction industry in the UK has realised the potential of the Internet and its applications, in particular e-commerce, and was ready to embrace this technology through the development of web-based systems. However, the level of implementation and penetration of such technology was not as expected. In January 2001, the building magazine has published a report on the failure of e-commerce to meet the expectation of the industry despite the many attempts made by larger organisations to set up sophisticated systems to improve their businesses. Large systems were brought to halt because they did not meet their objectives. The outcome of this paper coincides with all the research outcomes in this field, which shows that technology push is not the only critical success factor for effective implementation of technology. All the attempts were technology-driven and the quality of the process was not fully addressed. It is much more difficult to address the latter across the supply chain because of the different practices used in different organisations and the extra complexity dimension, which is added by the type and level of incompatible computer systems used by these organisations.

In order for the construction industry to successfully embrace web-enabled project management tools, at a large scale, it must equally consider technology, process, people and knowledge management. The efficiency of current processes must be carefully addressed and re-engineered to take advantage of the latest advances in technology. The industry should work towards minimum common standards to facilitate the flow of information across the supply chain. Such standards will add significant value up the chain by allowing exchanged information to be fully integrated with business processes. People must have the necessary skills and the rewarding environment to harness the benefits of the Internet. It will be extremely difficult for construction organisations to achieve the required results of implementing web-enabled tools without fully addressing the management of change and how people can best be taken on board.

11. Additional Reading

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Appendix A. List of cases and acronyms

This section consists of case references. The acronyms of cases are displayed in uppercase bold characters.

1. Cost savings through electronic document management (EDM) [33]. The project is concerned with an international firm of management and construction consultants. The case study is referenced as **INMANCO.**
2. The ALCOA project. [27]. The project team consists of members of ALCOA (an aluminium company), Microsoft, Hewlett Packard (HP) and suppliers and distributors of ALCOA. The case study is referenced as **ALCOA**.
3. Project Collaboration Case Study (Cathedral Quarter). [25]. The case study is concerned with the use of the software tool, "projectsOnline" for collaboration purposes. The case study is referenced as **CATHQUARTER**.
4. The Total Information Transfer System (TITS) and the Internet Based Project Information System Between Head Office and Site [19]. The case study is referenced as **TITS.**
5. Electronic Exchange of Project Information (3COM project, phase 2). [29,33]. The case study is referenced as **3COM**.

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