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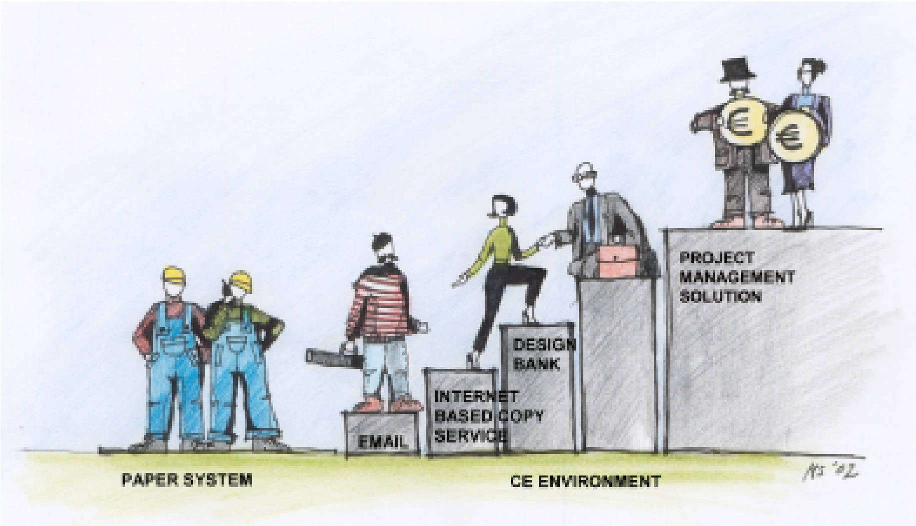

Kristiina Sulankivi, Antti Lakka & Mary Luedke

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Keywords project management, building projects, concurrent engineering, collaboration, Internet, construction, measuring frameworks, re-engineering, cost-benefit analysis, communication tools

Abstract

The primary objective of the Finnish-American research project was to develop the management and organization of multi-partner projects when using electronic data exchange and the concurrent engineering (CE) environment. A second objective was to develop functional indicators to measure impact of the CE environment in selected case study construction projects. As a result, the study presents key guidelines for realizing benefit by using electronic data exchange and the CE environment in multi-partner projects.

A fundamental conclusion of the study is that by using electronic data exchange and a modern CE environment, significant qualitative benefits can be reached in a multi-partner project. The CE environment makes it possible to change the traditional information flow, thereby radically improving it at the design and construction stages.

In addition to qualitative benefits, benefits measured in terms of time and money can be reached. In the European case studies, direct cost benefits were approximately double as compared to the operating costs, and the indirect cost savings were manifold as compared to the direct cost benefits. However, indirect cost savings were difficult to quantitatively measure in practice. In the American case study, cost benefits were even 20-fold as compared to the operating costs.

The model for benefit measuring was developed and tested mainly in the first analyzed case study, which, in August 2000, was completed and handed over to the client in Finland. Additionally, the framework was used in three other case studies, in Sweden, Great Britain, and the USA.

For more information http://www.vtt.fi/rte/cmp/projects/proce/

Sulankivi, Kristiina, Lakka, Antti & Luedke, Mary. Project Management in the Concurrent Engineering Environment [Projektin hallinta sähköisen tiedonsiirron ympäristössä/Internetstöd hantering av byggprocessens information]. Espoo 2002. VTT Publications 470. 100 s. + liitt. 1 s.

Avainsanat project management, building projects, concurrent engineering, collaboration, Internet, construction, measuring frameworks, re-engineering, cost-benefit analysis, communication tools

Tiivistelmä

Suomalais-amerikkalaisen tutkimusprojektin päätavoite on ollut kehittää usean osapuolen projektin johtamista ja organisoimista sovellettaessa sähköisen tiedonsiirron ympäristöä. Toinen tavoite on ollut kehittää toiminnalliset mittarit sähköisen tiedonsiirron ympäristön vaikutusten mittaamiseksi valituissa rakennushankkeissa. Tuloksena tutkimus esittää keskeiset pelisäännöt, joita noudattamalla sähköisen tiedonsiirron hyödyt voidaan saavuttaa usean osapuolen projektissa.

Tutkimuksen keskeinen johtopäätös on, että soveltamalla sähköistä tiedonsiirtoa ja modernia projektitietojärjestelmää usean osapuolen projektissa voidaan saavuttaa merkittäviä laadullisia ja toiminnallisia etuja. Projektitietojärjestelmä mahdollistaa perinteisen informaatiovirran muuttamisen radikaalisti paremmaksi suunnittelu- ja rakentamisvaiheissa.

Toiminnallisten ja laadullisten hyötyjen lisäksi saavutetaan ajassa ja rahassa mitattavia hyötyjä. Suorat kustannushyödyt projektitietojärjestelmien käyttämisestä olivat eurooppalaisissa esimerkkihankkeissa noin kaksinkertaiset verrattuna käyttökuluihin. Epäsuorat kustannussäästöt ovat moninkertaisia suoriin kustannussäästöihin verrattuna. Niiden mittaaminen on kuitenkin käytännössä vaikeaa. Analysoidussa yhdysvaltalaisessa rakennushankkeessa kustannushyödyt olivat jopa 20-kertaiset käyttökuluihin verrattuna.

Hyötyjen mittaamisen malli kehitettiin ja testattiin pääosin ensimmäisessä analysoidussa rakennushankkeessa, joka valmistui ja luovutettiin tilaajalle elokuussa 2000 Suomessa. Mittausmallia sovellettiin lisäksi kolmen muun rakennushankkeen analysointiin Ruotsissa, Isossa-Britanniassa ja Yhdysvalloissa.

Lisätietoja http://www.vtt.fi/rte/cmp/projects/proce/

Sulankivi, Kristiina, Lakka, Antti & Luedke, Mary. Project Management in the Concurrent Engineering Environment [Projektin hallinta sähköisen tiedonsiirron ympäristössä/Internetstöd hantering av byggprocessens information]. Espoo 2002. VTT Publications 470. 100 s. + bil. 1 s.

Nyckelord project management, building projects, concurrent engineering, collaboration, Internet, construction, measuring frameworks, re-engineering, cost-benefit analysis, communication tools

Sammandrag

Det främsta syftet med det finsk-amerikanska forskningsprojektet har varit att utveckla ett system för flera parter att leda och organisera ett projekt med utnyttjande av en elektronisk dataöverföringsmiljö. Det andra syftet har varit att utveckla operativa mätare för att mäta effekterna av den elektroniska dataöverföringsmiljön på valda byggprojekt. Resultatet av undersökningen är centrala spelregler. När dessa spelregler följs ger den elektroniska dataöverföringen fördelar för flera parters projekt.

Den främsta slutsatsen av undersökningen är att man kan uppnå avsevärda kvalitativa och operativa fördelar av att tillämpa elektronisk dataöverföring och ett modernt projektdatasystem i flera parters projekt. Projektdatasystemet kan förbättra det konventionella informationsflödet radikalt i planerings- och byggnadsskedet.

Utöver de operativa och kvalitativa fördelarna uppnås omfattande inbesparingar i tid och pengar. De direkta kostnadsinbesparingarna av projektdatasystemen i de europeiska modellprojekten var dubbelt så stora jämfört med driftskostnaderna. De indirekta kostnadsinbesparingarna var flerfaldiga jämfört med de direkta kostnadsinbesparingarna. Det är emellertid svårt att mäta dem i praktiken. I ett analyserat byggprojekt i USA var kostnadsinbesparingarna upp till 20-faldiga jämfört med driftskostnaderna.

För att mäta fördelarna utvecklades en modell som testades främst i det första analyserade byggprojektet. Modellen blev färdig och överläts till beställaren i Finland i augusti 2000. Därtill tillämpades mätmodellen för analys av tre andra byggprojekt i Sverige, Storbritannien och USA.

Närmare upplysningar http://www.vtt.fi/rte/cmp/projects/proce/

Preface

Project Management and Organization in the Concurrent Engineering Environment, ProCE, is a Finnish-American research project, in which VTT Building and Transport and the University of Wisconsin-Madison, USA, were partners. The study was carried out mainly at VTT in Tampere. The research team consisted of Senior Research Scientist Antti Lakka and Research Scientist Kristiina Sulakivi from VTT, and Visiting Research Scientist Mary Luedke from the University of Wisconsin-Madison.

The research project was guided by Professor Awad Hanna from the University of Wisconsin-Madison and led by a steering committee consisting of representatives from the Finnish construction industry. Steering committee members were: Chairman Juha Kuokkanen (Raksanet), Jari Virsunen (YIT), Hannu J. Mäkinen (Rakennustoimisto Pohjola), Kirsti Paasikallio (Valopaino), Aulis Toivonen (HKR Rakennuttaja), Arto Hägg (Skanska), Petri Laurikka (A-Rakennuttajat), Pekka Vaara (Artemis Finland), Mikko Viljakainen (Wood Focus) and Matti Leino (Optiplan).

The study was financed by the companies represented in the steering committee, TEKES, VTT, and the University of Wisconsin-Madison. The project webiste address is: http://www.vtt.fi/rte/cmp/projects/proce/.

The research team wishes to acknowledge participating company representatives for actively participating in the project. In addition, we would like to extend special thanks to all project participants for their support in making the project analyses possible.

March 2002

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VTT Building and Transport
Tampere

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1. INTRODUCTION

1. Introduction

1.1 Background

Organization and management of projects involving several parties can be significantly supported by using the concurrent engineering environment. Projects in which the design and construction phases partly overlap, or occur partially concurrently, can be particularly supported by the concurrent engineering environment. For the remainder of this report, the term CE environment is used to refer to the concurrent engineering environment and the associated electronic data transfer.

The basic technologies establishing the CE environment are already developed to quite a useful level. Existing basic technologies are those that are readily available to all companies and include things like the Internet, e-mail, mobile data transfer based on the global system for mobile communications (GSM) technology, wireless application protocol (WAP) technology, and the “I-Seek-You” (ICQ) quick messages. Various commercial CE environments founded on this basic technology already exist as services in the market. Commercial solutions have been taken into use at a remarkable volume and rapidly continue to become more common. Often, a problem with the available services is that the functionality has been developed to meet one party's needs. One party’s data transfer needs are served well, but all project parties do not benefit from using the service or are even not able to become system users. "The modern computer is designed, built, marketed, and sold to be a connection point to the Internet" /12/, to the information exchange between several parties.

1.2 Research Objectives

Project Management and Organization in the Concurrent Engineering Environment (ProCE) is a Finnish-American research project focused on developing the management and organization of multi-partner projects in the concurrent engineering environment. The objectives of the development project were to:

- Clarify the present use of the CE environment in building projects and identify opportunities for use based on the available, existing technology.

- Measure the impact of different CE environment features in multi-partner projects, showing the available benefits.
- Determine common multi-partner requirements for the CE environment.
- Determine new procedures for CE environment use in multi-partner projects, so that the available benefits can be reached.

1.3 Research Method

The first stage of the research project was a state-of-the-art study of CE environments used in construction projects. Properties of CE environments were studied by means of literature review and submission of questionnaire surveys to service providers. Based on these findings, properties were selected from which the impacts of CE environment properties were studied in detail.

To develop an understanding of the state of the art collaboration tools available, a list of over 300 available service options related to the CE-environment was compiled from existing lists (/11/, /5/) by reviewing literature and information on the Internet. After analyzing the main purpose of the listed sites, they were categorized into three groups: collaboration solutions, support, and eCommerce and reference information. Collaboration solutions were identified by different names, including project extranet and collaboration solution. In the collaboration solution group, 120 solutions were identified, with about 80 specializing in some aspect of the building process. From the group of 80, the authors selected about 30 service providers to analyze more deeply thereby gaining an understanding of the available features and capabilities. Nineteen service providers cooperated and provided more information by replying to a questionnaire. In alphabetical order, the sample companies represented the countries of Belgium, Finland, Norway, Sweden, the UK, and the USA. The inquiry was based on frequently appearing properties observed when analyzing the ASPs' Internet pages and product brochures. The feature occurrence rate is presented and discussed in the ProCE project intermediate report /7/.

During the second, major phase of the research project, the evaluation of benefits, a method resembling the Delphi research technique was used to analyze the effects of the CE environment. The Delphi method is often used in the study of the future and can be described as a means for structuring group discussion to deal with complex questions to which a single, correct answer does not exist. According to the method, the structured dialogue gathers expert opinions on the topic being examined. A standard series of questions are posed to the group of experts. Results from the expert group are collected and summarized for each question. The result summary is then presented to the interviewed experts for final opinions and comments based on the summary.

In the ProCE study, the expert dialogue was carried out in three stages. During the first stage, the parties of selected case projects having practical experience in using the CE environment for project activities were identified as experts and interviewed. The expert opinions were then gathered into a measuring framework and classified as the potential effects. The second stage consisted of distributing a questionnaire wherein the potential effects were presented again to the same experts. The questionnaire surveyed personal opinion on the identified effects of the CE environment and electronic data exchange in a specific/certain case project (the case project in question). The third and final stage analyzed the expert opinions regarding the CE environment and electronic data exchange in more detail using quantifiable methods and focused expert interviews. Mainly, specifics regarding time and cost effects were clarified during the focused interviews. The measuring model is described in more detail in section 3.1.

2. CE ENVIRONMENT

2. CE Environment

2.1 Foundation

The concurrent engineering environment supports project management, the control of project information, and promotes cooperation in the building process. The three foundational components are electronic information, centrally-accessible information storage, and networks connecting the users to the information storage and by which project information is transferred (Figure 1).

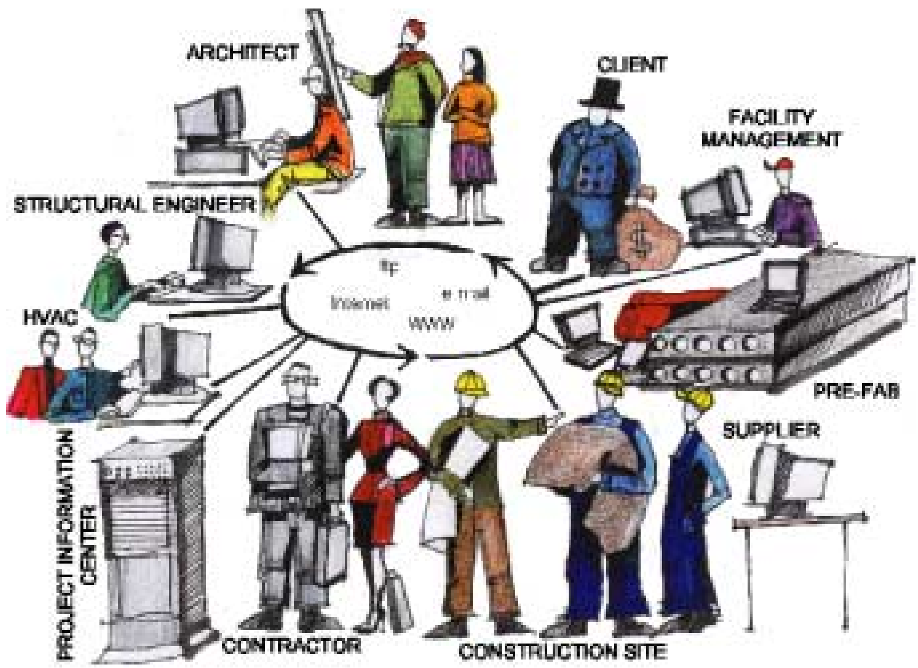


Figure 1. CE environment supports the cooperation in a multi-partner project. The information goes in an electric form with the help of devices connected to the Internet or telephone network, then from one system to another. Separate project parties communicate and update common project information with the help of the system. Figure by Minna Sunikka /6/.

Today centrally-accessible information storage is usually a server to which all project members have the option to access and a similar user interface. Information storage can also be decentralized to several servers. In the future, an organizations' internal system will probably be equipped with data transfer connections to the external projects' system (extranet) so that staff in companies can use their own familiar systems in different projects /4/.

At this time, the concurrent engineering environment has been used mainly for document management during design and project management during construction. In Figure 2 different implemented environments are shown in order of their respective developments. Supporting tools used for document management and communication in the projects include, but are not limited to, e-mail, Internet-based copy service, the design bank, and the project management solution. When using an Internet-based copy service, the plot files of designs are delivered to and filed electronically on a printing service server. A design bank is a technically similar solution that is used more extensively to include document management. In addition to document management features, project management solutions include features supporting project management or workflow. In reality, the classification of tools supporting document and project management is ambiguous because stand-alone e-mail software is often used in addition to a design bank for communication and notification.

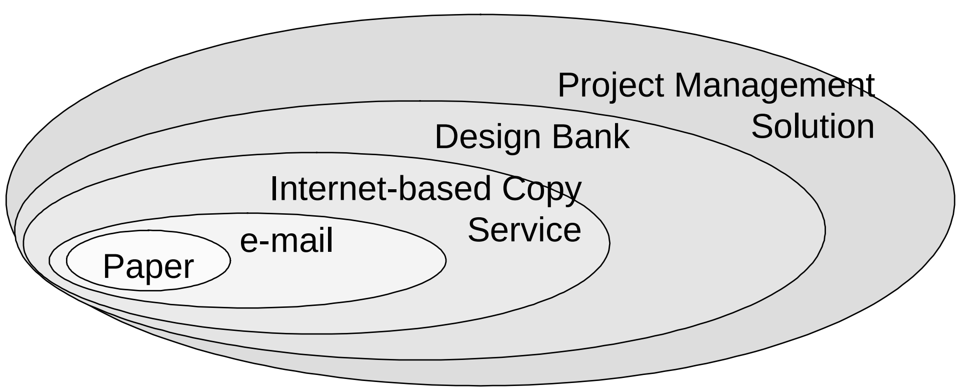


Figure 2. Steps in the development of project team collaboration solutions from the paper-based communication environment to project management solution.

In the 1990's, commonly used data transfer solutions combined the Internet and file transfer protocol (FTP) technologies. Today there are plenty of commercial applications for multi-partner projects available on the market that are based on dynamic Internet technology. Among today’s applications, the user interface has improved considerably, and in addition to document management features, many new capabilities have developed. The dynamic, Internet-based applications establish the foundation of the present CE environment for the multi-partner project /7/.

2.2 Features and Capabilities

A foundational element of the CE environment is a centralized database that serves all the users. Today, a common interface to centralized information storage is an Internet-based, project team collaboration application developed for document and project management and provided by application service providers (ASPs). An ASP-based application means that for a fee the ASP provides the application and server space and the user needs only an Internet browser to use the basic application features.

Existing tools have been created for document management, project information sharing, on-line communication, design workflow, construction workflow, time control, and securing information /9/. However, the widely used application features are fairly simple; today's applications serve well as centralized document management systems with some integrated work flow models, communication tools, and possibly links to other services, such as printing.

In addition to the widely used features described, there are also newly developed features, which are still in limited use. Some of the features described in the following text are at the time of writing only limitedly available or have not been taken into common use in actual projects. Nevertheless, application development is active and the features users find good quickly become common in leading applications (Table 1).

Table 1. CE Environment Features.

Category	Feature / Functionality	Description
User Software	Uses Web-browser	A Web browser such as Netscape or Microsoft Internet Explorer (IE) is required to use some or all features of the solution.
	Requires ASP-software	To fully use all solution features and capabilities, the user is required to install unique software provided by the Application Service Provider.
	Other software	Excluding file viewing software (see file viewing), other software is required for use of some or all capabilities.
Communication Tools	Standard e-mail	Email is not a feature of the solution. To compose and send emails, users must use email software.
	Internal e-mail	Email to collaboration solution users only can be composed and sent from within the solution.
	Integrated standard e-mail	Email to both collaboration solution users and non-users can be composed and sent from within the solution.
	Automated notification	System initiated notifications to users.
	Online discussion forum	A facility hosting real time, sequential or threaded text conversations.
Document Management	Traditional Folder Tree	Internal document management is organized in the traditional, fixed folder tree structure.
	Other file management method	Internal document management is organized using architecture other than traditional, fixed folder tree format, e.g. dynamic folder view or indexed database.
	Defined and searchable document metadata	Data about each file is defined and stored to enable file searching. Examples of defined and stored data include file Title, Subject, Author, and Manager.
	Full text search	The collaboration solution is capable of conducting searches throughout the full text contained in the body of each file.

	File Name search	Users are able to search for documents based on the file name.
	Archive option	The collaboration solution offers to archive all project data, e.g. burn information onto Compact Discs (CDs).
	Real time	Project information is updated by transaction. In other words, when a user uploads a file to the system, it is immediately in the system and accessible to other users.
	Extraneous	Project information is made accessible to other users by a collaboration solution human action. For example, a solution provider employee needs to manually transfer uploaded files to make them accessible to all system users.
	Notification of changes	Users are notified of changes in the hosted project information. Notification can be initiated by the user making the change, or automated - refer to automated notification to determine if the system supports automated notification.
	Version management	The solution provides a technique for managing different versions of the same file.
	Document audit trail	The solution provides a method for tracking actions taken regarding each file. For example, it records when and who uploaded the file to the system, and when and who viewed or downloaded the file.
CAD Features	CAD Viewing	Original CAD files (e.g. dwg, dgn, dwf, dxf, or plt) can be opened within the solution and viewed without having CAD software or installing file viewing software.
	CAD Viewing with plug-in	Original CAD files (e.g. dwg, dgn, dwf, dxf, or plt) can be opened within the solution and viewed without having CAD software, but users are required to install file viewing software (usually a browser plug-in).
	CAD Redlining	System users are able to redline CAD files (dwg, dgn, dwf, dxf, or plt) without having specialized markup software.

Other Document Features	File viewing without plug-ins	System users are able to view documents (other than CAD files) without having the software necessary for creating the document or installing file viewing software.
	File viewing with plug-ins	System users are able to view documents (other than CAD files) without having the software necessary for creating the document, but are required to install file viewing software (usually a browser plug-in).
	Document redlining	System users are able to redline documents (other than CAD files) without having specialized markup software.
Construction Workflow Applications	Request for Info (RFI)	The solution has an established RFI management system. For example, within the system a request for information can be initiated by the contractor, and then sent to the architect. The architect receives the RFI, answers the question, sends the response to the contractor, and posts the information for project viewing if applicable.
	Submittals	The solution has an established Submittal management system. The submittal process tracks items as they move through an approval process often involving the owner, architect, contractor and subcontractors. For example, the painting subcontractor needs to submit paint samples for approval by the architect and owner. The submittal process would document the paint sample's progress through the approval system.
	Issues	The solution has an established issue management system. An issue is any open problem or project issue. The issue process would document the problem's progress through the reconciliation system.

	Change orders	The solution has an established change order management system. Change orders are formal changes to the project design that do not alter the original project scope. The change order system documents the process from the initial Request for Change Order through approval and implementation.
	Punch Lists	The solution has an established punch list management system. Punch lists are formal lists of items generated between the contractor and owner when the project is nearly completed. The items need to be addressed before the project is considered complete.
Time Control	Calendar	A calendar where project meetings, target dates, and other date-sensitive project information can be created and managed for each system user.
	Project schedule	Users are able to create, maintain, and manage the anticipated time schedule for completion of the project and its specific tasks (this does not include viewing an image of the schedule).
	Event manager	Reminds the users of the application of events and target days important to the project.
Project Information	Contact information	Name, company name, mailing address, email address, telephone number, fax number, etc. for each individual involved in the project.
	Daily field reports	The solution has an established model for daily field report documentation and management that predetermines some and allows for customization of required information. Daily field reports document the resources used on site and the activities occurring each day.

	Offline Communication Log	The solution has an established offline communication documentation and management system. Offline communications are those project communications that occur outside of the hosted solution, such as telephone calls or letters delivered by post.
	Meeting minutes	The solution has an established model for meeting minute documentation and management that predetermines some and allows for customization of required information.
Links to other services	Link to printing services	The solution has a defined and modeled technique for initiating, coordinating, and managing reprographic/printing services.
Security	Login with username and password	The basic approach. Access to the solution is limited to users with a username and password.
	Variable document access control	In comparing to the basic approach, this is more enhanced. The user view can be regulated at the folder-level or rights at the file-level one inside the repository.
	Electronic identification	Access to the solution is limited to users with electronic identification.
	Information Back-up	The service includes information back up. It has taken measures to ensure that the existence of the information will not be eliminated because of unforeseen events.
	Service Reliability Guarantee	The solution guarantees reliability of service. It has taken measures to ensure that service will not be eliminated because of provider technical problems.
	Virus scan	The solution scans files to eliminate viruses.
Special Features	Language options	The user can choose the language of the application from several alternatives him/herself. In a certain project, there can be parties that represent different nationalities and use the application in different languages.

	Links to other services	In addition to the printing service, a weather forecast service corresponding to the site location is offered for the *site staffs'* and supervisors' use.
	Web- and digital cameras:	The site can be monitored with the use of a picture transmitted by web camera.
	New user interfaces and data terminal equipment	Project information can be captured and used also by mobile data terminal equipment, such as the WAP-equipped telephone
	On-line status	The user is able to know which other users are currently logged into the system.

2.3 New Potential Technologies

Especially among the largest construction-related companies, basic commercial CE environments have been quite widely implemented. Because these users have experience with the tools, new, sophisticated features and capabilities can be implemented. Examples include integrating previously separate solutions or services so that they are easier to use. The new technologies can bring significant benefits to data exchange and management in multi-partner building projects.

New potential technologies refer to those that are not yet commonly used. The new technologies can be grouped into industry independent and construction industry specific /13/. New, industry independent technologies are:

- Web conferencing
- Extensible Markup Language (XML)
- Common synchronization protocol (SyncML)
- Hand computers like Palm, Psion
- Wireless data, like WLAN
- Mobile data like SMS short messages and data based on GSM cellular network systems

New Architecture / Engineering / Construction (AEC) specific technologies are:

- Industry Foundation Classes (IFC)
- aecXML

An obstacle in the development of **web conferencing** has been a limited scope in network data transfer capacity, which has restricted data types like video. However, tools are under development with which two parties can open a common workspace in each individual's workstation and examine together, for example with the mouse's pointer, the details of a document on the worktable. By integrating the technique into the CE environment, a part of negotiations commonly requiring physical meetings can be carried out by remote connection without a need for traveling.

The descriptive language **XML**, used to structure information, provides the opportunity to transfer the information that structures contain from one system to another and handle the same information with a variety of data terminal equipment like a personal computer and hand-held computer. The open synchronizing protocol **SyncML** aims to allow synchronization of a hand computer's calendar and contact information with all devices and software supporting the protocol. Today the need for synchronizing lies mainly with personal computer calendar and contact information. In the future, it could be possible to synchronize hand-held computer or mobile phone information with the group calendar and contact information in the centralized database. Development focused on the construction industry, **aecXML** aims to enhance data exchange independent of separate organizations' data structures. A possible application target could be data transfer between the centralized, project database and a company's own data structures.

One weakness of drawings traditionally used in construction, is the requirement that interpretation of the contained information needs to be done by human beings, data interpretation cannot be automated. Traditionally, a human being interprets the lines and enters the necessary information into the computer, e.g. in the form of a list of quantities. With the help of the definition of the **IFC** data structure in the construction industry, it is possible to describe a building as a product model. The biggest advantages of the product model is that information about building components can be included in the product design and it is possible for the information to move as data structures from one system to another.

Wireless data can be used to build a light local area network through which the possibility exists to be, for example, on site and connected through data input equipment with a centralized database irrespective of location. However, **mobile data** provides still more significant, new opportunities in multi-partner projects.

Perhaps the biggest advantage of mobile data is the fact that it is possible to use data input devices in various networks so that building project parties typically working outside the office can be connected with a centralized database irrespective of location. Quick messages, used on the Internet, and short message (SMS) technology, used in mobile telephones, resemble each other from the user viewpoint and when adding those into the CE environment remarkable benefits can indeed be expected.

2.4 Mobile Collaboration

A new approach to collaboration in the construction process is mobile collaboration, *mCollaboration*. MCollaboration can encompass most of the functions of traditional and online data transfer; only graphical information remains currently inaccessible. The first mCollaboration features in the CE-environment are notifications to and from mobile phones, and the viewing and searching of text-based data through mobile phones. Suitable text-based data for mobile phone user interface is all non-graphical information like document lists, RFI-data, contact information, task lists, and calendars (Figure 3).

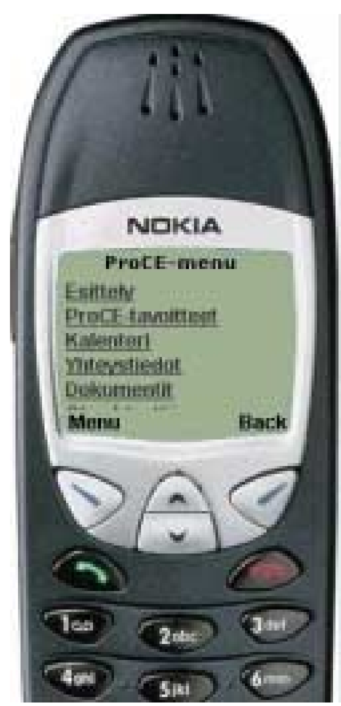


Figure 3. Wireless data terminal equipment as part of the CE environment. An example of a mobile telephone equipped with a wireless application protocol (WAP) browser and user interface to a project information center.

MCollaboration has a special significance to the mobile parties in the construction process that need to access project data from several places. Such parties include main contractor's and sub-contractors' on-site staff, and building component suppliers. These mobile parties spend most of their working time in the field, away from their own offices (Figure 4).

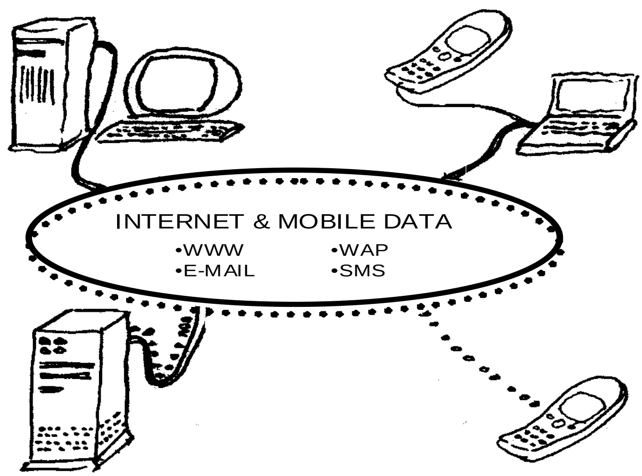
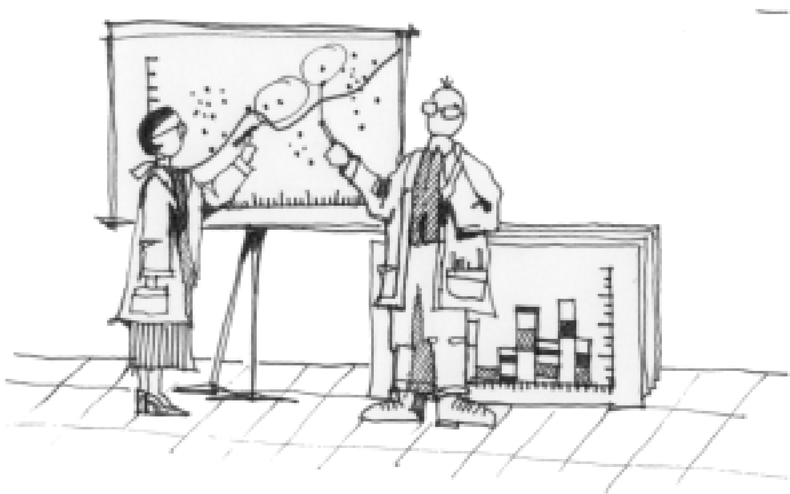


Figure 4. CE-environment for multi-partner projects with mobile devices.

One benefit of using the CE-environment is the decrease in request for information (RFI) response time. This decrease can even be boosted further by a mCollaboration application. Mobile staff can send the RFI to the designer via mobile phone using SMS, or the CE environment RFI-system can send notification to the mobile phone of the party who made the RFI when the response becomes available.

Another common task that is sometimes even a problem on the construction site, is determining the most recent version of a drawing. The crew or foreman cannot be sure if he or she has the latest design version. The mCollaboration solution to this problem is access to the most current list of designs by viewing the document metadata using a mobile phone.

3. MEASURING BENEFITS



3. Measuring Benefits

3.1 Measuring Framework

The model for measuring the benefit of using the CE environment in a construction project consists of four tools: (1) a benefit identification checklist, (2) assessment forms, (3) a summary table, and (4) possible indicators. The primary content of and purpose for each tool is described in Table 2.

Benefits consist of three types:

1. Monetary Benefits: Quantifiable in monetary terms

2. Other Quantifiable Benefits: Quantifiable, but not in monetary terms

3. Qualitative Benefits: Non-quantifiable, described qualitatively

The benefits measured quantitatively are divided into monetary and other quantifiable benefits. A matrix was formed by grouping benefits according to type and relation to activities in the building process. Because of the building process perspective, it was possible to analyze the benefits resulting in the entire project, in contrast to analysis from the viewpoint of a single organization (Figure 5).

Table 2. Model for measuring the benefits of using CE environment.

MEASURING FRAMEWORK	
Part 1.	**Checklist** (Table 1)
	• A list of all potential and achievable benefits gathered into one table • Three categories for different benefit types: MONETARY BENEFITS: Quantifiable in monetary terms. OTHER QUANTIFIABLE BENEFITS: Quantifiable but not in monetary terms QUALITATIVE BENEFITS: Non-quantifiable, described qualitatively • Grouped by building project activity (where a specific benefit can be achieved) • Purpose: helps to identify expected/perceived benefits.
Part 2.	**Evaluation sheets** (Tables 2a, 2b and 2c)
	• One table for each of the three benefit types • Columns: 1. Activities of building project (where CEE has some influence) 2. Identified benefits 3. Indicator/means by which benefit will be measured 4. Expected result / Possible result 5. Measured result • Purpose: Documentation and recording calculations when a target is set for the use of the CE environment, and when reached benefits are determined. If only post-project estimation is conducted, instead of target setting, maximum benefit potential and methods for achieving the benefits can be determined.
Part 3.	**Summary table** (Table 3) • Cumulative result for each of the three benefit types, summarized in one table
Part 4.	**Indicators, related to the checklist benefits** • Some examples/proposals for indicators

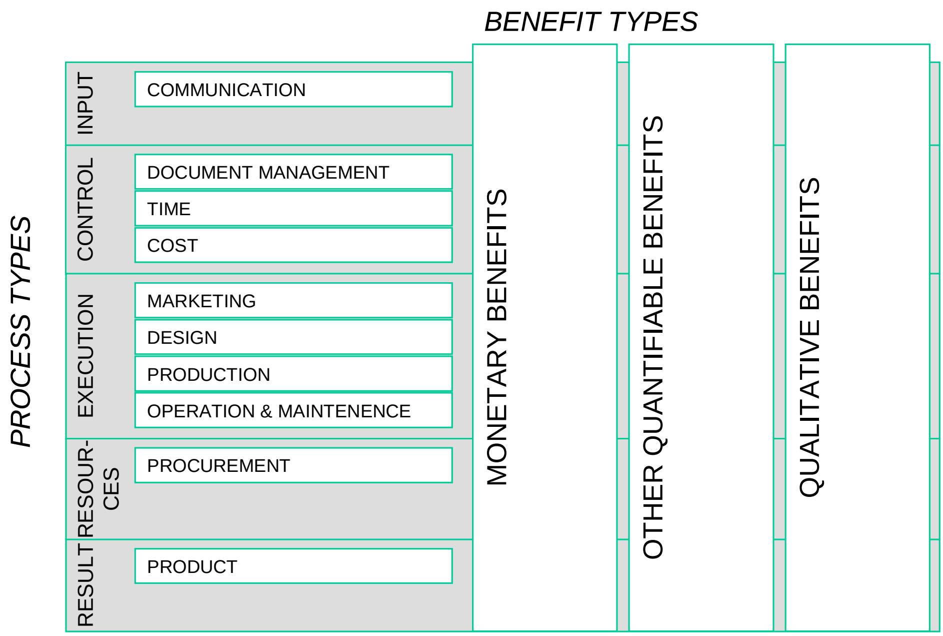


Figure 5. Benefit classification matrix /8/.

3.2 Framework Application

Four main stages exist in the implementation of the measuring model: (1) identification of benefits, (2) preparation for measurement, (3) measurement, and (4) conclusions (Figure 6).

During the first stage, benefits expected or acquired in the project are determined. Expected benefits are those benefits believed to be probable or possible in the project beginning or in progress. Acquired benefits are those that can be observed when a completed project is examined. Identification of benefits is based on basic project information and the expectations and experiences of project staff. The framework's benefit checklist (Framework Table 1) and project staff interviews can be used during this stage.

When preparing for measurement, the benefits selected for measurement are recorded as identified benefits onto the evaluations sheets (Framework Tables 2a, 2b, and 2c). Indicators and a measuring method for each identified benefit are also chosen using the framework's indicator table. Also performed during Stage 1, the information needed for measurement and the data collection methods are defined, and needed questionnaires prepared. An initial observation of the benefits reached in the project is the result of the benefit identification stage. The indicator used in measurement provides evidence that the corresponding benefit resulted and aims to measure the level of attainment. For example, when measuring qualitative benefits, the indicator first establishes that a certain feature was used, and then the indicator measures the level of benefit attainment.

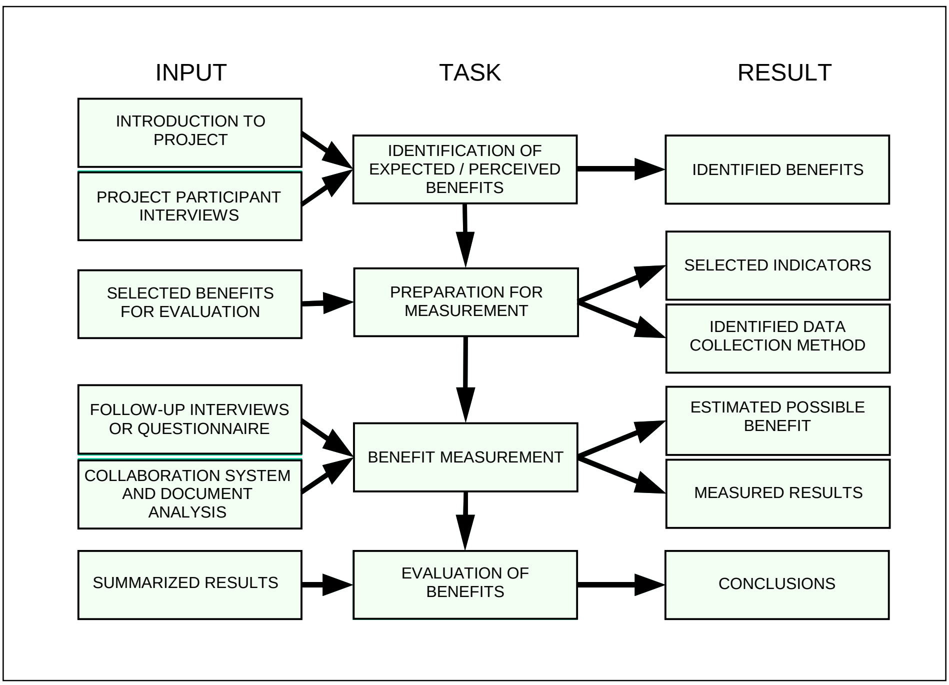


Figure 6. Estimation of CE environment implementation in case studies.

The measurement stage determines the extent of benefit attainment. If analyzing an on-going project, the measurement stage may also include project follow-up. When a project begins, a prediction of attainable benefits can be made and targets set for CE environment use. In post-project evaluation, the needed information is collected through project staff interviews, questionnaires, from the centralized server system, and from project documents. If the project has been completed without target setting, it is highly likely that the maximum possible benefits were not been achieved, and. an estimate of benefit potential may be appropriate. At this point, an estimate of benefit potential identifies the benefits that could have been reached and the requirements for attainment.

Overall results for each benefit type are collected and the significance of the acquired benefits is estimated during the final stage of benefit measurement. Furthermore, benefits resulting from use of the application are compared to incurred costs. Additional information regarding the framework application is located in Section 4.4 and the Master's thesis /10/ done in conjunction with the ProCE project.

3.3 Discussion

3.3.1 IT Investment Evaluation Methods

Existing approaches to the evaluation of information technology investments were reviewed during the research from the viewpoint of project management and organization within multi-partner projects. Previous research showed that most construction organizations use no formal methodology to evaluate the benefit of IT investments, and formal cost-benefit analyses are not widely used /3/, /2/. Meanwhile, in other industries IT investments are evaluated. However, in recent years the construction industry has also recognized the need for effective benefits assessment /1/.

The measuring framework developed by Construct IT /3/ /1/aims to support IT investment evaluations within a single company. The framework can be used to compare competing investments, or show the relative impacts of a proposed investment. One of the basic principles of the framework is a matrix classifying benefits according to type and business process stage. The framework is not suitable for measuring the benefits in a multi-partner construction project.

3.3.2 Measuring Benefits in a Multi-Partner Project

A framework for measuring the benefit of using the CE-environment was created to evaluate benefits in case projects. The framework can be applied to evaluate benefits in a single multi-partner project. It is also suitable for measuring the benefits in concluded projects. Additionally, it is applicable when setting targets for and evaluating the results of using the CE environment in on-going projects. To evaluate long-term benefits, the underlying basis for the process model should be modified from the project process. Long-term benefit analysis should consider additional issues such as the evaluation of changes in the construction industry and project management routines, or the implications of not implementing an innovation /1/.

A project-based process model was selected for the ProCE measuring model because the benefit of CE environment use is divided between several organizations participating in the project. Furthermore, the costs incurred by using the commercial CE environment will usually be related to a specific project. The project approach supports the overall comparison of acquired benefits with application operating costs.

To measure benefits attained because of using the CE environment, benefits must first be defined. Because the project-based approach was selected for benefit measurement, the process-based benefit classification system was also developed.

The preliminary measuring model was tested and significantly developed during the first case study. With respect to related research carried out earlier, a specific development is the qualitative benefit measurement.

4. BENEFITS OF CONCURRENT ENGINEERING ENVIRONMENT

4. Benefits of Concurrent Engineering Environment

4.1 Case Studies

Effects of various features of the CE environment on multi-partner projects were analyzed with help of four case study projects. The first project was chosen from Finland, the second from Sweden, third from England, and fourth from the USA. In addition to location, the case projects differed from each other in building type, size, and delivery method. Basic project information is presented later in this chapter in connection with each case description.

Two of the case studies were completed construction projects and two were on going at the time of analysis. Application versions used corresponded to the project start dates, with the properties changing and improving already during the research project. The majority of the application users had not previously used the application used in the respective case study.

4.2 Identified Benefits

Benefit measurement followed the ProCE project framework, in which benefits are divided into three types:

- Monetary benefits
- Other quantifiable benefits, and
- Qualitative benefits.

Table 3 is the measuring model checklist showing the reachable CE environment benefits for each benefit type found in this study. As shown in Table 3, for each benefit, a code and corresponding verbal description have been developed. The benefits identified in case studies are highlighted with bold text. The table also includes benefits that the authors consider reachable by way of new procedures, in other projects, using other applications available at the time of writing, or with the introduction of new application features. The benefits presented in plain text can be considered potential benefits to be reached for.

The benefit codes were created to aid in analysis and handling of data, and were used throughout all of the case studies. The codes also occur later in the presentation of results, and continue to correspond to the descriptions in Table 3. To simultaneously view the figures presenting qualitative benefit results and the descriptions of benefit codes appearing in the results, a table can be opened from the back cover of the report.

Table 3. List of possible benefits resulting from the implementation of the CE Environment in a building project. Benefits found at least in one case project are highlighted by bold text.

Activities of building project		Monetary benefits	Other quantifiable benefits	Qualitative benefits
Input	Communica-tion K=communication	**K11 Reduced communication costs** (travel, phone, fax) **K12 Labour cost savings because of a more effective use of time**	**K21 Faster distribution of information** **K22 Faster information exchange rate** (e.g. response time) **K23 More effective use of time** (less traditional meetings or several web confer-ences instead of a meeting) **K24 Improved meeting productivity** (distributing materials before the meeting saves time, not reading during the meeting, and allows people to think about issues more in depth) **K25 Fewer disputes because of docu-mented information in audit trail**	**K31 More communication facility options and better information exchange** **K32 Increased awareness of project changes and news** (i.e. new project information). K33 More consistent information **K34 Increased individual accountability** K35 Fewer misunderstandings **K36 Easier to deliver information to late parties joining the project (they get more complete information than traditionally)** **K37 Improved quality of discussion**

Control	Document management - (D=Document management)	D11 Reduced document distribution costs (printing, courier, mailing) D12 Labour cost savings because of a more effective use of time D13 Lower archiving costs (space & container hire / purchase)	D21 Faster distribution of documents / Information is accessible earlier (indicator 1) time @ upload, 2) Faster delivery of paper copies) D22 More effective use of time (less searching, collecting, and handling of paper; possibility to work remotely) D23 Fewer tasks (e.g. server document eliminates the need for file backup, updates are made to a central location by one person, like contact info) D24 Reduced need for archiving space at office / on site D25 Reduced paper waste	D31 Project information available without time, location, or user organizational dependency D32 Documents are in better order and easier to find in a single, organized collection D33 Increased awareness of new information D34 Versions of a document are in better order, easier to find, and readable D35 Project information is easy to retrieve for own use D36 Improved filtering of information (Elimination of paper delivery of unnecessary information because of user defined information requirements) D37 Easier distribution of documents to other parties
	Time (A=time management)	A11 Cost savings from compressed schedule	A21 Opportunity for compressed schedule / more flexible planning of own time (same quality level in shorter time) A22 Reduced risk of exceeding schedule	A31 increased opportunities to plan use of own time
	Cost (KU = cost mgmt)		KU21 Reduced risk of exceeding budget	

Execution	Marketing M = marketing	M11 Reduced distribution costs (of marketing materials)	M21 Improved company image (indicator could be better or wider service to client) M22 Generating new business (new projects) M23 Wider marketing area (geographically)	M31 More complete project information
	Design S = design	S11 Reduced labor and adminis-trative costs (locating product information faster) S12 Cost savings due to fewer design errors (less rework)	S21 Time savings due to fewer design errors (less rework) S22 Improved quality of design (fewer design errors, improved constructability) S23 Faster design change process S24 Fewer administrative tasks S25 Faster decision making S26 Faster specification of building products and materials (eCommerce and other info sites) S27 Time savings from reusing information more effectively (e.g. sharing electronic building layout)	S31 Better tools for collaboration improve collaboration possibilities S32 Easier to share common electronic infor-mation (e.g. building layout) S33 Improved coordination of geographically dispersed resources. S34 Increased awareness of task status S35 Easier to publish updated / revised docu-ments S36 Increased accessibility to up-to-date proj-ect information S37 More complete and consistent recorded and retrieved project information S38 Easier to monitor design progress (e.g. for design coordinator)

			S28 Fewer PCs need design software installed (can use viewer).	**S39 Improved coordination of designs (e.g. management of specialty contractor designs)** **S40 More efficient decision-making cycle** S41 Increased documentation of decision background. **S42 Helps to manage design change process** **S43 End users of the building have more opportunities to influence design decisions because they can follow design progress**
	Construction (R=Construction)	**R11 Cost savings due to less rework** (labour, material, equipment costs) **R12 Reduced labor costs because of more effective use of time** (e.g. using electronic forms or data input and transfer by using mobile communicator)	**R21 Time savings due to less rework** (field errors and rework) **R22 Time savings in data collection and transfer** (e.g. using electronic forms or data input and transfer by using mobile communicator) R23 Fewer administrative tasks **R24 Reduced time for decision making**	**R31 Easier to collect and transfer data** (daily field reports, communicator) R32 More complete and consistent recorded and retrieved project information R33 Improved coordination **R34 Increased accessibility to up-to-date project information** **R35 More efficient decision making cycle** R36 Better tools for collaboration improve collaboration possibilities

			R25 Faster access to manufacturer safety and installation information R26 Time savings from reusing information more efficiently (using text from specifications, etc.) R27 Fewer PCs need design software installed (can use viewer)	R37 Improved workflow management R38 Increased awareness of task status R39 Easier to monitor construction progress (e.g. by web camera, posting digital photos) R40 Increased documentation of decision background. R41 Easier to share common electronic information (e.g. design-manufacturing-construction progress tables)
	Operation and Maintenance (KP=operation and maintenance)	KP11 Cost savings because of electronic archive (e.g. no need to use scanning service) KP12 Labor cost savings because of more efficient use of time due to faster access to completed project information	KP21 Time savings due to faster access to O&M data (O&M data collected and transferred to owner)	KP31 Facilities to create a complete, searchable, electronic Operation and Maintenance manual. KP32 Standardized documentation (form and content) KP33 Full electronic archive created for the client (e.g. as-built documents, design / construction decision background) KP34 Improved full-life cycle information management KP35 Project information is maintained in a useable form and remains available to future users on the service provider's server.

Resources	**Procurement** (H = procurement)	H11 Labour cost savings because of a more efficient use of time (submitting tender material via the centrally-accessible server) H12 Reduced document distribution costs (printing, courier, mailing)	H21 Time savings from reusing information more efficiently (quantitative information)	H31 Easier to locate information about available products and human resources (product info, subcontractor contact info) H32 Easier to transfer information between parties (quantitative information)
Result	**Product / building** (T = product / building)		T21 Improved quality (fewer errors, items on the punch list)	

4.3 Benefit Generation

Traditional benefit evaluations often concentrate on cost comparisons. In the ProCE research project, special effort was put toward analyzing qualitative benefits. In addition to these, time and other quantifiable benefits and monetary benefits were measured.

With the CE environment, many important benefits easing or simplifying operation are reached, yielding time and other quantifiable benefits. These time benefits then lead to monetary benefits. The direct monetary benefits can be measured, but it is often difficult to measure the indirect monetary benefits. In the project specific case-analyses, it was possible to estimate only a small part of the monetary benefits reached as consequence of qualitative benefits (Figure 7).

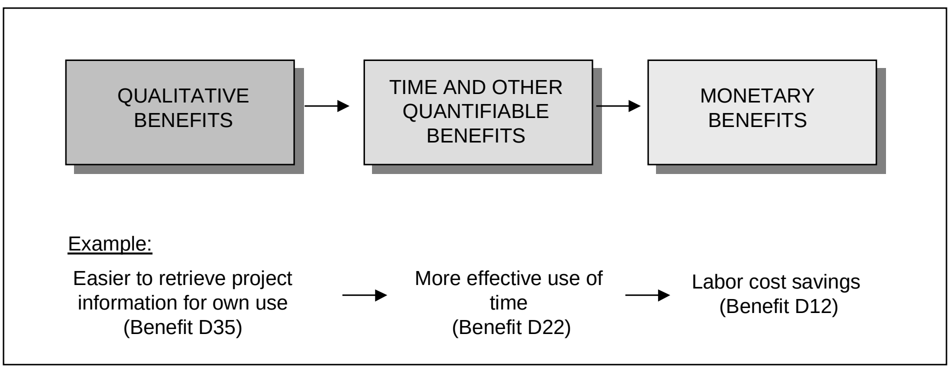


Figure 7. Generation of benefits. Qualitative benefits result in time benefits yielding monetary benefits /14/.

4.4 Measurement and Presentation of Results

To measure the benefits of using the CE-environment, case study publishing and dissemination procedures have been compared to the corresponding processes occurring in the traditional paper environment. Some of the described benefits can be reached to some degree using more modest environments. The development degree of the implemented environment nevertheless influences which benefits are achieved and to what extent. The measured results presented, correspond to the benefits reached by the environment implemented in the project under consideration when compared to the traditional paper environment mode of operation.

All identified benefits were measured. Benefit measurement was preceded by definition of a benefit indicator and obtaining the information needed for measurement. Information was gathered through interviews with case project staff, by questionnaire submitted to project staff, from the collaboration solution and documents contained by the application. No application history of use (audit trail) was available for Cases 1 and 2, which was the biggest obstacle to the use of some benefit indicators and to the analysis of the benefit realization in these case studies.

Qualitative benefits were measured by way of a questionnaire directed at the application users. Benefit realization was measured on a six-point rating scale (-1–4). All questions measuring qualitative benefits followed the example shown in Table 4.

Table 4. Example question from the questionnaire used for measuring qualitative benefits.

6. Distribution of documents to other parties was easier than in projects where a similar system was not used?	
4	Far easier
3	Substantially easier
2	Somewhat easier
1	Minor aid
0	Use of application made no difference compared to traditional mode of operation
-1	Negative impact: use of application caused problems/extra work, etc. If this is the case, what/why/how?
E	Cannot say since I did not use the application for the indicated purpose
Your response:	

Information about work time savings was also obtained through questions in the questionnaire, and asked responders to estimate time savings related to certain tasks. For example, monetary savings due to travel are savings indicated by individual responders, and not generalized for other parties. Because the inquiry was sent only to solution users, a conservative estimate of savings was made in most cases. Others in the companies may have also been able to avoid traveling.

The project-specific analyses are not intended to be an exhaustive cost-benefit analysis and as a result do not include all costs corresponding to the benefits attained. Costs associated with the following are not considered: printing devices, increased use of ink, maintenance service agreements, installing and maintaining integrated services digital network (ISDN) lines for the internet connection, increase in electricity usage due to increased use of the computer. It depends on the level of the IT infrastructure and prevailing procedures of the company, if the use of the CE environment requires investments, like acquisition of a new computer or printer.

Basic information about the measuring model used to estimate benefits is located in Chapter 3, and more detailed information in the Master's thesis /10/ done in conjunction with the project.

Measured benefit results are first presented in a brief summary in Section 4.5. Overall results are located in Sections 4.6–4.8.

The overall results are based on the results of Cases 1, 2, and 3. In these cases, the CE environment was used for project management based on many of the same principles. For Cases 1, 2, and 3, the feature common to all projects was a centralized, document archive containing the project documents as comprehensively as possible. In practice, the overall results contain a combination of both the average results and individual project results. The reason for the result combination is due to individual project characteristics the identified and measured benefits were not the same in all three projects.

The collaboration solution used in the American case study was used only for the distribution and filing of two specific document types: requests for information and the drug policy. The use of the application and the acquired benefits were related to the project culture in United States. Due to different project procedures, the Case 4 benefits would not be reached to same extent if used by one of the other case study countries. It was not suitable to combine these results with the results of the other cases.

4.5 Summary of Overall Case Study Results

Project-specific results are shown in Table 5 for Cases 1–4. When benefits and costs are examined from the perspective of the entire project team, for all cases measured monetary benefits exceeded the direct costs incurred by the use of the applications.

Table 5. Summary of the individual results for Cases 1–4. In the comparison of monetary benefits with the application operating costs, direct costs include only the ASP use fee.

Case no:	**Qualitative benefits** Overall score in scale -1–4	Time and other quantifiable benefits	Monetary benefits	Monetary benefits / costs of use
1	2,6 "The tool substantially helped in document and project management"	• Time savings about 200 hours (29 work days) • About 1700 days less information distribution delays.	Altogether about 17 300 USD (17 300 €)	2,6
2	2,2 "The tool was somewhat helpful in document and project management"	• Made about 4 months tighter schedule possible. • Work time savings about 50 hours (about 7 work days) • Time delays in the information distribution about 530 days less • Fewer disputes, related to the information distribution	about 8 100 USD (70 000 SEK, 8 100 €)	1,8
3	2,3 "The tool was somewhat helpful in document and project management"	• Time savings about 162 hours (about 20 work days) • Time delays in the information distribution 2344 days less approximately. • Less field errors	19 000 USD (£ 12 000, 19 000 €)	1,3
4	2,3 "The tool was somewhat helpful in document and project management"	• Time saving related to RFI process on average about 40 percent (2 days). • Time delays related to RFIs about 326 days less. • Time savings about 365 hours (about 46 work days)	27 000 USD (27 000 €)	22

Due to cultural differences, the remarkably high monetary benefits reached in Case 4 would not be reached to same extent if used by one of the other case study countries.

In Case 1, good results were achieved, especially for qualitative benefits. The result is partially a combined effect of using two separate applications. The application used for the design stage served document management only. The application used experimentally in the construction stage, contained properties developed especially to support the construction stage. Because both applications were relatively easy to use, and the features did not overlap, together they offered a good selection of useful properties, supporting document and project management. Still, better results would probably have been achieved if one application offered all the same features and capabilities for use in the project duration. If looking at the present state of the applications used in Case 1, this feature diversification has been the direction of development. Both of the solutions independently include almost all the features used in Case 1.

In Case 2 and 3, the most interesting benefits are the acquired time benefits. In both building projects, the revised design distribution procedures made the faster project completion possible. In Case 3, elimination of time delays seems to be especially high. The target to reduce paper in Case 3 was also reached to some extent.

The combined results of case studies 1–3 are presented in the following sections.

4.6 Qualitative Benefits

4.6.1 Impact on Project and Document Management

Benefits not readily measurable in monetary or other quantifiable terms, called qualitative benefits, were measured as influence of the CE-environment on document and project management on a scale from –1 to 4 as follows:

4 = Solution was very helpful
3 = Substantially helpful
2 = Somewhat helpful
1 = Only slightly helpful as compared to traditionally
0 = Use of application made no difference compared to traditional mode of operation
-1 = Negative impact: Use of the application caused problems or more work

The average overall score for qualitative benefits reached in Cases 1–3 was 2.4. The nearest verbal description that corresponds to this score is: ***The solution was somewhat helpful in document and project management.*** The results for individual benefits are shown in Figure 8.

On average, the following benefits were reached best, having an average result of greater than 2.5 for each:

- The completion and approval of the electronic daily field report was far easier than the traditional paper reports. (R31 Easier to collect and transfer data)
- The distribution of documents to other parties was substantially easier (D37)
- Substantially better possibility to stay up-to-date on changes and news concerning the project (K32)
- The application significantly supported remote work (D31)
- It was significantly easier to retrieve project information for own use (D35)
- It was substantially easier to publish updated / revised documents (S35)

- Substantially easier to access up-to-date project information in design stage (S36)
- Substantially easier to access up-to-date project information in construction stage (R34).

The CE environment had the highest impact on recording/saving, distributing, and publishing information, and on the access of real-time information. Independence from other project parties and from time and place are related to the access of the information. Some benefits applied only to a small group of users, as shown in Figure 8.

The questionnaire also contained score -1= Negative impact: use of application caused problems or extra work. The response was given a few times, but was not included in average project results, and is also not included in the combined results.

In addition to the benefits presented in Figure 8, benefit A31 (opportunity for more flexible planning of own time) was measured as a qualitative benefit. The benefit is missing from the result figure, because an attempt was originally made to measure this quantitatively. However, enough information was not received by the inquiries for quantitative estimation and at the end of the study, the benefit was moved into qualitative benefits. The A31 average result for Cases 2 and 3 was 2.0; at the personal level, *a somewhat more* flexible arrangement of assignments was obtained because of the use of the centralized system. Benefit A31 applied to a total of 13 questionnaire inquiry responders.

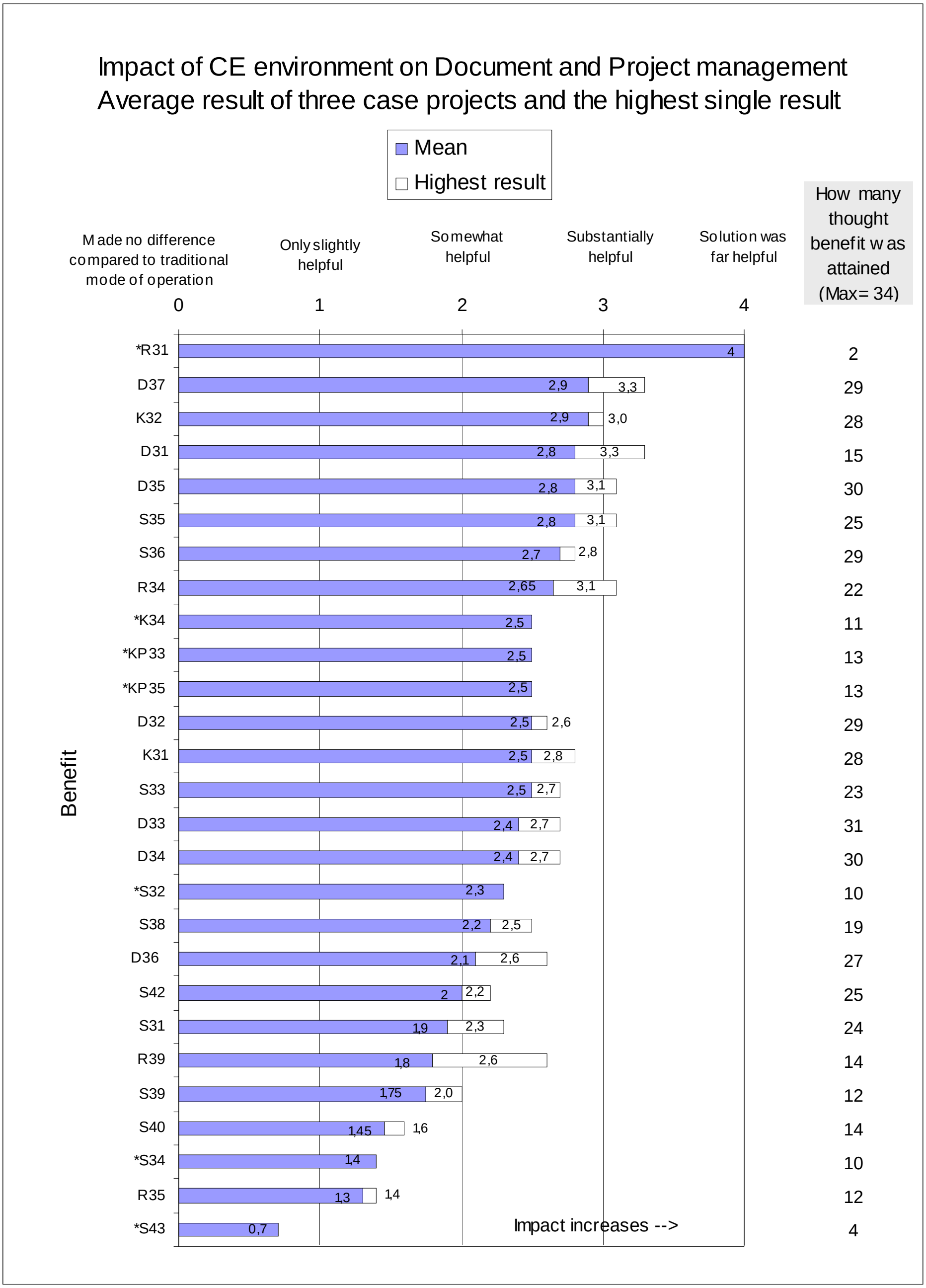


Figure 8. Qualitative Benefits Obtained by Using the CE Environment. The average for the three case studies (Cases 1, 2, and 3) and the highest project-specific result measured are shown. A star in front of the benefit means that the benefit was reached and measured in only one of the cases. Benefit codes are described in Appendix 1. The questionnaire also contained alternative -1= Negative impact: the use of the application caused problems or extra work.

4.6.2 Frequently Occurring Benefits

Four qualitative benefits occurred frequently among Cases 1, 2, and 3. These benefits were reached in all the three cases with at least a result of 2.5 and were attained in the majority opinion of the responding group.

- Distribution of documents to other parties significantly easier (benefit D37, in 29/34 responding opinions was reached)
- Significantly easier to publish the updated documents (benefit S35, in 25/34 responding opinions was reached)
- Significantly better opportunity to stay up to date concerning the changes & news in the project (benefit K32, in 28/34 responding opinions was reached)
- Significantly easier access to the real-time project information (benefit S36, in 29/34 responding opinions was reached).

From the viewpoint of the information producer, the ease of document distribution and information publication can be considered the most typical benefits. From the viewpoint of the information receiver, the most typical benefits are the better availability of real-time project information and easier following of changes.

4.6.3 Benefit Attainment Compared to Importance

The questionnaire also surveyed how important responders, i.e. the users of applications, considered the measured benefits. In this connection the following scale was used:

4 = Extremely important

3 = Important

2 = Fairly important

1 = Of little importance

0 = No practical significance.

The importance of measured benefits and the impact have been compared in Figure 9. Almost all the measured benefits were considered important, equating to an average verbal score of “significant”. Many benefits were well reached in relation to their importance.

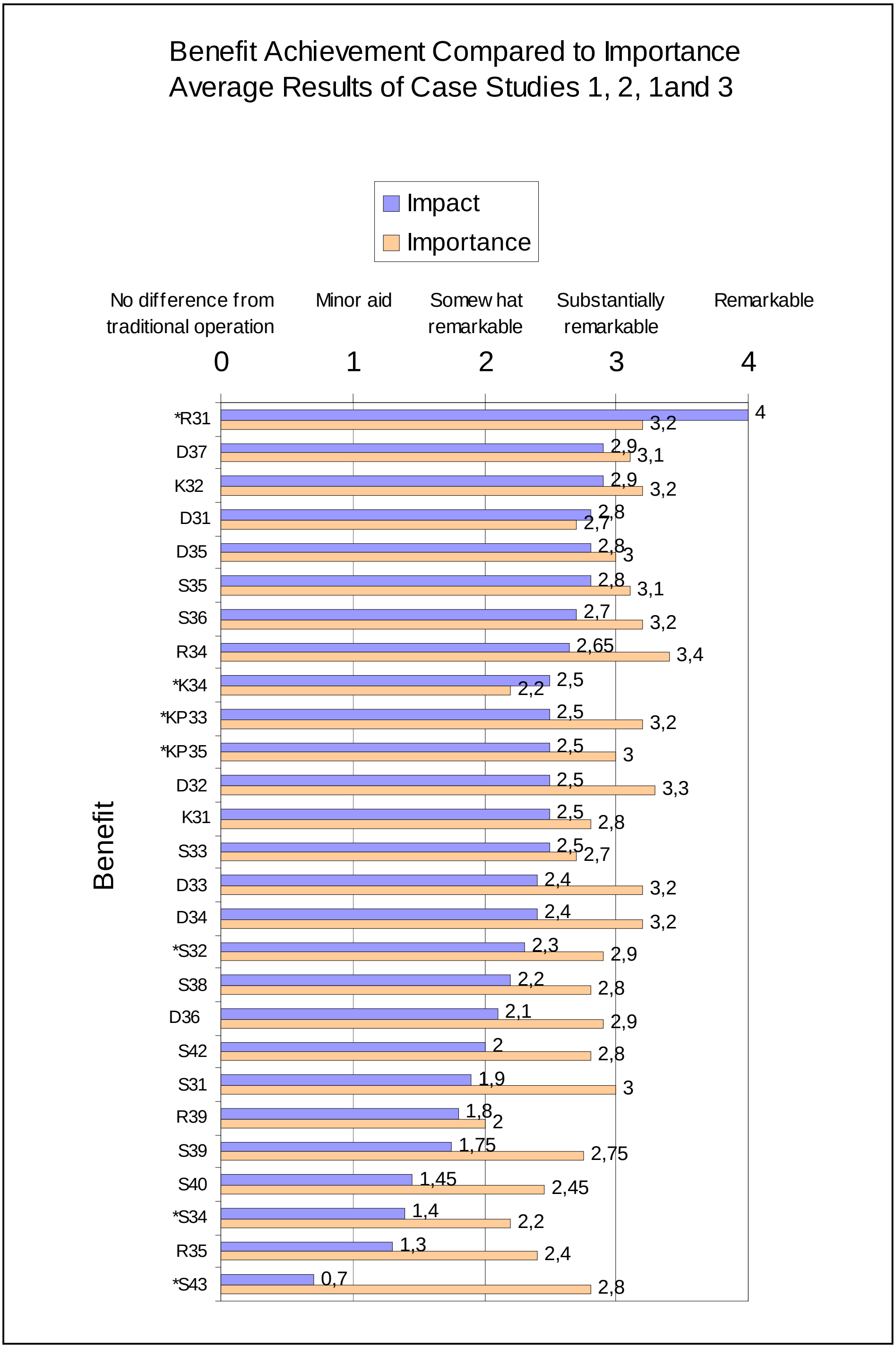


Figure 9. Average Benefit Achievement and Importance in Cases 1–3.

Figure 10 shows four benefit groups emerging from the comparison of benefit importance and impact:

I Important and well-reached benefits: The applications corresponded well, on average, to these needs.

II Important but weakly acquired benefits: The applications corresponded weakly, on average, to these needs. There would be development potential in this area.

III Less important benefits but well acquired on the measuring scale: the properties of the applications supported on their practical significance the less important needs.

IV Less important weakly acquired benefits

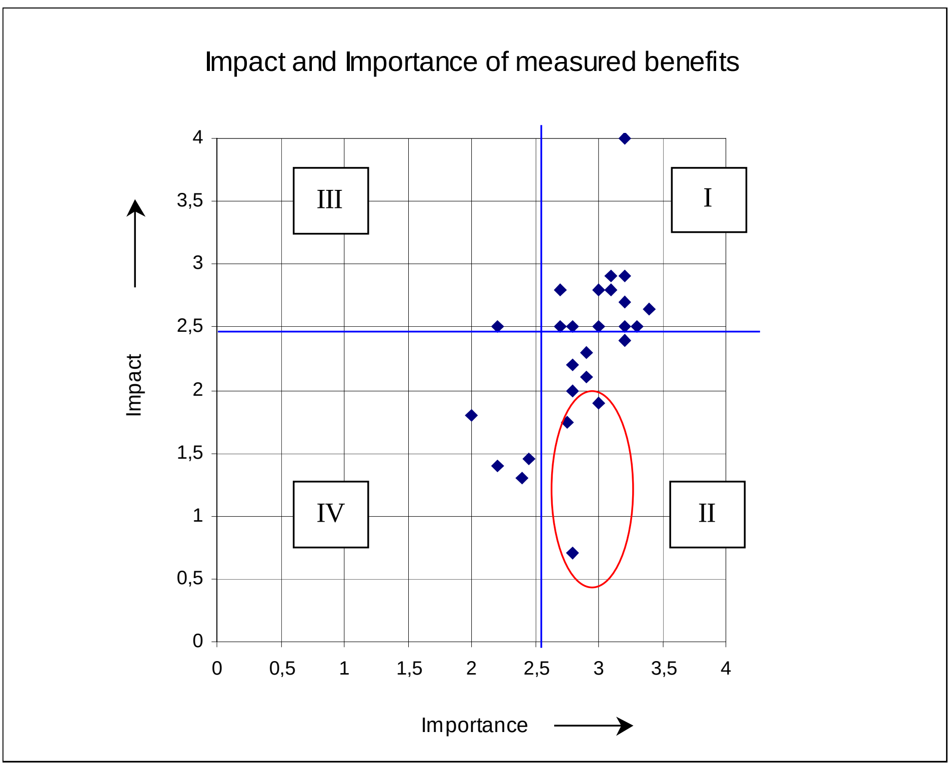


Figure 10. Benefit Achievement Compared to Importance. The results are average for Cases 1, 2 and 3.

The most modestly reached benefits ringed in Figure 10 in respect to their importance are:

- Impact of the application on the participation of the building end users (S43)
- Increase in opportunities for cooperation (collaboration), (S31)
- Support in coordination of designs (S39).

Regarding these, the use of the applications was not a big advantage, but features should perhaps be developed so that the benefits would be reached. Developing the properties that support the functions should therefore be considered.

4.6.4 Benefits to the Various Parties

In all the analyzed case projects a different ASP application was used as a centralized information storage. The CE environment used in the three European case projects was so similar that by combining their data, benefits to the different parties can be analyzed, shown in Table 6. When studying the results, it must be remembered that the sample is relatively small and suggestive of results.

When analyzing the benefits from the viewpoint of the various parties, the strongest influence of the CE environment on document and project management was in the supervisors' and clients' groups. For both parties the average measured result was 3, "the application helped significantly". A total of five people in these two groups responded in the three projects. Based on the contractors' 13 replies, the average opinion was "helped a little". The same average result was achieved from the 16 replies that were received from the designers. However, the highest acquired benefits were mainly different for different parties. The common benefits, applicable to several parties were easier access to the up-to-date project information and easier retrieve of the information for own use.

Table 6. The views of different parties' concerning the impact of the CE environment to document and project management in Cases 1–3.

Party	**Number of replies**	**Impact on average** (scale -1–4)	**Party-specific highest benefits to the own work**
Designers	16	2,2 "Was somewhat helpful in document and project management"	– *Distribution of documents to other parties easier* – *Easier to publish the updated documents* – *Increased individual accountability* – *Easier access to the real-time project information* (Measured result 2,8 to each)
Contractors (General and subcontractors)	13	2,3 "Was somewhat helpful in document and project management"	– *Easier to record/save the project information* – *Better opportunity to stay up to date the changes & news concerning the project* – *Easier to retrieve the project information into own use* (Measured results 3,1–3,2)
Supervisors	3	3,1 "Was substantially helpful in document and project management"	– *More communication facility options and better information exchange* – *Easier access to the real-time project information* – *Distribution of documents to other parties easier* – *Faster insight into progress of design and construction work* – *Easier to record/save the project information* (Measured result 4,0 to each)
Owners	2	3,0 "Was substantially helpful in document and project management"	– *Easier to retrieve the project information into own use* – *Elimination of unnecessary information because of user defined information requirements* (Measured results 4,0)

In the contractors' group, easier recording of information into the electronic daily field report and a better opportunity to stay up-to-date on the changes and news concerning the project were the most achieved benefits. The greatest perceived impact in the designers' work was easier distribution and publication of documents and increased individual accountability, meaning that it was easier to follow the completion of the tasks and responsibilities at the personal level. The designers also predicted the benefits reached by other parties, in addition to their own benefits. Benefits for building operation and maintenance climbed to a high level in the impact results. In Case 3, the designers predicted the following operation and maintenance benefits: project information is maintained in a useable form and remains available to future users on the service provider's server (KP35), and full electronic archive created for the client (KP33).

4.7 Time and Other Quantifiable Benefits

In the analyzed building projects numerous time and other quantifiable benefits were observed. The following time advantages were observed:

- Work time savings
- Support for design and construction carried out with tighter schedule
- Reduction in the time delays for information distribution
- Partly as a consequence of the previous benefit, at the personal level, increased opportunities to plan the use of own time.

The following quantifiable benefits were also observed:

- Fewer field errors
- Slightly fewer disputes because of documented information exchange
- Less paper to be filed.

Design information flow can be radically changed with the help of electronic data transfer. As a consequence of time and other quantifiable benefits, direct cost savings are obtained. Their most significant effect is that the project information flow becomes more simple and faster.

In the paper environment, design information is transferred on paper only. Most typically, a courier from the design office brings the plans to the printing service by car, if the copy service and design office are not located within walking distance from each other. The time elapsed is usually 0–2 days, depending on the distance and priority of the task. The copying service delivers the drawings according to the distribution list by traditional post or the distribution is handled by courier. Overall, the delay in the information distribution is 0–4 days. For example, the delivery of a drawing (paper copy, blue print) from the designer to the building site takes about 2 days on average. The traditional process is shown at the bottom of Figure 11. The same figure shows the alternatives offered by electronic data transfer.

In Case 1, design information was distributed to the project participants in electronic mode by the help of the centralized system. Traditional paper distribution was also used in parallel with design files being sent digitally to the printing service. Significant in this action is that the design information can be delivered to other parties in electronic form without distribution delays: as soon as the design is saved in a centralized system, it is available to the other parties. The design information will be available in paper form on average one day later, because of the distribution delay related to paper copies. Even if the project participants received paper drawings from the copying service, the delivery delay was on average one day shorter than in the traditional paper environment described previously and shown in Figure 11.

In both Cases 2 and 3, the design information and the paper mode drawings were available to the other parties immediately after the designer put his plan to the system. The designers saved the A3-sized designs onto the centralized system, where other parties were able to get them in electronic form and print out the paper drawings as needed. In the reformed procedure, all the distribution delays are eliminated and the critical schedule tasks can be supported. Because self-performed printing has some costs, cost savings are not always reached and, as shown in the uppermost process of Figure 11, benefits are primarily time benefits.

By the reformed procedure, based on self-printing and use of A3-sized plans, a quick and economical distribution of the design information can be achieved. The procedure is not suitable as such for building projects in which a printer for very large drawings, A0-sized for example, is needed. By the procedure, cost savings are reached as the consequence of the diminished use of printing service.

However, the total saving is reduced because of the self-printing. The time benefits must be considered as the primary benefit reached with the procedure.

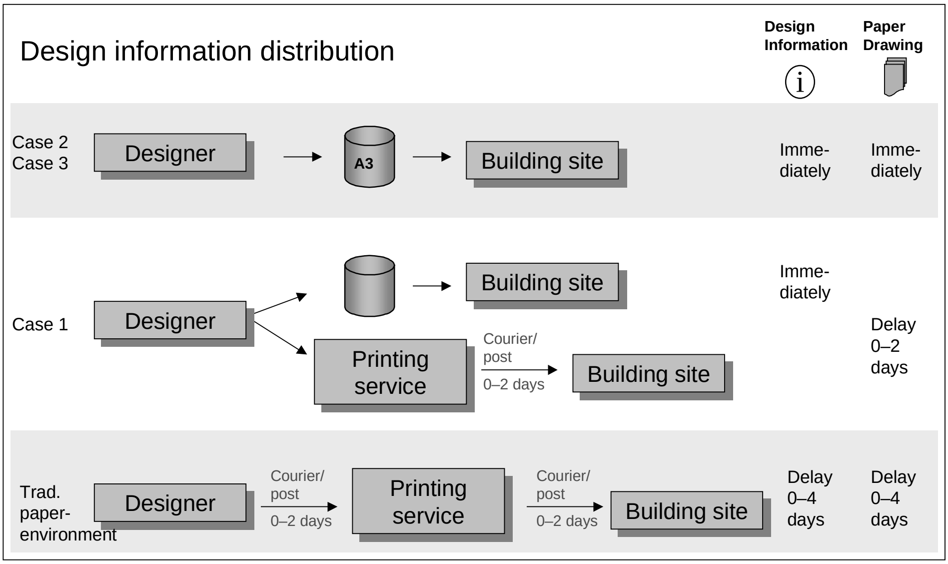


Figure 11. Impact of the New Design Information Distribution. The symbols shown in the upper, right corner correspond to design information available in electronic and paper form. Beneath, distribution delays related to each procedure used are shown.

Delivery of drawings to other parties using the file formats meant only for document viewing and printing can also be a useful solution. An example of this kind of file format is the Adobe pdf file. Compared to the original CAD program, benefits of the pdf file include smaller file size and more easy-to-use software.

4.8 Monetary Benefits

In Case Studies 1, 2 and 3 perceived monetary benefits were on average about 15 000 USD (15 000 €) per project. When monetary benefits are compared to the costs, the benefit is on average:

- about 1.9-fold with respect to the service providers charge
- about 1.7-fold with respect to total costs of using the applications
- about 0.08 percent of the total costs of the project.

The direct cost savings were connected mainly to communication and document management. In the analyzed case projects, the main contractors and owners received the most monetary benefit. The following monetary benefits were observed in the study:

- Savings in the mailing costs of meeting minutes etc.
- Reduced traveling costs
- Reduced paper copy costs related to drawings
- Reduced telephone expenses
- Labor cost savings because of more efficient time use.

Time is not usually as important in conjunction of the distribution of the meeting minutes as in the distribution of the design information. However, a common document archive is created by using a centralized electronic distribution and significant sums can be saved in mailing costs (Figure 12). In the analyzed case projects the potential saving related to the mailing costs was approximately 2 000 USD (2 000 €) per project. From the viewpoint of the drafter, the information distribution is also easier and quicker because the delivery to the other project parties is possible by a single upload. The labor costs are related to the handling of paper documents are moved to the receiver in this new procedure.

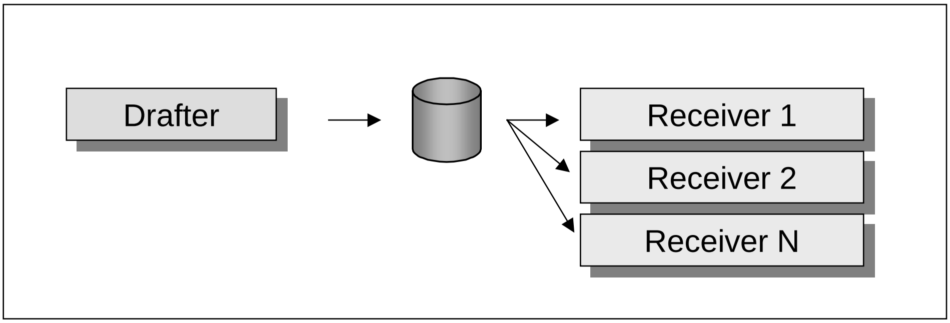
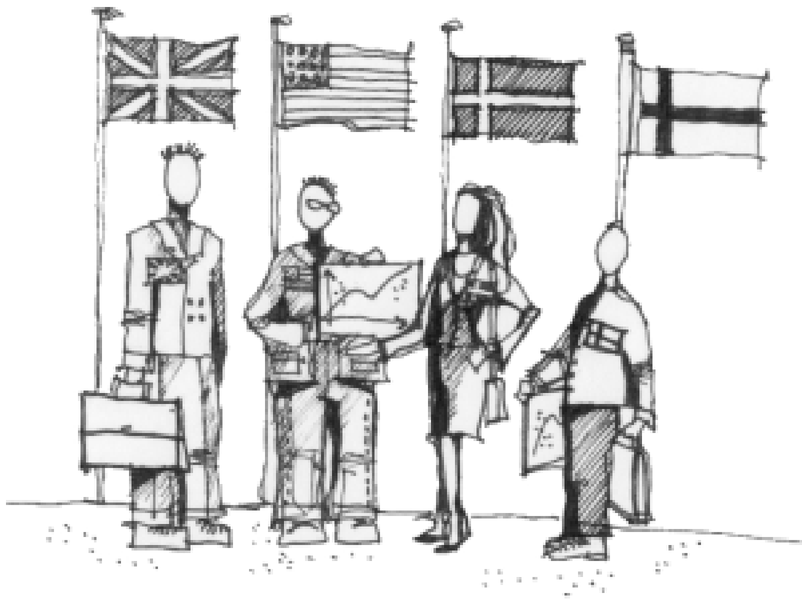


Figure 12. Centralized Electronic Distribution.

If a receiver is satisfied with the reading, handling, and filing of the information in electronic form, the transfer of costs turns to labor cost savings. The same kind of reforming and cost saving potential exists also for the distribution of bid documents.

5. ANALYZED PROJECTS



5. Analyzed Projects

5.1 Case Study 1, Finland

The first building project analyzed in the study was a mixed-used office building in Finland housing educational and office premises (Table 7).

Table 7. Case Study 1 Basic Project Information.

Case 1	
Building type:	Mixed-use office building: educational and research premises, office space leased to companies.
Project size:	25 million € (about 25 million USD) 19,500 m^2 gross (210, 000 sf)
Delivery method:	Privately financed, public project delivered by way of a construction management contract
Project Parties:	Main contractual parties located around the country and financier abroad.
Schedule:	Project planning started Spring 1997, Construction in Summer 1999, Completion and handover Late Summer 2000.
Project and solution status at the time of analysis:	Completed project; Implemented commercial applications developed significantly after use in the project construction phase.

In Case 1, the traditional paper and concurrent engineering environment were used in parallel for communication and document distribution. In terms of the CE environment, two ASP-solutions were used for document and project management, Raksanet during the design phase and Työmaatieto (now known as Project Info and both solutions of Buildercom), during the construction phase.

Furthermore, separate electronic mail (e-mail) programs were used because the e-mail feature of both applications was limited to sending document update announcements. In other words, it was not possible to compose and send e-mail messages via the applications.

Raksanet was used in the design phase as the centralized document archive. The electronic document archive replaced the practice of sending drawings as email attachments, except in delivery to the printing service where printable formats of the drawing files continued to be emailed as attachments. Designs continued to be delivered in paper form to the parties. Design meeting minutes were also delivered traditionally on paper. Building end users were given the opportunity to access the electronic document archive, allowing them to follow the progress of design.

In the construction phase, Raksanet served as the design archive, and a second solution, Työmaatieto, was taken into use to serve as the project management tool. Project background information, contact information, construction phase meeting minutes, and some production planning documents such as the construction schedule were stored in the Työmaatieto application. Additionally, the application's electronic site journal feature was used to record daily construction site activities, as well as the web camera. The application displayed pictures taken by the web camera, which allowed project team members to follow building frame construction remotely. Most meeting minutes were delivered through the system, but because subcontractors did not use the solution, the number of documents delivered by traditional, paper means remained high.

A total of ten project participants responded to the case study questionnaire. Responses were obtained from the designers, the main contractor's staff, a construction supervisor, and real estate owner. About 70 percent of the respondents had not used a similar ASP application earlier.

5.2 Case Study 2, Sweden

The second project analyzed in the study was a school building built in Sweden (Table 8).

Table 8. Case Study 2 Basic Project Information.

Case 2	
Building type:	Primary School Building
Project size:	6500 m^2 64 million SEK (about 7.5 million USD and 7.5 million €)
Procurement method:	Design – Build
Project parties:	Main parties located within a maximum radius of 100 km
Schedule:	Aggressive time schedule: Design began 9/1999, construction only 1.5 months later 10/1999, and building handover 6/2000.
Project and solution status at time of analysing:	Completed project. An updated version of the application exists as compared to that used during the project. Features have developed in some degree after the case.

In Case Study 2 an ASP-solution called Byggnet was used for both document and project management. The solution was developed with the intent to suit document management, but also included notifications that closely resembled email features. In addition to the Byggnet notifications, many parties also used standard email software. In the design phase, all project information was delivered by the Byggnet system. The system was also an important distribution channel during the construction phase. However, not all subcontractors could access Byggnet; as a result, project documents were delivered to those parties on paper.

Routine paper document delivery was not used in the project. In addition to meeting minutes, lists of drawings, and other typically A4-sized documents, approximately 80 percent of designs were delivered by the Byggnet system. A plotter and PC having CAD software were used to print the designs onto paper on the construction site. Because almost all information on the Byggnet system was available in the PDF file format, other project parties ordered paper copies from a copying service printing from the PDF format. Architectural designs were saved to the system in both DWG and PDF format so that all parties were able to access and use the files as needed.

In addition to document delivery and management, the Byggnet system was used to post project notices to an electronic bulletin board and follow construction with a web camera. In the design change process, the request for information (RFI) feature was also used. The RFI feature has been developed to formally request and provide additional information, and to document decisions.

Benefit measuring was performed in the same way as in Case Project 1. A total of seven questionnaire responses were received. The responding group consisted of designers, the main contractor's staff, the construction supervisor, and the owner's representative. Nearly 60 percent of the respondents, four of the seven, had previous experience with the Byggnet application.

5.3 Case Study 3, England

The third project analyzed was a retail business building built outside of London that was a part of a larger development (Table 9).

Table 9. Case Study 3 Basic Project Information.

Case 3	
Building type:	Commercial retail store (supermarket) and adjoining development
Project size:	£16 million (about 25 million USD and 25 million €) Total of 22 acre (9 ha) development, Store size: 84,500 sf gross (7,900 m^2)
Procurement method:	UK JCT standard traditional contract amended to reflect the Owner's partnering philosophy
Project parties:	Main parties located within a 200 mile (300 km) radius
Schedule:	Design started Mid-summer 2000; Steel frame started late spring 2001; Completion and handover early autumn 2001; 17 week store construction schedule (including neither site preparation nor adjoining development)
Project and solution status at time of analysing:	Analysis began while construction was still in progress, and continued after project completion. Commercial application did not change while in use in the construction project.

In case 3, Sarcophagus' "the-project" application was used during the construction phase to electronically publish, disseminate, and archive a significant number of project documents and amount of project information. Documents included drawings, specifications, component schedules (e.g., finishes, reinforcement), progress reports, meeting minutes, approved changes (PARs), anticipated final expenditures (AFEs), health and safety (CDM) documents, and risk assessments. In most cases, the tool replaced posting, emailing, or faxing drawings and other documents to different parties, and also served as a centralized project archive for documents, contact information, and site photos. The owner, design team, construction manager, main contractor, and several subcontractors used the tool.

In addition to the use of the CE-environment, Case Study 3 possessed a second, unique information dissemination characteristic: the client established and enforced a directive for all designs to be drawn in a 1:50 (1-inch to 50-feet) scale on A3-size paper whenever allowable. This directive eliminated all A0- or A1-sized drawings except for specialty trade designs done in 1:500 and 1:1000 scales, mainly mechanical and electrical designs, and significantly influenced the way the CE-environment was used. Because designs were on A3-sized paper, nearly all were distributed electronically between the main parties, and each was responsible for printing document copies to fulfill their own needs.

The benefit measurement was performed in the same way as in projects 1 and 2. A total of 17 questionnaire responses were received, consisting of responses from the main designers, specialty designers, main contractor, subcontractors, and inspectors. Seventy percent of questionnaire respondents had never used an ASP-tool before, 18 percent had used "the project" previously, and 12 percent had used some comparable tool previously.

5.4 Case Study 4, USA

The fourth building project analyzed was an addition to teaching premises in the United States (Table 10).

Table 10. Case Study 4 Basic Project Information.

Case 4	
Building type:	Addition to educational training center
Project size:	5.2 million USD (about 5.2 million €) 35,000 sf gross (3,200 m^2)
Delivery method:	CM/GC: Construction manager / General contractor
Project parties:	All parties located in the state of Oregon in close proximity to the project
Schedule:	Design started 1/2001; Construction started 5/2001; Completion and handover 10/2001; 25 week construction schedule
Project and solution status at time of analysis:	Analysis began while construction was finishing, and continued after project completion. Some features of the commercial application significantly changed while in use in the construction project.

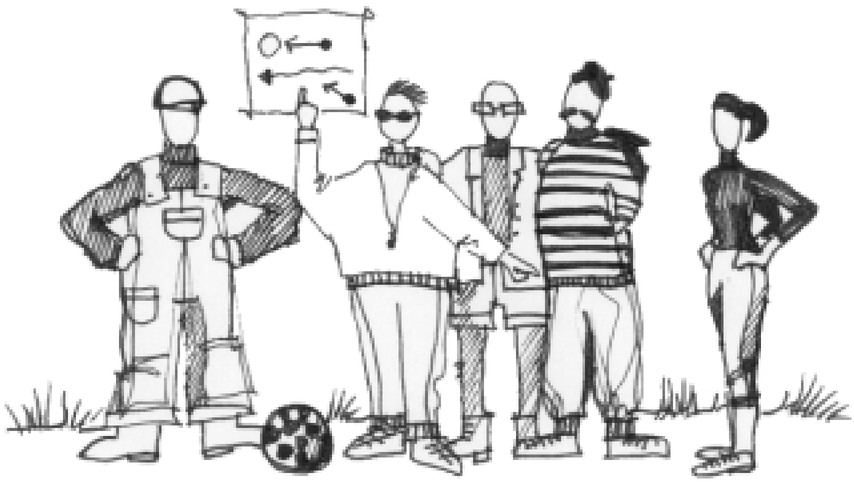
In case 4 the Buzzsaw-solution was used during the construction phase to publish, disseminate, respond to and archive requests for information (RFIs) and publish, disseminate, and archive the contractor's drug policy. The Internet application partially replaced faxing RFIs and the drug policy to different parties, and also served as a centralized project archive for RFIs, contact information, and the drug policy. In addition to the CE-environment, traditional fax continued to be used to disseminate RFI responses from some parties, notifications, sketches corresponding to the RFI, and confirmations of information or action directives. For legal reasons, and because two media were used to deliver corresponding information, paper copies of the RFIs continued to be archived by most of the parties.

A request for information is a formal document that indicates further information is required. Most often, the RFI conveys a question asked by the contractor and answered by a designer, and documents the information exchange for later reference. The subject is often detailed information that is unclear or in error in the original design documents, such as dimensions or location of specific items, or clarification of component specification. RFIs are not used for actions that do not need documenting, such as requesting another copy of a drawing. Traditionally RFIs are disseminated by fax between the parties.

The owner, design team, and construction manager/main contractor used the tool. Forty-three percent of questionnaire respondents had never used an ASP-solution before, and 57 percent had used an ASP solution previously, but not the tool implemented in this case.

The benefit measurement was performed in the same way as in the projects 1, 2, and 3. A total of seven inquiry responses were returned: the owner's representative, the designers, and the main contractor.

6. PROJECT MANAGEMENT AND ORGANIZATION



6. Project Management and Organization

6.1 General

The cooperation of separate project parties can be supported and the information exchange enhanced with the help of the CE environment. Common building project requirements for the CE environment are described in Section 6.2. The requirements described are mainly those expressed by the application users, or requirements derived from problems emerging in the case studies. Some requirements were also identified from the survey of solution features and capabilities as user needs that were not being served. In addition to the functionality and features of the application used, the Internet connection, especially its data transfer rate, has a significant influence on the usefulness of the application.

Requirements for user guidelines also exist and must be developed to make use of the available collaboration solution benefits. The procedures for best practice implementation presented in Section 6.3 are based mainly on the experiences gathered in the case studies, but also from the literature review. Many of the guidelines already recorded in pilot projects related to the Rative study /6/ proved to be still appropriate.

6.2 Common Multi-Partner Requirements for the CE Environment

Information must be easily available: The primary project information sources must be available through a single point of access. When creating the interface to project information, the Internet, web browser, and additional programs functioning with the browser (plug-ins) are key. When drawings are replaced by object-oriented designs, and the current document format is replaced by database-based documents (for example meeting minutes in XML format), completely new possibilities for searching and using the information will emerge: the project information search can be done effectively based on the data content, and access to project information needed by a certain user or for a specific situation will be obtained.

A system reliability guarantee must exist: The operation of the solution must be guaranteed to ensure that it will operate in real time without breaks in service, including during system failure situations and maintenance work. One way to ensure operation is with the use of a contingency server. Users expect technical reliability in both the service and the information. Breaks in system service are frustrating to the application users who have become accustomed to a real-time working method.

The application must be easy to use: At a beginning of a project, the collaboration solution must be able to be taken into use quickly. The introduction threshold must be low so that a wide variety of project parties will become part of the user group and the application will really be used. Ease of use does not necessarily mean a scant number of the features. With time, the basic features are used more and more routinely and the functionality can be increased gradually. Basic features such as storing information to the system and searching for information as needed must remain simple. When a project begins, the application functions must be ready defined, whereas from the organization perspective the solution platform must be flexible (see the next requirement: flexibility).

The application must be flexible: Application flexibility makes it possible to develop a suitable application from the company standpoint. For example, a company may have a history of creating their own documents for management routines. Some solutions offer tools for users to create these custom electronic forms to suit their own specific needs. An application’s standard forms are not necessarily wanted, because companies want to retain the procedures and related documents that they have developed without sharing them for competitors' use.

From the project viewpoint, flexibility is not such an important feature. A project needs a ready-defined solution, which is easy to implement into project practices without a long configuration phase at the beginning of the project. Many simple documents that are currently saved to project servers as traditional text documents could be used more efficiently if tools for form creation are offered in a solution (Figure 13).

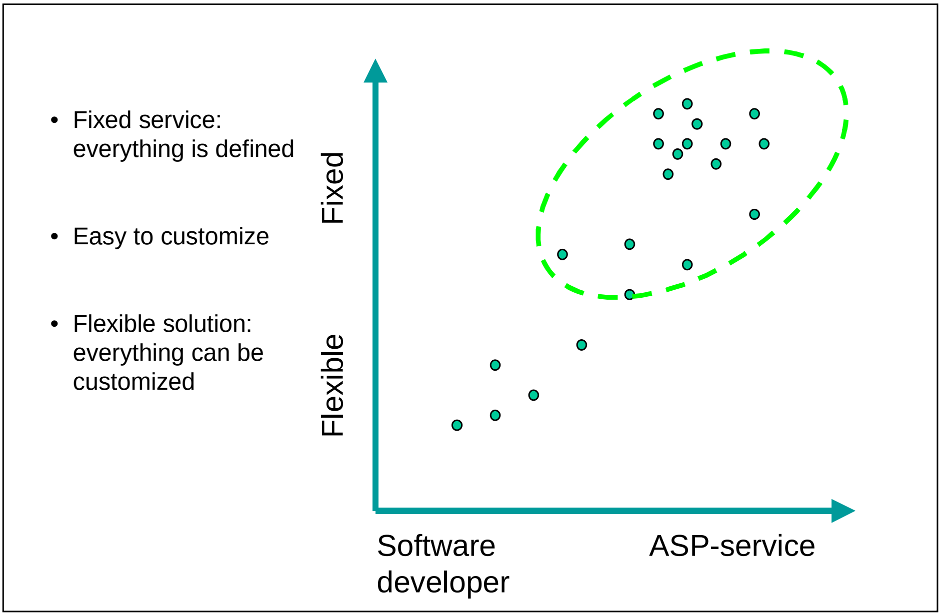


Figure 13. Flexible and Fixed Commercial CE Environments. Software developers are able to offer solutions tailored to the needs of the company. In the ASP service, the functionality has usually been determined and it is ready to be taken into immediate project use. However, flexible ASP applications offer the users the possibility to create traditional documents as electronic forms.

A traceable project history must be created: Project information and information about actions taken regarding each file must be recorded to the system so that users can find, for example, earlier versions of documents, see who has recorded certain information and when, or uploaded a document to the system. The documentation of information exchange can be realized to some extent by the use of an e-mail program, but a centralized system provides the opportunity through the organized solution, serves all the parties, and includes the whole project history.

Notification features related to changes and updates done on the server must be appropriate: The user group must be informed about project information updates concerning them. It must also be possible to record information in the system so that the user group will not get unnecessary update notifications. This requirement is met when:

- The system generates one user notification for all information updates done at one time.
- The announcements are not automatically sent to the whole user group, but only to those people who have the right to read the document.
- It must be possible to make the update notifications without using e-mail. One example is the user who has logged in to the system and identifies the new file as marked with a flag. Because of this example technique, all useful information worth filing can be saved and is recorded onto the system. In the opposite situation where emails are sent for each transaction, information may not be saved to the system because knowing that other parties would receive a large number of e-mail notification messages concerning information that is at the moment important to only a few project participants could deter the publisher.

Project news and notices must be transmitted to the project participants: If a new piece of news is conveyed as an automatic notification (as an e-mail) to all project members, the so-called bulletin board provides additional information to users about project matters. News is centrally archived and users stay up to date more easily than before.

It must be possible to upload or download a large number of files between the server and own system at one time: It must be possible to save new files or update existing files as a group. When a function must be performed on individual files, the saving procedure will often bind the person to this task for too long (for example saving a bid package to the server). A similar need exists when retrieving several files at one time from the server to another system; it should be possible to download the files as a group.

It must be easy for new parties to join the system: For example, the project manager should be the system administrator so that he is able to give system access to parties joining the project team later.

Electronic user identification must be implemented: A new, device-independent, electronic user identification operating in all devices connected to the Internet would be needed. Several alternative electronic identification technologies are available, which are used in login and electronic signatures. The most significant weakness of the available technology is the need for special devices and programs, depending on the data terminal equipment. These special demands reduce the usability of the present electronic identification techniques. Replacing several project-specific user names and passwords with the user's electronic identification would clarify and simplify login in the multipartner CE environment, where each party of the project usually has several projects going on simultaneously.

Virus rejection must be implemented: Damages to the system and project information caused by viruses should be prevented. Introduction can be prevented if the application scans files for viruses before saving them to the common server. If it is not possible to eliminate the virus before saving, polluted files should be rejected. The system should notify the person saving the file if the file has been successfully uploaded to the system or not.

Pricing should be reasonable: The pricing of a license to use a commercial team collaboration application must not set obstacles to the introduction of the system. The pricing should be attractive to all parties participating in the project. If some companies decide not to use the solution because of disproportionate pricing with respect to benefits, reachable benefits for the remaining parties decrease.

6.3 Procedures

The advanced CE environment makes it possible to radically reform the data flow in a multi-partner project. The reform does not succeed by only bringing a new communication tool next to the traditional communication; the project procedures must also be reformed.

6.3.1 Reforming Data Flows

The general information mainstream in a building project can be described in the following simplified way. The data flow starts from the architectural design. From architectural design the data flow goes to the special design, then to production planning, then to production, and after the building has been completed, to the real estate. If examined in more detail, this mainstream of the information consists of numerous small data flows. The data flow goes through several parties, from which the producer of the information can be considered an internal supplier of the process and the receiver of the information an internal customer of the process. The internal customer may ask for additional information after checking the received, new information or after identifying new information needs later (Figure 14).

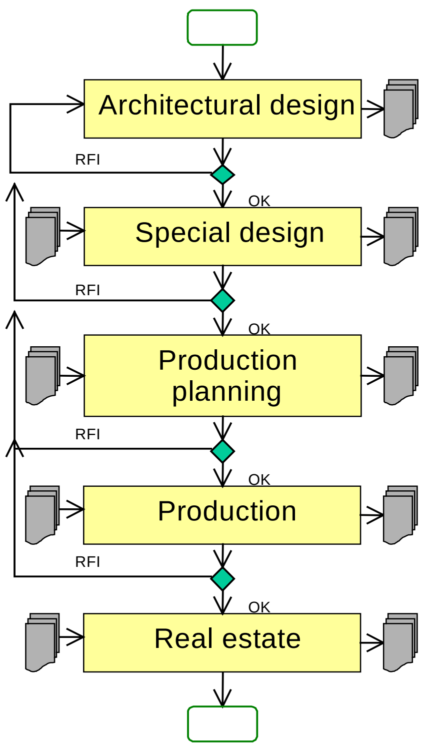


Figure 14. Theoretical data flow of a project. The general data flow of the building project as an example.

In the description of the theoretical data flow, a conditional return back to a previous step can be used, and a so-called loop is formed in the data flow. For example, computer programs can perform this kind of loop several times in a fraction of a second before transition to the next task. However, in the data flow of a project, one cannot go back to an earlier time, for example to the previous week, to carry out a task again. Because of this, the real data flow cannot contain loops and iteration circuits without time moving forward, for example to the next day or week. The real data flow of a project consists of sequential tasks that, instead of forming a loop, are repeated several times consecutively (Figure 15).

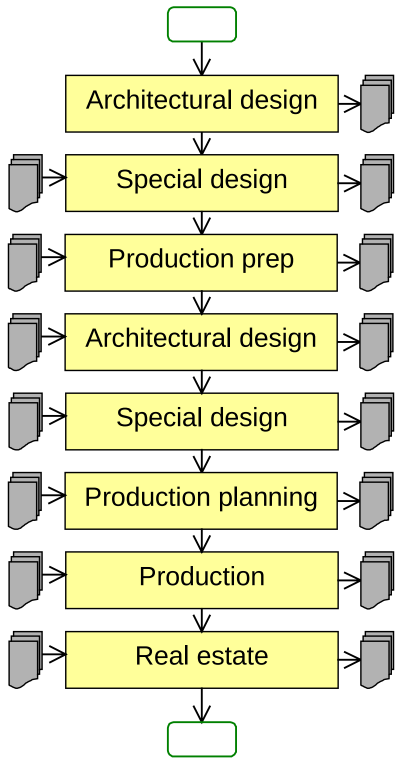


Figure 15. Real data flow. As an example a building project, at the production planning phase of which, an additional information need concerning the architectural design has occurred.

With the help of the advanced CE environment, the real data flow in a project can be reformed radically. Centralized information storage makes the reform possible by connecting the project parties to the information without the long delays caused by the communication. In the reformed data flow, with the help of the CE environment, additional information needs can be filled in several different ways, depending on what kind of need there is for the additional information. Additional information needs can include the following:

- The internal customer of the process does not know whether the document that he has is the final version, or if some newer version exists.
- The internal customer of the process perceives needing additional information, for example information produced by the supplier.
- The internal customer of the process perceives a conflict or a mistake in the information that he has.

The following is an example of the old process used to produce additional information. The internal customer of the process orders the additional information from the supplier as soon as he reaches the supplier by telephone or at the next meeting. The internal supplier sends the additional information by messenger/courier service or e-mail to the copying service, which then delivers the additional information to an internal customer. In some cases, the internal supplier does not have time to go into the information request and sends just in case, to the internal customer, the defective information delivered already earlier once again.

An example of the reformed process for producing additional information with the help of the modern CE environment is the following. Using the common information storage database, the internal customer of the process checks which is the latest change in the present document and what other documents exists describing the matter, and downloads additional information needed to his own use without delays. If a customer perceives a need to produce new information, he notifies the supplier by e-mail or with help of the RFI-feature of the solution (Figure 16).

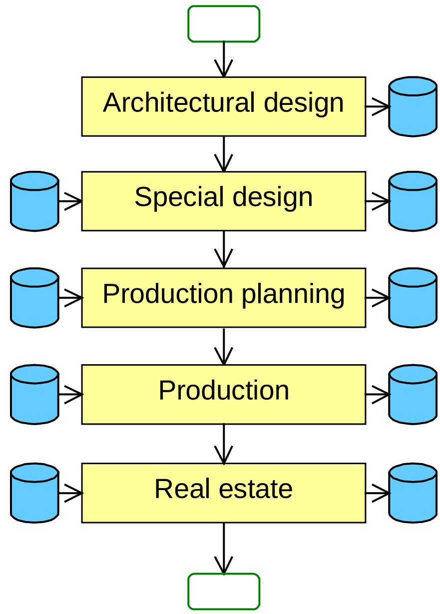


Figure 16. With help of the modern CE environment, radically reformed data flow. The general data flow of the building project as an example.

6.3.2 New Procedures for Best Practice Implementation

In the following text, the procedures that should be followed to obtain as big benefit as possible from the CE environment in multipartner projects are described. In using the CE environment, there are three leading principles, described in more detail by the following procedures:

1. Use the CE environment as extensively as possible

2. Common rules should be followed

3. Introduction of the tool should be controlled and user support given.

A target must be set for use of the collaboration solution: Setting a target means that the information and documents that are to be distributed, filed or managed with the help of the system are defined. The target naturally has an influence to the acquired benefits. If there is no target for electronic document distribution only via the centralized system, the procedures can easily break down and several parallel methods be used.

No parallel information distribution: According to the rules agreed to for the project, electronic data transfer based on the collaboration solution should be the only method of information distribution. The project-specific analyses carried out in this study pointed out that available benefits, such as savings of work hours, will not be reached fully if parallel systems are used. The parallel distribution procedures can lead to situations in which it is not clear where to search for certain information. Furthermore, according to the experiences had in the Rative pilot projects /6/ as well as according to the study /12/, electronic data exchange in addition to traditional methods is not practical, because the extra-work generates resistance among the project participants.

Information flows through the centralized system as comprehensively and early in the project as possible: The earlier that distribution and archiving with the help of the centralized system is performed, the better the project information will be saved. Benefit potential exists in the more comprehensive use; for example, all the unnecessary time delays could be avoided in the building systems' coordination drawing circulation.

All parties buy in, including subcontractors: To make the information distribution as easy and efficient as possible for the information sender, delivery should be done as one upload to the system. Subcontractors have typically stayed typically outside of the system user group. When all parties use the system, it is possible to more efficiently take advantage of savings in work time and potential monetary benefits. From the viewpoint of subcontractors and other parties who join the team later, the biggest benefit is probably that they can get as comprehensive and similar information as possible that has been delivered in earlier stages of the project.

The users are introduced to the application and its use when the project starts: The threshold to start using the application can be high for those who have not used the chosen application or some other similar system. The inexperienced computer users can even shun the application. About a one day introduction will probably be sufficient to introduce the application and practice using it, so that the users become able to use at least the basic solution tools needed in the project. If the application is already familiar to the user group, and user training unnecessary, some kind of kick off meeting is still needed to agree on specifically how the application will be used in the project.

Kick off meeting and IT protocol: At the kick off meeting, the project team agrees on targets and rules concerning electronic data exchange and application use. Example topics of agreement include identifying the information shared only with the help of the system, software used, file formats to be used, naming, the responsibilities and rights of various parties /6/.

The established procedures and rules must be followed: All the agreed on information must be uploaded to the server and be up to date. The documents or other information that are to be maintained in the centralized databank may not be delivered outside of the system, for example by e-mail, nor by free-form communication that is against the agreement. When new information and updates are saved into the common databank, it becomes available to all project parties. For example, if one party has asked by phone for updated information, the same information does not need to be sent the following day to someone else asking for the same information. Different versions of the same document also will not exist among the project parties.

"On-line support": In the pilot-projects of the Finnish Rative project /6/, user support for the project databanks, including “on-line support,” was offered. In an urgent problem situation, such as having difficulties accessing the system, the user group was able to ask for help by telephone. Several years have passed after these pilot projects, and the applications have developed, but a similar need still appeared in the project analyses carried out in this study. Extensive and regular use of the tool was hindered by the absence of designated expert users. Designated individuals should have had a solid, fundamental foundation of information technology and knowledge of application used, to act as experts in their organizations. The existence of designated experts would have fostered additional, experimental confidence in those having limited computer experience, as they would have had a contact person to answer questions.

Information must be in electronic form: The basic condition for creating as extensive central distribution and archiving of project information as possible is that all essential information for the project such as designs, specifications, meeting minutes, schedules etc. exists in electronic form. This aim is also held by new application features like off-line communication documentation (defined in the chapter that deals with the CEE properties). However, situations are still found in practice in which not all traditional meeting discussion summaries are done directly to an electric form.

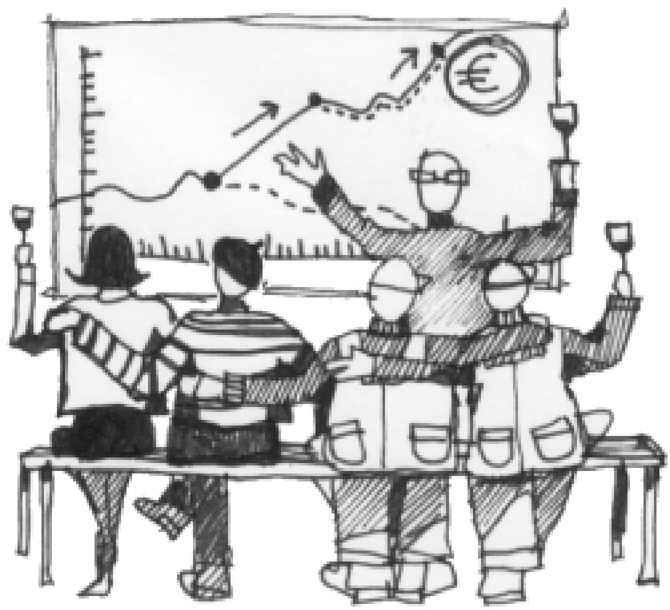
The form of the electronic information must be suitable for real estate: Earlier the importance of making an agreement on the computer software and information saving formats was discussed, primarily to guarantee that the parties involved in the design and building stages are able to open the files and use the common electronic information. This still must be established, but the use of the information in the real estate after the project has been competed sets format demands also. The viewpoint of the real estate is more important than before because of the aim to more effectively use the information collected during the design and building stages.

The explanation field should be used when saving new information on the server: From the information receiver viewpoint, it is usually important to quickly and unambiguously find the changes in a document, especially if the designs are in question. For this reason, an explanation field should to be used when the file is uploaded, if the application offers this possibility.

Responsibilities and rights: With the help of the common central databank, the various parties of the project have the opportunity to access more comprehensive project information. On the other hand, with the help of the new tool, individuals now have to search for the information produced by others for their own use instead of expecting that someone sends, for example all necessary drawings to them. Awareness of the rights and responsibilities related to the new situation should be raised among project participants so that they will know their role and how one should act.

A possibility for product end users to follow the progress of the design and building stages more widely: More often than done currently, the project team should consider providing the project end users with the opportunity to follow the design and building progress with the help of the centralized system. Technically this is already possible: variable document access control within the project server makes establishing appropriate limits on individual rights possible. In many cases, it will be good for the final result if the end users are able to influence the planning solutions by reviewing designs and giving feedback. However, this can mean extra work to the designer, for example if different parties need various file formats delivered.

7. CONCLUSIONS



7. Conclusions

A fundamental conclusion of the study is that by using electronic data exchange and a modern CE environment, significant qualitative benefits can be reached in a multi-partner project. The CE environment makes it possible to change the traditional information flow radically improving it during the design and construction stages. The enhanced information flow simplifies daily routines and improves the parties' abilities to work as one team.

In addition to qualitative benefits, quantifiable benefits measured in terms of time and money can be reached by all project parties. The most significant, quantified time benefit at the overall project level is the opportunity to compress the project schedule. A compressed schedule is supported by the elimination of delays attributed to the time required for information distribution in a traditional paper environment, and the more efficient use of time. Because of the elimination of distribution delays, design information is distributed more quickly. At the individual level, reductions in tasks' required work time and the possibility for more flexible planning of one's own time are the most significant benefits. The work time reduction results from a reduction in the need to request information by telephone from other parties, reduced need to travel, and electronically inputting recorded information more quickly during the construction phase.

In the European case studies, direct cost benefits were approximately double as compared to the operating costs. The indirect cost savings are manifold as compared to the direct cost benefits. However, in practice indirect cost savings are difficult to quantitatively measure. The monetary benefits were even 20-fold as compared to the operating costs in the analyzed American case study.

The introduction of advanced applications based on dynamic web pages into the market has positively supported the implementation of the CE environment in building projects. The features of the commercial applications are often similar among themselves and they have been developed mainly to improve the document management of multi-partner projects. There are also many advanced services available that contain various workflow applications for the support of project management. Culture differences can be perceived in North European and American services. Improving project communication is emphasized in

Northern Europe and the documentation of the communication among the separate parties' is emphasized in the United States.

The benefits measured in the study can be attained by CE environments having various properties. The study found that the most benefits are reached using the most advanced systems (Figure 17).

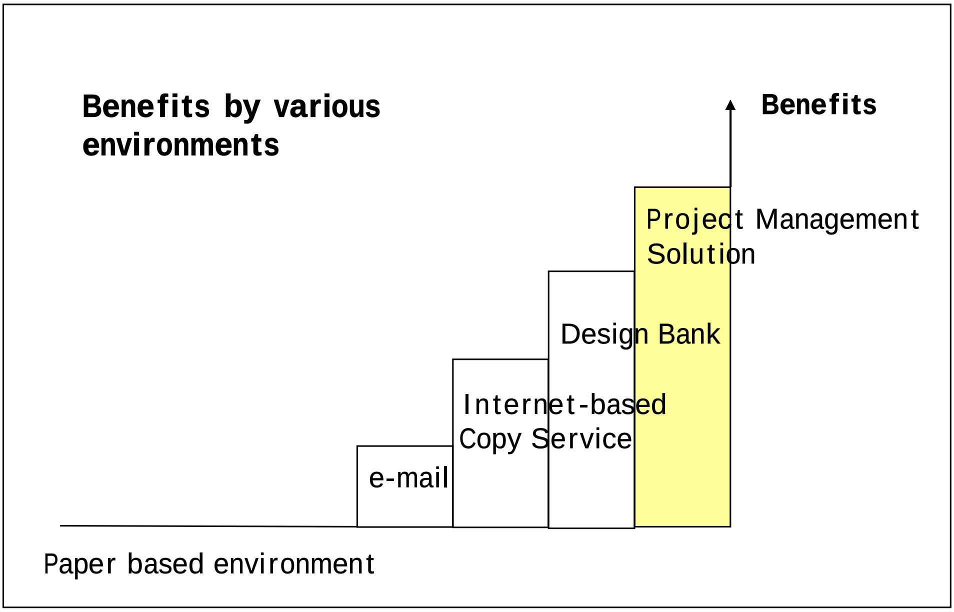


Figure 17. Effect of the CE environment level of development on attainable benefits.

Unused potential became apparent in the analyzed case studies mainly because the CE environment and electronic data exchange were used side-by-side with traditional, paper-based procedures, or not all parties used the application. In the future, the potential for direct monetary benefit will be especially high in the centralized electronic distribution of bidding documents. Development of wireless technology can also bring interesting, new benefits.

The advanced CE environment makes it possible to radically reform data flows in multi-partner projects. The reformation does not succeed by joining a new communication tool with traditional communication; instead, project communication procedures must also be reformed. To reach the available potential benefits, an attempt must be made to follow the three principles of CE environment use: 1) the CE environment should be used as often and widely as possible 2) common guidelines for use in a project should be established and followed, and 3) introduction and use should be controlled and supported.

Electronic transfer of the information is evolving to include the use of electronic information. Among designers, an attempt to use electronically transferred information has existed for some time. In the construction phase, until now, electronic documents have been mainly used to deliver information more quickly and cheaply. However, an example of the varied use of design information in the construction stage is choosing to use A3-sized printouts on site whenever possible. In the future, a diverse use of electronic information will probably become more common. One example includes, bid documents electronically delivered to bidders after which willing bidders develop material quantities from electronic plans using, for example, the CAD area calculation feature. With the introduction of product models, the numbers could even be obtained more easily and in more detail.

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Timo Hyttinen, University of Jyväskylä
Juha Marttinen SRV Viitoset Oy
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Ari Sipinen, Arkkitehtitoimisto Arto Sipinen Oy
Kari Hyvätti, Insinööritoimisto Helander & Nirkkonen
Jukka Vasara, Granlund Kuopio Oy
Tarmo Wilen & Tapani Mäkelä, Granlund Tampere Oy
Mikko Syrjä, SRV Viitoset Oy, phone discussion
Göran Henriksson, Peab Sverige AB
Cecilia Lundh, Håbo kommun

Rolf Danielsson, ÅF-VVS Projekt Ab
Anette Nyberg Grau, Peab Sverige Ab
Kent Forsman, Hageruds Elteknik Ab
Dag Gustavsson, Dag Gustavsson Byggadministration AB
Bertil Boström, Theorells Installationskonsult AB
Yngve Zilen, Knut Jönsson Ingenjörsbyrå Ab
Toni Pinchess, Altonwood
Christopher Callard, HGP Greentree Allchurch Evans Limited
Martin Hathaway, Clarke Bond Structural Engineering Ltd
Daniel Bilton, Christopher Smith Associates
Claire Jarvis, Carillion
Kirk Pearson, Clackamas Community College
Jamin Aasum, Yost Grube Hall
Scott Vollmoeller, GLUMAC International
Patrick Houck, DPR Construction

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Appendix 1:

Codes and descriptions for qualitative benefits measured in the building project analyses.

Code	Benefit description
	DOCUMENT MANAGEMENT
D31	Project information available without time, location, or user organizational dependency
D32	Documents are in better order and easier to find in a single, organized collection
D33	Increased awareness of new information
D34	Versions of a document are in better order, easier to find, and readable
D35	Project information is easy to retrieve for own use
D36	Improved filtering of information (Elimination of paper delivery of unnecessary information because of user defined information requirements)
D37	Easier distribution of documents to other parties
	COMMUNICATION
K31	More communication facility options and better information exchange
K32	Increased awareness of project changes and news
K34	Increased individual accountability
K36	Easier to deliver information to late parties joining the project
K37	Improved quality of discussion
	DESIGN
S31	Better tools for collaboration improve collaboration possibilities
S32	Easier to share common electronic information
S33	Improved coordination of geographically dispersed resources.
S34	Increased awareness of task status
S35	Easier to publish updated / revised documents
S36	Increased accessibility to up-to-date project information
S38	Easier to monitor design progress
S39	Improved coordination of designs (e.g. management of specialty contractor designs)
S40	More efficient decision-making cycle
S42	Helps to manage design change process
	CONSTRUCTION
R31	Easier to collect and transfer data
R34	Increased accessibility to up-to-date project information
R35	More efficient decision making cycle
R37	Improved workflow management
R39	Easier to monitor construction progress
R40	Increased documentation of decision background.
	OPERATION AND MAINTENANCE
KP33	Full electronic archive created for the client
KP35	Project information is maintained in a useable form and remains available to future users on the service provider's server.

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Title

Project Management in the Concurrent Engineering Environment

Abstract

The primary objective of the Finnish-American research project was to develop the management and organisation of multipartner projects when utilizing electronic data exchange and the concurrent engineering (CE) environment. A second objective was to develop functional indicators to measure impact of the CE environment in selected case study construction projects. As a result, the study presents key guidelines for realizing benefit by using electronic data exchange and the CE environment in multipartner projects.

A fundamental conclusion of the study is that by using electronic data exchange and a modern CE environment, significant qualitative benefits can be reached in a multipartner project. The CE environment makes it possible to change the traditional information flow, thereby radically improving it at the design and construction stages.

In addition to qualitative benefits, benefits measured in terms of time and money can be reached. In the European case studies, direct cost benefits were approximately double as compared to the operating costs. The indirect cost savings are manifold as compared to the direct cost benefits; however, in practice indirect cost savings are difficult to quantitatively measure. In the American case study, cost benefits were even 20-fold as compared to the operating costs.

The model for benefit measuring was developed and tested mainly in the first analysed case study, which in August 2000 was completed and handed over to the client in Finland. Additionally, the framework was utilized in three other case studies, in Sweden, Great Britain, and the USA.

For more information http://www.vtt.fi/rte/cmp/projects/proce/

Keywords

project management, building projects, concurrent engineering, collaboration, Internet, construction, measuring frameworks, re-engineering, cost-benefit analysis, communication tools

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Nimeke

Projektin hallinta sähköisen tiedonsiirron ympäristössä

Tiivistelmä

Suomalais-amerikkalaisen tutkimusprojektin päätavoite on ollut kehittää usean osapuolen projektin johtamista ja organisoimista sovellettaessa sähköisen tiedonsiirron ympäristöä. Toinen tavoite on ollut kehittää toiminnalliset mittarit sähköisen tiedonsiirron ympäristön vaikutusten mittaamiseksi valituissa rakennushankkeissa.

Tutkimuksen keskeinen johtopäätös on, että soveltamalla sähköistä tiedonsiirtoa ja modernia projektitietojärjestelmää usean osapuolen projektissa voidaan saavuttaa merkittäviä laadullisia ja toiminnallisia etuja. Projektitietojärjestelmä mahdollistaa perinteisen informaatiovirran muuttamisen radikaalisti paremmaksi suunnittelu- ja rakentamisvaiheissa.

Toiminnallisten ja laadullisten hyötyjen lisäksi saavutetaan ajassa ja rahassa mitattavia hyötyjä. Suorat kustannushyödyt projektitietojärjestelmien käyttämisestä olivat eurooppalaisissa esimerkkihankkeissa noin kaksinkertaiset verrattuna käyttökuluihin. Epäsuorat kustannussäästöt ovat moninkertaisia suoriin kustannussäästöihin verrattuna.

Hyötyjen mittaamisen malli kehitettiin ja testattiin pääosin ensimmäisessä analysoidussa rakennushankkeessa, joka valmistui ja luovutettiin tilaajalle elokuussa 2000 Suomessa. Mittausmallia sovellettiin lisäksi kolmen muun rakennushankkeen analysointiin Ruotsissa, Isossa-Britanniassa ja USA:ssa.

Avainsanat
project management, building projects, concurrent engineering, collaboration, Internet, construction, measuring frameworks, re-engineering, cost-benefit analysis, communication tools

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Internetstöd hantering av byggprocessens information

Referat

Det främsta syftet med det finsk-amerikanska forskningsprojektet har varit att utveckla ett system för flera parter att leda och organisera ett projekt med utnyttjande av en elektronisk dataöverföringsmiljö. Det andra syftet har varit att utveckla operativa mätare för att mäta effekterna av den elektroniska dataöverföringsmiljön på valda byggprojekt. Resultatet av undersökningen är centrala spelregler. När dessa spelregler följs ger den elektroniska dataöverföringen fördelar för flera parters projekt.

Den främsta slutsatsen av undersökningen är att man kan uppnå avsevärda kvalitativa och operativa fördelar av att tillämpa elektronisk dataöverföring och ett modernt projektdatasystem i flera parters projekt. Projektdatasystemet kan förbättra det konventionella informationsflödet radikalt i planerings- och byggnadsskedet.

Utöver de operativa och kvalitativa fördelarna uppnås omfattande inbesparingar i tid och pengar. De direkta kostnadsinbesparingarna av projektdatasystemen i de europeiska modellprojekten var dubbelt så stora jämfört med driftskostnaderna. De indirekta kostnadsinbesparingarna var flerfaldiga jämfört med de direkta kostnadsinbesparingarna. Det är emellertid svårt att mäta dem i praktiken. I ett analyserat byggprojekt i USA var kostnadsinbesparingarna upp till 20-faldiga jämfört med driftskostnaderna.

För att mäta fördelarna utvecklades en modell som testades främst i det första analyserade byggprojektet. Modellen blev färdig och överläts till beställaren i Finland i augusti 2000. Därtill tillämpades mätmodellen för analys av tre andra byggprojekt i Sverige, Storbritannien och USA.

Närmare upplysningar http://www.vtt.fi/rte/cmp/projects/proce/

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In the publication, results of a Finnish-American study are presented in which a measurement model was developed for the measurement of the benefits of the electronic information exchange and the benefits of the electronic information exchange were analyzed in a Finnish, in a Swedish, in an English and in an American building project.

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