

BENEFITS OF CENTRALIZED DIGITAL INFORMATION MANAGEMENT IN MULTIPARTNER PROJECTS

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SUMMARY: *Centralized digital information management is used to support project management, management and distribution of project information, and to promote cooperation in the building process. 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). Commercial applications have been taken into use at a remarkable volume and in recent years the construction industry has recognized the need for assessment of benefits of them as well as benefits of ICT in more general. This paper presents results of VTT's ProCE research (Project Management and Organization in the Concurrent Engineering Environment) carried out 2000-2002. One objective of the Finnish-American research project was to measure the impact of different Concurrent Engineering (CE) environment features in multi-partner projects, showing the available benefits. A framework for measuring the benefit of using the CE-environment was created to evaluate benefits in case study projects. With respect to related research carried out earlier, a specific development is the qualitative benefit measurement. The model 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. A fundamental conclusion of the study is that by using digital information 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. However, the study showed that indirect cost savings are difficult to quantitatively measure in practice.*

KEYWORDS: *collaboration, document management, Internet, construction, concurrent engineering, measuring, re-engineering*

1. INTRODUCTION

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

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 that can be used for multi-partner projects and are based on dynamic Internet technology. Currently, a centrally-accessible information system usually consists of a server to which all project members have the option to access and a common user interface. The common user interface is typically 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.

A number of commercial tools have been created for document management, project information sharing, on-line communication, design workflow, construction workflow, time control, and securing information (Luedke et al 2001). These commercial applications have been adopted by industry at a remarkable rate and continue to become more and more commonplace. However, the most widely used application features are fairly simple; in addition, 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. More information concerning available features can be found in the ProCE project intermediate report (Lakka et al 2001) and in the final project report (Sulankivi et al 2002), available on the project website <http://www.vtt.fi/rte/cmp/projects/proc>

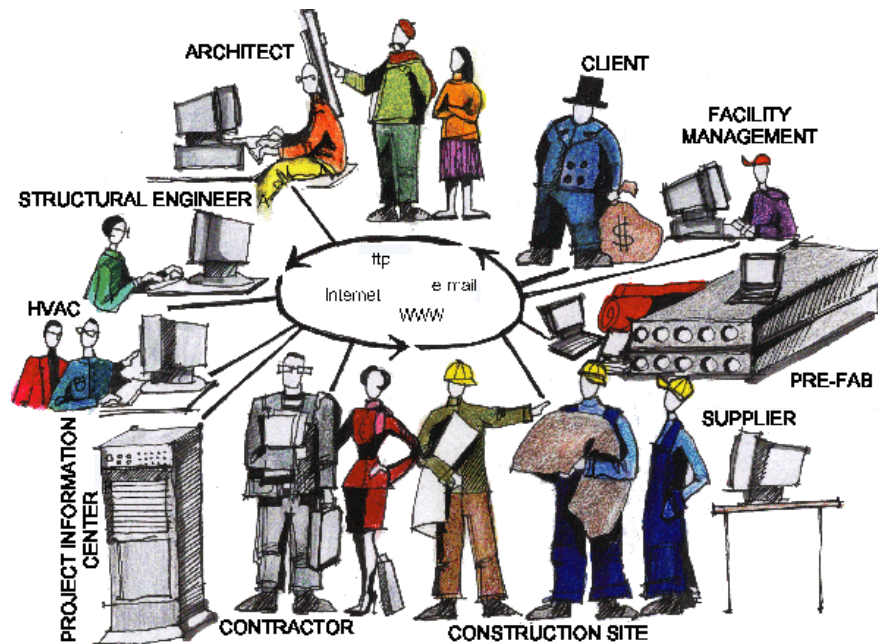


Figure 1. Separate project parties communicate and manage common project information digitally with the help of the CE environment. Figure by Minna Sunikka (Lakka & Sulankivi 1998).

2. RESEARCH OBJECTIVES

VTT's ProCE (Project Management and Organization in the Concurrent Engineering Environment) research project was carried out in the years 2000 to 2002. The ProCE project focused on developing the management and organization of multi-partner projects in the concurrent engineering environment. The objectives of this development project were to:

- Clarify the present use of the CE environment in building projects and identify opportunities for CE 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.

This paper presents the results of the research concerning the measurement of benefits of using digital information exchange and a modern CE environment in multi-partner projects (Sulankivi et al 2002).

3. MEASURING MODEL DEVELOPMENT

Existing approaches to the evaluation of information technology (IT) 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 do not employ a formal methodology to evaluate the benefit of IT investments, and formal cost-benefit analyses are not widely used (Churcher et al 1996). Meanwhile, IT investments are evaluated in other industries. However, in recent years the construction industry has also recognized the need for effective benefits assessment (Carter et al 1999).

Some suitable methods for assessing the benefits of IT in the construction sector have been developed. The

measuring framework developed by Construct IT (Construct IT 1998) 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, but applicable parts of that approach have been used effectively in ProCE model, and developed further to better suit the evaluation of benefits of using the CE-environment in construction projects.

A project-based process model was selected for the ProCE benefit measuring model in order to evaluate the benefits of using the CE environment on a project-wide basis, and because benefits are typically distributed across several organizations participating in the building project. Furthermore, there is usually a project-specific charge for use of the commercial CE environment. This project approach supports the overall comparison of the benefits achieved to the application operating costs expended. To evaluate the long-term benefits of using the CE environment application, the underlying basis for the ProCE measuring model should be modified. 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 (Carter et al 1999).

To measure benefits attained from implementing a CE environment application, these benefits must first be identified. Because the project-based approach was selected for benefit measurement, a building process-based benefit classification system was also developed. Literature showed that benefits can be typified in different ways; the most general example distinguishes between quantifiable and non-quantifiable benefits (Lakka et al 2001). In addition to having different methods for typifying benefits, previous research showed that different building process models also exist. For example, Construct IT utilized a business process view in their measuring framework to model the building process from the enterprise perspective. The business process consisted of business planning, marketing, information management, procurement, finance, client management, design, construction, operation and maintenance, and human resources. Back and Moreau (2000) developed a measuring framework based on the engineer / procure / construct (EPC) process. This research emphasized using the building process approach as the measuring basis in order to accurately determine the significance of the realized benefit with respect to the entire process, as opposed to within one organization only. Extending this idea, the Quality Management System model (Sjøholt 1995) was developed based on the building life-cycle process that included facility management. In general process model, there is input, control, resources and result of the process. Input can be basic information of the process or some result of the previous process. Control can be different types of efforts that are needed for planning and follow-up of the process. Resources can be work, material and equipment, and result is that what the process produces. Based on these ideas, a suitable classification framework was developed and used to classify benefits of utilizing the CE environment in the building process.

The preliminary measuring model was created based on literature study. That preliminary model was then tested and significantly developed during the first case study. A specific development in this model was the qualitative benefit measurement.

A method resembling the Delphi research technique was used to analyze the effects of the CE environment in the case study projects. 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 study 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 digital data exchange in a certain case study project. The third and final stage analyzed the expert opinions regarding the CE environment and digital 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 chapter 4.

4. MEASURING BENEFITS

4.1 Measuring Framework

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

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 2).

Table 1. Measuring framework for measuring the benefits of using CE environment.

MEASURING FRAMEWORK	
Part 1.	Checklist
	<p>Purpose: helps to identify expected/perceived benefits.</p> <ul style="list-style-type: none"> • A list of all potential and achievable benefits gathered into one table • Three categories for different benefit types: <p>MONETARY BENEFITS: Quantifiable in monetary terms.</p> <p>OTHER QUANTIFIABLE BENEFITS: Quantifiable but not in monetary terms</p> <p>QUALITATIVE BENEFITS: Non-quantifiable, described qualitatively</p> • Grouped by building project activity (where a specific benefit can be achieved)
Part 2.	Evaluation sheets
	<p>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.</p> <ul style="list-style-type: none"> • One table for each of the three benefit types • Columns: <ol style="list-style-type: none"> 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
Part 3.	Summary table
	<ul style="list-style-type: none"> • Cumulative result for each of the three benefit types, summarized in one table
Part 4.	Indicators, related to the checklist benefits
	<ul style="list-style-type: none"> • Some examples/proposals for indicators

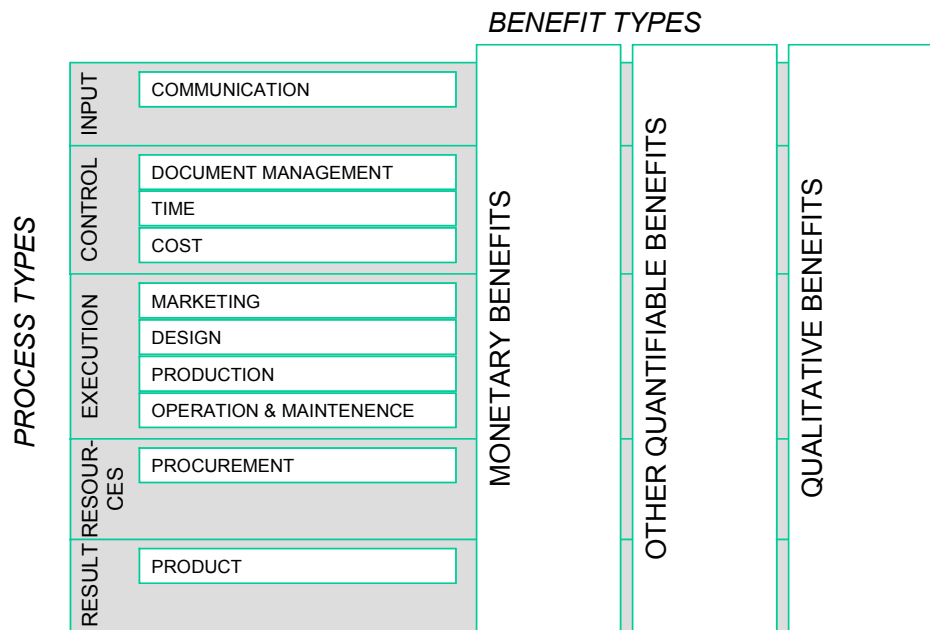


Figure 2. Benefit classification matrix (Lakka et al 2001).

4.2 Framework Application

The measuring framework can be applied to evaluate benefits in a single multi-partner project. It is suitable for measuring the benefits in completed projects. Additionally, it is applicable when setting targets for and evaluating the results of using the CE environment for on-going projects.

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

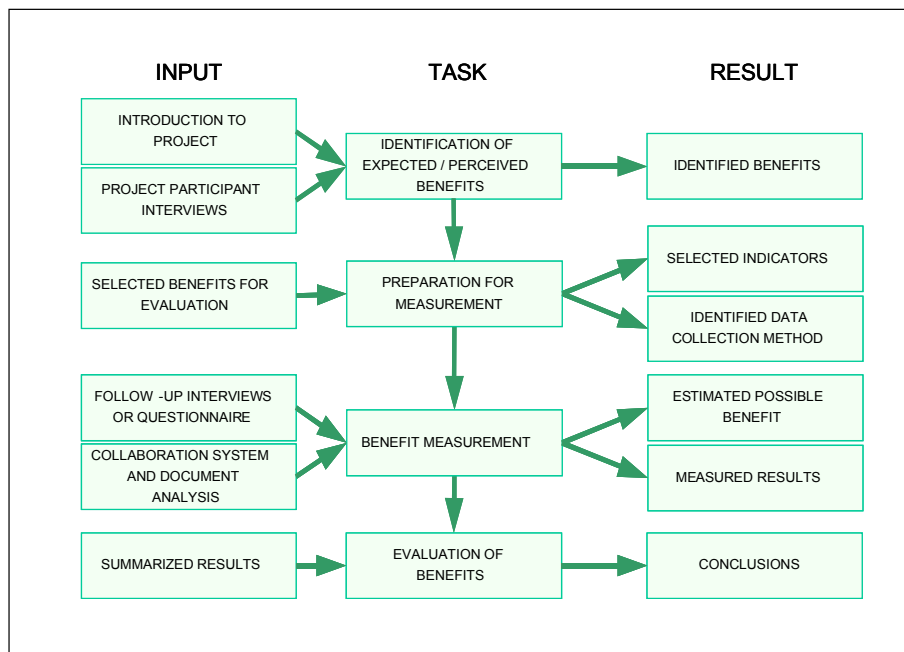


Figure 3. Estimation of benefits in case studies.

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 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. Indicators and a measuring method for each identified benefit are also chosen using the framework's indicator table. Also performed during Stage 2, 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 attempts 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.

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 (e.g. log files), and from project documents. If the project has been completed without target setting, it is highly likely that the maximum possible benefits were not achieved, and an estimate of benefit potential may be interesting and useful. At this point, an estimate of benefit potential identifies the benefits that could have been reached and the requirements for reaching these goals.

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.

5. BENEFITS OF CONCURRENT ENGINEERING ENVIRONMENT

5.1 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 case study project was chosen from Finland, the second from Sweden, third from England, and fourth from the USA. In addition to location, the case study projects differed from each other in building type, size, and delivery method. 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 features of the applications changing and improving already during the research project. The majority of the application users had not previously used the application in the respective case study. Basic project information and the use of applications in the analyzed case studies are described in Appendix 1.

5.2 Identified Benefits

The table in Appendix 2 is the measuring model checklist showing the reachable CE environment benefits for each benefit type found in the case study. As shown in the table, 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 specific project did not reach, but the research team considered achievable in other construction projects, using other applications, or in the future if using new procedures and application features. The benefits presented in plain text in the appendix can be considered potential benefits to be reached. The benefit codes were created to aid in the analysis and handling of data, and are used throughout all case study results.

5.3 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 case studies, it was possible to estimate only a small part of the monetary benefits reached as consequence of qualitative benefits

(Figure 4).

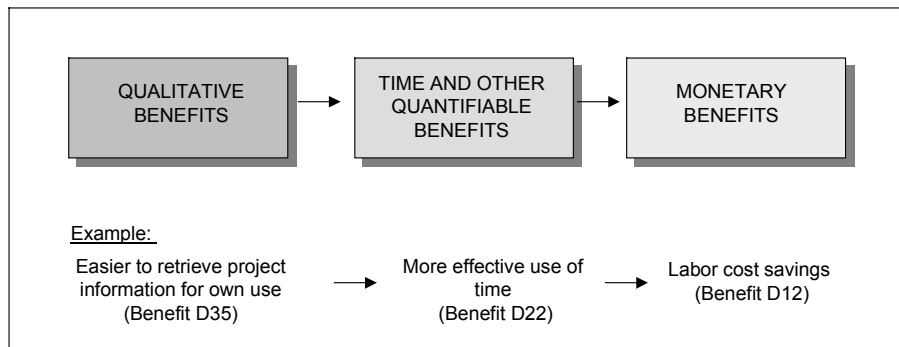


Figure 4. Generation of benefits (Sulankivi 2001).

5.4 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 applications. The development degree of the implemented environment nevertheless influences which benefits are achieved and to what extent.

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 study project staff, by questionnaire submitted to the staff, from the collaboration application and documents contained by the application. No application history of use (audit trail, log files) 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 2.

Table 2. 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 saving of work time was also obtained through questions in the questionnaire; responders were asked to estimate time savings related to certain tasks. For example, monetary savings due to decreased travel are savings indicated by individual responders, but are not generalized for other parties. Because the inquiry was sent only to CE-environment users, a conservative estimate of savings was made in most cases; for example 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. These costs depend on the level of the IT infrastructure and prevailing procedures of the

company, or if the use of the CE environment requires investments, like acquisition of a new computer or printer.

Measured benefit results are first presented in a brief summary in Section 5.5. Overall results are located in Sections 5.6–5.8 and are based on the results of Case Studies 1, 2, and 3. In these case study projects, the CE environment was used for project management based on many of the same principles. The feature common to all of them was a comprehensive centralized document archive containing the project documents. Due to individual project characteristics the identified and measured benefits were not the same in all of the three case studies. As a result, a few of the results in the following figures are based on single case study result only, instead of being an average result for Case Studies 1, 2, and 3.

The collaboration application 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 CE application and the acquired benefits were related to the project culture in United States. Due to different project procedures, the Case Study 4 benefits could 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 case studies.

Benefit codes for identified and measured qualitative benefits are presented in Table 3. The full benefit code descriptions, including monetary and other quantifiable benefits, are presented in Appendix 2.

Table 3. Codes and descriptions for qualitative benefits measured in the case study project analysis.

Code	Benefit description
	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
	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
	TIME MANAGEMENT
A31	Increased opportunities to plan use of own time
	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
S43	End users of the building have more opportunities to influence design decisions because they can follow design progress
	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.

5.5 Summary of Overall Case Study Results

The Case study project-specific results are shown in Table 4 for Cases 1–4. For all of the case studies, measured monetary benefits exceeded the direct costs incurred by the use of the applications, when benefits and costs are examined from the perspective of the entire project team. In the comparison of monetary benefits with the application operating costs the costs of using the CE environment includes the ASP user fee only.

Table 4. Summary of the individual results for Cases 1-4.

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"	<ul style="list-style-type: none"> Time savings about 200 hours (29 work days) About 1700 days less information distribution delays. 	Altogether about 17 300 € (17 300 USD)	2,6
2	2,2 "The tool was somewhat helpful in document and project management"	<ul style="list-style-type: none"> 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 € (70 000 SEK, 8 100 USD)	1,8
3	2,3 "The tool was somewhat helpful in document and project management"	<ul style="list-style-type: none"> Time savings about 162 hours (about 20 work days) Time delays in the information distribution 2344 days less approximately. Less field errors 	19 000 € (£ 12 000, 19 000 USD)	1,3
4	2,3 "The tool was somewhat helpful in document and project management"	<ul style="list-style-type: none"> 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 € (27 000 USD)	22

Remarkably high monetary benefits were reached in Case Study 4. Due to cultural differences, the benefits would not be reached to same extent by using the same ASP application in other case study countries.

In Case Study 1, good results were achieved, especially for qualitative benefits. The result is partially a combined effect of using two separate applications: (1) the application used for the design stage served document management only, and (2) 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 their features did not overlap, together they offered a good selection of useful properties, supporting both document and project management. Still, better results would probably have been achieved if one application offered all the same features and capabilities. Today, Buildercom (application service provider) owns and offers both of the applications used in Case Study 1.

In Case Studies 2 and 3, the most interesting benefits are the acquired time benefits. In both case study building

projects, the revised design distribution procedures made for faster project completion. Especially in Case Study 3, there was a remarkable elimination of time delays in the information distribution. The target to reduce paper in Case Study 3 was also reached to some extent.

The combined results of Case Studies 1-3 are presented in the following sections.

5.6 Qualitative Benefits

5.6.1 Impact on Project and Document Management

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

4 = Application 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 in the rating system is: *The application was somewhat helpful in document and project management.* The results for individual benefits are shown in Figure 5.

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

- The completion and approval of the digital daily field report was far easier than the traditional paper reports. (Table 3 -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 (Figure 5).

The questionnaire also contained score -1= Negative impact: use of application caused problems or extra work. This response was selected on a number of occasions.

In addition to the benefits presented in Figure 5, 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.

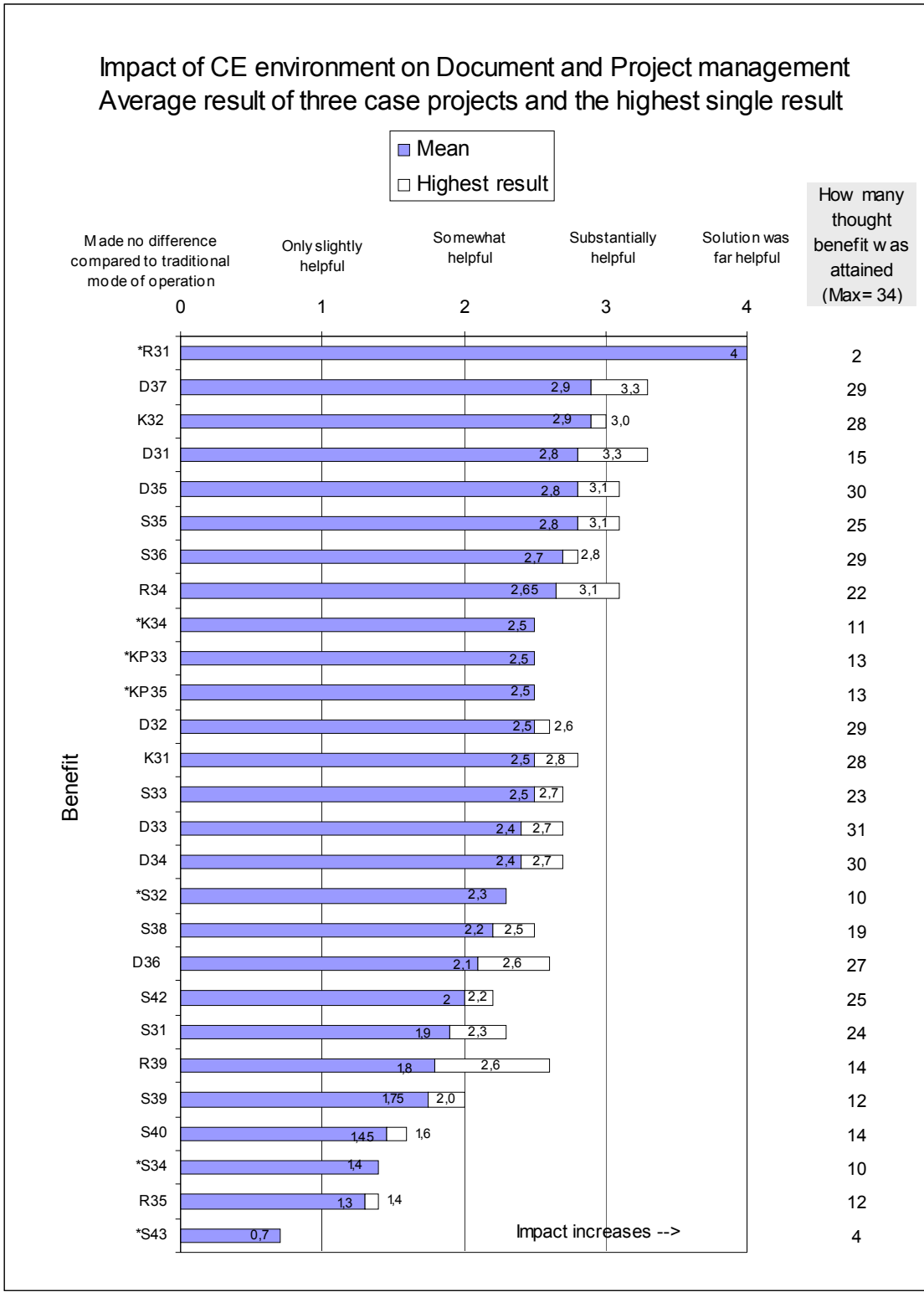


Figure 5. Qualitative Benefits obtained by using the CE environment in Case Studies 1-3: The average for the three case studies and the highest case study-specific result. A star (*) in front of the benefit means that the benefit was reached and measured in only one of the cases. Benefit codes are described in Table 3.

5.6.2 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, was attained in 29 of 34 respondents' opinions)
- Significantly easier to publish the updated documents (benefit S35, in 25 of 34 respondents' opinions)
- Significantly better opportunity to stay up to date concerning the changes & news in the project (benefit K32, in 28 of 34 respondents' opinions)
- Significantly easier access to the real-time project information (benefit S36, in 29 of 34 respondents' opinions)

The ease of document distribution and information publication can be considered the most typical benefit from the viewpoint of the information producer. The most typical benefits from the viewpoint of the information receiver are better availability to real-time project information, and better awareness of project changes and new project information.

5.6.3 Benefit Attainment Compared to Importance

The questionnaire also surveyed how responders, i.e. the users of applications, considered the importance of 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 6. Almost all the measured benefits were considered important, equating to an average verbal score of “significant”. Many benefits considered important by respondents, were also well reached.

Benefit Achievement Compared to Importance Average Results of Case Studies 1, 2, 1 and 3

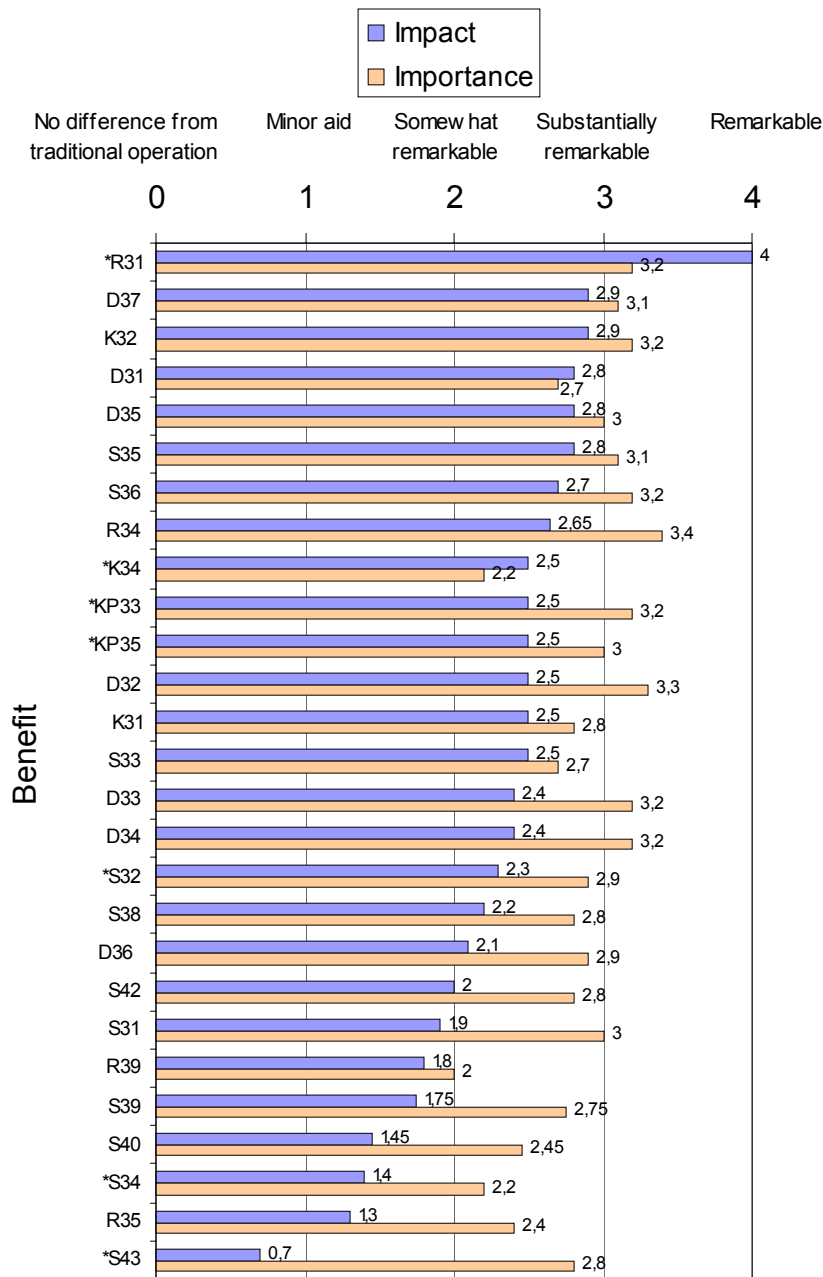


Figure 6. Average Benefit Achievement and Importance in Cases 1-3. A star (*) in front of the benefit means that the benefit was reached and measured in only one of the cases. Benefit codes are described in Table 3.

Figure 7 shows four benefit groups emerging from the comparison of benefit importance and impact. The following table outlines the scale used

- 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

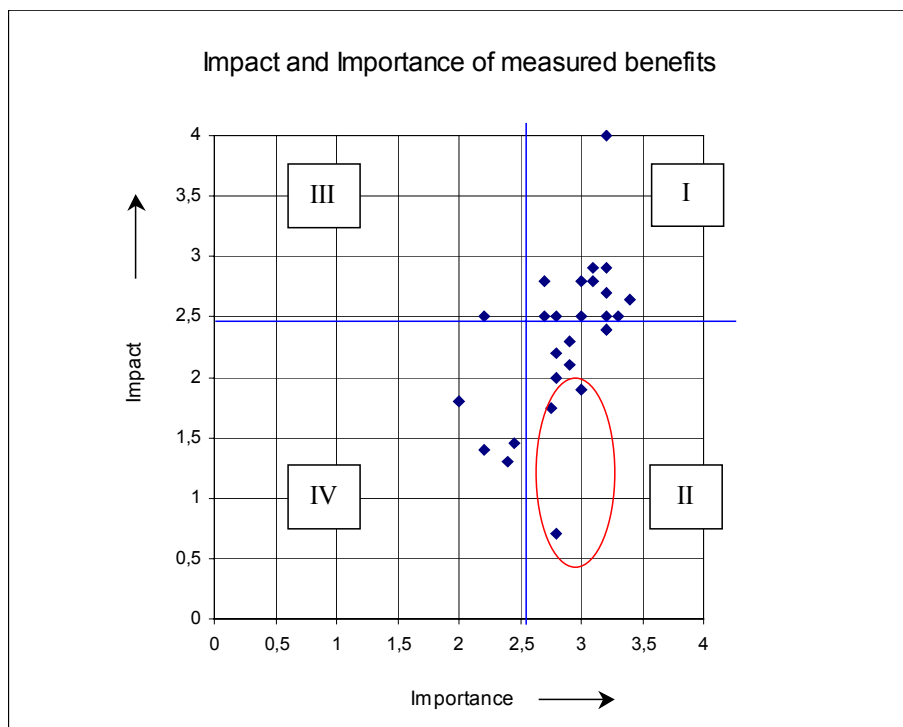


Figure 7. Benefit Achievement Compared to Importance. The results are average for Cases 1, 2 and 3.

Important but negligibly acquired benefits are circled in Figure 7. These benefits 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)

The use of the CE environment applications was not a big advantage regarding the benefits listed above, but software features should perhaps be developed so that the benefits would be reached. Application service providers should therefore consider developing the software features that support these needs.

5.6.4 Benefits to the Various Parties

In all the analyzed case study projects a different ASP application was used as centralized information storage. The CE environments used in the three European case study projects were so similar that by combining their data, benefits to the different parties can be analyzed, as shown in Table 5. When studying the results, it must be remembered that the sample is relatively small.

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 case study 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 (Table 5). The common benefits, applicable to several parties were easier distribution of documents to other parties (D37), easier access to up-to-date project information (S36 and R34), and easier retrieval of information for one's own use (D35).

Table 5. The views of different parties' concerning the impact of the CE environment to document and project management in Case Studies 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"	<ul style="list-style-type: none"> – Distribution of documents to other parties easier (D37) – Easier to publish the updated documents (S35) – Increased individual accountability (K34) – Easier access to the real-time project information (S36) (Measured result 2,8 to each)
Contractors (General and subcontractors)	13	2,3 "Was somewhat helpful in document and project management"	<ul style="list-style-type: none"> – Easier to record/save the project information (R31) – Better opportunity to stay up to date the changes & news concerning the project (K32) – Easier to retrieve the project information into own use (D35) (Measured results 3,1–3,2)
Supervisors	3	3,1 "Was substantially helpful in document and project management"	<ul style="list-style-type: none"> – More communication facility options and better information exchange (K31) – Easier access to the real-time project information (R34) – Distribution of documents to other parties easier (D37) – Faster insight into progress of design and construction work (S38 and R39) – Easier to record/save the project information (R31) (Measured result 4,0 to each)
Owners	2	3,0 "Was substantially helpful in document and project management"	<ul style="list-style-type: none"> – Easier to retrieve the project information into own use (D35) – Elimination of unnecessary information because of user defined information requirements (D36) (Measured results 4,0)

In the contractors' group, easier recording of information into the digital daily field report (R31) 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 on 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 Study 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 digital archive created for the client (KP33).

5.7 Time and Other Quantifiable Benefits

In the case study projects analyzed, numerous time and other quantifiable benefits 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 digital 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 8. The same figure shows the alternatives offered by digital data transfer.

In Case Study 1, design information was distributed to the construction project participants in digital 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 digital 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 construction 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 8.

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 the drawing on the system. The designers saved the A3-sized designs onto the centralized system, where other parties were able to get them in digital 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 8, benefits are primarily time benefits.

In 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. In this 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.

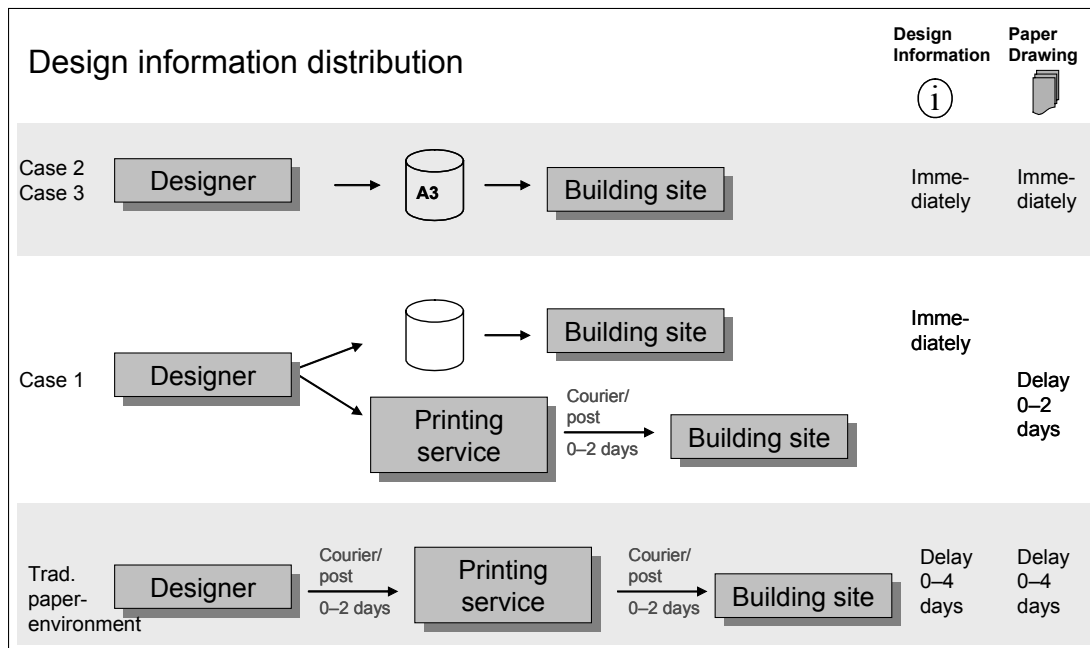


Figure 8. Impact of the New Design Information Distribution. The symbols shown in the upper, right corner correspond to design information available in digital and paper form. Beneath, distribution delays related to each procedure used are shown.

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 and CAD files, benefits of the PDF include smaller file size and easy-to-use readers.

5.8 Monetary Benefits

For all case studies, measured monetary benefits were higher with respect to the service providers charge. In Case Studies 1, 2 and 3 the perceived monetary benefits were on average about 15 000 € (15 000 USD) per case study. When monetary benefits are compared to the actual costs, the benefit is on average:

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

The direct cost savings were related mainly to communication and document management. In the analyzed case study projects, the general 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.

In the distribution of the meeting minutes the speed is not usually as important as in the distribution of the design information. However, a common document archive can be created by using a centralized digital distribution and significant sums can be saved in mailing costs, as shown in Figure 9. In the case study projects analyzed, the potential saving related to the mailing costs was approximately 2 000 € (2 000 USD) per case study 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 related to the handling of paper documents are moved to the receiver in this new procedure.

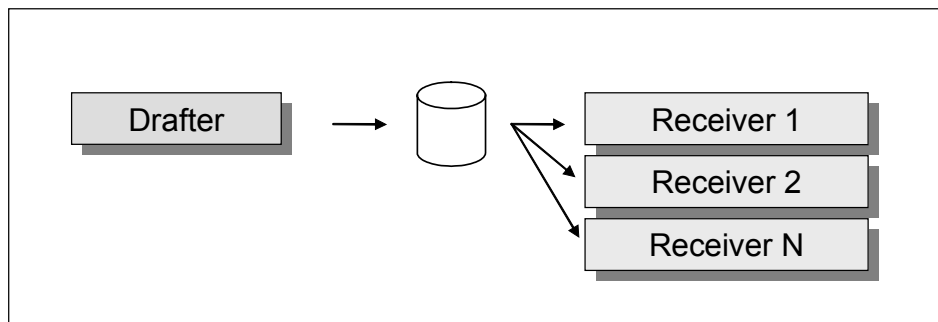


Figure 9. Centralized Digital Distribution.

If a receiver is satisfied with the reading, handling, and filing of the information in digital 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.

6. CONCLUSIONS

A fundamental conclusion of the research study is that by using digital 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, as well as 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 digitally inputting recorded information more quickly during the construction phase.

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

The introduction of advanced applications in the market based on dynamic web pages has positively supported the implementation of the CE environment in building projects. The features of the commercial applications are often similar 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 several different CE environment applications, in respect to application features. The study found that most benefits are reached using the most advanced systems.

Unused potential became apparent in the case studies analyzed mainly because the CE environment and digital 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 digital distribution of bidding documents.

The advanced CE environment makes it possible to radically reform data flows in multi-partner projects. The change does not succeed by simply 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 of CE should be controlled and supported.

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8. REFERENCES


- Back W.E., and Moreau K.A. (2000). Cost and Schedule Impacts of Information Management on EPC Process, *ASCE Journal of Management in Engineering*, Vol. 16, No. 2, 2000, pp. 59-70.
- Carter, C., Thorpe, A., and Baldwin, A.N. (1999). Benefits Assessment. (ISOCCCrates Deliverable 3) a report on the ISOCCCrates Project, published by Department of Civil and Building Engineering, Loughborough University.
- Churcher, D.W., S.T. Johnson, R.W. Howard, and D.M. Wager. (1996). "IT in construction - quantifying the benefits." CIRIA Report 160, Construction Industry Research and Information Association, London.
- Construct IT (1998). Measuring the Benefits of IT Innovation. Construct IT Centre of Excellence, Salford University.
- Lakka, Antti & Sulankivi, Kristiina (1998). Open Network for Construction (In Finnish, Rakennusalan avoin tietoverkko). Espoo: VTT Building Technology, 1998. 76 pages. + appendixes 18 pages. (VTT Research Notes 1916). (URL: <http://www.inf.vtt.fi/pdf/>).
- Lakka, Antti, Sulankivi, Kristiina and Luedke, Mary (2001). Features and Capabilities in the Concurrent Engineering Environment. ProCE project Intermediate Report, 15 March 2001. 15 pages & appendixes.
- Lakka, Antti, Sulankivi, Kristiina, and Luedke, Mary (2001). Measuring the benefits of CE-environment solution in the multi-partner projects. In Proceedings, 2nd Worldwide ECCE Symposium. June 6-8 2001, Espoo Finland. 6 pages.
- Luedke, Mary, Lakka, Antti, and Sulankivi, Kristiina (2001). Existing Features And Attributes In The Concurrent Engineering Environment. In Proceedings, 2nd Nordic Conference on Construction Economics and Organization. April 24-25, 2001. Gothenburg Sweden. 8 pages.
- Sjøholt O. (1995) From Quality Assurance to Improvement Management. Project Report. Norwegian Building Research Institute. Oslo, 1995.
- Sulankivi, Kristiina (2002). Benefits of CE environment and digital data exchange in project management and organisation. (Sähköisen tiedonsiirron hyödyt projektin johtamisessa., In Finnish.) Vera -information Networking in the Construction Process -Technology Programme Seminar 20.11.2002.
- Sulankivi, K., Lakka, A., Luedke, M. (2002). Project management in the concurrent engineering environment. VTT Publications. (Available in Finnish and in English). Technical Research Centre of Finland. <http://www.vtt.fi/rte/cmp/projects/proce/indexe.html>

APPENDIX 1. THE CASE STUDIES

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 1).

Table 1. Case Study 1 Basic Project Information.

<p>Case 1</p>	
<p>Building type:</p>	<p>Mixed-use office building: educational and research premises, office space leased to companies.</p>
<p>Project size:</p>	<p>25 million € (about 25 million USD) 19,500 m² gross (210, 000 sf)</p>
<p>Delivery method:</p>	<p>Privately financed, public project delivered by way of a construction management contract</p>
<p>Project Parties:</p>	<p>Main contractual parties located around the country and financier abroad.</p>
<p>Schedule:</p>	<p>Project planning started Spring 1997, Construction in Summer 1999, Completion and handover Late Summer 2000.</p>
<p>Project and application status at the time of analysis:</p>	<p>Completed project; Implemented commercial applications developed significantly after use in the project construction phase.</p>

In Case Study Project 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-applications were used for document and project management, Raksanet during the design phase and Työmaatiето (now known as SiteInfo and both applications of Buildercom), during the construction phase. Furthermore, separate digital 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 digital 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 digital document archive, allowing them to follow the progress of design.


In the construction phase, Raksanet served as the design archive, and a second application, Työmaatiето, 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 Työmaatiето application. Additionally, the application's digital site diary 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 application, 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.

CASE STUDY 2, SWEDEN

The second project analyzed in the study was a school building built in Sweden (Table 2).

Table 2. Case Study 2 Basic Project Information.

<p>Case 2</p>	
<p>Building type:</p>	<p>Primary School Building</p>
<p>Project size:</p>	<p>6500 m2 64 million SEK (about 7.5 million € and 7.5 million USD)</p>
<p>Procurement method:</p>	<p>Design - Build</p>
<p>Project parties:</p>	<p>Main parties located within a maximum radius of 100 km</p>
<p>Schedule:</p>	<p>Aggressive time schedule: Design began 9/1999, construction only 1.5 months later 10/1999, and building handover 6/2000.</p>
<p>Project and application status at time of analysing:</p>	<p>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.</p>

In Case Study 2 an ASP application called Byggnet was used for both document and project management. The application 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 a digital 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 Study 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.

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 3).

Table3. Case Study 3 Basic Project Information.

<p>Case 3</p>	
<p>Building type:</p>	<p>Commercial retail store (supermarket) and adjoining development</p>
<p>Project size:</p>	<p>£16 million (about 25 million € and 25 million USD) Total of 22 acre (9 ha) development, Store size: 84,500 sf gross (7,900 m2)</p>
<p>Procurement method:</p>	<p>UK JCT standard traditional contract amended to reflect the Owner's partnering philosophy</p>
<p>Project parties:</p>	<p>Main parties located within a 200 mile (300 km) radius</p>
<p>Schedule:</p>	<p>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)</p>
<p>Project and application status at time of analysing:</p>	<p>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.</p>

In Case Study Project 3, an ASP application called the-project (by Sarcophagus) was used during the construction phase to digitally 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 with only a few exceptions. This directive eliminated all A0- or A1-sized drawings except for specialty trade designs (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 digitally between the main parties, and each party was responsible for printing document copies to fulfill their own needs.

The benefit measurement was performed in the same way as in Cases 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.

CASE STUDY 4, USA

The fourth building project analyzed was an addition to teaching premises in the United States (Table 4).

Table 4. Case Study 4 Basic Project Information.

<p>Case 4</p>	
<p>Building type:</p>	<p>Addition to educational training center</p>
<p>Project size:</p>	<p>5.2 million USD (about 5.2 million €) 35,000 sf gross (3,200 m²)</p>
<p>Delivery method:</p>	<p>CM/GC: Construction manager / General contractor</p>
<p>Project parties:</p>	<p>All parties located in the state of Oregon in close proximity to the project</p>
<p>Schedule:</p>	<p>Design started 1/2001; Construction started 5/2001; Completion and handover 10/2001; 25 week construction schedule</p>
<p>Project and application status at time of analysis:</p>	<p>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.</p>

In Case Study Project 4 the Buzzsaw-application was used during the construction phase to publish, disseminate, respond to and archive requests for information (RFIs) and to 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 faxing continued to be used to disseminate RFI responses to some parties, to deliver notifications, sketches corresponding to the RFI, and to supply 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 is a request for 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 .

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

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

APPENDIX 2.

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

Activities of building project		Monetary benefits	Other quantifiable benefits	Qualitative benefits
Input	<p>Communication</p> <p>K=communication</p>	<p>K11 Reduced communication costs (travel, phone, fax)</p> <p>K12 Labour cost savings because of a more effective use of time</p>	<p>K21 Faster distribution of information</p> <p>K22 Faster information exchange rate (e.g. response time)</p> <p>K23 More effective use of time (less traditional meetings or several web conferences instead of a meeting)</p> <p>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)</p> <p>K25 Fewer disputes because of documented information in audit trail</p>	<p>K31 More communication facility options and better information exchange</p> <p>K32 Increased awareness of project changes and news (i.e. new project information).</p> <p>K33 More consistent information</p> <p>K34 Increased individual accountability</p> <p>K35 Fewer misunderstandings</p> <p>K36 Easier to deliver information to late parties joining the project (they get more complete information than traditionally)</p> <p>K37 Improved quality of discussion</p>

Control	<p>Document management - (D=Document management)</p>	<p>D11 Reduced document distribution costs (printing, courier, mailing)</p> <p>D12 Labour cost savings because of a more effective use of time</p> <p>D13 Lower archiving costs (space & container hire / purchase)</p>	<p>D21 Faster distribution of documents / Information is accessible earlier (indicator 1) time @ upload, 2) Faster delivery of paper copies)</p> <p>D22 More effective use of time (less searching, collecting, and handling of paper; possibility to work remotely)</p> <p>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)</p> <p>D24 Reduced need for archiving space at office / on site</p> <p>D25 Reduced paper waste</p>	<p>D31 Project information available without time, location, or user organizational dependency</p> <p>D32 Documents are in better order and easier to find in a single, organized collection</p> <p>D33 Increased awareness of new information</p> <p>D34 Versions of a document are in better order, easier to find, and readable</p> <p>D35 Project information is easy to retrieve for own use</p> <p>D36 Improved filtering of information (Elimination of paper delivery of unnecessary information because of user defined information requirements)</p> <p>D37 Easier distribution of documents to other parties</p>
	<p>Time (A=time management)</p>	<p>A11 Cost savings from compressed schedule</p>	<p>A21 Opportunity for compressed schedule / more flexible planning of own time (same quality level in shorter time)</p> <p>A22 Reduced risk of exceeding schedule</p>	<p>A31 increased opportunities to plan use of own time</p>
	<p>Cost (KU = cost mgmt)</p>		<p>KU21 Reduced risk of exceeding budget</p>	
Execution	<p>Marketing M = marketing</p>	<p>M11 Reduced distribution costs (of marketing materials)</p>	<p>M21 Improved company image (indicator could be better or wider service to client)</p> <p>M22 Generating new business (new projects)</p> <p>M23 Wider marketing area (geographically)</p>	<p>M31 More complete project information</p>

	<p>Design</p> <p>S = design</p>	<p>S11 Reduced labor and administrative costs (locating product information faster)</p> <p>S12 Cost savings due to fewer design errors (less rework)</p>	<p>S21 Time savings due to fewer design errors (less rework)</p> <p>S22 Improved quality of design (fewer design errors, improved constructability)</p> <p>S23 Faster design change process</p> <p>S24 Fewer administrative tasks</p> <p>S25 Faster decision making</p> <p>S26 Faster specification of building products and materials (eCommerce and other info sites)</p> <p>S27 Time savings from reusing information more effectively (e.g. sharing digital building layout)</p>	<p>S31 Better tools for collaboration improve collaboration possibilities</p> <p>S32 Easier to share common digital information (e.g. building layout)</p> <p>S33 Improved coordination of geographically dispersed resources.</p> <p>S34 Increased awareness of task status</p> <p>S35 Easier to publish updated / revised documents</p> <p>S36 Increased accessibility to up-to-date project information</p> <p>S37 More complete and consistent recorded and retrieved project information</p> <p>S38 Easier to monitor design progress (e.g. for design coordinator)</p>
			<p>S28 Fewer PCs need design software installed (can use viewer).</p>	<p>S39 Improved coordination of designs (e.g. management of specialty contractor designs)</p> <p>S40 More efficient decision-making cycle</p> <p>S41 Increased documentation of decision background.</p> <p>S42 Helps to manage design change process</p> <p>S43 End users of the building have more opportunities to influence design decisions because they can follow design progress</p>

	<p>Construction (R=Construction)</p>	<p>R11 Cost savings due to less rework (labour, material, equipment costs)</p> <p>R12 Reduced labor costs because of more effective use of time (e.g. using digital forms or data input and transfer by using mobile communicator)</p>	<p>R21 Time savings due to less rework (field errors and rework)</p> <p>R22 Time savings in data collection and transfer (e.g. using digital forms or data input and transfer by using mobile communicator)</p> <p>R23 Fewer administrative tasks</p> <p>R24 Reduced time for decision making</p> <p>R25 Faster access to manufacturer safety and installation information</p> <p>R26 Time savings from reusing information more efficiently (using text from specifications, etc.)</p> <p>R27 Fewer PCs need design software installed (can use viewer)</p>	<p>R31 Easier to collect and transfer data (daily field reports, communicator)</p> <p>R32 More complete and consistent recorded and retrieved project information</p> <p>R33 Improved coordination</p> <p>R34 Increased accessibility to up-to-date project information</p> <p>R35 More efficient decision making cycle</p> <p>R36 Better tools for collaboration improve collaboration possibilities</p> <p>R37 Improved workflow management</p> <p>R38 Increased awareness of task status</p> <p>R39 Easier to monitor construction progress (e.g. by web camera, posting digital photos)</p> <p>R40 Increased documentation of decision background.</p> <p>R41 Easier to share common digital information (e.g. design-manufacturing-construction progress tables)</p>
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	<p>Operation and Maintenance</p> <p>(KP=operation and maintenance)</p>	<p>KP11 Cost savings because of digital archive (e.g. no need to use scanning service)</p> <p>KP12 Labor cost savings because of more efficient use of time due to faster access to completed project information</p>	<p>KP21 Time savings due to faster access to O&M data (O&M data collected and transferred to owner)</p>	<p>KP31 Facilities to create a complete, searchable, digital Operation and Maintenance manual.</p> <p>KP32 Standardized documentation (form and content)</p> <p>KP33 Full digital archive created for the client (e.g. as-built documents, design / construction decision background)</p> <p>KP34 Improved full-life cycle information management</p> <p>KP35 Project information is maintained in a useable form and remains available to future users on the service provider's server.</p>
Resources	<p>Procurement</p> <p>(H = procurement)</p>	<p>H11 Labour cost savings because of a more efficient use of time (submitting tender material via the centrally-accessible server)</p> <p>H12 Reduced document distribution costs (printing, courier, mailing)</p>	<p>H21 Time savings from reusing information more efficiently (quantitative information)</p>	<p>H31 Easier to locate information about available products and human resources (product info, subcontractor contact info)</p> <p>H32 Easier to transfer information between parties (quantitative information)</p>
Result	<p>Product / building</p> <p>(T = product / building)</p>		<p>T21 Improved quality (fewer errors, items on the punch list)</p>	

This paper is available electronically at <http://itcon.fagg.uni-lj.si/~itcon/index.htm>