End-user attitudes towards EDM use in project work

A case study of the Kamppi Center project

Mathias Hjelt, 992610

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Information Systems Science

Swedish School of Economics and Business Administration

Examiner: Bo-Christer Björk

HANKEN – Swedish School of Economics and Business Administration

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Abstract

This study set out to explore attitudes towards EDM from the perspective of individual end-users. The objective was to explore how implementation efforts and the benefits enabled by EDM are perceived in different end-user segments across the project group.

Combining quantitative and qualitative research methods, the study was conducted as a cross-sectional case study of a large construction project in which EDM was used extensively. Responses from a survey were combined with data from system usage log files to obtain an overview of attitudes prevalent in different user segments. In order to gain a deeper understanding of key issues, the survey was followed by semi-structured interviews with representatives of different roles of the project group. Finally an industry expert was allowed to comment on the findings.

In the case studied, a reassuring majority of users from all segments of the project group considered EDM as a valuable aid in their work processes, despite certain functional limitations of the system used and the complexity of the information mass. However, users who perceived EDM use as difficult or inefficient were quick to revert to other channels of communication. The use of parallel channels of communication was, in turn, found to be a significant source of frustration among users. A key finding was that functionality and the actual contents of the EDM system are both important drivers behind usefulness and ease of use. Consequently, training efforts provided should cover both aspects.

Although the general applicability of the results are somewhat limited due to the fact that only one case was studied, a model describing the key factors affecting end-user EDM adoption is proposed. In an attempt to integrate the empirical findings of the study with existing literature, the model draws on insight from studies of EDM enabled projects and theoretical frameworks on technology acceptance and success of information systems.

The proposed model attempts to show that adoption factors are influenced in part by properties of the service provided and in part by properties of the end-users. Key service properties include system quality and information quality, as well as availability of support resources which are divided into technical training and project-specific guidelines. On the end-user side, the individual's involvement in the information process is a key factor affecting effort and performance expectancy. Furthermore the model highlights that individual end-users are subjected to social influences and facilitating conditions originating not only from project management but also from their employing organisations.

Keywords
Electronic document management, technology adoption, end-user perspective

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1 Introduction

1.1 Background

Although construction may intuitively be perceived as an industry concerned primarily with labour and material intensive processes, construction work is highly dependent on information and communication. The material process can only function in integration with an information process, which gives birth to design information describing *what* to build and management information describing *how* to build it (Björk 1999). The amount of documents produced within the information process during the course of a construction project is overwhelming. Consequently, proper management of documents is of key importance regarding efficiency and quality management.

Software developers and practitioners within the construction industry have realised the benefits achievable by the means of electronic communication and storage, and a large number of software solutions for electronic document management (EDM) have emerged on the market. Declining costs of end-user computing and network communication have further fuelled the development and adoption of such technologies. EDM software, sometimes integrated in larger project management solutions, is referred to using a variety of terms in the literature and among practitioners; *project webs*, *project banks*, *project (collaborative) extranets*, *concurrent engineering (CE) software* are commonly used terms. For the sake of simplicity, the term EDM will be used throughout this study, and is intended to cover any software packages including, but not limited to, EDM functionality.

The use of EDM and related technologies in construction projects has been the subject of a growing body of research. Research topics have covered various aspects such as the typical features required (e.g. Hartvig 2001, Degerstedt 2000, Lakka et al 2001), practical benefits achieved (e.g. Ruikar et al 2005, Löwnertz 1998, Björk 2001), financial gain achieved (e.g. Sulankivi et al 2002), usage patterns (e.g. Andresen et al 2003, Thorpe and Mead 2001), industry-level adoption as well as project specific implementation challenges (e.g. Peansupap et al 2005, Ruikar et al 2005, O'Brien 2000).

As will be covered in greater detail in chapter 2, previous research indicates that EDM technology has a huge potential as an enabler of quantitative and qualitative benefits in construction. While it appears difficult to empirically prove financial savings of signifi-

cant magnitude, case studies report that adopters believe EDM use allows for improved speed, quality and cost efficiency in the information process (Sulankivi et al 2002), thus affecting the entire construction project positively.

However, in order for EDM to deliver any of the potential benefits within a construction project, it must be properly implemented throughout the entire project organisation. Being a relatively new tool for many practitioners (as shown by the survey results presented in this study), the implementation process must be planned and executed carefully. Researchers agree that proper implementation requires strong management commitment, detailed document management guidelines, sufficient training etc, resulting in widespread and proper use of the tool (e.g. Sulankivi et al 2002, O'Brien 2000). EDM adoption causes changes in work routines across the entire project organisation and requires efforts from everyone involved, but yet it is often thought that the realised benefits are distributed unevenly among the participants. Project management is in a position to dictate EDM use and receives the majority of the benefits which arise – but cooperation of the entire project organisation is required in order to reach the goals set.

The idea and research topic of this study emerges from this apparently uneven distribution of efforts/benefits and decision power across the organisation. Where many previous case studies on the topic of EDM adoption and usage are based on data collection among project managers, this current study sets out to explore attitudes towards EDM *across various segments* of the construction organisation on an *individual level*. In pursuing the individual end-user perspective, the study draws on theoretical models of ICT adoption and technology acceptance.

1.2 Aim and objectives

The aim of this study is to explore end-user attitudes towards EDM usage in a large construction project. Research questions of interest are:

1. How do users across the project organisation perceive the implementation efforts employed?

2. How do users across the project organisation perceive the benefits of EDM?

3. Which factors influence the individual end-user's adoption of EDM?

These research questions, which are largely of an exploratory or even descriptive nature, serve two purposes. The first objective is to provide insight into the practical issues of EDM adoption in the case project studied, adding to the existing body of data on EDM use. Such findings may be of value for future research, but also for practitioners planning future implementation efforts and software developers fine-tuning their software offerings targeted at the construction industry. The second objective is to propose a theoretical model for understanding factors affecting end-user adoption of EDM in project organisations.

1.3 Structure of the study

Chapters two and three are based on a review of literature in the area and present a set of theories supporting the empirical part of this study. Chapter two introduces document management in construction, covering previous research on the benefits and implementation challenges related to EDM use. Chapter three approaches the topics of innovation diffusion and end-user acceptance of ICT on a general level.

The case project under study is briefly described in chapter four, while the actual research design is laid out in chapter five. Empirical data is presented and analysed in chapter six. The results are discussed and evaluated in chapter seven.

2 Document management in construction

2.1 Construction project basics

Studying the issues of information and IT management in the construction business requires a fundamental level of insight in the properties and peculiarities of construction projects. While a detailed discussion of the multitude of different approaches to construction management lies beyond the scope of this study, this section aims to describe specific features that are characteristic of this type of project work. The following is based largely on (Kankainen & Junnonen 2001; Vuorela, Urpola & Kankainen 2001).

Life cycle and phases. The complete life cycle of a building can be divided into the following phases: design, construction, use, reconstruction and demolition. The phases are not necessarily executed in a linear, sequential manner. In fact, the design and construction phases are partially overlapping in an iterative, integrated process which ends once the building is handed over to the user. Similarly reconstruction activities can be carried out several times during the usage phase, as an integrated part of facility management activities.

Table 1 below describes the phases of a construction project in more detail. Even though electronic document management can be of use throughout the entire life cycle of a building, this study is primarily focused at the design and construction phases.

Table 1 The phases of a construction project

Phase	Description
1. Requirements planning	The client's need for facilities is examined. If a definite need is identified, a construction project is launched.
2. Project planning	The scope and goals of the project are defined, as well as objectives regarding quality, costs and schedule. The project organisation takes shape and alternative approaches are examined.
3. Architectural and structural design	Increasingly detailed drawings emerge, evolving from architectural sketches to detailed structural drawings. The drawings are often used in tendering rounds aimed at choosing entrepreneurs for the construction phase.
4. Construction	The actual construction work is carried out.
5. Use and maintenance	The building, a facility management book and the final drawings are handed over to the client.

Project group properties. With the exception of partnering projects (where a consortium is formed with the intent of collaborating over an extended period of time) each construction project is typically carried out by a *temporary* project group, a constellation assembled during the early design phase and dissolved after the construction phase has been completed.

The group composition is often *unique* for each project. The task of designing and constructing a building requires input from a wide range of professional disciplines, where the scope is determined by the size and complexity of the project. In a small scale construction project, it is possible for one single company – or even one single person – to take responsibility of all the tasks and roles. However, as the project grows bigger, the project organisation grows *heterogeneous* in terms of participating companies. In a large scale project, such as the Kamppi Center project discussed further on, hundreds of separate companies can be involved. Such inter-organisational project groups are often called *virtual organisations* in literature. The contractual and hierarchical relationships present within the organisation vary depending on the construction management approach employed in a specific project.

Furthermore it should be pointed out that the *degree of involvement* of each individual varies across the project group. While some may be employed full-time by one single project, other may be working with several projects simultaneously. Likewise, some are likely to be involved in the project from start to finish, while other participants may be active only during a short period of time. In other words, the group composition remains dynamic throughout the length of the project.

2.2 Construction documents

Several different types of documents are produced in the information process of a construction project: architectural and structural drawings, technical specifications, financial calculations, contracts, bills of materials, schedules, meeting minutes, etc. In terms of content, construction documents of today still bear resemblance to those of the mid 20th century. The means for producing and exchanging these documents have, however, undergone major changes.

Photocopying simplified the distribution of documents in the 1970’s, and the facsimile allowed to bridge geographical gaps and shorten delivery delays in the 1980’s. Since the

definite breakthrough of personal computing in the late 1980's and early 1990's, most of documents are produced with the help of computers, and can thus also be distributed electronically. Prior to the internet era, electronic distribution could be committed over expensive, dedicated private networks or simply by exchanging diskettes.

Towards the late 1990's, increasingly widespread access to the e-mail enabled a significant step towards faster and cheaper collaboration in the digital domain. However, given the amount of documents produced in a construction project, e-mail is far from an ideal solution for managing and exchanging information. In the following sections, the concept of electronic document management is introduced.

2.3 A brief introduction to electronic document management

The aim of electronic document management systems (EDM) is to support information processes by providing users with simple, logical and quick ways of storing, finding and retrieving documents. This section, largely based on (Degerstedt 2001; Löwnertz 1998; Ekman 1999), provides a short introduction to the features commonly available in EDM systems.

What is a document? Before personal computers became commonplace, a document was typically thought of as information printed on paper. ISO 3613-1 offers a more abstract definition:

> *A structured amount of information for human perception that can be interchanged as a unit between users and systems.*

A document doesn't have to be tied to any particular physical form. The information and representation rules that constitute a document can be stored in any arbitrary electronic format on any arbitrary electronic media. Furthermore, an electronic document can be compounded from a multitude of different elements (text, images etc), stored in different digital formats on different media or physical locations. Applying different rules for representation and layout, the same underlying data can be viewed in visually disparate forms. (Löwnertz 1998)

The role of an EDM system. In theory, an EDM system does not have to include a storage repository for documents. A rudimentary EDM could function like a bibliographical reference database containing a mere index of documents stored in other loca-

tions. However, many of the currently available EDM solutions include an integrated storage capability, which gives the system an additional role as a central document archive and strengthens its role as a central gateway to accessing the documents.

Navigation. A document management system can employ several different approaches to making the information proper easy to navigate. Basic systems provide a single hierarchical folder structure, where each document is stored under a single distinct folder (much like files and folders in the Windows operating system.) More advanced systems support dynamic, multidimensional hierarchies, where one single document can be found through several different hierarchical paths.

As the volume of documents managed by an EDM grows, various search methods assisting users in locating documents become increasingly important. Search queries can be targeted at different types of data:

- **Basic document properties** such as name of the submitted file, type of file, date of submission and owner.
- **Meta-data,** i.e. information that describes each document. Meta-data can include various categorisation tags, status fields, keywords, etc.
- **Full text.** Search queries are performed at the actual contents of documents. This type of search is efficient for pure textual documents but of limited use on CAD drawings.

Access control and security. EDM tools usually provide means of handling access control, making it possible to regulate access to documents or folders on a per-user or per-group basis. Careful assignment of access levels (e.g. read, write, modify, delete) is an essential part of managing information security. Furthermore all actions are logged, making it possible to identify any possible security breaches.

Revising and workflow. Information based processes often contain rules regarding workflow, i.e. rules for how new versions of a document are approved by various departments or individuals before release. EDM systems can provide support for such rules.

Version control. During the life cycle of a document, several new versions may be produced over time, replacing previous ones entirely. It is often desirable to keep only the latest release visible to the public, but it can be equally important to keep an archive of all previously released versions. EDM systems can provide functionality for such version control.

2.4 Benefits

This section discusses the benefits that academics and practitioners consider reachable by utilising electronic document management in construction projects.

2.4.1 Improved flow of information

In an ideal setting, EDM gives each project participant real-time access to up-to-date information, regardless of geographical distances or organisational boundaries. As discussed in the following, this stands in stark contrast to the traditional ways of distributing paper copies.

Reduced distribution delays. Document flow between geographically dispersed partners has traditionally involved printing, copying, faxing, sending paper by courier or mail. A copy shop has typically been involved in construction projects, functioning as a distribution hub for paper documents, relieving the sender from the task of producing and shipping off copies to each intended recipient.

Physical distribution of paper copies is bound to be hindered by transportation delays, ranging from a few hours to a few days, depending on the geographical distances and the transportation methods utilised. Publishing documents by the means of an EDM, in contrast, gives recipients access to any document immediately as it has been published by the information producer. Figure 1 below illustrates the difference between traditional and EDM based distribution of documents.

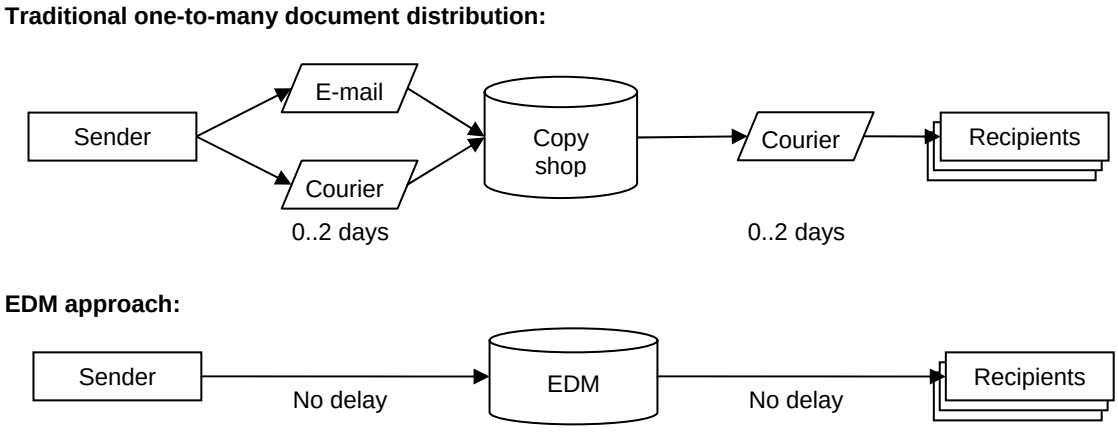

Figure 1 Document distribution using EDM

The number of documents exchanged between parties in a construction project is staggering. Case studies report considerable savings achieved (Ruikar et al 2005) in terms of reduced printing costs; other reports downplay the financial impact.

Push vs. pull. Rapid distribution of electronic documents can, indeed, be implemented without a dedicated EDM system. E.g. e-mail allows users to deliver documents near-instantly to numerous recipients. However, e-mail is far from an ideal solution. As Thorpe and Mead (2001) point out, the traditional practices of distributing information within construction projects tend to pose a significant burden on the document recipients. Technological inventions such as the photo copier and e-mail have caused increasing volumes of information to be distributed on a *just-in-case* basis, where information producers push out documents to a large number of recipients regardless of whether each individual recipient actually needs the information at that point in time. This has forced recipients to deal with the daunting task of organising a constant flow of incoming documents which may or may not be of interest at some undetermined point in the future. A properly used EDM system, on the other hand, relieves information recipients from this burden, as documents can be retrieved *just-in-time*, in a pull-fashion, when they are actually needed.

2.4.2 Revising and version control

Retrieving information *just-in-time* from an EDM system rather than *just-in-case* as discussed above not only reduces desk and mailbox clutter but also plays a significant role in maintaining version control. The fewer physical copies[1] there are in circulation, the smaller the risk is that someone unknowingly acts upon an outdated document, which already has been superseded by revised editions. (Löwnertz 1998) Yet Hartvig (2001) points out that EDM necessarily doesn't solve this problem unless a rigid document management policy is enforced; users easily end up storing local copies of documents that have been retrieved from the EDM.

2.4.3 Improved transparency and tracking

Having all documents relevant to a construction project stored in central location allows any participant (within the limits of his or her access rights) to keep up with the progress of the project. Ruikar et al (2005) suggest that the improved transparency creates greater levels of trust among group members.

Furthermore, EDM systems typically maintain detailed logs of all actions performed by the individual users. Where traditional communication has allowed parties to lag behind their schedule without getting immediately exposed, an EDM system keeps an audit trail revealing when each document has been stored and by whom. This feature has been considered of great help in settling any disputes regarding documents and distribution (Ruikar et al 2005), and gives participants an extra incentive to keep their deadlines and publish documents rapidly. However, while this constitutes a clear benefit from the project management's point of view, other parties may actually perceive this as a barrier to adoption. (Thorpe 2001; Bäckblom et al 2003)

2.4.4 Quality assurance perspective

An axiom central to quality assurance is to "do things right at once". In construction, much like any in other production process, this stipulates a need for detailed and accurate planning as well as equally precise execution. Any deviations from this goal cause

[1] "Physical copies" should here be interpreted as both paper copies and digital copies of the original document

the quality level as perceived by the customer to plummet, while total costs may sky-rocket. (Vuorela et al 2001)

Vuorela et al (2001) define the quality of a construction project as a product of:

- the project manager's ability to manage the process
- the quality of the design as seen in relation to the needs and expectations of the customer
- production quality, which is the degree to which the finished product complies to the designs and specifications

It can be argued that a properly utilised EDM solution can give substantial support in all of the above quality aspects.

Process management perspective. The project manager's demanding task of supervising the entire project is significantly alleviated by swift access to accurate and up-to-date information.

Design quality. The flexible and effortless distribution of documents fuels the communication between the customer and the design group as well as the communication between the different designers involved.

Production quality. As explained in section 2.4.1 above, version control reduces the risk of someone acting upon outdated information. Furthermore, as Degerstedt (2000) points out, the workflow capabilities of an EDM system give tools for enforcing proper review rounds. When properly implemented, workflow rules can reduce the risk of erroneous designs reaching the construction site.

2.4.5 Life cycle perspective

While the design and construction phases of a building are immensely intensive in terms of information flow, they constitute only a small part of the full life cycle of the facility. A building may outlast generations, and it can be argued that there is a need for managing information concerning the building just as long. (Löwnertz 1998)

Up-to-date drawings and specifications are in fact valuable assets during facility management activities such as renovations and reconstructions throughout the entire life

cycle. Löwnertz (1998) points out that maintaining information regarding the technical solutions and materials used is essential from an environmental point of view.

An EDM system that has been actively used during the entire design and construction phase of a project can constitute a valuable basis for a rich, dynamic archive of facility documentation. The maintenance manual of the facility can be based on the EDM contents. (Sulankivi et al 2002)

2.4.6 Measured benefits in terms cost and quality

Early EDM research estimated that the cost savings of utilising EDM could rise to 5-10 % of the total costs of a construction project (Johansson et al 1995). Yet it has been difficult to present empirical results that prove financial benefits of this magnitude.

Methods of measuring EDM-related benefits. It can be hypothesised that the discrepancy between expected and observed savings stems from the difficulty of finding reliable methods for measuring the impacts of EDM. One aspect of the problem can be illustrated through an analogy to studies of medical drugs – one single patient cannot simultaneously be subjected to both a drug and a placebo, which makes it impossible to know for sure how this particular individual reacts to the drug. In order to reach reliable knowledge about the impacts of the drug, researchers must carry out comparative studies between sufficiently large test and reference groups, whose members have been randomly selected in order to eliminate external effects. (Lundahl & Skärvad 1999)

Similarly, one cannot reliably measure the impact of EDM by studying only one construction project. Unfortunately, carrying out a “clinical” and statistically valid study coverings hundreds of construction projects may pose an insurmountable challenge as each project is unique in terms of group composition, schedule, total budget, external environment etc. Björk (2003) points out that the data available from projects so far isn’t large enough for reliable studies where external effects and the impact of the learning curve could be omitted.

Consequently the task of measuring benefits of EDM use must rely on estimations. As part of the ProCE project, Sulankivi et al (2002) have developed a model for formulating, evaluating and applying metrics on individual construction projects. The ProCE-model proposes measures of benefits comparing actual observations with previously determined expectations and beliefs regarding potential benefit.

The ProCE study classifies benefits in three categories:

- cost benefits which can be measured directly in financial terms
- other benefits which can be measured quantitatively but not in financial terms
- qualitative and functional benefits that can primarily be described verbally

Benefits belonging to separate categories are often inter-related through causal dependencies between the metrics as shown in Figure 2.

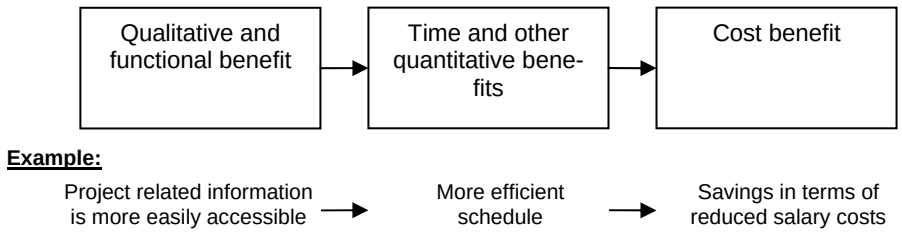

Figure 2 Causual dependencies between different types of benefits (Sulankivi et al 2002)

A similar categorisation of benefits is present in the MBITI model (Measuring the Benefits of IT Innovation) developed by Construct IT. An MBITI analysis, based on interviews, reports expected benefits as well as measured benefits (Andresen et al 2003).

Identified cost benefits. As an example, one attempt at estimating cost benefits will be described here. Within the scope of the ProCE study, Sulankivi et al (2002) applied their framework for determining EDM benefits on four different construction projects. In one of the cases, carried out during 1997-2000 with a total budget of 27 million €, the total savings enabled by EDM were estimated to a value of 17,600 €.

- Paper related expenses (e.g. mailing, scanning, copying, paper) where reduced by 5,600 €
- Travelling reduced by 10,000 km and improved efficiency in reoccurring routines accounted for 200 man-hours saved, with an estimated monetary benefit of around 12,000 €.

While the estimated benefits clearly exceeded the cost of 8,500 € charged by the EDM software provider, the net benefit of approximately 9,000 € seems insignificant considering the total project budget of 27 million €. Looking at only the financial benefits measured, the three other construction projects analysed in the ProCE study gave equally modest results. However, as will be discussed later, other significant benefits were identified in the study.

Another example is provided by Andresen et al (2003) who analysed EDM benefits and costs in two construction projects using the MBITI framework. In both cases, the costs of implementing and using the EDM tool actually exceeded the estimated financial benefits by several times. However, the disappointing results can to some extent be explained by the fact that the project webs were adopted at short notice and with insufficient planning in the cases studied.

To summarise, available results of empirical research indicate that the measurable financial benefits of EDM are insignificant. O'Brien (2000) suggests that growing insight in this matter was a driver behind the falling prices of EDM software during the late 1990s.

Identified non-economic benefits. Sulankivi et al (2002) found several forms of measurable benefits that could not be directly converted into financial terms:

- Fewer work hours
- Possibility of tighter schedule
- Fewer errors on the construction site
- Fewer disputes thanks to well documented flow of information
- Less paper to archive

While the above quantifiable benefits are likely to have impacts on cost, it is difficult to estimate the effect in financial terms.

Many of the benefits perceived by end users are more of a qualitative type and as such difficult to measure. The key qualitative benefits of EDM as identified by Sulankivi et al (2002), Ruikar et al (2005) and Andresen et al (2003):

- Distributing documents across the project organisation is easier
- Easier access to up-to-date information

- Easier to keep up with updates and news
- Easier to communicate with other participants of the project
- Good support for telecommuting

2.4.7 Summary

When used in an efficient manner, an EDM system can reduce the time needed to create, publish, search, transfer, archive and organise information related to a construction project. The time saved can be put to better use, allowing for a tighter overall project schedule and more fluent co-operation between parties. Furthermore the EDM system can improve information quality, allowing for reduced construction errors.

2.5 Implementation challenges

In order to achieve the goals described above, implementation of an EDM system needs to be planned carefully. Literature describes several challenges related to implementation. The following issues will be discussed in this section.

- Technical requirements
- Compatibility with paper-based routines
- Management commitment

2.5.1 Technical requirements and challenges

Many of the EDM tools available today are provided as *application service provider* (ASP) solutions, where the ASP operator takes full responsibility of managing server infrastructure, security, backups, testing, software updates etc. This concept is highly attractive from the customer's point of view, as it means low initial investments, enables quick implementation and doesn't tie up in-house ICT resources.

The costly private networks and specialised client software previously used in client-server applications have to a great extent been superseded by commonplace technology: the internet and web browsers. The IT-Barometer study (Samuelsson 2002) reports that an increasing share of companies in the construction industry have access to the internet. Given the ubiquitous nature of the internet and the administrative ease of subscribing to an ASP package, the technical barriers to deploying an EDM system in a con-

struction project are low. Still attention must be paid to certain issues such as software compatibility and network performance.

Security. Ensuring a high level of security is important. While sceptics may doubt the level of security provided by ASP based systems, it has not been considered a major barrier to implementation. As two case companies interviewed by Ruikar et al (2005) put it:

> *"[EDM] is probably more secure than a site office where important project drawings, documents and equipment are stored."*

> *"[T]he issues of confidentiality, authentication etc have always been there regardless of the medium of communication used."*

Life cycle perspective. Several technical challenges emerge if the goal is to reach the possible long-term benefits discussed in section 2.4.5. One issue is brought up by Björk (2003) who points out that the lack of standards makes migration of data between different EDM systems a complicated issue. The potential implication is that the highly valuable repository of documents created during design and construction is "locked" to the particular EDM solution used during the project. If the tool used was ASP-based, the customer can even be locked in to this particular operator.

Furthermore, the extent to which current EDM systems can be regarded as document *archives* becomes questionable when the technology is viewed from a life cycle perspective. While paper documents from the early 20th century are still easily readable, viewing electronic documents stored in the 1980s can pose huge challenges. First, electronic file formats tend to evolve as software applications grow more sophisticated over time, which means that conversion tools may be needed to view old files in modern software. Second, the rapid development of storage technologies poses problems as the equipment needed for reading old storage media can be difficult to find. Furthermore, many types of media used today are hardly suitable for archiving as they may deteriorate over time.

Yet, many EDM customers are aware of the potential benefits of managing construction data throughout the life cycle of a facility, and ASP-providers are eager to defy the challenge of long-term digital archival. Buildercom Ltd, a company providing construction

software like Raksanet and SiteInfo on an ASP basis, have already signed contracts obliging them to maintain their customers' documents "for ever." (Jyrälä 2005)

2.5.2 Paper still needed

Given that the majority of construction documents are already created using computers and that current EDM technology enables flexible distribution of documents in the digital domain, will construction projects become completely paperless in the foreseeable future? As will be discussed below, there are still several hindrances to such a leap.

The advantages of paper. During design meetings, printouts and pencils offer a direct, intuitive and efficient way of conveying ideas to and collaborating with people around the same table. Tablet computers[2] could offer a replacement, but the currently available tablets provide no real match for paper copies due to limited screen size and resolution. If electronic paper ever becomes feasible[3], it may be the technology that finally replaces traditional "paper and pencil" collaboration. (Kuokkanen 2005)

Similarly, printouts still have an indisputable edge over computers on the construction site during the construction phase. In contrast to laptop computers, paper is easy to carry around and doesn't need to be handled with care.

Habits. Even if the technology required for working entirely without paper becomes widely available within the next ten years, the end users in the construction business are likely to be slower to adopt the innovations. While CAD has gained massive ground in design activities, there are still architects who prefer to work on paper, and while electronic communication seems to have indisputable benefits, people are still quick to revert to older, more familiar channels of communication such as facsimile and mail (O'Brien 2000). Case studies have shown that users consider EDM as a facilitator of a "less paper office", rather than a "paperless office" (Ruikar et al 2005).

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[2] A tablet computer or tablet PC is a computer with an integrated touch-sensitive display. The unit can be handheld or kept laying flat on a desk.

[3] Various approaches to electronically rewritable paper are being researched and some commercial applications exist (e.g http://www.eink.com)

Implications. What are the practical implications of the above discussion? Recalling the social informatics perspective – which stipulates that a technologically advanced system fails to deliver value unless it is well aligned with its context – it leads us to the conclusion that the information management strategy of a construction project must strike a sound balance between strong EDM commitment and realistic, proven methods. Put in practical terms, the EDM tool and guidelines enforced must provide support for conveniently working with paper in order to be accepted by the end users.

Sulankivi et al (2002) propose that construction EDM systems should be capable of logging offline communication and keeping track of documents located outside of the central document database. Such functionality, however, lies beyond the scope of many systems. A paper related feature more commonly available in construction oriented EDM systems is an integrated link to a copy shop, a facility capable of producing and distributing paper printouts of documents stored in the EDM. Such a feature enables users to order and distribute paper copies of electronic documents with minimal effort. Some ordering routines may even be fully automatic. The obvious benefit of such an integration feature is that printouts can easily be produced for occasions where paper copies are needed. The potential downside, however, is that excessive amounts of paper copies may be ordered, eroding some of the potential benefits of EDM.

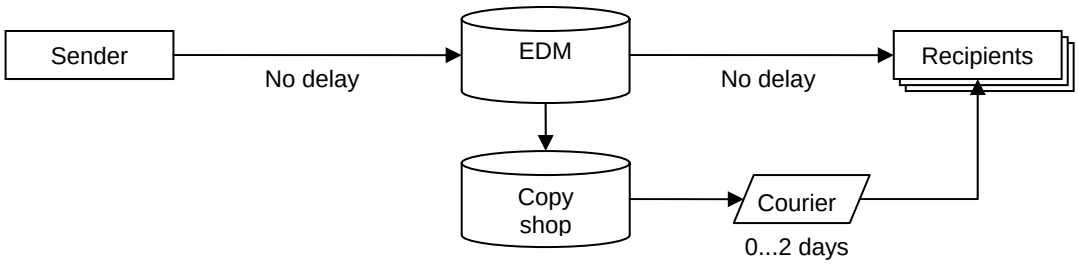


Figure 3 EDM with integrated link to a copy shop

2.5.3 Management commitment

Much in line with Rogers' (2003) work on the diffusion of innovations, several studies (e.g. Thorpe & Mead 2001; Ekman 1999; Andresen et al 2003) emphasise that strong commitment regarding EDM among the central parties constitutes a key prerequisite for widespread EDM adoption, and widespread use on the other hand is of key importance for reaching benefits (Sulankivi et al 2002).

Early initiative. Choosing and implementing an EDM system should be considered a task of high priority at an early stage of any construction project (Löwnertz 1998; O'Brien 2000). Case studies have arrived at the same conclusion, showing that significant savings can be achieved if the EDM system is utilised in the early tender rounds, i.e. at a stage where the final project group composition is yet to be defined but large amounts of documentation are already being exchanged (Ruikar et al 2005, Sulankivi et al 2002). Hence it can be concluded that the task of choosing and implementing an EDM system should be carried out by the client or the main constructor. Companies participating in tender rounds and eventually joining the project group will therefore have to accept the fact that the EDM system to be used is already decided upon (Ruikar et al 2005). Thus, two conclusions can be made:

- Companies participating in construction projects must have the technical capability and user skills needed to work with many different EDM systems.
- The party responsible for choosing the EDM system to be used must take the needs of all project group members into consideration.

A detailed discussion of the process of choosing a suitable system lies, however, beyond the scope of this study. Several studies (e.g Lakka et al 2001; Degerstedt 2000) summarise both the features considered important in a construction oriented EDM and the features available on the market, and Hartvig (2001) presents a framework for evaluating project webs.

Guidelines. The most important manifestation of commitment to EDM-based work is a clear set of guidelines concerning document management within the project. The guidelines should describe *how* the system should be used (what kinds of communication should be committed through EDM?) and *why* (which are the actual benefits that are targeted?) (Andresen et al 2001). Furthermore management needs to decide on how to structure the information and how to assign access privileges.

Process fit. Depending on the participant's degree of familiarity with EDM-based work, management may have to put an effort into process improvement. Implementing EDM as a replacement for conventional methods of exchanging documents is bound to cause changes in work routines. (Ruikar 2005) However, research (e.g. Andresen et al 2003) indicates that the actual benefits of merely replacing paper based routines with EDM-

based routines are limited. In order to reach the maximum potential of an EDM based system, work processes must be reshaped at a larger scale. This is consistent with criticism on the previously widespread misconception suggesting that implementation of an IT-based system "automatically" results in benefits within an organisation or a process. (Koskela and Kazi 2001) The rationale behind this reasoning has been that ICT makes certain activities less time-consuming and hence more cost effective. Consistent with Davenport's view of business process re-engineering, Koskela and Kazi (2001) suggest that changes in information processes as well as material processes are inevitable prerequisites for achieving relevant benefits through IT-investments. As mentioned earlier, end-users may not always have the skills or motivation to independently develop creative and efficient ways of utilising new technology in their work, emphasising the need for management to carry the responsibility of process improvement.

2.6 Earlier empirical studies – methods and results

As discussed above, the rationale behind the envisioned benefits of using EDM in construction is convincing and the technical barriers to implementation are low. But how well has the electronic approach to document management been accepted by the construction industry? This section summarises a number of empirical studies that have been carried out regarding different aspects of EDM in construction.

2.6.1 EDM adoption

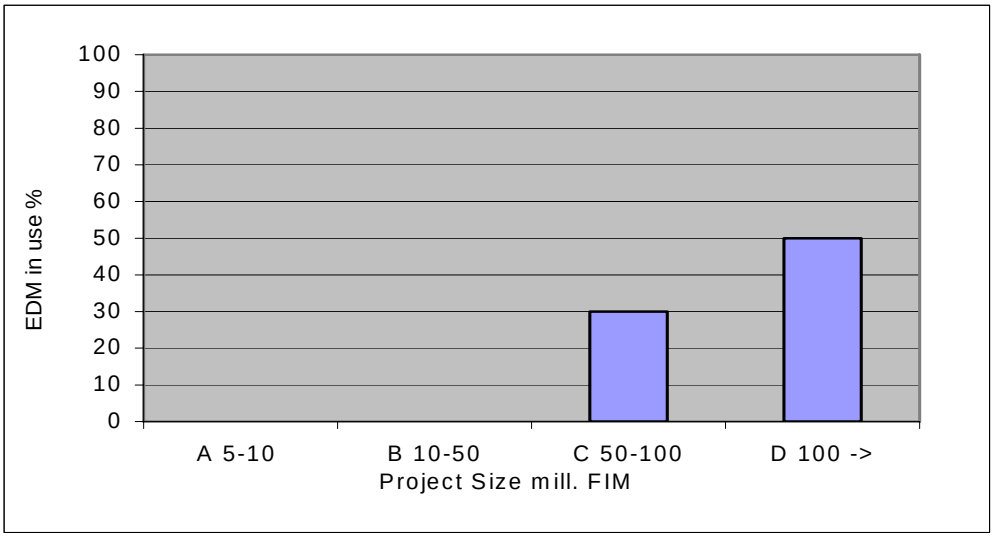


Figure 4 The use of EDM systems in Finnish Construction Projects (1 euro = 5.94 FIM)

How common is EDM? In order to examine the penetration of EDM in the Finnish construction industry, Bäckblom et al (2003) carried out a study where project managers from 100 ongoing construction projects were interviewed by phone. The respondents where randomly selected from a list of all projects active in Finland at the time of the study. The data was stratified in four levels on the basis of total project budget. The results are presented in Figure 4 above.

It is worth noting that at the time of the study, none of the projects with a budget below 50 million FIM (approx. 8.4 million euros) utilised any form of EDM.

How is EDM used within the project organisation? Thorpe and Mead (2001) and Howard and Petersen (2001) have studied the role of project webs in the communication within construction projects. Both studies are based on *social network analysis* which aims to determine the frequency of communication between group members. Thorpe and Mead (2001) examined the degree of centrality obtained by the EDM system in three different cases. EDM was utilised extensively and, as a result, reached a high degree of centrality in two of the cases. In the third case, EDM use and therefore centrality deteriorated as a result of lacking IT knowledge among project management – a finding which underlines the need for strong management involvement.

Andresen et al (2003) studied EDM usage by examining log files extracted from a particular EDM system used in three different construction projects. Again a social network analysis approach was utilised to summarise how different parties utilised the EDM tool during the course of the projects. In all three cases, the architect was found to be the most significant information producer, storing large amounts of CAD drawings in the system. However, usage patterns among the other parties varied from case to case, making it impossible to draw any general conclusions. The study did however find that the customer – the owner or client of the construction project – did not utilise the EDM system to any significant degree.

One further approach to examining EDM use by the means of analysing log files is presented by Ruohtula (2003). While Andresen et al (2003) studied use on a group level, Ruohtula conducted the analysis on a per-user level. Despite certain limitations – only the construction phase of one single case was studied – the study gave certain interesting insights. Over half of the registered users accessed the system less than twice a month, and 35 % of the users used the system less than 10 times during the course of the

entire project. The study also revealed that very few documents were modified after being stored in the EDM, which indicates that the system mainly was utilised as a storage point rather than a collaboration tool.

2.6.2 Identified problems

Barriers to implementation. In the study carried out by Bäckblom et al (2003), as many as 75 % of the surveyed construction projects where carried out without any kind of EDM tools. Studying the responses of non-adopters gives interesting insight regarding attitudes toward EDM implementation. Non-adoption decisions are here classified according to UTAUT factors (the *Unified Theory of Acceptance and Use of Technology* is described in chapter 3.3.1.)

When asked why the projects they represented did not use EDM, 30 % of the respondents explained the situation along the following lines, indicating lacking *facilitating conditions*:

- the decision regarding implementation has not yet been made
- he/she does not have decision-making power in this matter
- he/she would be interested in EDM but has failed to convince other parties

It seems plausible to believe these projects could have become EDM adopters under other circumstances.

27 % of the non-EDM respondents claimed that the projects were so small, simple or geographically focused that EDM was judged unnecessary or that standard e-mail was sufficient as a means of document distribution. 26 % judged that the potential benefits of using EDM would not justify the costs of such a system. Thus, adoption has been hindered by low *performance expectancy*.

Only 9 % considered EDM software to be too technical or difficult to use, thus explaining non-adoption with high *effort expectancy*. The last 8 % admitted that their knowledge of EDM was too limited. (Bäckblom et al 2003)

Problems in EDM based projects. EDM competes with numerous traditional, well-established channels of communications such as facsimile, e-mail, phone, courier services etc. As these still play an important role in EDM-enabled projects, users may be quick to revert to these (O'Brien 2001). Andresen et al (2003) found that especially us-

ers who face technical difficulties in using EDM are quick to fall back to traditional channels of communication. An example given was compatibility problems between different CAD systems; an issue that should be prevented by the means of proper guidelines or standards.

Perhaps somewhat surprisingly, certain features of EDM which have previously been mentioned as *benefits* can constitute significant sources of aversion towards the technology. A frequently mentioned (e.g. Thorpe 2001; Bäckblom et al 2003; Jyrälä 2005) example is based on the improved transparency and audit trail provided by EDM. Where traditional communication has allowed parties to lag behind their schedule without getting immediately exposed, an EDM system keeps undeniable logs of when each document has been stored and by whom.

3 Adoption of ICT innovations

3.1 The successful innovation

Build a better mousetrap and the world will beat a path to your door.[4]

This widely quoted adage implies that any great innovation will sell itself once presented to the market. However, assuming that this holds true for *any* technical innovation is an unfortunate and misguiding oversimplification. In his work on the diffusion of innovations, Rogers (2003) poignantly shows that modern history is sprinkled with examples of apparently brilliant innovations which, for a wide range of reasons, failed to take off. As it turns out, the challenge lies in pinpointing the proper judgment criteria used for evaluating new mousetraps; technological superiority is not the only criterion of relevance.

ICT innovations are no exception to this observation. On the contrary, systems development and implementation efforts that are narrow-mindedly guided by a belief in the value of new technology run a high risk of failure. As will be discussed in more detail in this chapter, research shows that the actual adoption rate of an ICT solution cannot be estimated or measured solely by evaluating the technological merits of the system.

Several theoretical models attempting to explain the non-technological factors of ICT success (measured in terms of individual acceptance, accrued benefits etc) have been developed over the past decades. One such model is the Information System Success Model, originally proposed by DeLone and McLean in 1993 and revisited with modifications based on empirical testing and peer scrutiny in (DeLone & McLean 2003). The Updated D&M IS Success Model, as shown in Figure 5, describes causal relationships between various properties of an information system and the net benefits enabled by the system. It highlights the fact that *system quality,* which can be interpreted as the technological features of the system, by no means is the mere driver behind benefits. *Quality of service,* e.g. support resources, and the *quality of information* present in the system

[4] R W Emerson (1803 – 1882) is often credited as the origin of this saying

are equally important drivers behind user satisfaction, end-users' intention to use and actual usage, which in turn are the key drivers behind net benefits.

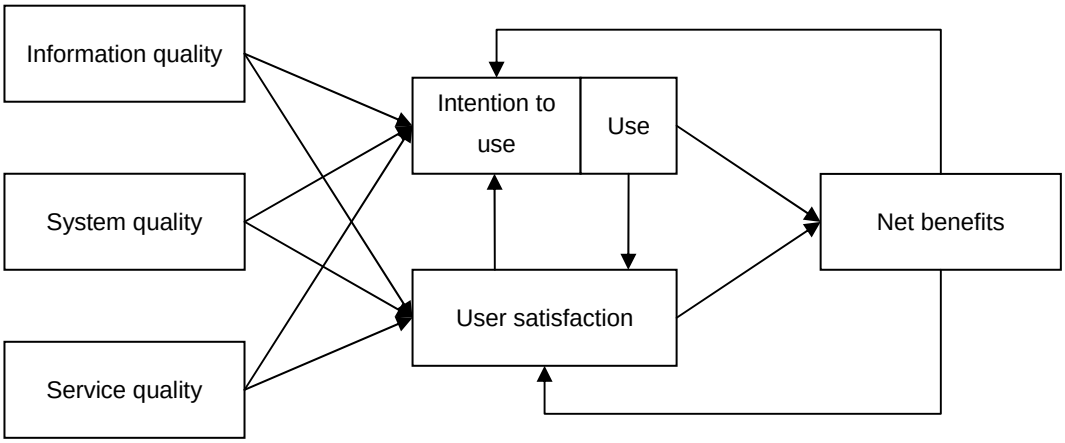


Figure 5 The Updated D&M IS Success Model (DeLone & McLean 2003)

Although this model leaves out many of the "soft" factors accounted for by ICT acceptance models, it is largely consistent with the *social informatics* perspective advocated by Kling (2000) among others. Social informatics suggests a more holistic view of ICT systems as *sociotechnical interaction networks*, encompassing people and support resources in addition to the purely technological dimensions of hardware and software.

To summarise, it can be stated that unless a computer system is well aligned with the institutional and cultural context (Kling 2000) it is intended for, the expected benefits may actually erode into financial loss and increasing frustration among users. In the following sections, more elaborate models of organisational innovation adoption and ICT implementation within organisations are presented.

3.2 Introducing innovations in organisations

In his work on the innovation diffusion theory (IDT), Rogers (2003) lays out a framework for understanding how ideas, practices or objects are adopted by individuals or organisations. Diffusion is defined as "the process by which an *innovation* is *communicated* through certain *channels over time* among the members of a *social system.*" (Rogers 2003) In the process of introducing a new ICT solution in an organisation, both the ICT in itself and the changes in work processes it brings can be regarded as innovations. From this perspective, diffusion theory appears applicable to the study of ICT implementation.

However, as Gallivan (2001) among others points out, much of the traditional innovation diffusion theory is based on studies of how individuals make *independent* (albeit socially shaped) adoption decisions, limiting its applicability on the study of ICT implementation within an organisational context. Figure 6 below illustrates the innovation adoption processes typically encountered in an organisation.

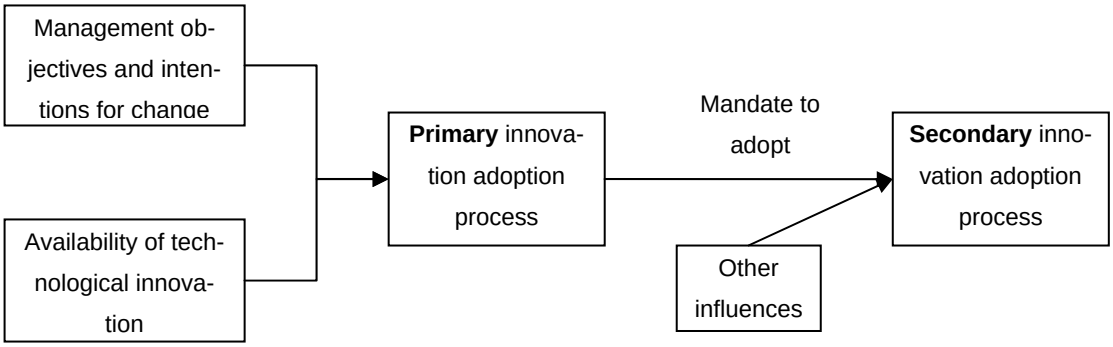


Figure 6 Primary and secondary innovation adoption (Gallivan 2001)

Based on management objectives, intentions for change and knowledge of available technological innovations, a primary adoption decision (i.e. "*should the organisation adopt this*?") is made by top management. Depending on the type of secondary adoption strategy chosen (i.e. "*how do we communicate this to the employees and partners?*"), the actual end users may have little or no decision power regarding individual adoption.

3.3 Secondary adoption success

Gallivan (2001) describes three different management approaches to promoting secondary adoption, each giving end users a different degree of freedom regarding adoption decisions:

1. **Total commitment implementation strategy.** The innovation is propagated to end-users as a *mandatory* change in work routines.

2. **Support strategy.** The organisation provides infrastructure and support for further adoption, but end-users are allowed to make *voluntary* adoption decisions

3. **Advocacy strategy.** Pilot projects are launched within the organisation, aimed to produce proof of concept and interest in the innovation.

Regardless of which secondary adoption strategy is chosen, a number of factors will influence the end users' perception of the new technology. In a voluntary setting, these factors affect the rate of adoption, whereas in a mandatory setting, the factors rather predict user satisfaction. In either case, the outcome is equally important, as lacking user satisfaction easily erodes the benefits envisioned for the new system.

3.3.1 Acceptance models

The Updated D&M IS Success Model (DeLone & McLean 2003) introduced earlier describes three dimensions of quality affecting users' intention to use an information system: *system quality*, *information quality* and *service quality*. Intention to use is further affected by a *user satisfaction* construct. While the model explains the prerequisites for information system success at a general level, it gives limited insight into the underlying mechanisms which affect user satisfaction.

Over the years a number of competing theories and models of factors governing user acceptance or actual usage of ICT systems have been presented, some of which give more sophisticated explanations for user behaviour than the DeLone & McLean model. Rather than covering all of these traditional technology acceptance models, which borrow much from each other, this section reviews the Unified Theory of Acceptance and Use of Technology (UTAUT) proposed by Venkatesh et al (2003) as a synthesis of the commonly used models. UTAUT sets out to combine the best parts of the theories listed in table 2 below. The table lists the core constructs that each model has incorporated as important determinants of individual technology acceptance.

As can been seen from the summary table, many of the models include the very same or similar constructs; perceived ease of use, perceived job-related and personal benefits etc. In their study, Venkatesh et al (2003) compare the models presented above by testing each of them on the same data set, collected and coded specifically to allow for fair comparison. Based on their findings, they propose a unified new model, the UTAUT, depicted in Figure 7. The new model was tested for fit on the same data set that was initially used to compare the traditional models. Statistical analysis shows that the new model explains variance considerably better than any of the original underlying models (Venkatesh et al 2003).

Table 2 Acceptance models (adopted from Venkatesh et al 2003)

	Core constructs	Explanation
Theory of Reasoned Action (TRA), Theory of Planned Behaviour (TBP)		
	Attitude Toward Behaviour	Individual's positive or negative feelings about performing the action
	Subjective Norm	Perception of what other people think the person should do
	Perceived Behavioural Control	Perceptions of internal and external constraints on behaviour (TBP only)
Technology Acceptance Model (TAM and TAM2)		
	Perceived Usefulness	The degree to which the person thinks using the system would improve his job performance
	Perceived Ease of Use	Perception of how easy the system is to use
	Subjective Norm	TAM2 extends the original TAM with this construct from TRA (see above)
Motivational Model (MM)		
	Extrinsic Motivation	The perception that using the system gives benefits not related to the actual activity
	Intrinsic Motivation	Using the system is beneficial for the task at hand
Model of PC Utilization (MPCU)		
	Job-fit	The degree to which the person thinks using the system would improve his job performance
	Complexity	Perception of how difficult the system is to use
	Long-term consequences	Perception that system use enables future pay-off
	Affect towards use	Emotions associated with the activity
	Social factors	
	Facilitating conditions	Factors making system use easier, e.g. support
Innovation Diffusion Theory (IDT or DoI)		
	Relative advantage	The degree to which the innovation appears superior to previous solutions.
	Ease of use	Perception of how easy the system is to use
	Image	Perception of how system use affects user's social status
	Visiblity	"Degree to which one can see others using the system in the organisation"
	Compatibility	The degree to which the innovation is consistent with existing values, past experiences and needs.
	Results demonstrability	Tangible, observable and communicable results from using the system
	Voluntariness of use	Degree to which use is perceived as voluntary
Social Cognitive Theory (SCT)		
	Perfomance outcome expectations	Perception of impact on job performance
	Personal outcome expectations	Perception of impact on individual attitudes such as esteem and sense of accomplishment
	Self-efficacy	Perception of capability to use the system
	Affect	Affective emotions associated with the activity
	Anxiety	Negative emotions associated with the activity

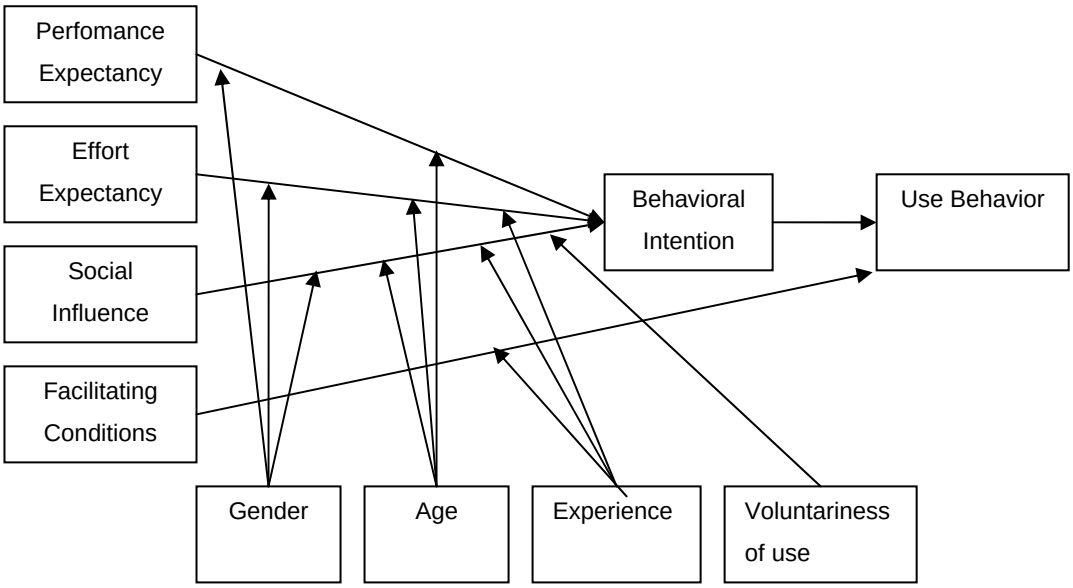


Figure 7 Unified Theory of Acceptance and Use of Technology (Venkatesh et al 2003)

The UTUAT model defines three factors (*performance expectancy*, *effort expectancy* and *social influence*) having impact on *behavioural intention* to use. Actual *use behaviour* is in turned influenced by the behavioural intention and a fourth factor, *facilitating conditions*. The actual impact of the factors is affected by four moderators (*gender*, *age*, *experience*, and *voluntariness of use*). These factors and moderators are discussed below.

Performance expectancy. Measuring the individual's perception of how using the system will improve his or her job efficiency, this factor has been included in most other models under various names; e.g. perceived usefulness (TAM), extrinsic motivation (MM), relative advantage (IDT), outcome expectations (SCT). Testing has showed that this is one of the strongest influences on intention to use. Unless the end user expects the system to have positive impact on his or her productivity, motivation to adopt the system is low.

Effort expectancy. Based on their existing knowledge of the system and general computer literacy, users form their opinion on how easy or difficult the system will be to operate. Measured in previous models as perceived ease of use (TAM and IDT) and complexity (MPCU), effort expectancy works hand in hand with performance expectancy in determining intention to use. If a system is perceived as difficult to use, motivation may be low even if the expected impact on job performance is positive. The system

quality construct of the Updated D&M IS Success model can be viewed as a determinant of effort expectancy, under the presumption to that a system of high quality is easy to use.

Social influence. This construct depicts the perceived influence of other people's position on adoption. Similar constructs exist in other models; subjective norm (TRA, TAM2, TPB), social factors (MPCU) and image (IDT). In a mandatory adoption context, the social influence is high.

Facilitating conditions. This factor measures the user's perception of the organisational and technical infrastructure in place, covering areas such as availability of support resources. The information and support quality constructs of the Updated D&M IS Success Model can be regarded as such facilitating conditions. However, it should be pointed out that the facilitating conditions of the UTAUT are expected to affect actual use rather than intention to use, while the IS Success Model regards information and support quality as determinants of intention and user satisfaction.

Influence of gender and age. In formulating and empirically testing the UTAUT, Venkatesh et al (2003) reached some generalisations on the moderating impact of gender and age on the factors described above. The importance of performance expectancy as a determinant of intention to use was found to be of stronger for men and younger users. Effort expectancy and social influence, on the other hand, had bigger influence among women and older users.

3.3.2 End-user personalities

While the UTAUT and underlying models do account for end user perceptions of various factors and moderating variables, little attention is paid to the influence of personality. Rogers (2003), on the other hand, proposes a categorisation of individuals on the basis of how quick they are to embrace available innovations.

- *Innovators* – venturesome
- *Early adopters* – respect
- *Early majority* – deliberate
- *Late majority* – sceptical
- *Laggards* – traditional

Furthermore, Rogers (2003) presents a range of generalisations about the personal attributes of earlier adopters as compared to later adopters. In general diffusion research, earlier adopters have been found to have higher education, greater rationality, higher intelligence, better ability to deal with abstractions, higher aspirations and more knowledge of innovations than later adopters. Early adopters tend to be less dogmatic and less resistant to change. (Rogers 2003)

How well do these findings apply to ICT implementation in a mandatory adoption setting where the rate of adoption is more or less fixed? Based on observations, O'Brien (2000) suggests users can be categorised along the Bell curve in a manner similar to that of Rogers':

- *Innovators* – who intuitively see possibilities offered by new technology
- *Pragmatists* – the majority of the population – who are willing to adopt new methods once they see proof of benefits
- *Sceptics* – who resist change and are likely to avoid the innovation if at all possible

It could be hypothesised that personality type, as defined above, has significant influence on how different individuals form their perception of factors such as *effort expectancy*.

3.3.3 Organisational challenges

The UTAUT construct of *facilitating conditions* refers to user's perception of support resources in place. *Social influence* includes the aspect of managerial and organisation support. In the following, these aspects of implementation efforts are examined in more detail.

Learning and knowledge sharing. When learning how to operate a new system, users can obtain knowledge through self-learning, learning from experts or learning from peers (Peansupap et al 2005). Formal learning from experts may be the preferred method if the system is new to all users of the organisation. If certain users already are experienced with the system, management may opt to promote learning from peers, i.e. knowledge sharing within the organisation.

Learning and training should not only be restricted to communicating information on basic operation of the system. O'Brien (2000) observes that many users lack the ability to independently develop creative and efficient ways of utilising new technology in their work. Management should help users understand the potential of improved efficiency enabled by the system, thus boosting performance expectancy.

Targeting of diffusion efforts. Rogers (2003) observes an innovativeness paradox, in which individuals who would benefit the most from an innovation typically are the last ones to adopt it, while early adopters gain less from adopting the same innovation. The paradox is generally caused by unduly targeting diffusion efforts at groups of *least* resistance. As Rogers (2003) concludes, efforts should rather be targeted at groups of *greatest* resistance, i.e. the sceptics and the laggards, who otherwise are unlikely to adopt the innovation. The same can be applied to training efforts in implementation projects.

3.4 Discussion

The literature presented above is mostly concerned with the process of implementation and adoption behaviour within a single organisation. However, as shown in chapter 2, many construction projects occur in inter-organisational project group settings, where the end-users are spread across numerous companies and geographic locations. This section attempts to discuss how the presented adoption frameworks can be applied to the study of EDM adoption in construction project groups.

The basic concepts used for describing the individual end-user's intention to adopt are rather universal in the sense that they can be used for modelling the behaviour of individuals in a wide range of settings. The personality types proposed by Rogers (2003) and the UTAUT factors of performance expectancy, effort expectancy, social influence and facilitating conditions (Venkatesh et al 2003) affect the intention to adopt regardless of whether the subject of study is an independent consumer or perhaps an employee within a large organisation. Presumably, the same concepts are equally valid in an inter-organisational project group setting.

The two-stage innovation adoption process (Gallivan 2001) presented in chapter 3.2 is also consistent with the adoption process of a project group. *Primary* adoption occurs as project management decides to utilise certain technology in a forthcoming construction

project. *Secondary* adoption occurs as the participating companies adopt the technology which is either mandated, advocated or supported by project management, depending on which secondary innovation adoption strategy is employed. It could be argued that the secondary stage should be divided into an additional stage of *tertiary* adoption, referring to the phase where project managers of the participating companies promote the technology to individual end-users. However, the model properly illustrates the concept of adoption within project groups even without such a modification.

To summarise, the innovation adoption models presented in this chapter appear suitable for the study of how end-users perceive implementation of new technology and practices in project groups.

4 Introducing the case project

4.1 Background

With a total budget of 550 million euros, the Kamppi Center has been described as the single most expensive construction project to be carried out in Finland to this date, excluding infrastructure projects and nuclear plants. The aim of the project was to transform the former open-air bus station of Helsinki into a complex consisting of two underground bus terminals hosting over 1700 departures a day, a cargo handling centre handling 10,000 parcels a day, a total of 6,000 m² of residential apartments, 12,000 m² of office space, a shopping centre of 35,000 m² and an underground parking facility. The Center also includes a new entrance to the Kamppi subway station. Approximately 200 000 people will move through the Kamppi Center per day.

Figure 8 During and after construction

The fact that the construction site was located right in the busy city centre of Helsinki posed several interesting challenges which underlined the need for detailed planning and flawless execution – i.e. areas where efficient usage of ICT tools can make considerable difference. Firstly, the demolition of the old bus station and the isolation of the entire site caused substantial changes to traffic arrangements in the city centre. This affected not only bus commuters, drivers and pedestrians, but also businesses located in the surrounding areas. As the societal impact of the construction phase were significant, deviations from the original schedule and plans had to be kept at a minimum. Another challenge arose from the fact that there was very little excess storage space in or around the site, which meant that the logistics of raw materials and waste had to be planned meticulously, and again, keeping the schedule was vital.

Project organisation. The project was initiated by the City of Helsinki and a design competition was announced. The proposal submitted by SRV Viitoset Ltd was chosen, resulting in a *design & build* contract by which SRV was appointed main constructor for the entire complex. Three separate architectural offices were contracted, each given responsibility for a distinct part of the complex. Roughly 20 structural and technical design offices participated in the design phase, and hundreds of subcontractors and suppliers were involved in the actual construction work. At most the Kamppi Center project employed over 1,200 persons.

Schedule. Construction was initiated in 2002. Keeping the original schedule, the bus terminals and parts of the shopping centre were opened to the public in early summer 2005. The entire complex was finished by March 2006.

4.2 Document management

The following section describes the document management practices used in the Kamppi Center construction project.

4.2.1 EDM initiative and system choice

Well aware of the size and complexity of the Kamppi Center project, SRV Viitoset Ltd decided to utilise only familiar and thoroughly tested software in the project. Their choice regarding which EDM system to use was made prior to joining the design competition announced by the City of Helsinki.

In terms of document management, the Kamppi Center project relied on Raksanet, a web based EDM solution provided by Buildercom [5]. The main driver behind the choice of system was SRV Viitoset Ltd's previous experience with the system. The construction company has successfully been using Raksanet as their main EDM system in several large projects since the late 1990s. One important factor contributing to SRV Viitoset Ltd's previous satisfaction with the system lies in the development team behind Raksanet, which has showed strong commitment to implementing new features and improvements as suggested by customers at short notice. (Harmaajärvi 2005)

[5] Buildercom at http://www.buildercom.fi

4.2.2 Raksanet features

Raksanet is a web based, ASP-hosted document management application specifically targeted at the construction industry. The EDM features are fairly basic, with support for access control, revising and version control. A static hierarchical folder structure (partly visible at the left hand side of Figure 9) is provided for navigating the information mass, and the meta-data stored for each document is basic; a status field and a free-text description. The location of a document within the folder structure should, however, be considered as a source of meta-data.

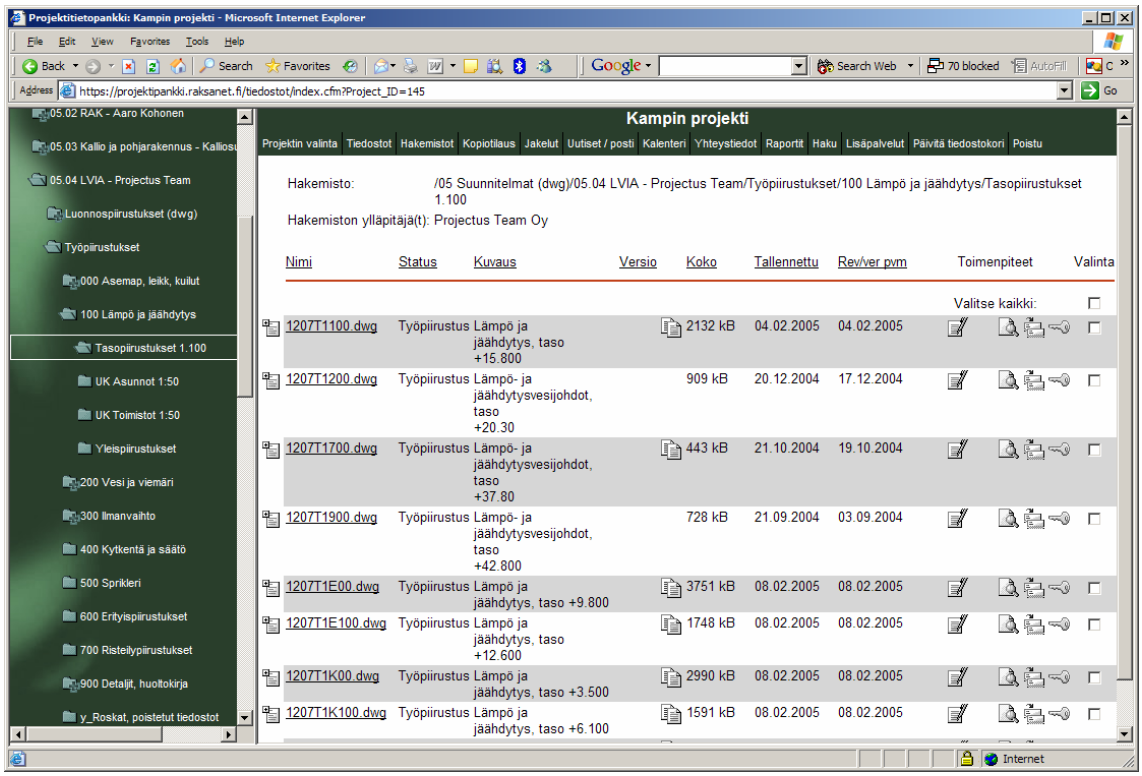


Figure 9 Raksanet screenshot - folder and document view

In addition to downloading documents for viewing, users can also view documents online. This is facilitated through a Java applet, AutoVue, which is capable of viewing a large number of different file formats online. The applet also provides basic drawing tools which allow the user to add comments and drawings on top of the document viewed. These additions, however, cannot be stored directly back into the EDM; the user has to save a local copy or print it out.

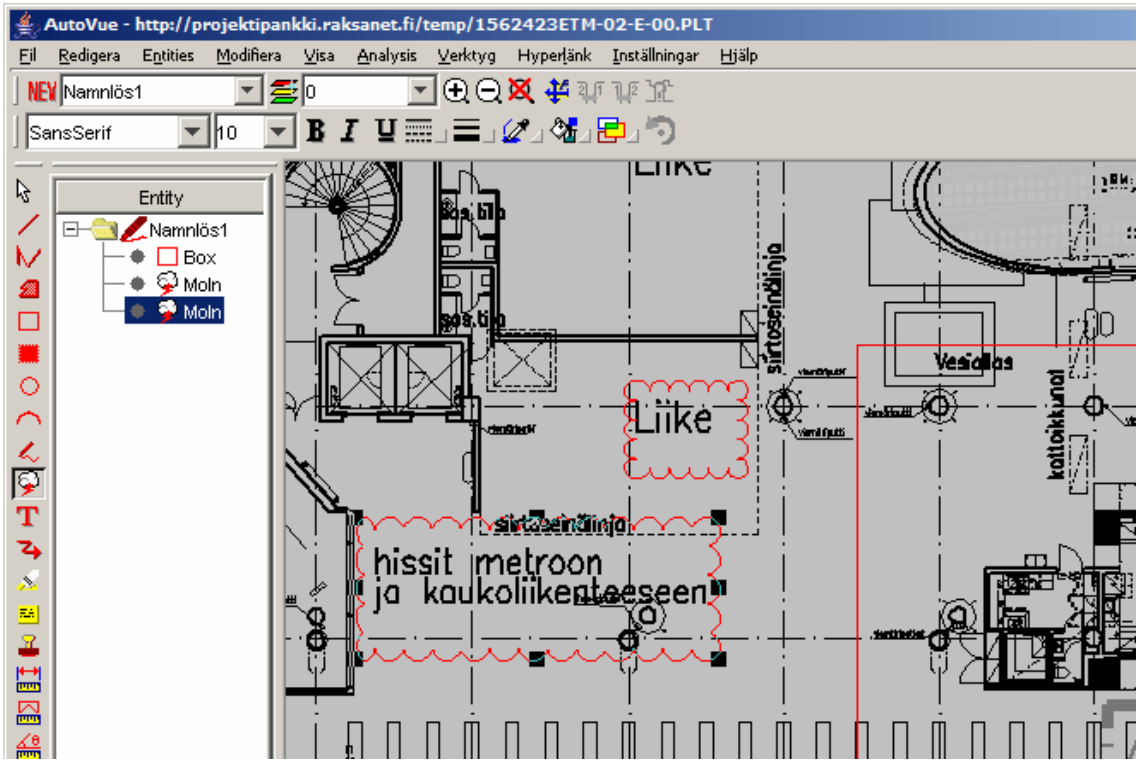


Figure 10 Online viewer of Raksanet

An integrated link to Valopaino Oy, a separate copy shop, is available. End users can order full-size printouts of any documents through the web interface. Valopaino produces the required amount of copies for the chosen documents and sends them to the intended recipients by courier.

In order to inform users of changes in the contents of the EDM, Raksanet can send out update notification emails to users. Users can choose if they want to receive automatically generated emails notifying them of updated or new drawings immediately, once a day or never.

Additional features of Raksanet include e-mail notifications of changed or added documents, built-in help, address book of project participants, project news board, etc.

4.2.3 Actual EDM implementation and use

All project participants who need access to drawings and other documents were given access to the EDM system. The contents of the EDM was partitioned into two separate instances, the main one aimed at architects, technical consultants and subcontractors, and secondary one made available to the end-users of the facilities.

Folder structure. The folder structure was designed primarily by SRV Viitoset staff with help from Raksanet consultants. The typical structure partly based on the Talo80 building element classification system which SRV has used in previous projects had to be expanded significantly in the Kamppi Center project. One challenge was posed by the fact that three different architectural offices and more than 20 technical design offices were working alongside in the project. The resulting folder structure contained 1680 folders as of Aug 2005.

Access control. Typical users gained read access only to folders they specifically needed, and write access was only given to users who actually needed to update contents in specific folders.

Automatic copy distribution. At the outset of the project, SRV chose to deploy a system which allows power users to set up automatic distribution of paper copies. This was agreed upon after certain parties insisted on having easy access to paper rather than only having access to a web based software. The system allows for distribution lists to be defined on a per-document level. Whenever a document is stored or updated in a folder linked to a distribution list, the system automatically orders a predefined set of print-outs to be sent to the members of the assigned recipient list. The upside of this arrangement is that it bridges the gap between traditional ways of working with the brand new EDM world, alleviating adoption resistance among users who are uncomfortable with the practice of personally ordering print-outs they need. The downside, however, is that the automatic print-outs cause some of the most important EDM-related benefits to remain out of reach; documents are distributed in a just-in-case fashion rather than just-in-time, and due to the coarse granularity of the distribution list / folder –mappings, a lot of unnecessary print-outs are produced.

Usage. As demonstrated by Figure 11, EDM usage increased steadily over the course of the entire project, peaking in late 2004.

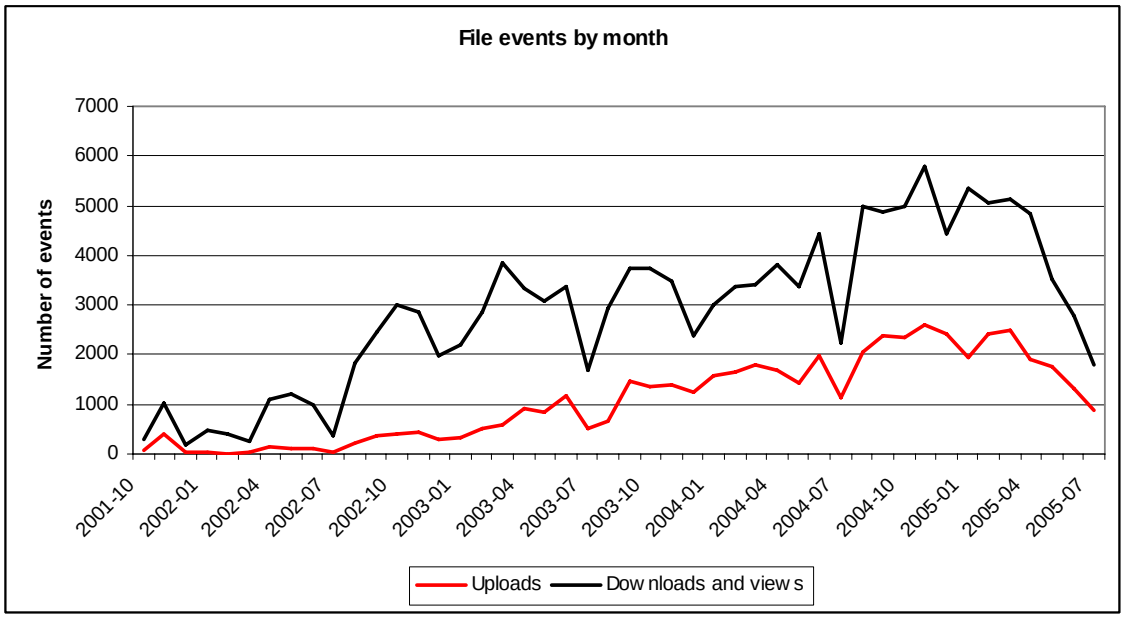


Figure 11 Uploads and downloads over time

By 2005, the system hosted some 17,000 documents used by 334 users from 90 different organisations.

The most common uploads were CAD designs in AutoCAD format (DWG) and plot files (PLT). Text documents in Microsoft Word (DOC) format, mostly used for meeting minutes, accounted for 16 % of all downloads and online viewings. Other frequently used file types were documents in Adobe PDF format and Microsoft Excel spreadsheets (XLS).

Table 3 File types uploaded and downloaded

File type	Uploads		Downloads and viewings	
	# of events	*% of total*	*# of events*	*% of total*
PLT	23,764	48 %	16,053	12 %
DWG	14,866	30 %	76,174	58 %
PDF	8,050	16 %	12,748	10 %
XLS	1,130	2 %	4,472	3 %
DOC	1,034	2 %	20,558	16 %
ZIP	619	1 %	1,364	1 %
JPG	10	- %	597	- %
Other	61	- %	341	- %
Total	**49,534**	**100 %**	**132,307**	**100 %**

5 Research methods

This chapter describes the research design and methods chosen for the empirical part of the study.

5.1 Research design

Much of the previous research on adoption and end-user acceptance of EDM systems has been conducted using qualitative methods such as semi- and unstructured interviews. This choice of method has been justified as EDM use has been considered a rather new field of research and interviews are well suited for exploratory studies. Furthermore, interviews allow the researcher to probe into the fine shades of attitudes that would elude quantitative methods, and is consequently favoured in social studies.

However, technology adoption and acceptance is not a new field of research per se. As shown in chapter 3, numerous theoretical models explaining acceptance have been proposed and empirically tested over the past decades. A large portion of these models have successfully been validated using quantitative research methods such as surveys. This fact does not restrict the applicability of these models to quantitative research, but rather shows that quantitative methods are indeed well suited for this type of studies.

While both quantitative and qualitative methods are useful as such, it can be argued that a combination of the two approaches is fruitful. In their study of data collection methods utilised in previous MIS research, Pinsonneault and Kraemer (1993) concluded that combining different methods of data collection in a study is beneficial, but nevertheless an approach rarely used. Eisenhardt (1989) suggests triangulation between quantitative and qualitative data, as quantitative data aids putting the qualitative findings in a proper perspective.

The research design decided upon for this case study attempts to combine the strengths of quantitative and qualitative methods by employing a two-stage data collection process encompassing a quantitative survey, log file analysis and interviews. Due to the limited time scale and resources available, only one case was selected. The combination of data collection methods, however, attempts to extract as much data as possible from this single case.

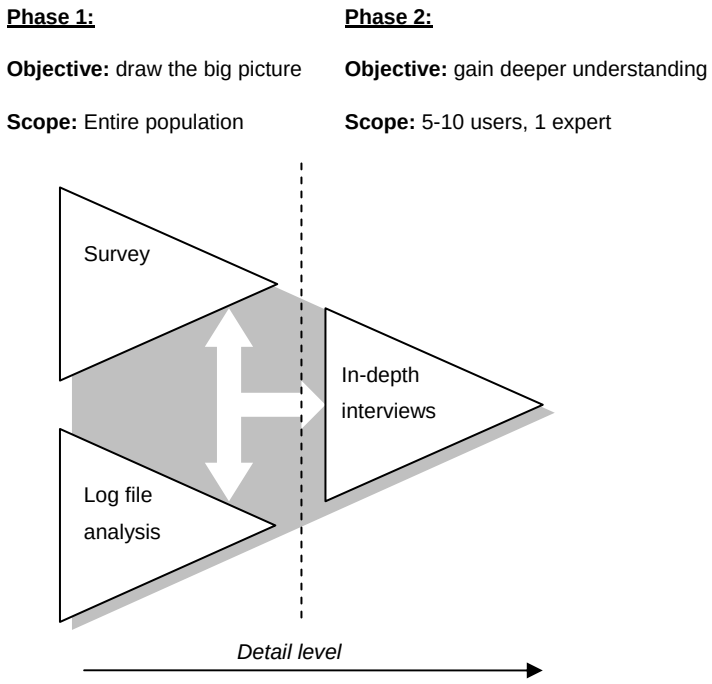


Figure 12 Data collection process and objectives

The first phase of the empirical research focused on obtaining an overview of how the EDM tool was used and perceived among the different groups of practitioners involved in the Kamppi Center project. The main objective was to get rough user experience measures covering a large portion of the population. A secondary objective of the first phase was to refine the research questions and, most importantly, identify interesting user segments and individuals to be studied at greater detail in the second phase. This first phase was carried out by performing an online survey and combining questionnaire responses with log file measures.

The second phase of the empirical research aimed at obtaining more detailed insight into end-user attitudes and experiences by conducting semi-structured interviews with project participants. Finally an expert interview was carried out with the intention of obtaining a further point of triangulation, representing the perspective of an industry specialist.

5.2 Case selection

Several different aspects make the Kamppi Center project an interesting case to examine. Most importantly, the high number of companies involved in the construction group

and the considerable number of actual EDM users provide a sufficiently large population for examining attitudes among various segments.

Factors of convenience. Certain factors of convenience influenced the choice on less scientific grounds:

- **Timing.** The project had reached a suitable stage by the time this research was launched.
- **Location** in the centre of Helsinki, close to the university where the study was conducted.
- **Existing contact.** The supervisor of this study, prof. Bo-Christer Björk, had personal contacts to the company supplying the EDM system. This fact greatly alleviated the process of establishing the initial contact.

Implications. As only one case is studied, the possibility of reaching generally applicable results is limited. Both reliability and validity may suffer, as will be discussed later. However, the objective of this study is not to formulate new general theories, but rather to provide insight. And as Eisenhardt (1989) points out, case studies can result in valid theories when findings are triangulated against previous literature.

An argument against the choice of this particular case is related to the fact that the Kamppi Center is hardly representative of typical construction projects in the Finnish industry.

5.3 Data collection and analysis

5.3.1 Phase one – survey and log analysis

A quantitative survey was carried out among the end-users in order to measure prevailing opinions, attitudes and experiences and receive demographic data. The survey results were combined with data extracted from the activity logs recorded by the EDM tool used in the Kamppi Center project.

Survey method. The survey was executed as a self-administered online questionnaire. Each respondent was sent an email message containing a brief description of the study and a personalised link to a web site hosting the actual questionnaire. Respondents were

required to answer all questions before submitting the responses, eliminating the risk of receiving partially filled-out questionnaires.

The personalised link contained a unique ID tag which allowed for easy tracking of respondent actions. With the help of the ID tag, each response was be identified and coupled with data from the user database (e.g. role) and measures extracted from log files as will be described in greater detail below. The web survey system used also logged data on how many respondents attempted to submit incomplete responses, and how many who viewed the questionnaire but never attempted to submit it.

Population and sample frame. The population of interest was defined as the group of Kamppi Center project participants who had used the Raksanet system within the scope of the project. While it had been tempting to include the entire population (n=334) in the survey, the actual sample frame was reduced due to reasons of feasibility and reliability as discussed below.

Comparing Raksanet activity logs with the user database showed that 52 users who had evidently used the system at some point were no longer present in the user database by Aug 1st 2005. These were omitted from the sample frame, partly because no contact information was readily available, and partly because the majority of these had been inactive since 2004, raising doubt as to whether they would remember their Raksanet experience. Furthermore it should be noted that 55 of the users still registered showed no logged activity at all. These were also omitted from the sample frame.

While the resulting sample frame covered only 84 % (n=282) of all Raksanet users with any logged activity, it should be noted that the selected users were responsible for 97 % of all uploads and 96 % of all online viewings logged by Aug 1st 2005. Thus it can be concluded that the selection appears sufficiently large to reliably sample the population regarding user experience issues.

Questionnaire content. The questionnaire was designed to gather information on the following topics:

1. basic demographic and profiling data such as age, length of personal involvement in the project, amount of work hours devoted to the project and previous EDM experience

2. end-user perceptions along the various dimensions of the DeLone and McLean Updated IS Success Model and the Unified Theory of Acceptance and Use of Technology described in chapter 3,

3. freely formulated qualitative comments on EDM use in the project

It should be noted that the objective of the survey was not to test the Updated D&M IS Success Model or the UTAUT, but rather to obtain an overview of user attitudes related to the actual case at hand. Rather than directly adopting the questionnaire contents proposed by any of the underlying acceptance models, the set of 19 questions was freely formulated to address specific issues which have been recognised as important in previous EDM research. Appendix A shows how the final questions relate to acceptance literature.

Coding. The questionnaire contains one free-text question and 19 quantitative questions, of which 15 follow a four-point Likert-scale (*agree completely*, *tend to agree*, *tend to disagree*, *disagree completely*.) A neutral middle choice was left out on purpose, in order to force respondents to take a stand on each issue. The choices were coded as 1=disagree completely…4=agree completely. On two questions, a "*don't know*"-option was added and coded as -1.

Using a rather coarse four-point scale was justified by the assumption that fewer choices make the questionnaire appear easier to fill out, resulting in a higher response rate. This is consistent with the objective of the survey, which was to gather "ballpark" measures covering a broad spectrum of users.

Pilot testing. Saunders et al (2003) stress the importance of pilot testing a questionnaire in order to ensure content validity and to verify that all questions are properly understood by the respondents. The questionnaire draft was piloted with two regular respondents who were allowed to comment orally on the questions while filling out the survey. Furthermore the questionnaire was discussed with an expert group of two practitioners and one EDM researcher. Drawing on feedback from the piloting phase, certain questions were reformulated and the total number of questions was reduced by one third. In the light of the objective of the survey, achieving a satisfactory response rate was considered more important than achieving a great amount of detail. Finally, as suggested by

from the pilot respondents, a free-text field was added to the questionnaire form, giving respondents a chance to include a freely formulated comment regarding EDM use.

Response rate issues. As Saunders et al (2003) predict low response rates for questionnaires of the e-mail / online type, several measures where taken in order to secure a satisfactory number of responses:

- **Cover letter credibility.** The cover email was signed by the Kamppi Center's director of design, lending credibility to the research project. His name and address were also featured in the *From*-field of the email, reducing the risk of having the message classified as spam. The actual cover letter was composed according to practice suggested by Saunders et al (2003).

- **Low effort.** The questionnaire was designed so that it could be completed in 5-10 minutes, showing all questions on one page.

- **Non-monetary incentives.** The possibility of affecting the development of EDM software and processes by participating in the survey was mentioned in the cover letter.

- **Monetary incentives.** Two gift certificates worth 100 € each were drawn among the respondents.

- **Timing.** The survey was launched in early September after most respondents had returned from summer holidays. The first mail was sent out on a Monday, as research shows that response rates tend to be lower toward the end of the week (Saunders et al 2003)

- **Follow-up.** Recipients who had not responded after 7 days received a reminder email.

The final questionnaire, cover letter and a screen shot of the web implementation are presented in Appendix A.

Usage log data. In order to add a dimension of actual EDM usage to the data set, certain usage statistics were calculated per user and linked to the questionnaire responses. These variables are described in table 4 below.

Methods of analysis. The resulting data set, consisting of questionnaire responses combined with usage statistics, was loaded into SPSS for analysis. Given the objective of the survey, the relatively small sample at hand and the coarse Likert-scales used, no attempts were made at proving significant correlations between variables through the means of advanced statistical methods. Focus was rather kept at "drawing the big picture", measuring the overall satisfaction or dissatisfaction with various aspects of EDM usage across different segments. Primarily methods of descriptive statistics, such as comparing means across groups, were used.

Table 4 Usage statistics extracted for analysis

Variable	Explanation
First and last action	Dates of first and last actions logged
Number of events	Total number of events performed by the user, summed by type of event: • Files uploaded • Files downloaded • Files viewed online • Files moved or deleted • Changes to meta-data • Prints ordered
Usage amount	A usage amount indicator was constructed by banding respondents into four quartiles based on the number of file access events (uploads + downloads + online viewings): • Q1 "Light users" • Q2 "Medium light users" • Q3 "Medium heavy users" • Q4 "Heavy users"
Usage type	A download / upload measure depicting the ratio of uploads to downloads + viewings, giving a value of 0% for only uploads and 100% for only downloads. For the sake of analysis, the measure was further banded into three categories: • "Heavy uploaders" (download/upload measure of < 50 %, i.e. users who have uploaded more files than they have downloaded or viewed) • "Mixed usage" (50%...99%) • "Pure downloaders" (100% downloads, no uploads whatsoever)

5.3.2 Phase two – interviews

Phase two of the empirical study focused on obtaining a more detailed, in-depth understanding of the attitudes prevailing in different user segments. In order to achieve this, semi-structured interviews were carried out with a limited number of users.

Selection. Interviewees were selected among the survey respondents. The selection was guided by an intention to interview people from different segments along the following dimensions:

- group role
- previous EDM experience
- focus and length of involvement
- length of involvement
- overall satisfaction as measured by the questionnaire

Interview method. Interviews were conducted face-to-face and in several cases with a computer at hand, allowing the interviewee to demonstrate certain procedures on screen. Rather than having a set of written-out questions, the semi-structured interviews were guided by a list of themes (shown in Appendix B). This allowed the interviewer to let the discussion progress freely and approach themes in any order they surfaced. The method allowed each respondent to focus on the issues he or she found most relevant to his particular role within the project. The discussions were recorded on tape and transcribed shortly afterwards.

Analysis. In transcribing the end-user interviews, the material was sorted according to the pre-defined list of themes.

Expert interview. After the end-user interviews were transcribed and analysed, an expert was asked to comment on the preliminary findings. Due to his background as founder of Raksanet, the expert chosen possesses first-hand experience of the challenges related to document management in construction. Furthermore, he was involved in the early stages of planning the EDM implementation used in the Kamppi Center project. Despite this highly involved background, he was able to provide unbiased and balanced opinions due to the fact that he left the industry a few years ago. By commenting on the findings obtained in the survey and end-user interviews, the expert provided valuable insight into how and why the daily operations in construction projects differ from ideal scenarios.

5.4 Limitations of the research design

5.4.1 Reliability

This section discusses some issues related to reliability problems present in the research design employed. As the chances of extracting generally applicable results from only one case is small, reliability as below is mainly concerned with how well the research managed to sample the attitudes prevailing in the case at hand.

Survey. Reliability can suffer in self-administered surveys since it is difficult to ensure each respondent processes the questionnaire privately. Respondents may feel tempted to discuss the survey with colleagues (contamination) or even let someone else answer the survey on their behalf. (Saunders et al). Although the cover letter emails were sent out to specific individuals who hade used the EDM tool, it can be assumed that not everyone responded personally but rather forwarded the link to a colleague.

Furthermore it can be argued that the four point Likert scales used for grading responses were too coarse to reliably reflect the respondent's opinions. With only two *agree*-choices and two *disagree*-choices, choosing one option over the other has a considerable impact on the mean score. On a ten-point scale, the "rounding errors" introduced by the scale would be less severe.

Interviews. Certain threats to reliability are present in semi-structured interviews as well. During the course of the interview, the interviewer's personal opinions may colour and bias the discussion. Similarly the respondent may be biased by a perception of what he or she is expected to answer. (Saunders et al)

5.4.2 Validity

An obvious risk regarding validity relates to the difficulty of identifying and isolating causal relationships correctly. This is further accentuated by the fact that only one construction project is studied. At several stages during the research process, this very question emerged: what is this respondent *really* saying? Is he or she talking about EDM in general or about how Raksanet was implemented in the Kamppi Center project? A respondent with no previous EDM experience is probably unable to separate EDM *as a concept* from the *practical* experience with the *specific software* used, whereas a more seasoned respondent may take a more holistic perspective in answering questions.

Despite all efforts to keep issues of process fit, implementation efforts and software usability separated in the analysis of data, the research results are bound to be coloured by the fact that respondents – and sometimes the researcher – jump to invalid conclusions regarding causal relationships.

5.4.3 Other limitations

Rogers (2003) as well as Pinsonneault and Kraemer (1993) emphasise the benefit of observing adoption by the means of longitudinal studies. However, since the Kamppi Center project had already been using EDM for three years when this research project was launched, a cross-sectional approach was a given.

6 Empirical results and analysis

6.1 Survey

6.1.1 Introduction

While 13 of the intended respondents proved to be unreachable due to incorrect email addresses or over-quota mailboxes, a satisfactory 167 of the 269 reachable individuals responded, giving an active response rate of 62 %.

51 % of the responses were received within the first 8 hours after sending out the cover email. As illustrated by Figure 13 below, another significant peak of responses arrived during the following Monday, when a follow-up email was posted to those who had not yet submitted.

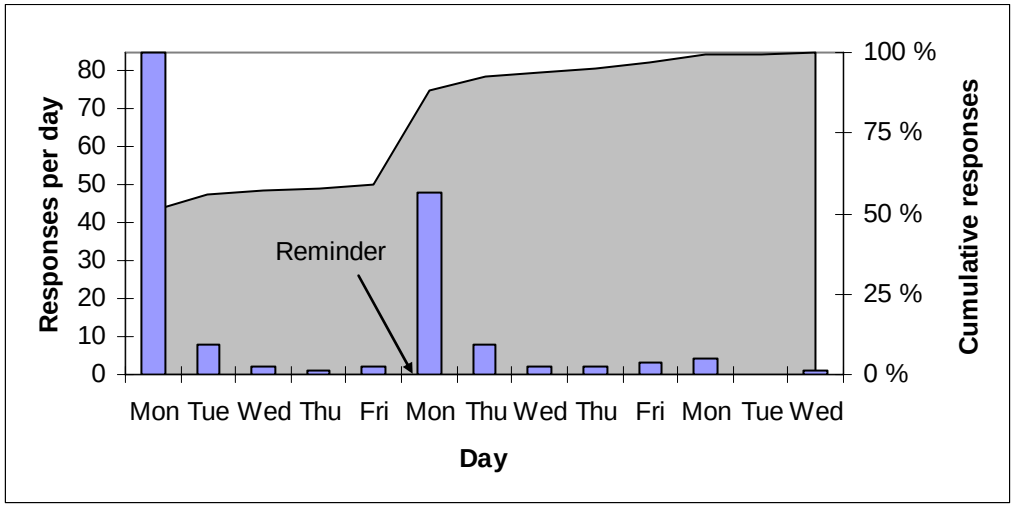


Figure 13 Responses received over time

Non-responders. Logs reveal that 20 % of the non-respondents did access the online questionnaire, but never completed or submitted the form. The other 80 % did not bother to follow the link provided in the cover e-mail.

As a side note on the survey method, it can be pointed out that the choice of forcing respondents to answer all questions before submitting can be considered successful. In total, 20 individuals attempted to submit incomplete responses. Out of these, 13 subsequently answered the missing questions and submitted a complete questionnaire, while 7 lost interest altogether. Thus, the no-missing-fields rule turned 20 partially answered

questionnaires into 13 complete ones; a loss in quantity well balanced by gained quality in the data received.

Reliability. The obtained survey data covers 50 % of the actual Raksanet user base. As Figure 14 reveals, the respondents were responsible for 59 % of all logged actions, indicating that the respondents have been more active than the users on average. Further analysis of event logs reveal that the respondents were responsible for 92 % of all logged upload events, 75 % of all downloads and 63 % of the online viewings. As such, the sample can be considered large enough to provide a representative view of the user base as a whole. However, these findings indicate that the obtained data is skewed towards more active and thus, perhaps, more positive users.

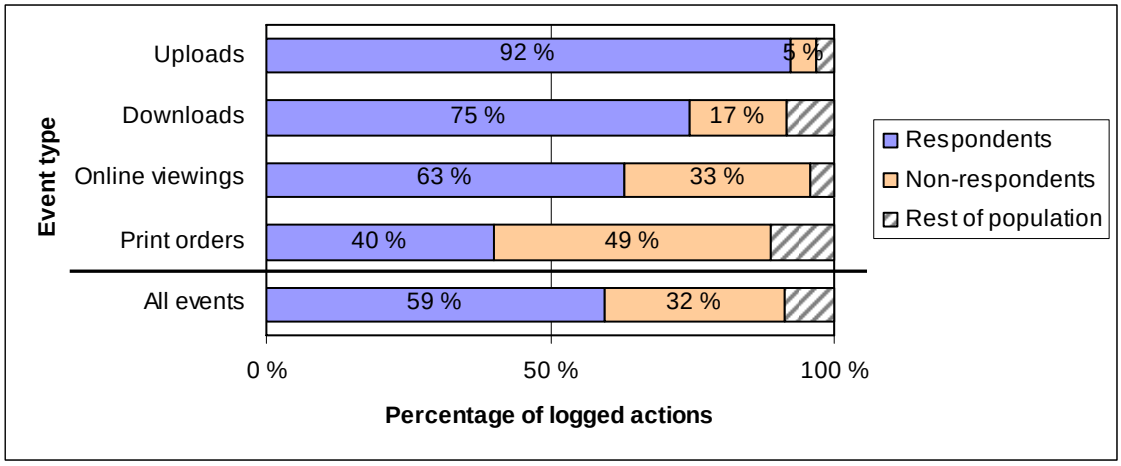


Figure 14 Distribution of actions across the population

As mentioned in the research design chapter, the objective of the survey was not to gather accurate data for testing existing models or formulating new theories based entirely on statistical methods, but rather to gain a fundamental understanding of prevalent attitudes and opinions. Still the presumed sample bias should be kept in mind when interpreting the results.

6.1.2 Respondent background

This section describes the demographics, role distribution and previous EDM experience of the respondents sampled. Additional variables presented are length and intensity of involvement, time of joining, EDM usage frequency and behaviour.

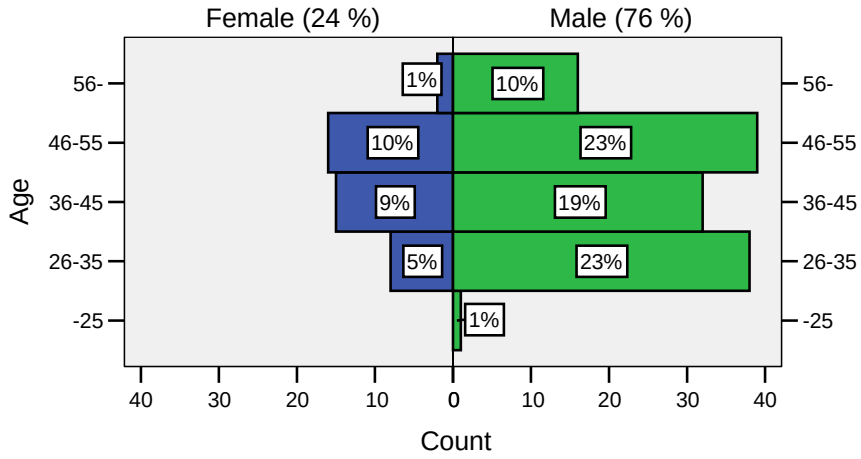


Figure 15 Respondent demographics

Age and sex, summarised in Figure 15, were recorded to allow for testing of the UTAUT presumption that these variables have a moderating impact on other factors affecting adoption rate.

Roles represented. The respondents were categorised in the following groups based on their employing organisation as recorded in the EDM user database: *architects*, *technical design*, *subcontractors*, *project management* and *facility end users*. This particular division of roles was decided upon as a compromise between two objectives: providing truthful representation of actual job tasks versus achieving sufficiently large groups that would allow for meaningful usage of descriptive statistics. One particular simplification was made in categorising the main contractor's staff – they were all labelled as project management, regardless of their widely varying job tasks within the organisation.

The scope of the *facility end user* role requires some clarification. It consists of individuals representing the actual end-users of the complex being built. However, the respondents are almost exclusively limited to the bus terminals, i.e. consisting of representatives of bus operators and commuter traffic planning departments. The end-users of the shopping centre, as well as the interior design offices hired by these, were using a separate Raksanet document database, which unfortunately was left out of this study altogether. Due to the resulting small number of respondents in this category (n=6), conclusions cannot be drawn from the statistics provided.

Previous EDM experience. As demonstrated in Figure 16, roughly half of the respondents were first-time EDM users. 36 % had used EDM in 1-4 projects and a modest 10 % possessed more extensive EDM experience.

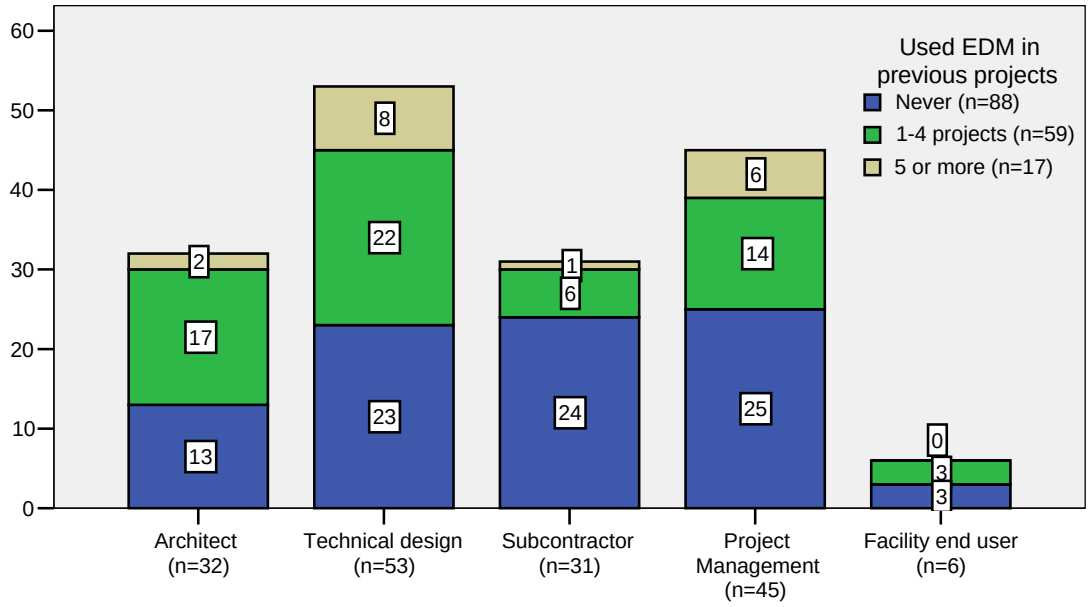


Figure 16 Respondent roles and previous EDM experience

Based on these figures, it can be concluded that the construction industry still is in a rather early stage of the EDM adoption process. A closer look at the variance between project roles reveals architects as the most experienced users, while this technology still is new ground for the vast majority of subcontractors. The distribution is related to the degree to which these groups are involved in the information process. The work carried out by architects and technical consultants is primarily information related, while subcontractors need less input from the information process to perform their actual work on site.

Length and intensity of involvement. The degree to which an individual is committed to a construction project is hypothesised to affect his or her motivation or capability to adopt the document management procedures and tools used within the project. Consequently respondents were asked to estimate how big a share of their working hours were devoted to the Kamppi Center project and for how long they were personally involved.

Figure 17 below demonstrates that subcontractors were in general devoting less of their time to the project than architects and project management. This is an important observation that should be kept in mind when studying attitude differences between role groups.

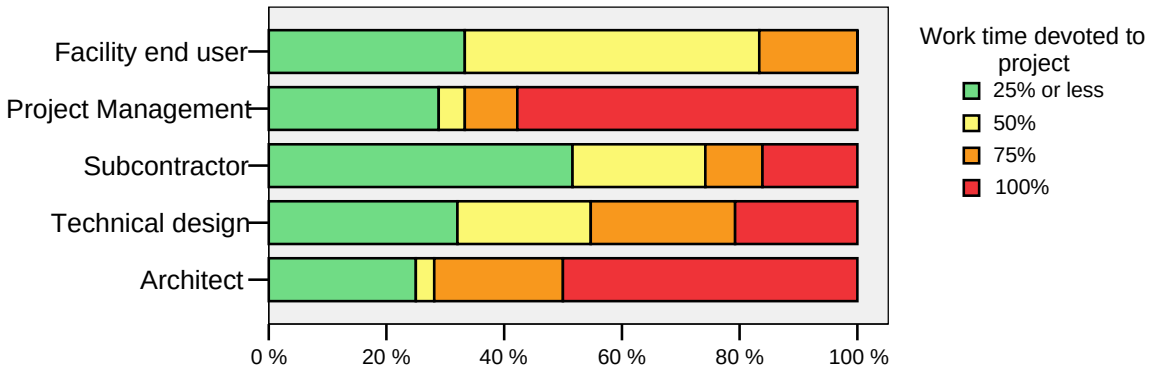


Figure 17 Work time devoted to project

Furthermore, Figure 18 indicates that the share of respondents working for 3 years within the project or more was considerably lower among subcontractors than in other role groups. Notably 25 % of the architect respondents were involved for only a year or less.

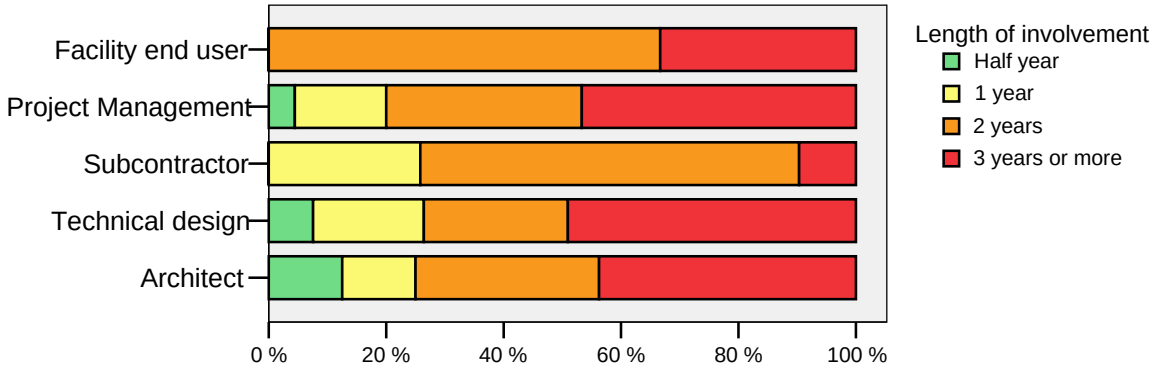


Figure 18 Length of involvement

Time of joining. At the time of launching the EDM implementation in late 2001, only project management, architects and technical consultants were represented. The number of users has grown steadily over the following four years, but as Figure 19 below shows, there are considerable differences across the roles.

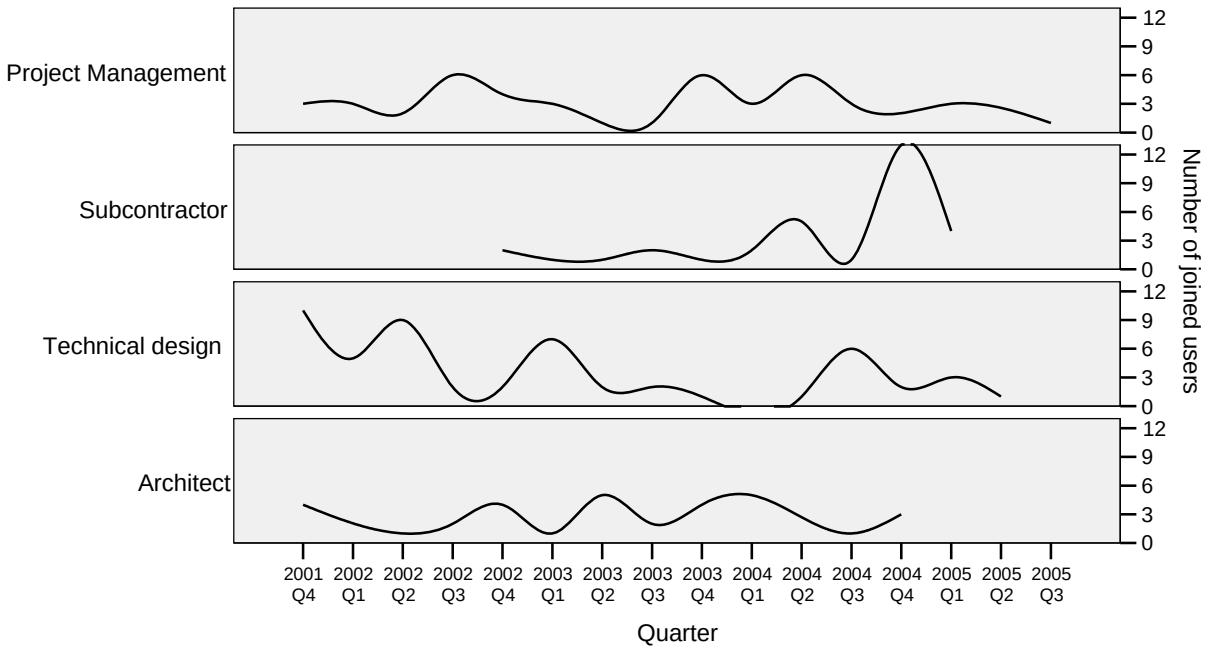


Figure 19 New EDM users over time

The graph is based on data of when each respondent used the EDM system for the first time, thus showing the number of new EDM users per quarter. Of particular interest is that the majority of subcontractors had their contact with the EDM system at a rather late stage in the project, when the system had already been in use for a couple of years and the amount of documents already stored was considerable. This is of relevance when viewed in the light of comments from survey and interview respondents who mentioned the overwhelming and confusing amount of files and folders as one of the biggest challenges in adopting the system.

Usage behaviour. As previously mentioned, the parties involved in a construction project play different roles in the information process. Figure 20 shows clearly that architects and technical consultants are the biggest information providers while subcontractors primarily are pure information retrievers who never store any documents in the EDM. Only 2 of 31 subcontractors have uploaded any documents to the system, while roughly half of the architects have uploaded more than they've downloaded (see chapter 5.3.1 for a definition of the classification scheme used.) The implication of this is that users from different roles use the EDM tool in remarkably different ways. Consequently, individual perception of factors such as ease of use and usefulness are bound to differ between e.g. architects and subcontractors since they utilise entirely different parts of the software in their daily work.

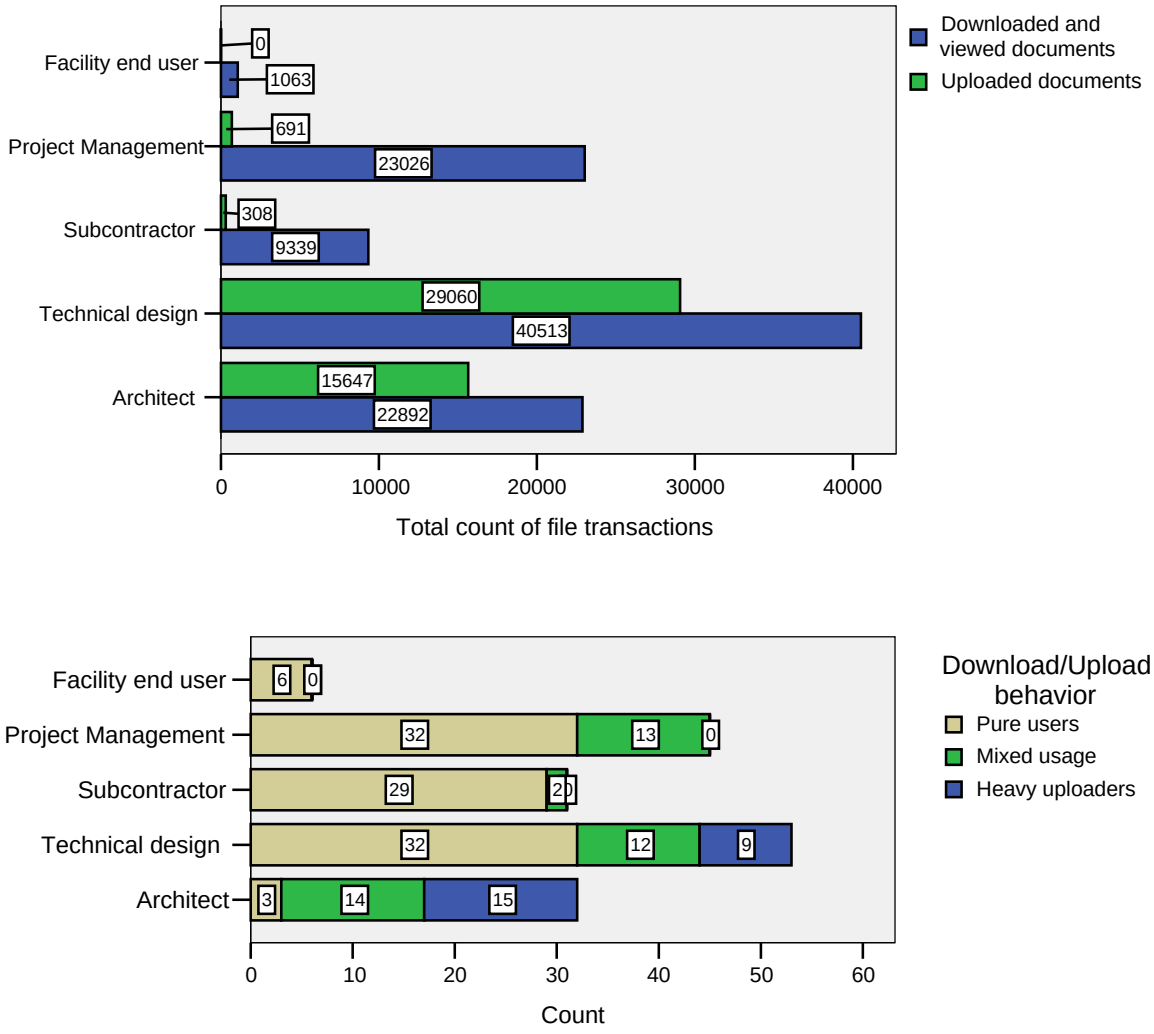


Figure 20 Respondents' upload / download behaviour

Conclusions. To summarise the data presented above, there are significant differences across the roles regarding the following background variables:

- previous EDM experience
- time of joining
- intensity and length of involvement in the project
- frequency and type of usage across the respondent roles.

All of these variables can be hypothesised to influence the user's subjective perception of ease of use and usefulness. As a result, caution should be exercised when drawing conclusions from the survey data presented below. If one role group seems more positive towards an issue than others, the question remains whether the variance is due to differences in previous EDM experience, involvement, usage behaviour or perhaps time

of joining? Unfortunately a data set of this size doesn't allow for statistically valid answers to these questions.

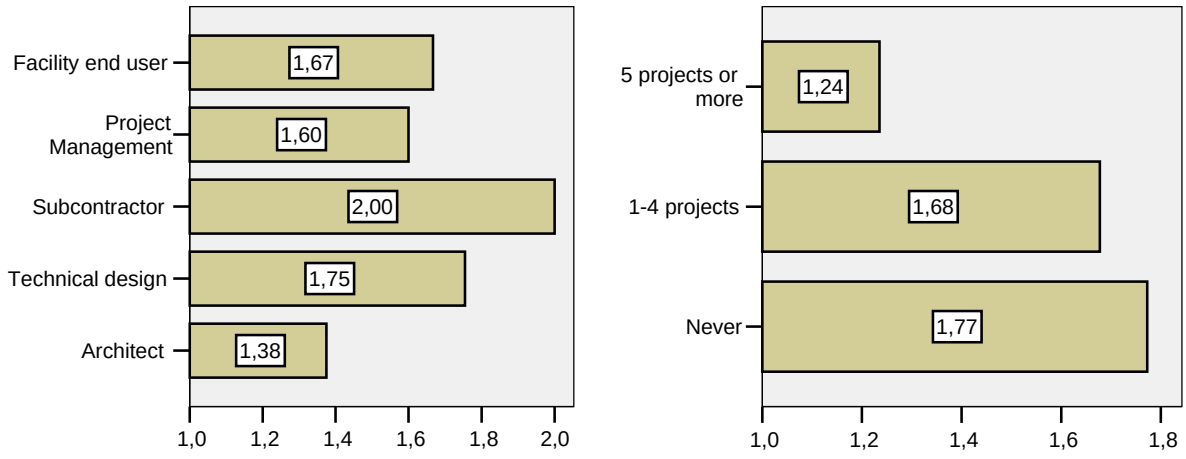
6.1.3 Initial attitude

Q5. At the outset of the project, I was sceptical about the benefits of EDM.

Initial scepticism towards the benefits of EDM usage was surprisingly low. Only 10 % agreed somewhat and 2 % agreed completely with the statement. As demonstrated by Figure 21 below, users who had previous experience of EDM use appeared less sceptical regarding the benefits. There are two plausible explanations for this finding, one being that users with previous EDM experience have had a chance to witness the benefits reported in earlier research (see chapter 2.4) while inexperienced users haven't. The other explanation relates to factors discussed in the section on secondary adoption success in chapter 3.3, i.e. resistance to change and the sceptical attitude towards any new inventions that is prevalent in certain segments of the population.

The fact that subcontractors seemed more sceptical than architects can presumably be explained by the fact that subcontractors, in general, have had less experience with EDM and IT in general and than e.g. architects. Another explanation may lie in the fact that the inner workings of the information process only affect subcontractors to a limited extent.

One subcontractor commented that EDM usage *"pushes too much work from designers to subcontractors!"*, probably indicating a lacking understanding of the EDM concept.



Scale used: 1=disagree completely, 4=agree completely

Figure 21 Initial scepticism towards EDM benefits

One respondent expressed concern regarding the reliability of EDM systems and the problems that may arise in case of system failure or minor glitches.

> *"Who is responsible for complications and delay fines that arise if documents won't update properly? The burden of proving system malfunction falls on the document producer, who doesn't have any contract with the actual EDM [ASP] provider."*

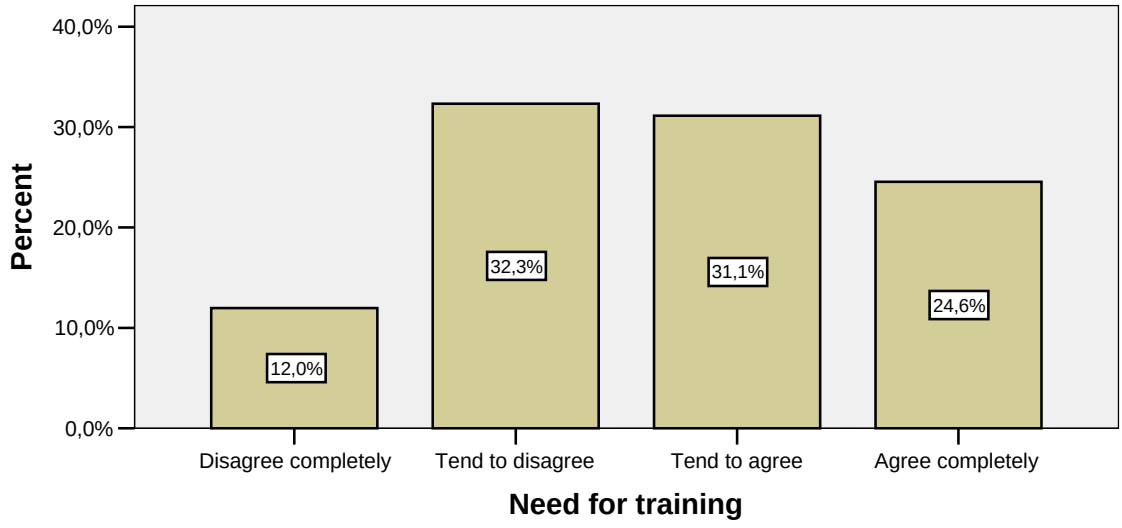
6.1.4 Support quality

> *"In order to achieve the best benefits, more effort should be put into training and instructing the users."*

As defined by the Updated D&M IS Success Model, *support quality* refers to the various facets of support resources that are provided to users of an information system. The UTAUT model refers to these as *facilitating conditions*. Training and support/helpdesk are among these factors. Two questions in the survey were intended to measure the degree to which appropriate training had been received, and two further questions sampled the respondents' awareness and satisfaction with support resources.

Q6. Upon joining the project, I felt that I needed training regarding EDM use.

With 25 % of the respondents agreeing completely, and 31 % agreeing somewhat, the perceived need for training arrived at an average score of 2.68 on a 1-4 range. Hardly surprising, the need for training was higher among first-time EDM users (2.91) than among those who had used EDM in 1-4 projects (2.52) or more (2.12). Furthermore a correlation was found between initial negative attitude towards EDM (measured by Q5) and perceived need for training. No significant variance was found across roles.



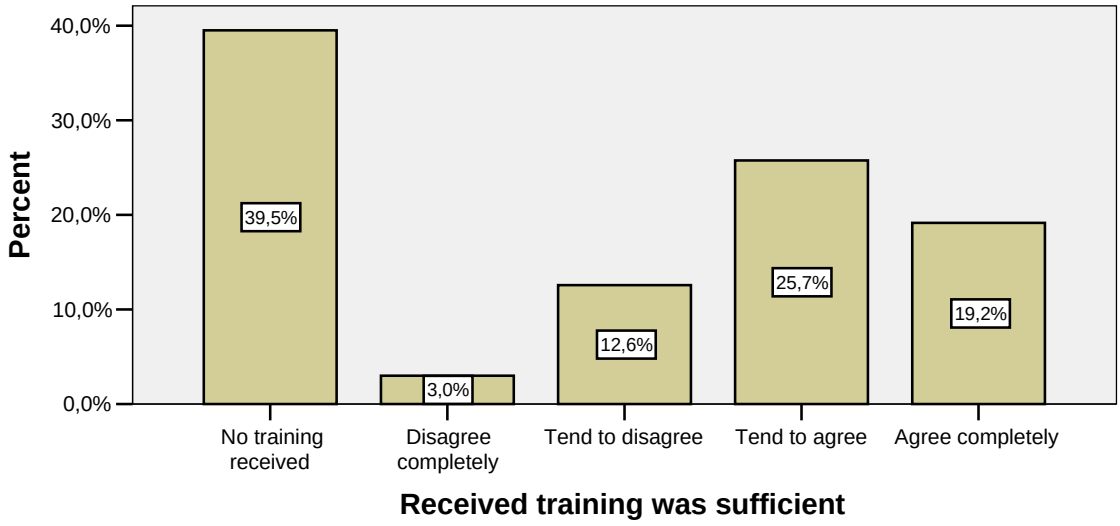
Q7. The training I received was sufficient.

With over half of the respondents reporting a need of training in Q6, it was curious to find that 40 % of the respondents had not received any training at all. It can be considered especially alarming that 47 % of the first-time EDM users received no training. The voluntary comments shed further light on this issue.

> *"I missed the introduction events as I joined halfway through the project. I learned the system by myself, with the help of other users at the office. Later on I've instructed planners on the use of the system. They haven't received enough information about the system."*

> *"...the person responsible for training [at our company] apparently didn't have enough time to instruct me."*

Among those who had received training, however, the majority were completely or somewhat satisfied, giving an average score of 3.01 on a 1-4 range.



This indicates that the actual training was of rather high quality, but targeting was far less successful.

Q10. I've received clear and detailed guidelines regarding management of drawings and other documents *(e.g. what files should be stored in the EDM, in what folders, how files should be named, Status- and Description fields, etc.)*

A strong correlation exists between satisfaction with received training and satisfaction with received guidelines. With almost half of the respondents disagreeing completely or

somewhat regarding availability of clear and detailed document management guidelines, it appears that this is one issue where the Kamppi Center project has failed to meet the suggestions put forth in previous EDM research regarding the importance of communicating guidelines.

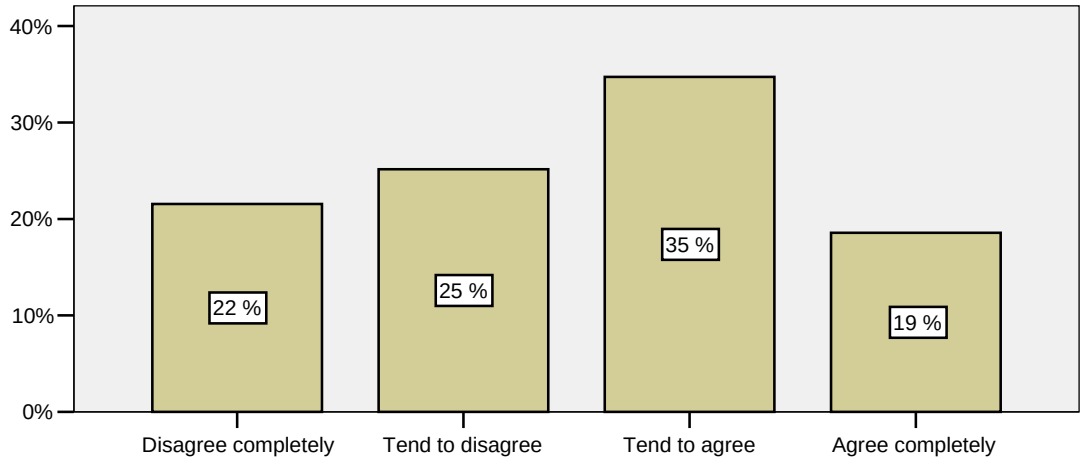


Figure 22 Satisfaction with guidelines received

Some free-text comments tangent the issue of guidelines, e.g. complaining that it has been unclear who is allowed to change what documents.

Q8 If I need help regarding EDM use, I know where I can get help. / Q9 I've received help quickly and with little effort.

Despite that targeting of training was less than successful, end-users appear to have had access to sufficient support resources. Q8 and Q9 measured the degree to which users knew where to get help in case of problems and how satisfied they have been with the help received. 3/4 of the respondents were somewhat or completely aware of the support channels available. A similar majority of the users who had asked for help where somewhat or completely satisfied with the support received. 16 % of the respondents had no experience of asking for help.

6.1.5 System quality

A few questions were intended to measure respondents' perception of *system quality* as a function of ease of use and frequency of technical problems. While the answers to Q14 and Q15 seemed quite positive, a large number of free-text comments regarding nuisances and suggestions for improvement were received.

Q14. Storing and retrieving files is quick and easy

A majority of respondents considered EDM usage in terms of storing and retrieving files as rather quick and easy. Figure 22b below shows a correlation between satisfaction with training received and perceived ease of use.

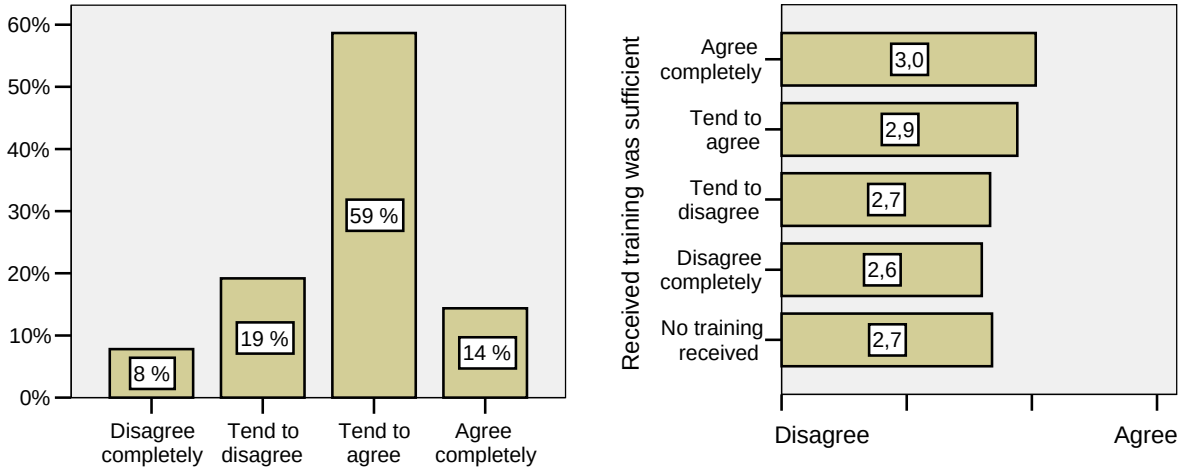


Figure 23 Storing and retrieving files is easy

The more complex the information structure, the greater the need for flexible, easy-to-use search tools that assist users in locating documents, folders etc based on a various types of search criteria. Several respondents commented on the search engine available in the EDM system, with complaints regarding speed, ease of use and usefulness.

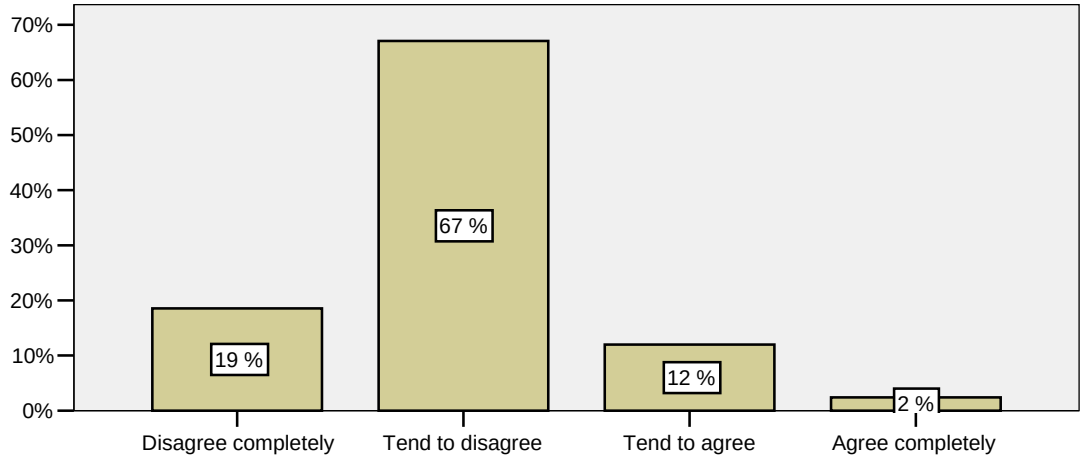
> *"Finding documents with the help of the search feature didn't work. Maybe it was because I didn't know the precise file name, author or date."*

Some suggested increased search functionality that would assist in the task of locating documents, e.g. based on actual contents or context such as location within the 3D space of the construction site. Implementing these features would require more detailed meta-data to be collected for each drawing – yet some respondents commented that filling out the meta-data fields is time-consuming as such.

One considerable suggestion was a "*most recently used*" –feature, giving the user quick access to folders and documents that he or she recently has worked with.

Q15. There have been a lot of technical problems in using the system.

A vast majority reported that they tend to disagree regarding frequent technical problems in using the system.



Speed and reliability issues. Given the availability of high-speed network connections and fast computers, there should be no technical barriers to designing fast and reliable web applications. While some respondents did indeed describe the EDM as a quick and convenient way of retrieving information, many disagreed. Roughly 15 % of the free-text comments contained complaints about the EDM responding slowly to user commands. Especially the online viewing feature received criticism for being slow and impractical. One subcontractor, mainly an information retriever, goes as far as questioning the usefulness of EDM as a result of the slow action:

> *"Usage is clumsy and slow. Looking up information from paper copies is actually quicker than logging in and opening drawings. [...] I wonder who actually has benefited from this."*

Not only subcontractors were unhappy with speed. A project management respondent observed that:

> *"Viewing drawings is by practical means impossible due to the slow action. [...] With computer performance constantly increasing, it's rather puzzling to see how things slow down in real life as you sit there waiting for drawings to appear in the Java window."*

Several respondents commented on sluggish and unreliable action related to the procedure of storing documents in the EDM.

"It's really time consuming and annoying when you fill out all the [meta-data], attempt to store the document and the system freezes for some reason, and you have to start all over."

Other comments on system quality. In the following, respondents' freely formulated comments on system quality issues are briefly presented. While the comments are sparse, they can give some hints about factors affecting responses to Q14 and Q15.

Usability and user interface issues were commented on by several respondents. The web interface received some negative feedback – particularly from respondents using other web browsers than Internet Explorer. Certain features, such as the online viewer, were unavailable or working sporadically for users of the Mozilla Firefox browser. Some frames or lists were found too narrow to cope with the long names of files and folders, a problem especially annoying to Mozilla Firefox users who were unable to change the size of window frames. However, the system did also receive positive feedback comparing Raksanet to other EDM tools.

"User friendly. The Help-feature is good, I think it works excellent."

"The system is partly confusing in terms of structure, but yet more useful than the project webs I've used previously."

"Well functioning package, lots of choices. In the end it's the best of the many EDM tools I've used so far."

Software compatibility issues were reported by a few respondents. One user, representing a city authority organisation using solely MicroStation CAD software and Firefox, underlines the disastrous effects of running incompatible software:

"Due to software incompatibility, we were unable to print or even view any drawings. The only thing we could use the EDM for was retrieving meeting minutes, and we would rather have received those by email."

Email notifications intended to alert users of new or updated documents have caused some frustration, mainly due to the excessive amounts of drawings included in the reports. A few users commented that they'd prefer to receive notifications concerning only their particular area of interest.

Problems with printing or ordering copies were occasionally reported among the voluntary comments. Issues included difficulties printing drawings at a proper scale. Ordering

individual copies and managing distribution lists were also commented on as being difficult and time consuming.

> *"We received copies although we had reported that we don't need them any more. Unnecessary waste of paper."*

6.1.6 Information quality

According to the Updated D&M IS Success Model, information quality is concerned with the quality of the actual data that is processed within an information system. Q12 and Q13 of the survey aimed at sampling two aspects of perceived information quality; folder structure and the degree to which users trust that contents are up-to-date and complete.

Q12. I feel confident that the latest versions of drawings and documents are available in the EDM.

Unless end-users are confident that all relevant documents are available in the EDM, and that the contents of the EDM are up-to-date, users may revert to other channels of communication. This puts information providers in an important role. If they fail to upload relevant documents and make sure the latest revisions are always available in the EDM, other users may lose confidence in the system and usage erodes.

> *"It's always a good idea to check with the designers whether the latest revisions are available in the EDM."*

25 % of respondents agree completely and 55 % tend to agree that they can rely on EDM contents to be up to date. Interestingly, technical consultants were less confident than architects in this regard, despite the fact that they were responsible for a large share of all uploads.

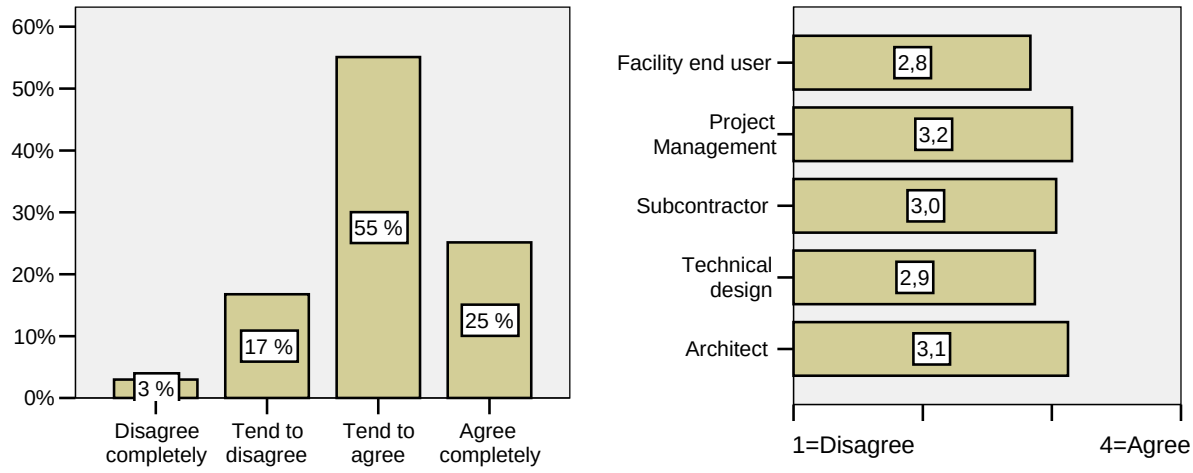


Figure 24 Confident that EDM contents are up to date

While the responses to Q12 seem largely positive, several comments indicated a slight doubt regarding the availability of up-to-date drawings, perhaps explaining why only ¼ of the respondents felt completely confident in this regard:

> *"It worked great, but updates were sometimes late for some drawings. In urgent situations we had to call the designers directly. This is understandable when a drawing needs to be updated often."*

> *"I think [EDM] is a great tool if everyone keeps the information up to date"*

> *"As a concept, EDM use is OK, but there's always a slight doubt whether the latest files have already been uploaded. Naturally, EDM works better in smaller projects. In a project of this size, there's bound to be problems with file management."*

Some respondents commented on the parallel use of DWG and PLT file formats. Two subcontractors mentioned that they benefit more from DWG files since these are of more use in the subcontractor's own work processes, and one complained about discrepancies between the DWG and PLT versions available of the same drawing.

Q13. The folder structure is well designed, making it easy to find the right folder despite the extensive amount of information.

> *"The folder structure was well planned, and files were usually found easily."*

With only 4 % disagreeing completely, 25 % disagreeing somewhat, 60 % agreeing somewhat and 11 % agreeing completely, the mean score across all respondents was 2.78 on a 1-4 scale.

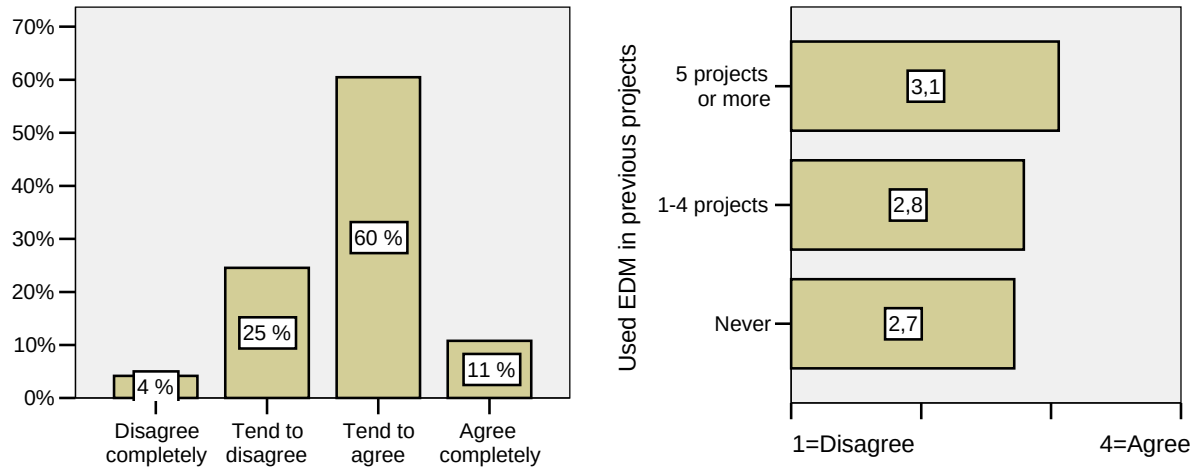


Figure 25 Folder structure is well designed

Comparing the means across different segments reveals that heavy uploaders (i.e. architects and technical design) were somewhat more satisfied (mean score 2.92) with folder structure than pure downloaders (2.77). Again, this gives further weight to the presumption that the degree or type of involvement in the information process affects the way end-users experience EDM. Furthermore, it was found that respondents who had previously used EDM in five or more projects were more satisfied (3.06) than first-time EDM users (2.72). This may indicate that the learning curve of handling construction information through a hierarchical folder tree is considerable. However, no strong conclusions can be made on the basis of this data, due to the ambiguity of the actual causal relationships.

Despite the rather high scores mentioned above, a considerable number of respondents used the free-text field to comment on the folder structure, most of them expressing dissatisfaction with the amount of folders and complexity of the tree, asking for a more consistent and self-explanatory structure.

> *”In my opinion, folder structure should have received more attention. Sometimes it was very difficult to find drawings.”*

> *“The complexity and amount of folders made it difficult to find files, even with the help of the search engine.”*

> *“Folder structure is too complex. Finding what you’re looking for is difficult and slow.”*

> *“In a project of this size, it would have been valuable to design the structure well, having one person in charge of it.”*

The fact that update notification emails were triggered for changes in any folders that the user had read access to caused some users to receive notifications regarding documents that didn't actually concern their work. One respondent suggested a more fine-grained folder structure in order to remedy this problem.

6.1.7 Process fit and user satisfaction

The above questions measured end-user perceptions of rather specific details regarding the implementation process, usability of EDM system used and the actual contents. Moving to a more general level, the following questions attempt to describe the overall satisfaction with EDM work and ultimately measure the actual benefits as viewed by the individual users.

Q11. EDM-based work routines suit me.

Recalling that 54 % of the users had no previous EDM experience, their responses to this question are solely based on the Kamppi Center project. This stands in contrast to respondents with a more extensive history of EDM use, whose answers may be based on the cumulative experience gained during several previous projects. As Figure 26 demonstrates, users with previous experience were considerably more content with EDM-enabled work processes than the first-time users.

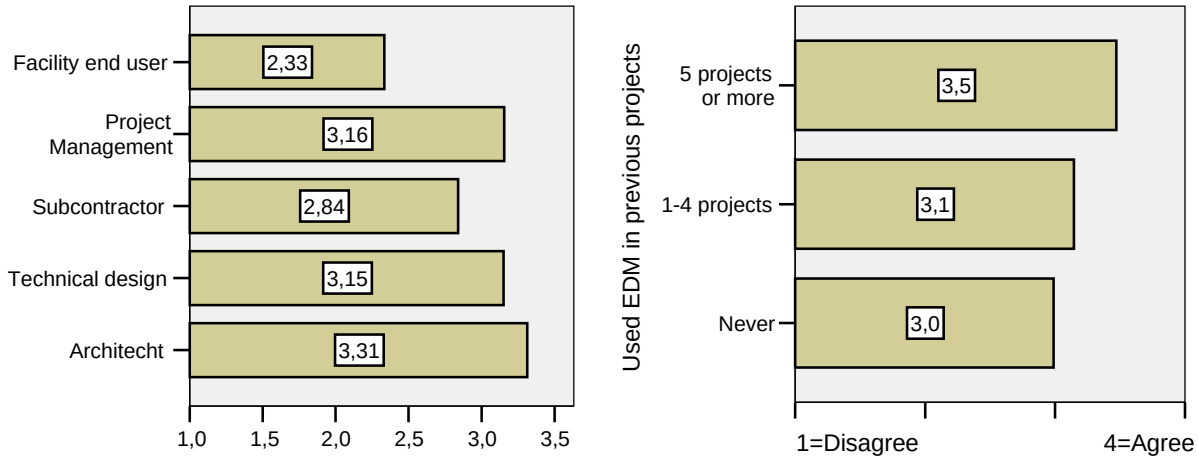


Figure 26 EDM-based work suits me

Several respondents regarded EDM as a convenient addition to their work routines. EDM was described as a quick and easy way of keeping up to date with new revisions and receiving documents. Not all voices were equally positive. One subcontractor re-

garded EDM, as implemented in the Kamppi Center project, as a burden rather than a benefit:

> *"I do endorse the use of email and digital transfer of drawings, but this kind of project-wide document management is slow and cumbersome. No one has time to read all the reports flowing in from Raksanet. "*

Q16. I prefer watching/reading drawings and text on paper rather than on screen.

The respondents were divided evenly across *tend to disagree*, *tend to agree* and *agree completely* in this matter. Only 3 % of the respondents preferred on-screen viewing completely. This finding is important as it supports the previously quoted statement that EDM by no means enables a paperless office, but rather a "less paper office."

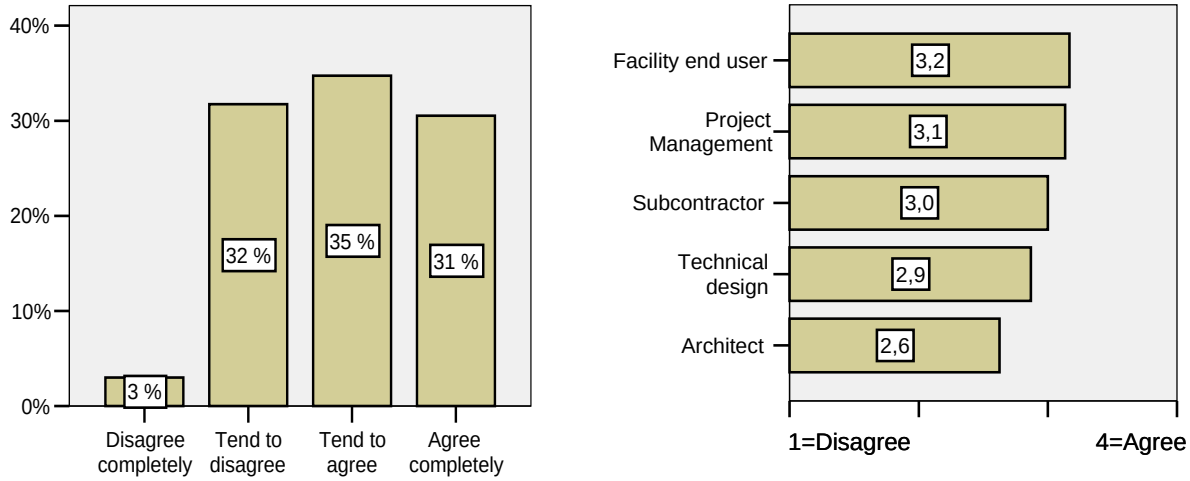


Figure 27 Prefer to read from paper than on-screen

Architects, who are among the most active participants of the information process, appear more willing to work on-screen than the other user groups. Somewhat surprisingly, project management seemed more skewed towards paper than subcontractors, who in other regards have proved to be the least enthusiastic user group.

Q17. Email, facsimile, courier etc are still important methods of sending drawings within the project group

The responses to this question leave no doubt as to whether an EDM system can replace all traditional channels of communication in a construction project. According to 82 % of the respondents, email, fax and courier are still important.

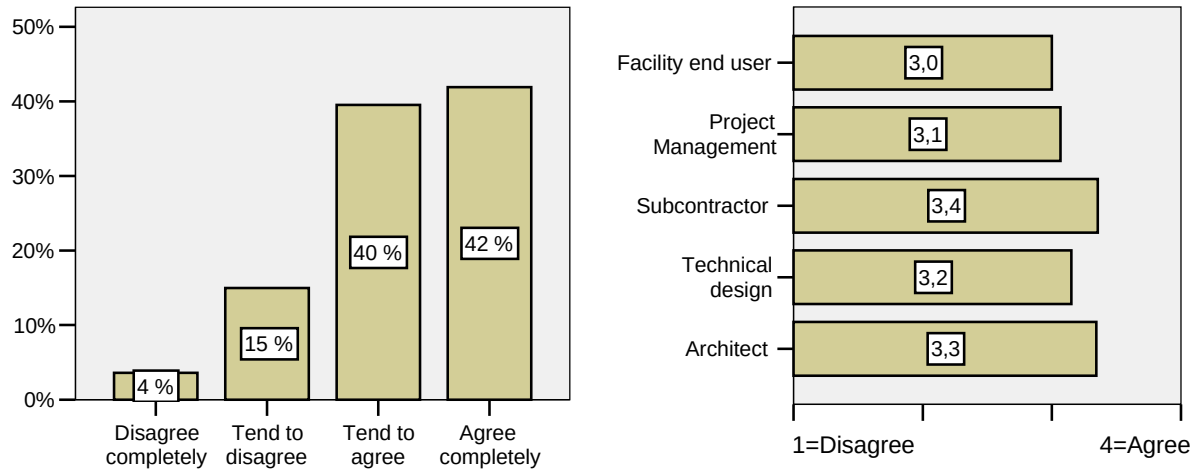


Figure 28 Email, fax and courier still important

The survey data does not give insight in the underlying reasoning, but this issue will be discussed in further detail in the interview section. However, two aspects emerged among the free-text survey comments. One respondent mentioned email as a convenient way of exchanging drafts of upcoming revisions which are not yet ready for public release. Another user considered email as a necessary addition to EDM-based work, e.g. for informing other parties of new revisions.

Q18. The company or organisation that I represent could have performed its tasks just as easy - or even easier - without the use of EDM.

The net benefit of EDM usage, as perceived by the project participants, was measured by asking respondents if they feel they could have managed as well without the support of EDM. A convincing 84 % of the respondents disagreed somewhat or completely, thus validating the assumptions regarding actual benefits presented in previous EDM research. The size and complexity of the Kamppi Center project seems to be one factor contributing to the positive attitude:

> *”Very much needed – without EDM it would’ve been pretty impossible to pull this off.”*

> *“Without EDM, this amount of information cannot be managed or distributed successfully.”*

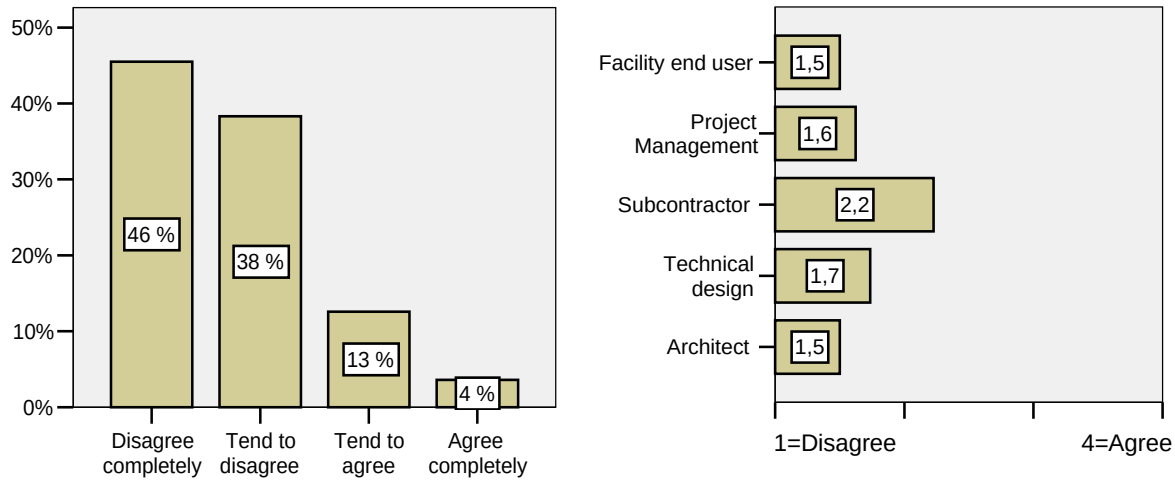


Figure 29 We could've done it without EDM

Subcontractors appeared less dependent on EDM than the other groups. Again, this can be explained by the subcontractors' limited involvement in the information processes. For pure information users, it doesn't really matter how the information is managed or how they receive data, as long as they get the drawings needed to carry out their actual work.

Q19. My attitude towards EDM has changed for the better due to this project.

How has the Kamppi Center experience affected participants' attitudes towards EDM? Recalling that subcontractors constituted the most sceptical group regarding benefits in the beginning of the project (Q5), it is interesting to find that the same group reported the biggest attitude shift towards the better. As a majority of subcontractors were first-time EDM users, their attitude has shifted from being based on prejudice to actual personal experience.

> *'"I enjoyed my first experience with EDM and the possibilities it offers. EDM is a good solution in many projects."*

Judging from Figure 30, the attitude improved among a majority of the respondents. The largest share of sceptics was found among project management.

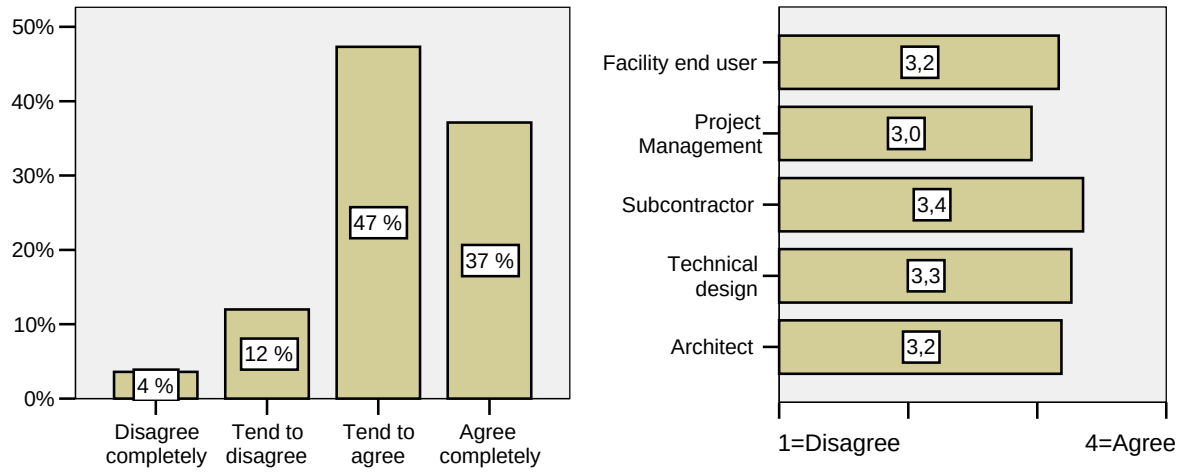


Figure 30 Change in attitude towards the better

Studying correlation between initial negative attitude (Q5) and change in attitude during the project (Q18) shows that many who were explicitly sceptical at the beginning reported that their attitude did not improve. Similarly, those who were most confident regarding benefits in the beginning also reported the highest improvement in attitude at the end of the project. This finding evokes the thought that the respondents may have been influenced by their *current* attitudes when answering the retrospective Q5. This is a limitation of the cross-sectional research design chosen, which forced users to think back 1-4 years regarding their initial attitude. A longitudinal approach to data collection would have enabled a more reliable follow-up of how attitudes have changed over time.

Comments on usefulness. Numerous respondents used the free-text field of the survey to comment on EDM use as a whole. With a few exceptions, the comments were decisively positive.

> *"As project manager for a subcontractor, my EDM use was limited to viewing and printing plans, drawings and reports. Raksanet served me well, night and day, business days and holidays."*

> *"The important features of EDM are: archival of previous document versions, huge capacity compared to email, and up-to-date drawings made available for everyone."*

> *"Excellent system. If only EDM was used in all projects!"*

> *"I can't imagine a large scale construction project not using EDM nowadays."*

> *"In a project of this size, EDM use is the only way to go."*

"Worked as a channel of communication as planned."

A few respondents did take the opportunity to mention that although the EDM system served them well, there is still room for further development.

> *"Excellent service by all means! Some fine-tuning can surely be done, but this wasn't too bad."*

6.1.8 Conclusions regarding survey data

At an early stage of processing the survey responses, an apparent mismatch was found between qualitative and quantitative data. A majority of the free-text comments seemed negative, containing numerous complaints about problems encountered in using the system, giving a rather gloomy picture of EDM success. Nevertheless, the quantitative data indicated the opposite, showing that a majority of the users were rather satisfied with the EDM system and the benefits it had provided.

However, as the received comments were sorted by attitude and topic, it appeared that the negative comments concerned rather *specific*, *mainly technical details* (e.g. search engine being far from effective, folder tree being difficult to navigate, the system reacting slowly etc.) Respondents who took the opportunity to comment on the usefulness of EDM use on a more *general level* seemed far more positive, and thus more in line with the results found in the quantitative data.

The conclusion is that on a general level, the system did not only allow users to "get things done" in a satisfactory manner, but actually provided great support. The responses to Q18 ("*we could've done it as well without EDM*") leave no doubt regarding the benefits provided by EDM in this project. Still on a more specific level, there are areas which deserve attention and further improvement. The numerous negative comments received should be viewed in the constructive perspective offered by this respondent:

> *"The concept is good, and much of the functionality is also good, but I still think it needs further development."*

In the light of the survey data, the areas which need improvement cover all three dimensions of quality: *support quality* (implementation efforts such as training and guidelines), *system quality* (search engine functionality, user interface issues and cross-

browser compatibility, overall speed and reliability), *and information quality* (especially folder structure and confidence in content being up to date.)

Implementation efforts. Judging from the survey data, the most apparent shortcoming of the implementation process in the Kamppi Center project was related to training and guidelines. Analysing mean scores on the various quantitative questions shows that those who received no or completely unsatisfactory training were more negative regarding both ease of use and usefulness of the system. By properly targeting training to *all* end-users, project management could expect a higher degree of EDM adoption, which in turn would benefit all participants since more communication could be committed through this particular channel.

In order to avoid the innovativeness paradox described by Rogers (2003), project management should identify which users are in the biggest need of support when getting started, and target extra training efforts at these. While the survey data at hand does not allow for reliable statistical tests isolating the impact of all different factors affecting perceived ease of use and usefulness, basic analysis (such as comparing means across groups) does shed some light on which user segments were more sceptical or unconfident. At the outset of the study, it was hypothesised that the length and degree of involvement of users affects their motivation or opportunities to learn using the system efficiently. Responses indicate that respondents working full-time with the project were indeed slightly more confident in using the EDM system than those devoting only a share of their time to the project. Similarly heavy users were more satisfied than sporadic users. While the influence of length of involvement remained ambiguous, the time of joining appears to correlate with perceived training (indicating that project management has failed to offer training to late joiners) and satisfaction with folder structure (late joiners being more confused regarding the structure.) Age or sex did not appear to influence attitudes.

Ease of use. In case of the Kamppi Center project, the folder structure received criticism from the survey respondents. It was regarded as complex and difficult to get a grip of. Likewise the search tools were found insufficient by some respondents, and many complained about the system responding slowly when browsing the data structures. Improving the folder structure to any significant degree would probably have been difficult given the sheer amount of data and the large number of participants involved. Instead

certain improvements on the technical side would appear as a viable solution. Improving the response speed of the system and adding more search features such as “most recently used documents / folders” would help users cope better with the complexity of the information structure.

6.2 Interviews

6.2.1 Introduction

The objective of the interviews was to gain deeper insight into issues which the quantitative survey only provided glimpses of.

Interview objects. As mentioned in the research design chapter, the interviewees were chosen with the intention of covering a wide range of user types, representing different parts of the information process.

A1. Working for one of the architect offices involved in the project, A1 managed the flow of design information between architects / technical consultants and the interior design offices hired by shopping centre end-users. Having participated in numerous EDM-enabled construction projects in the past, but being a first-time Raksanet user, she was able to put her observations of the Kamppi Center project in a wider perspective. Relating both to her own tasks and to the work carried out by other staff at the same architect office, A1 provided valuable insight.

Table 5 Interviewees

Code	Role	Previous EDM experience	Usage type	Usage amount
A1	Architect	> 5 projects	Heavy uploader	Medium heavy
C1	City planning (traffic planning)	None	Pure downloader	Medium heavy
C2	City planning (urban planning)	None	Pure downloader	Very light
P1	Project management (project engineer / architectural design)	None	Mixed usage	Heavy
P2	Project management (site manager)	1-4 projects	Mixed usage	Medium heavy
S1	Subcontractor	None	Pure downloader	Medium heavy

C1. A first-time EDM user responsible for traffic planning, C1 had received no training or guidelines at all. When attempting to demonstrate how she had used Raksanet, it became apparent that C1's general computer skills were fairly limited. Well aware of this, C1 explained it as a result of belonging to "the old generation" of people who find it difficult to adopt new technology such as mobile phones, VCRs etc.

C2. Working for the city planning department, C2 works frequently with CAD software and is thus familiar with computer based design tools. However, she was a first-time EDM user who received no training.

S1. A first-time EDM user, who received one-on-one training upon joining the project, acted as project leader for a subcontractor involved primarily in the early stages of the construction phase.

P1. In charge of supervising architectural design, P1 was a first time EDM user. However, by the time of the interview he had already been transferred to a new construction project, where he was in charge of setting up guidelines for EDM use, administering the EDM system used etc. He had, thus, gone from EDM novice to expert/administrator.

P2. Heading the main contractor's technical department, P2 had extensive EDM background.

The interviews were carried out in late 2005, at a stage where some of the interviewees were already working primarily with other projects, but most still had their Kamppi Center experiences in fresh memory.

Structure of reporting. Given the semi-structured approach used, the discussions were allowed to evolve rather freely around a pre-defined set of themes. This approach gave each interviewee an opportunity to focus on issues particularly important for his or her job role, allowing many interesting details, nuances and sub-themes to emerge. However, it also made reporting slightly more challenging since interviewees indeed focused on rather different aspects of EDM use. Another challenge rose from the fact that some respondents seemed incapable of separating the topics of EDM as a concept from the technical functionality of the system used. When asked about ease of use, respondents sometimes confused the issues of technical usability, difficulties caused by lacking training and challenges posed by the sheer amount of information available in the system. Consequently interview responses cannot be directly compared to each other.

In the following sections, the findings which emerged during the interviews have been grouped into the following structure:

- Getting started
    - First impressions
    - Viability of self-learning, formal training and informal knowledge sharing
- Technical / information perspective
    - Usability
    - Navigating the information mass
    - Coping with the flow of information
- Process perspective
    - Job fit and benefits

6.2.2 Getting started

Each interviewee was asked to describe his or her previous experience with EDM, at which stage of the Kamppi project they received information about the EDM system to be used, how they reacted to that information, how they perceived the training and guidelines provided, and how well they got started using the system. These issues were of particular interest due to two factors – emphasis on proper implementation in previous EDM research, and the survey result showing that 47 % of the first-time EDM users had received no training at all.

First impressions. Only one of the respondents, C1, admitted to having felt some anxiety as she received knowledge that Raksanet will be used extensively in the project. The other respondents held a rather neutral or even positive initial attitude. It appeared as if they had taken for granted that EDM was a necessity in a project of this size.

A1 testified that only a small share of the employees at the architectural office she represented had bothered to actually "get started" with the EDM system, despite the fact that they were active providers and users of information in the Kamppi Center project. A1 explained this behaviour as a result of the overwhelming effort needed to learn the technical specifics of the system and, most importantly, to get a grip of the information structure:

> *"When you log in for the first time and try to do something, you simply don't get going. There's a terrifying amount of folders, structured by some logic – and that logic doesn't reveal itself."*

C1's first contact with the EDM system occurred without any prior training or information; she just received an email with login credentials, and soon she started receiving daily notifications of new or updated documents.

> *"It was kind of a strange thing... and it still is. You don't really get a picture what's in there because it's all so cumbersome. I looked in the Traffic Planning folder, and it was empty... that put me down, feeling that there's nothing in here."*

S1, P1 and P2 did not any report such problems in getting started. S1 explained that he actually received access to the system upon his own request, and has eagerly been using it ever since. A first time EDM user, P1 got started with some help from colleagues. He did find the existing folder structure confusing, but was in a position to improve it.

The need for training. The interviews indicate that the need for training varies from person to person. Although not explicitly illustrated by the UTAUT model, perceived ease of use – and hence, the need for training – is influenced in part by objective system properties and in part by the subjective skills and previous experience of the end user. The interviews also support the assumption that the degree to which a user finds the information mass as comprehensible and easy to navigate affects perceived ease of use as well.

These findings undermine the EDM solution provider's claim that the system is so easy to use that virtually no training is needed, and project management's assumption that the folder structure was so clear that it could speak for itself. The system may indeed be self-explanatory for computer literate users, but as the amount of information stored in the system increases during the project, the learning curve for late joiners gets steeper – even for computer literates, such as the architect colleagues of A1.

P1 acknowledges that project management provided organised training only at an early stage of the project, trusting that any users joining later would receive enough support from colleagues etc. Similarly, document management guidelines were discussed at early design meetings, but not communicated directly to users joining later. The results of this approach can be seen in the survey data, showing that almost half of the first-time EDM users had to train them selves through trial-and-error or by asking colleagues

for help, and that roughly half of the respondents were more or less unsatisfied with the guidelines received.

Still, according to P1 and P2, they received no requests for extra EDM training, supporting their presumption that people have managed to get started on their own. C1 and C2 explained that they haven't even thought of the *possibility* that they could request training. While opinions diverged on whether training should be given prior to first contact with the system or perhaps a bit later when the users have had time to explore it on their own, C1, C2 and A1 all agreed firmly that EDM training would have been of significant value to them, helping them get past their scepticism towards the system and reducing the time wasted trying to learn it on their own. The reasons for why these users lacked initiative to actually ask for training remain unsolved in this study, but we can safely assume that these weren't the only users who would have appreciated training but still failed to raise their voices.

Viability of self-learning. C1 and S1 are examples of users for whom self-learning was a challenge. Given her limited computer skills, it was apparent that C1 did not have the capability or motivation needed to efficiently discover anything but the most basic features through trial-and-error. Software incompatibility was a further barrier to self-learning. Many of C1's attempts to learn new functionality stopped short when her computer failed to recognise PLT and DWG files, simply because she used MicroStation CAD software instead of AutoCAD which was the standard chosen for the project. In fact, many of the problems that C1 ran into – and eventually eroded her interest in exploring by trial-and-error – lay beyond the scope of the actual EDM software, although C1 didn't see this distinction herself.

The subcontractor, S1, had received some basic training which helped him getting started, but beyond that, he clearly hadn't discovered any additional functionality on his own, and admitted that he was ignorant about most of the features available. For instance, S1 did not even know how to download drawings or order print-outs; he had attempted to, but not figured out how to do it. The only functionality he was familiar with was the online viewer, from which he printed drawings on his personal printer. Although he did manage to use the EDM successfully in his daily work despite his limited skills, more extensive training would have allowed him to benefit even more from the EDM.

For more computer literate users, self-training is less of a problem. With a rigorous background in EDM-enabled projects, A1 was familiar with the concepts of EDM but still considered self-learning a time consuming and sometimes frustrating process.

> *"Getting started wasn't a quick process. You sit there thinking, what's the catch here, what does the machine want me to do?"*

Formal training vs. informal knowledge sharing. Relying on support from colleagues can be a viable form of training in stable organisations. However, in case of the fast-paced but long-running Kamppi Center project, this prerequisite has not always been fulfilled. Many subcontractors have joined as late as 2004, completely missing the introductory training and not having any experienced colleagues within their own organisations to ask. Certain companies such as the architectural offices have indeed been involved from the very beginning, but A1 explains that only five of the current 20 employees have been with them since the launch of the Kamppi project. Some employees have actually been replaced several times over during the course of the project. With each person leaving the project or the company, a bit of knowledge is lost, and with each newcomer, there's an extra burden for the colleagues who must devote time to instruct the newcomer.

Conclusions. The interviews showed that the need for training varies from person to person. Even users who are familiar with EDM software may need training and guidelines explaining the folder structure and document management practices used in the project at hand. Self-learning is clearly not suitable for all users, and learning through support from colleagues does not necessarily work in a fragmented and constantly evolving construction project group.

6.2.3 Usability issues

Although web based Internet services have been commonplace for many years, none of the interviewees were enthusiastic about the web interface of the EDM system. A1 and P2 both mentioned that they'd much rather prefer a Windows-like user interface, which would react and function in the same way as all other software that users are accustomed to. A1 guessed that a Windows-based interface would significantly lower the barrier to adoption that many of her colleagues never passed. The complex information structure would perhaps appear less confusing to new users if the interface was familiar.

As S1 and C1 demonstrated their use of the system, it was easy to observe that they didn't intuitively know how to react to buttons and underscored links in the web interface. S1 hadn't noticed that he could download a document by clicking on its underscored file name – he thought his actions were limited to the icon buttons placed next to the file name. Consequently, he never managed to download files, only view them online.

All interviewees agreed that the web interface sometimes reacts annoyingly slowly. Again, observing S1 and C1 as they used the system, it became apparent that they often were confused by the fact that clicking a button or a folder usually didn't result in any immediate action. They kept clicking again and again every few seconds thinking that the first click hadn't been registered. Naturally, such behaviour only causes the response time to become even longer, since the system starts processing the same command over and over every time the button is clicked.

A1 stated that using the EDM software is so slow and requires such attention that she needs to devote time specifically for dealing with the system, putting of all other tasks for the moment. Using it while on the phone with a technical designer, for instance, was considered impossible, resulting in extra use of email as a channel of communication.

Clearly, many of the usability issues such as speed and user interface ambiguities could be corrected or remedied by the solution provider, but given the current state of the system, users would have benefited significantly from more rigorous training.

6.2.4 Information accessibility

The folder structure and navigation tools available received criticism from survey respondents. Interviewees were asked to comment on the issue.

Folder structure. Representing different departments of project management, P1 and P2 were both in a position to develop the folder structure used. P2 viewed the structure as a "best effort" result of the co-operation between project management and the ASP vendor, and did not see any simple means of improving it. He admitted that some parts of the folder tree have been of "less use" (i.e. no documents stored in them) but did not regard it as a problem. P1, on the other hand, was largely satisfied with the structure of the architectural design subfolders (for which he was responsible), but considered the technical design subfolders (supervised by P2) chaotic. A1 shared P1's view on this,

describing the architectural design folders as consistent with the proven logic of the Talo80 building element classification system, whereas the folders dedicated to technical design did not make any sense to her.

However, S1, who had been retrieving information solely from the technical design area which P1 and A1 regarded as unstructured, did not have any complaints whatsoever regarding the structure. According to him, the part of the folder tree concerning his work had made perfect sense to him from the very beginning. Navigating this part of the tree requires precise knowledge of the drawing numbering scheme and the coordinate system used to describe the 3D space of the construction site. S1 pointed out that knowledge of these is a requirement in any construction project, regardless of whether EDM is used or not.

C1 did not want to comment on whether the folder structure was successful or not, as she had no previous experience to compare the present structure with. However, she thought the structure appeared to follow some sort of logic, but due to the complexity and sheer volume of folders and documents, she often found it difficult to get a grasp of the contents.

Tools for navigation. P2 was the only of the interviewed users who reportedly used the document search functionality available in the EDM system. The other interviewees considered it easier to locate documents by browsing through the folder tree, despite the fact that the system often reacted so slowly to each mouse click that drilling down into several levels of subfolders could take up to 20 or even 30 seconds (as demonstrated by C1, S1 and A1 during the interviews) – even if you knew exactly which folder you are looking for.

Gaining insight into why the search tool was less popular than browsing the tree proved difficult as the interviewees had very little experience of searching and did not want to comment on it. However, A1 explained that she prefers browsing over searching as it allows her to keep an eye on new documents and folders in the EDM which might pass by unnoticed if she only used the search tool in conjunction with specific keywords. S1 considered it much more difficult to formulate proper search keywords than simply drill down to the hierarchical level of interest. P2, who used the search more than the others, reported that it sometimes requires some guessing to find the proper search keywords, as document meta-data isn’t always filled out quite properly.

C1 reported that she often accessed documents directly through the direct http:-links given in the update notification emails she received. This way she didn't have to bother with the folder tree nor the search tool. In fact, her interaction with the EDM software was minimised this way.

Conclusions. A key finding was that usefulness and ease of use are affected by both information quality and system quality. Detailed meta-data is of little importance unless suitable search engine functionality is provided, and a well-thought folder structure doesn't matter unless the graphical user interface allows for clear and quick navigation of the tree.

Although the folder structure received criticism among survey respondents and the interviewees, none of the interviewed users were able to provide any substantial suggestions for improvement. It seems as if some of the criticism originated from the individual user's lacking understanding of the folder structure as a whole. Proper training – with focus on the actual contents of the EDM – would probably alleviate the confusion regarding the structure and help users find the handful of folders they typically need in their work.

Technical improvements such as improved response speed could make the information structure appear more accessible to users. Several survey respondents suggested the search tool should be improved, but the interviewees were unable to elaborate further on this due to their limited experience.

6.2.5 Coping with the flow of information

Previous research mentions instant access to up-to-date information as one of the most significant benefits of EDM. Providing accurate information across the organisation supposedly minimises the risk of errors in design and construction. As the design and construction processes have been tightly intertwined in the Kamppi Center project, the need for up-to-date information has been exceptionally high. Both A1 and S1, representing diametric opposites of the information chain, mention that detail design has sometimes been progressing only a few days ahead of the construction work. As described in chapter 4, the following mechanisms have been employed to ensure new or updated documents reach their intended recipients rapidly:

- **Update notifications.** EDM users receive emails notifying them of changes in the EDM.

- **Automatic paper copies** are distributed to predefined recipient groups.

However, perhaps reflecting the stress caused by the tight design/construction schedule, only 25 % of the survey respondents were entirely confident that the contents of the EDM are up-to-date and complete. The interviewees were asked to elaborate further on this and describe how they manage the constant flow of information in the project.

The interviewees reported that architects and technical designers have been sufficiently quick in uploading their latest work to the EDM. However, other interesting issues regarding the availability of up-to-date information emerge.

Update notifications. The automatic update notification emails covers every updated file that the user has read access to. If read access has been given to a large portion of the folder structure, the notification emails produced can be overwhelmingly long during intense design phases.

According to P1, the default setting for all users is once-a-day. Yet e.g. S1 claimed he had never received any such update notifications, nor did he know it was possible to adjust the settings. A1 received updates for the main EDM project, but not for the facility end-user EDM project although she had attempted to adjust the settings for this. Several survey respondents complained about not receiving these notifications at all. In several cases, this could have been caused by incorrect email addresses stored in the user database (the survey mailing, which was based on the same list of addresses, resulted in several delivery failures.)

A1 pointed out that the email notifications are of limited use if the actual end-users of the information are not personally using the EDM tool. In many cases a project assistant is given the task of tracking EDM updates, downloading new files and distributing them within the office. If the project assistant is out of office or simply overworked, the information flow is hampered despite the inflow of automatic update notification emails.

Planning ahead. C2 pointed out that even though designers upload their drawings without delay, and even though users are automatically notified whenever new files have been published, you still need to contact architects or technical designers directly

to ask about upcoming revisions. P1 admitted that revisions not yet approved for release are kept entirely outside of the EDM. Consequently, there is no way an EDM user can know that a new, revised design may appear *in the near future*, rendering the revision currently available in the EDM obsolete.

Paper delay. While survey respondents expressed concern about how quickly / reliably new updates were published in the EDM, especially A1 and S1 were far more worried about the fact that the automatic hardcopy distribution often lagged several days behind the contents of the EDM. A1 pointed out that during phases of intense design work, the paper copies available on the construction site could be lagging behind by several revisions. With new revisions coming out daily during the construction phase, even a one day delivery delay could cause problems on the site, and the 4-5 day delays mentioned by A1 could be disastrous:

> *"During one day the size of a store could change from 500 m² to 400 or 700 m². [...] If you have 2-3 days old drawings in circulation, a separating wall could be built and immediately torn down. At one end, people would be erecting the wall, at the other end they'd be tearing it down."*

Pinpointing and rectifying the root cause of the delays seems difficult. A1 underlined the fact that several stages of human activity are involved in the process of copy distribution, regardless of the fact that the copy shop receives the print orders automatically and entirely in the digital domain. After the copy shop has produced and packaged the copy sets, a courier service is responsible for delivering them to the intended offices. At each office, a project assistant unpacks the delivery and distributes the copies to the actual recipients. At the architect office of A1, a project assistant works full-time with the demanding task of managing the flow of paper, carefully disposing all obsolete revisions, filing new updates etc. Similar work is carried out at the construction site office, where copies are distributed to most of the subcontractors working on site. All these human activities are error prone, and delay times can easily accumulate across the delivery chain.

Considering the problems related to automated paper distribution, the question arises whether this functionality is necessary at all. P1 and P2 both agreed that it is. First of all, many subcontractors supposedly don't have the equipment or skills needed to producing their own printouts from the EDM.

> *"Especially these subcontractors which have their bookkeeping in the trunk of their car – you can't expect them to have a computer."*

Secondly, the steady inflow of paper copies can serve as a constant reminder for parties who otherwise might lag behind their schedule.

End-user solutions. How, then, have the project participants managed to avoid problems related to information delay or overflow?

A1: Representing one of the architect offices, A1 testified that the office has used email extensively in order to keep the design processes running efficiently. In addition to storing new drawings in the EDM in compliance with the official document management guidelines, the architects have also emailed them to technical designers directly. This has meant double work for the architects and has made information management all the more complex for the recipient, who first receives a drawing by email, the following day receives a notification update email informing about the new drawing being available in the EDM, and a few days later received the same revision on paper. By then one or two new revisions may already have arrived by email. Despite these drawbacks, A1 considered the use of email unavoidable, still being the fastest and most convenient way of communication.

A1 mentioned that the office received overwhelming amounts of paper copies that did not always relate to their work in any way whatsoever, keeping their project assistants preoccupied with sorting and disposing an endless flow of paper. Still she regarded paper copies as inevitable, as architects need big printouts in their work and don't have time to produce those themselves.

C2: Remaining somewhat sceptic towards EDM technology, and not being very comfortable with browsing for updates herself, C2 always communicated directly with the designers in person to stay informed on what's happening ahead. In doing so, she avoided the risk of proceeding with her own work based on soon-to-be-revised drawings. C1 and C2 reportedly did not receive any automatic paper copies and were satisfied that way – they feared they would "drown in paper" if all revisions were distributed to them automatically on paper.

S1: Not receiving any update notifications by email, and dissatisfied with the slow delivery of paper copies, S1 took a strict *just-in-time* and *do-it-yourself* approach to infor-

mation retrieval and printing. Prior to going out on the construction site, he logged on to the EDM, manually browsed the folders for any new revisions, produced A4-size copies of any new details on his personal printer, and handed them out to his crew. Sometimes he would phone the technical design office and ask if any new revisions are up and coming. Although this procedure caused an extra burden on him, it gave him the comfort of knowing that his workers were always doing the right thing based on the most accurate designs, and it did not seem to bother him.

Agreeing that quick access to paper copies is an absolute requirement on the construction site, S1 underlined the importance of having an up-to-date and well organised archive at hand. The duty of keeping such an archive is, however, a strenuous task for a subcontractor, especially due to the high pace of revisions which need to be carefully sorted and disposed of.

Conclusions. Unlike the survey respondents, the interviewees did not express any concern regarding the availability of up-to-date information in the EDM. Instead they commented on the confusion caused by paper copies arriving a few days late, often only to be passed straight to the recycle bin. The use of email as a parallel channel of communication was described as inevitable, despite the fact that it adds to the complexity of the information management activities.

6.2.6 Process fit and estimated benefits

On a general level, the interviewees regarded EDM as useful. Yet none of the interviewees were capable of estimating personal, company specific or organisation wide benefits enabled by EDM use.

The architect. A1 spent a lot of her time receiving drawings from the designers hired by shopping centre end-users and integrating these into the main set of drawings. A few obstacles made this task rather labour intensive. First of all, the shopping centre end-users had been given access to a separate EDM instance, meaning that A1 essentially had to work with two different EDM projects simultaneously and was unable to move files from one instance to the other without downloading them to her computer and then uploading them to the other project. Second, many of the designers she worked with did not use the EDM at all, so she received much of the material by email. Third, she found the process of distributing drawings particularly exhausting, as she first had to produce a

number of PLT files from each DWG drawing, upload all these files to two different EDM instances, and finally email some of them to a number of recipients in DWG, PLT and PDF formats.

However, despite her criticism of the user interface, the folder structure, the overwhelming amount of paper produced, the delays related to paper distribution, and the labour-intensive distribution of drawings, A1 was firmly convinced that the Kamppi Center project could not have been successfully carried through within the schedule and budget specified without the help of EDM. Still, she believed the benefits would have been even bigger if the system had been easier to get started with (resulting in more adopters among her colleagues) and if the facility end-users and the designers hired by these had been integrated more tightly into the EDM processes (resulting in less double activities.)

The subcontractor. Despite his fairly narrow set of skills regarding the EDM tool, S1 was quick to embrace the concept of *just-in-time* information retrieval enabled by the software. He adopted the habit of checking the EDM for updates manually and printing out A4-size copies as an integral part of his work routines, and considered this a convenient and reliable way of knowing his crew is acting upon fresh information. Although he personally felt satisfied with the process support provided by the EDM, it is apparent that many manual steps could have been eliminated from his processes if he had only received automatic update notification emails. Again, this underlines the need for proper training – as suggested by O'Brien (2000), end-users aren't always capable of finding the most efficient ways to utilise IT tools.

S1 sometimes produced sketches or suggestions based on drawings printed out from the EDM and sent these back to technical designers by fax or email. He assumed that sending information back to the designers through the EDM system wouldn't have been of any noticeable benefit to him.

The city planners. C1 used the EDM as a source of information. Having access to drawings in the digital domain allowed her to minimise the amount of paper piling up in her office. However, it appeared that she could just as well have received the documents by email and might actually have preferred it that way, as the width and complexity of the EDM system mostly got her confused. Again, proper training would have helped her gain confidence regarding EDM use.

C2 produced considerable amounts of CAD drawings that she sent back to technical designers by email. With proper training she could have saved some extra steps by uploading her drawings to the EDM instead of sending them to multiple recipients. Not being able to upload, the potential of EDM benefit was not fulfilled.

Project management. Supervising the architectural design process, P1 was tightly involved in the flow of documents. As architectural offices produced new drawings or revisions, P1 reviewed them before approving the documents for release. Email played a prominent role in this process due to a policy decision banning unapproved documents from the EDM. The policy was intended to minimise the risk of someone acting upon unapproved data. Typically P1 received new design proposals as PDF attachments, inspected them on screen and notified the architects by email whether the drawings were approved for release or not. Once approved, the architect uploaded DWG and PLT copies of each new drawing to the EDM.

This appears as one area where processes could be more tightly integrated into the EDM. However, P1 did not consider the extensive use of email as a problem, and remained somewhat sceptical towards the suggestion that revisions awaiting approval could be uploaded to the EDM directly, and remain visible only to him until flagged as approved. He seemed to regard the use of email as considerably faster for this purpose.

Both P1 and P2 spent considerable amounts of time administering the distribution lists by which automatic copy orders were triggered for revised documents. However, P1 regarded the burden as insignificant if compared to the amount of work needed in projects where copy orders are produced and handled manually. Similarly he considered the cost of sending out perhaps excessive amounts of automatic copies as insignificant when compared to the cost savings achieved by not having to hire full-time document distribution assistants.

Conclusions regarding benefits. Over all, the interviewees assumed that EDM use had enabled significant savings in terms of time, in particular for information providers such as architects and technical design offices. Time saved thanks to the efficient means of document distribution translates into more time for other projects, and less costs for the client or project management.

Yet the processes described by the interviewees did not appear to be completely streamlined; information providers were still wasting considerable amounts of time on tedious tasks related to uploading files to the EDM and sending parallel copies by email. This indicates that there is plenty of room for development regarding integration of EDM into actual work routines and processes.

7 Discussion and conclusions

This study set out to explore attitudes towards EDM use from the perspective of individual end-users in a large construction project environment. Quantitative and qualitative research methods were used to examine how the challenges and benefits related to EDM based communication were perceived by users from different segments of the project group.

As EDM was used extensively throughout the entire construction project group, the case chosen proved to be a rich source of information on this topic. Roughly 330 users from 90 different organisations used the EDM system to exchange some 16,000 documents during the design and construction phases of the Kamppi Center project. The survey data obtained in the quantitative part of the study covered a satisfactory 50 % of all EDM users. In order to gain a deeper understanding of certain issues affecting end-user attitudes, the survey was followed by semi-structured interviews with representatives of different roles of the project group. Finally an expert with a strong background in the industry was asked to reflect on the empirical findings. His comments are included in the discussion below.

7.1 Case study findings

During the course of this study, numerous suggestions for improvements of the Raksanet EDM system and its implementation in the Kamppi Center project emerged. However, as many of these findings are highly specific to this particular EDM system, they are of limited scientific value and not reiterated here. The following summary focuses on more generic findings relating to the research questions of how end-users perceive the process of implementation and the benefits of EDM.

7.1.1 Implementation efforts

Roughly half of the users participating in the survey had no previous experience of EDM. This allowed the study to critically evaluate the effectiveness of implementation efforts provided by project management. Earlier EDM research stresses the importance of strong management commitment in planning, implementing and enforcing document management practices in construction projects. In the case studied, project management did indeed strongly promote the use of EDM, but nevertheless a large share of the end-

users received no training or guidelines whatsoever. Project management provided organised training for users joining the project at an early stage, assuming that later joiners would either receive sufficient support from colleagues or simply get started on their own. The EDM system vendor suggested that the system is so easy to use that virtually no training is needed, and project managers hoped that the structure of the contents would be rather self-explanatory.

However, the case study shows that these assumptions did not hold true. The lack of support resulted in a higher barrier to adoption especially among users with limited computer skills and, consequently, suboptimal utilisation of the technology available. Users unsatisfied with the training received appeared less confident regarding several aspects of EDM use than those who received satisfactory training. Findings of this study suggest that self-learning by trial-and-error is time consuming and viable only for users with good computer skills. Learning through workplace knowledge sharing, on the other hand, requires availability of colleagues experienced with the system – a requirement which isn't necessarily fulfilled in the dynamic setting of a project construction group.

Particularly those joining later on in the project reported problems in getting started, often quoting the complexity of the contents as one of the biggest challenges. This can be explained by the continuous growth of the information mass and folder structure over the course of the project. It also leads to the important finding that training efforts should not be limited to the technical aspects of using the EDM software, but also cover the document management principles employed in the project and explain the logic and structure of the EDM contents. Even experienced EDM users who already master the software tools should receive project-specific guidelines helping them come to terms with the structure and practices employed.

An expert interviewed suggested that the criticism of the content structure may indicate that a project of this size is already stretching the limits of what is feasible to manage through a single, static folder view of the information mass. His opinion was that a hybrid system combining the best practices of EDM with the object oriented principles of product model systems would significantly improve the accessibility and navigability of information, and thus reduce barriers to end-user adoption and reduce the time wasted using the system for simple tasks.

Regardless of the technology used, the findings of this study emphasise the need for providing formal, organised training and distributing guidelines to all EDM users across the project group. In targeting training efforts, project management should avoid the pitfall of focusing merely on the small group of heavy EDM users such as architects joining the project at an early stage. The numerous part-time users who may not get started on their own due to their short involvement in the process and lacking in-house experience should also be assisted as their adoption of EDM is of importance for project communication as a whole. The importance of widespread adoption is further discussed below.

7.1.2 Process fit and benefits

A reassuring majority of the users reported that the EDM system was of significant benefit throughout the project. Only one fifth of the respondents claimed they could've performed their part of the project just as easily or even easier without the help of EDM. This finding reinforces the results reported in earlier studies (e.g. Sulankivi et al 2002, Ruikar et al 2005) which suggest that a well implemented EDM system is far superior to traditional means of document exchange in project groups. Furthermore, findings indicate that the benefits of EDM aren't limited to the parties traditionally tightly involved in the information process (e.g. architects and technical designers.) While subcontractors were more sceptical regarding benefits of EDM than other groups at the outset of the project, they reported the biggest improvement in attitude at end of the project.

Despite the apparent satisfaction with the support provided by EDM, the case study findings indicate that the full potential of EDM was not achieved in this project. Studying the communication habits and work routines of individual users revealed a paradoxical situation: traditional, non-EDM means of communication such as e-mail and paper copies were considered important by a majority of the respondents, but simultaneously the use of parallel channels was reported as a significant source of frustration due to the redundant work and "information overload" caused. Information producers were faced with the burden of distributing documents in several formats by different means, and information users struggled to cope with the inflow of data arriving asynchronously over different channels. In other words, the envisioned ideal situation were EDM minimises copying costs, ensures that only the most recent revisions are available to information users, and reduces information overload by allowing users to fetch data just-in-time, was not achieved by far.

E-mail was used primarily because it was perceived as a faster and more convenient way of distributing documents than uploading to and downloading from the EDM. EDM use was considered time-consuming in part due to technical reasons, in part due to the complexity of the contents. Information producers were also forced to use e-mail when communicating with participants who had not adopted EDM at all. More efficient training could have increased the share of EDM adopters and reduced the perceived complexity of using the system, thus reducing the need for using parallel channels of communication, which in turn would reduce the burden on both information producers and information users.

However, as long as EDM is less convenient than other methods of communication, certain project parties will lack motivation to use EDM since they receive no benefits from it. The expert interviewed suggested that project management could define explicit goals regarding the degree to which EDM should be used, and use metrics to monitor how well project participants follow the stipulated document management principles. Compliance could be rewarded monetarily, thus distributing the benefits of EDM more evenly across the project group.

7.2 Model proposal

In an attempt to integrate the findings of this study with existing literature, a model describing the key factors affecting end-user attitudes towards EDM adoption in project work is proposed. The model, shown in figure 31 below, draws on insight from earlier studies of EDM enabled projects (e.g. Sulankivi et al 2002, Ruikar et al 2005), generic theories on technology acceptance (e.g Venkatesh et al 2003, Rogers 2003) and success of information systems (DeLone & McLean 2003).

The core constructs predicting adoption are borrowed from the Unified Theory of Use and Adoption of Technology (Venkatesh et al 2003). These are *effort expectancy* (perceived effort needed to use the system), *performance expectancy* (perceived usefulness or benefit of using it), *social influence* (influence from others) and *facilitating conditions* (technological and organisational factors including training and support.

Based on empirical findings, the proposed model suggests that these four factors are influenced by:

- *service properties*
- *end-user properties*, which can be divided into
    - individual properties (relating to the individual end-users)
    - company properties (referring to the different companies participating)

In the model which is shown below, the properties related to the service offering are shown on the left-hand side. These are largely under influence by project management and the EDM system provider. The right-hand side of the model represent the end-user perspective. These end-user factors are divided into individual properties such as skills, innovation personality type and involvement in the information process, and company properties which refer to the different companies participating in the construction project group.

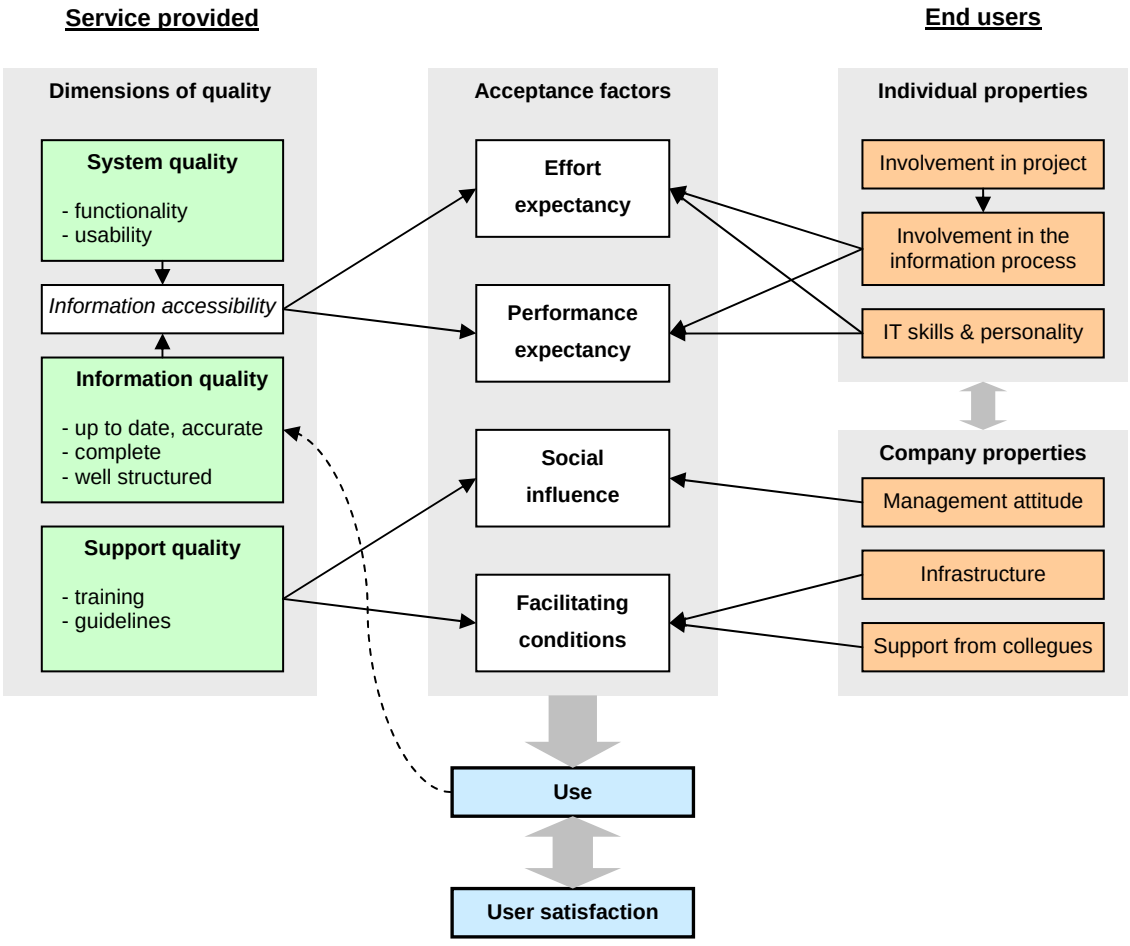


Figure 31 Factors influencing EDM adoption and end-user attitudes in project groups

The dashed connection running from *use* to *information quality* illustrates the role played by end-users in creating and maintaining the actual contents of the system.

7.2.1 Service properties

The three dimensions of quality borrowed from the Updated IS Success Model (DeLone & McLean 2003) are used to structure factors describing to the service provided. *System quality* refers to the technical properties of the system, *information quality* to the data processed within the system, and *support quality* refers to the facilitating resources provided.

Information and system quality. Whereas system quality aspects such as functionality and usability often are regarded as key enablers of usefulness and ease of use, the proposed model suggests that information quality is equally important a driver behind effort and performance expectancy. With the findings of this study in mind, the proposed model defines information quality as the degree to which the EDM contents are:

- up to date
- accurate
- complete (i.e. all necessary information is available in the EDM)
- properly structured and meta-tagged

However, well-structured and accurate information is not the sole key to EDM success. Proper system functionality and usability are required to make the information mass accessible to the users. Thus, the proposed model includes a construct labelled *information accessibility* as a measure of the degree to which the system gives users easy access to valid and relevant information – i.e. how it fulfils the ultimate purpose of EDM.

Support quality. The empirical findings of this study underline the need for two different types of support:

- *software training* – relating to the mechanical aspects of using the system, ensuring that users are aware of the functionality available
- *project specific guidelines* – relating to the contents of the system, ensuring that users understand how the structure and contents of the EDM relate to the document management practices used in the project

While end-users already familiar with the EDM software may need no mechanical training, the findings of this study confirm suggestions presented in earlier research, emphasising the need for project specific guidelines.

7.2.2 End-user properties

Section 2.1 described construction organisations as temporary and dynamic groups of people from a wide range of professions, where the degree, type and length of involvement in the project vary from company to company and from person to person. The model suggests that certain company specific and end-user specific properties affect adoption. One of the most important factors relates to the end-user's position and *involvement in the information process*. Other user specific properties included in the model are *ICT skills* and *innovation personality type*. Company specific properties included are *infrastructure* and *support from local management* and *colleagues.* In the following, these issues are discussed from a UTAUT adoption factor perspective.

Performance expectancy. An ICT system doesn't necessarily bring equal benefits to or require equal efforts from all parties in a multi-organisational project group. In the case of EDM in construction, the client benefits from reduced costs, fewer errors and tighter schedules (Sulankivi 2002), while other segments of the project group may see no evident benefits but rather an increased burden. Consequently performance expectancy, i.e. the end-user's belief that using the EDM system will be of benefit in performing his work, depends largely on the degree to which the user participates in the information process of the construction project. A project participant who only sporadically interacts with the information process may not see any particular benefit of EDM, while a heavy information user may benefit significantly.

Effort expectancy. The end-user's position within the information process does not only affect the usefulness of an EDM system, but also the efforts involved in learning and using it. Information providers (e.g. architects) and information users (e.g. subcontractors) utilise an EDM system in remarkably different ways. Information providers bear responsibility for maintaining information quality which translates to extra efforts regarding detailed meta-data input etc. Information users, on the other hand, reap the benefits as meta-data allow them to quickly find the documents they are looking for. Other variances in effort expectancy emerge from the heterogeneous nature of the project organisation. As mentioned earlier, the individual degree of involvement varies across the project group. Users who simultaneously participate in several different construction project groups face the challenge of working with different document management guidelines and systems. It can be hypothesised that this translates to a higher degree of effort expectancy.

Social influence. Previous EDM research (e.g Sulankivi 2002) mentions strong management commitment as a prerequisite for successful EDM implementation in construction projects. In order to maximise the benefits of EDM, adoption should be mandatory. In the terminology of Gallivan (2001) this calls for a total commitment adoption strategy, which enforces adoption among the actual end-users. Yet participants of a construction project may prioritise their own goals over those of the main contractor or client, indicating that the authority of project management isn't always sufficient (Löwnertz 1998). Presumably the mandate to adopt the EDM system will not be perceived as equally important across the entire project group, and the attitude of management in the participating companies will impact the individual end-users' eagerness to adopt project-specific EDM.

Facilitating conditions. While factors such as training, guidelines and support often are provided for by project management or the EDM system provider, the heterogeneous nature of construction project groups still causes variance among the participants. For one, the ICT skills and technological infrastructure available may vary significantly between participating companies. Furthermore the support available from colleagues will be greater in larger organisations with a longer history of EDM use.

7.2.3 Conclusions

The proposed model builds on the theoretical adoption framework of Venkatesh et al (2003) and attempts to show that adoption factors are influenced in part by properties of the service provided and in part by properties of the end-users. Key service properties include system quality and information quality, as well as availability of support resources which are divided into technical training and project-specific guidelines. On the end-user side, the individual's involvement in the information process is a key factor affecting effort and performance expectancy. Furthermore the model highlights that individual end-users are subjected to social influences and facilitating conditions originating not only from project management but also from their employing organisations.

7.3 Limitations of the study

An obvious limitation of the study is that data was collected from only one construction project. The findings are presumably coloured by the unique properties of the case studied. This is further accentuated by the fact that many of the respondents were first-time EDM users; their attitudes towards the technology are entirely based on their experience

with the particular EDM software chosen for the Kamppi Center project. Furthermore it should be noted that many of the challenges identified are related to the size and complexity of the construction project. Consequently, the general applicability of the results of this case study is limited.

Another unfortunate limitation was that an interesting segment of EDM users – facility end users and the interior designers hired by these – was almost entirely omitted from the study due to lacking communication between project management and the researcher. Any references to the facility end user group in the quantitative part of this study should be treated with care as the number of respondents was very low in this segment. A further limitation of the quantitative data relates to the coarse scales used, reducing the reliability of results. The questionnaire was designed to be as simple as possible in order to obtain a satisfactory response rate. In retrospect, one could argue that a slightly more detailed questionnaire, perhaps at the expense of response rate, would have been a worthwhile trade-off.

It should also be noted that the proposed model which describes factors affecting end-user adoption and attitudes in project groups has not been tested statistically. The quantitative data obtained in the survey was not detailed or broad enough to allow for testing. As such, the model is a synthesis of previous research and qualitative analysis of the empirical findings of this study.

7.4 Suggestions for further research

In order to validate or refine the proposed model of factors affecting end user adoption of EDM, further research could attempt to apply the model on a series of case studies.

Appendix A

Questionnaire content

The questionnaire is summarised in the table below. The scales used and factors measured are indicated for each question.

Question	Scale	Factors
Personal background		
Q1 Age	– 25 / 26 – 35 / 36 – 45 / 46 – 55 / 56 –	
Q2 Length of involvement in this project	Half a year / 1 year / 2 years / 3 or more	
Q3 % of work hours devoted to this project	Full-time / 75 % / 50 % / 25 % or less	
EDM background		
Q4 Prior to the Kamppi project, I had used EDM...	Never / in 1-4 projects / in 5 or more projects	Computer literacy
Q5 At the outset of the project, I was sceptical about the benefits of EDM	4 point Likert	Performance expectancy
Training		
Q6 Upon joining the project, I felt that I needed training regarding EDM use.	4 point Likert	Support quality, Facilitating conditions
Q7 The training I received was sufficient.	4 point Likert / “No training received”	Support quality, Facilitating conditions
Support		
Q8 If I need help regarding EDM use, I know whom to ask	4 point Likert	Support quality, Facilitating conditions
Q9 I've received help quickly and with little effort	4 point Likert / “No experience”	Support quality, Facilitating conditions
Guidelines and routines		
Q10 I've received clear and detailed guidelines regarding management of drawings	4 point Likert	Support quality, Facilitating conditions
Q11 EDM-based work routines suit me well	4 point Likert	Performance expectancy
Information quality / using the system		
Q12 I feel confident that the latest versions of drawings and documents are available in the EDM.	4 point Likert	Information quality Performance expectancy
Q13 The folder structure is well designed, making it easy to find the right folder despite the extensive amount of information.	4 point Likert	Information quality Effort expectancy
Q14 Storing and finding/retrieving files is quick and easy	4 point Likert	System quality Effort expectancy

Q15	There have been a lot of technical problems in using the system.	4 point Likert	System quality Effort expectancy
Q16	I prefer watching/reading drawings and text on paper rather than on screen	4 point Likert	Intention to use Effort expectancy
Q17	Email, facsimile, courier etc are still important methods of sending drawings within the project group	4 point Likert	Intention to use
Overall impression			
Q18	The company or organisation that I represent could have perfomed its tasks just as easy - or even easier - without the use of EDM	4 point Likert	Perfomance expectancy User satisfaction
Q19	My attitude towards EDM has changed for the better due to this project	4 point Likert	User satisfaction
Q20	Voluntary comment about using the system	Free-text	User satisfaction

Web questionnaire layout

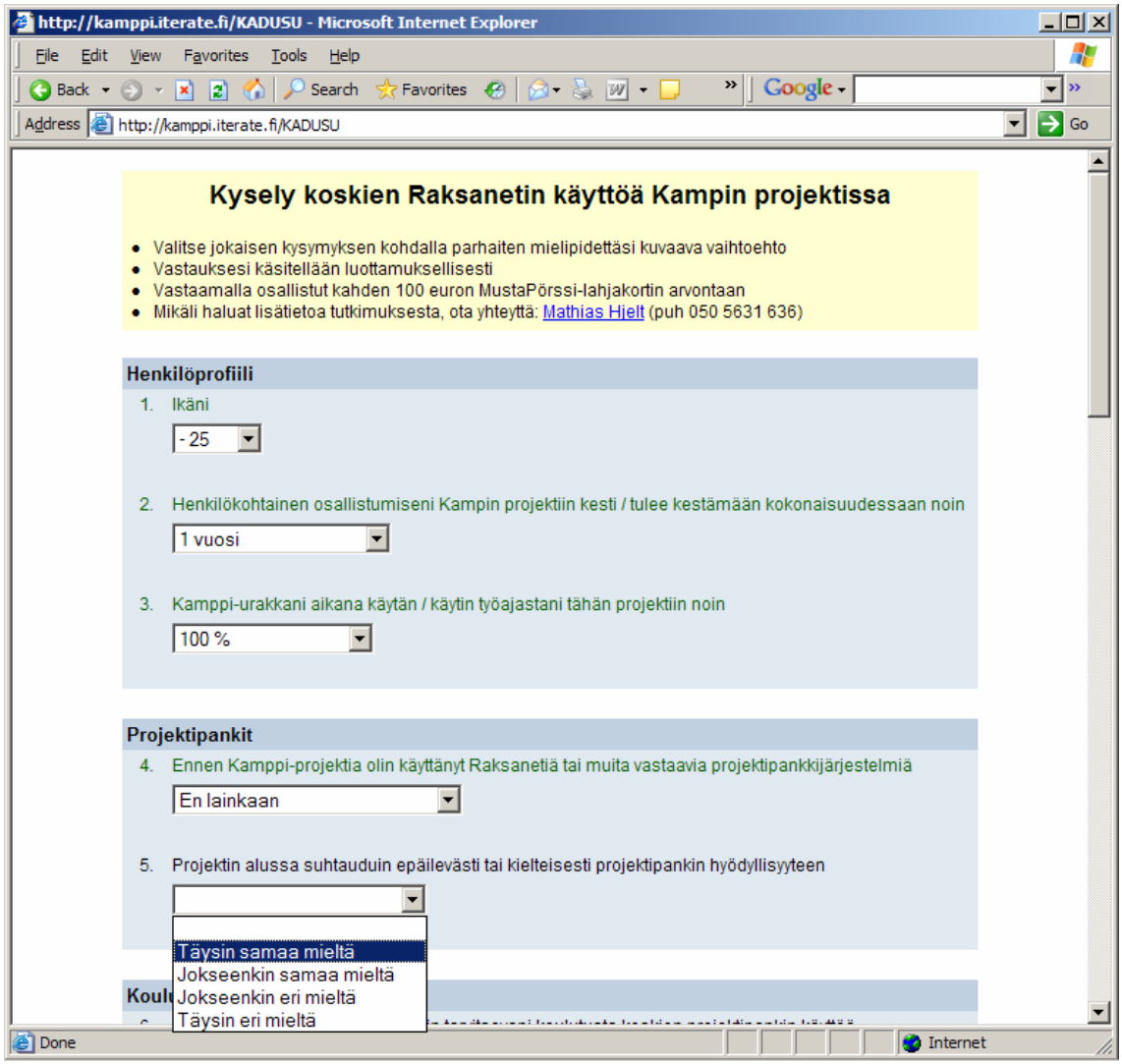


Figure 32 Screenshot of online questionnaire

Appendix B

Interview themes

Respondent background

- company's role within the Kamppi project?
- your role within the company?
- when did you join? did you work fulltime or part-time with this?

Implementation

- how did you react when you heard Raksanet will be used for EDM?
- what kind of experience with EDM did you have from previous projects?
- training and guidelines:
    - what kind of training was arranged?
        - was it suitable for you?
    - what about guidelines?
        - did you have a chance to comment on the folder structure, work procedures etc?
- how well did you get started?

Process view

- how did EDM fit into your work processes and routines – was it an extra burden or did it help you in your work?
- did you use other channels such as email? when / why? on your initiative or someone else's?
- do you feel that other parties involved in the processes have been able / eager to utilise EDM?
- staying up-to-date
    - automtaic copies – suitably / too little / too much?
    - email update notifications?

Technology

- functionality:
    - did you use the search feature? any comments on that?
    - did you order paper copies? any comments on that?
- any problems? how have you solved them?

Discussion

- do you think benefits are spread evenly across the project organisation?
- did EDM use leave you with a positive or negative feeling?
- what improvements would you suggest in order to benefit more from EDM?
    - in technology / functionality?
    - in training?
    - work routines / processes?

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References

Cited publications

Andresen, J., Christensen, K., Howard, R. (2003): Project Management with a Project Web. *Electronic Journal of Information Technology in Construction* (ITcon), Vol 8, *http://www.itcon.org/2003/3*, pp 29

Björk, B.-C. (1999): Information Technology in Construction – domain definition and research issues. *International Journal for Computer Integrared Design and Construction.* Vol 1, Issue 1, 1999

Björk, B.-C. (2001): Document Management – a key IT technology for the construction industry. *Information and Communications Technology in the Practice of Building and Civil Englineering*. 2nd worldwide ECCE Symposium, Espoo, Finland 6-8.6.2001, Association of Finnish Civil Engineers, Helsinki.

Björk, B.-C. (2003): Electronic Document Management in Construction – Research Issues and Results. *Electronic Journal of Information Technology in Construction* (ITcon), Vol 8, *http://www.itcon.org/2003/9*, pp 105

Bäckblom, M., Ruohtula, A., and Björk, B. (2003): Use of document management systems - a case study of the Finnish construction industry. *Electronic Journal of Information Technology in Construction (ITcon*) Vol. 8, Special Issue eWork and eBusiness, *http://www.itcon.org/2003/26*, pp 367

Degerstedt (2000): Inventering och utvärdering av elektroniska dokumenthanteringssystem i byggprocessen. M.Sc. Thesis, Royal Institute of Technology, Construction and management Economics, Stockholm.

DeLone, W., McLean E (2003): The DeLone and McLean Model of Information Systems Success: A Ten-Year Update. *Journal of Management Information Systems.* Spring 2003, vol. 19, no. 4, pp 9-30

Eisenhardt, K. (1989): Building theories from case study research. *Academy of Management Review*. Vol 14 (4) pp 532-550

Gallivan, M (2001): Organizational adoption and assimilation of complex technological innovations: Development and application of a new framework. *Database for Advances in Information Systems.* Summer 2001, vol. 32, no. 3.

Hartvig, S. (2001): *Evaluation Criteria for Project Webs.* Working paper, March 2001, unpublished. Technical University of Denmark.

Johansson, C., Löwnertz, K., Lindgren, N., Björk, B.-C. (1995): *Datorstödd hantering av dokument i bygg- och förvaltningsprocessen.* Rapport, Byggandets informationsteknologi, Kungl tekniska högskolan, och CITB, Chalmers tekniska högskola, Stockholm.

Kankainen, J. & Junnonen J.-M. (2001): *Rakennuttaminen.* Rakennustieto Oy, Tampere.

Koskela, L., Kazi, S. (2001): *Information Technology in Construction: How to realise the benefits.* Working paper, Technical Research Centre of Finland.

Lakka, A., Sulankivi, K., Luedke, M. (2001): *Features and Capabilities in the Concurrent Engineering Environment.* VTT Publications.

Lundahl, U. & Skärvad, P-H. (1999): *Utredningsmetodik för samhällsvetare och ekonomer.* 3rd ed. Stockholm.

Löwnertz, K. (1998): *Change and Exchange – Electronic document management in building design.* Licentiate Thesis, Royal Institute of Technology, Construction and management Economics, Stockholm.

O'Brien, W (2000): Implementation Issues in Project Web-Sites: A Practitioner's Viewpoint. *ASCE Journal of Management in Engineering.* May 2000, 16(3), pp 34

Pinsonneault, A. & Kraemer, K. (1993): Survey research methodology in management information systems: an assessment. *Journal of Management Information Systems.* Vol. 10 (2), pp 75-105

Rogers, E. (2003): *Diffusion of Innovations.* 5th ed. Free Press, New York.

Ruikar, K., Anumba, C.J., Carrillo, P.M. (2005): *End-user perspectives on use of project extranets in construction organisations.* Engineering, Construction and Architectural Management. Vol. 12, no. 3, pp 222-235.

Ruohtula, A. (2003): *Electronic Document Management Systems in Project Work – A Case Study.* M Sc Thesis, Svenska handelshögskolan.

Sulankivi, K., Lakka, A. & Luedke, M. (2002): *Projektin hallinta sähköisen tiedonsiirron ympäristössä*. VTT Publications.

Thorpe, T., Mead, S. (2001): Project-Specific Web Sites: Friend or Foe? *Journal of Construction Engineering and Management.* Sep-Oct 2001.

Venkatesh, V., Morris, M., Davis, G., Davis, F. (2003): User Acceptance of Information Technology: Toward a Unified View. *MIS Quarterly Vol 27 No 3.* Sept 2003

Vuorela, K., Urpola, J., Kankainen, J. (2001): *Johdatus rakennutamistalouteen.* Otamedia Oy.

Expert interviews

Jyrälä, J., Director of marketing, BuilderCom Oy (2005)

Kuokkanen, J., Founding partner of Raksanet (2005 and 2006)

Harmaajärvi, R. Director of planning, SRV Viitoset (2005)