AN EVALUATION MODEL FOR ICT INVESTMENTS IN CONSTRUCTION PROJECTS

REVISED:

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SUMMARY: Even though Information and Communication Technology (ICT) investments in construction projects generally represent minor commitments of project resources by comparison to the full project cost, it have serious consequences on the profitability. Despite this, many of the investment decisions are poorly thought through or examined. Taken during the procurement phase often merely based on intuition and rough estimations of the future costs and risks. Also, many of the traditionally used appraisal approaches have been shown inadequate in anticipating the consequences of such an investment. As a result, the investment is too often assumed to be negative since the benefits are not proper evaluated, included and weighted against the costs and risks the investment is expected to generate. Poor decision-basis does not only affect the actual decision-making in a particular project but also, in the long run, the motivation to innovate and to introduce new ICT tools and working methods into the construction industry.

In view of this, a new project-oriented evaluation model is developed for the purpose to provide for a structure and a work routine to be used by a multidisciplinary project team to evaluate the implications of realizing ICT investments in construction projects. Although primarily aimed at establishing future benefits and costs the model may very well be used for follow-ups. The models' application is illustrated using a case study.

KEYWORDS: Benefits, Construction project, Costs, Evaluation, ICT, Investment, Virtual Reality.

1. INTRODUCTION

Information and Communication Technology (ICT) has been widely applied across many sectors in order to increase competitiveness and reduce costs (e.g. Marsh et al 2000), and is today seen as a vehicle to gain a competitive advantage (Ives et al 1991, Earl 1993). The average annual growth rate of ICT investment in the construction industry is increasing every year and constitutes now a significant part of the total project cost. However, some studies indicate that the ICT utilization ratio is still relatively low in the construction industry. For example, a comprehensive study within the EU project InPro (Open Information Environment for Knowledge-based Collaborative Processes throughout the Lifecycle of a Building), which investigated the use of ICT tools in the European construction industry (InPro internal report D2, 2007), revealed a lack of use of ICT tools in construction projects, especially in the early stages, despite several good alternatives available. Some of the main causes for this were suggested to be deficient understanding and lack of knowledge about the possibilities of ICT, unsuccessful implementation into project organizations and limitations of software functionality. Another reason is most likely that construction companies often find it difficult to justify ICT investments in an industry that suffers from low profit margin (Alshawi et al 2003) and that many managers often view ICT investments as a process of consumption rather than capital expenditure (Irani et al 2002) and do not realize the importance of evaluating the IT investment (Willcocks et al 1997). Moreover, the traditional approaches to evaluate investments have been shown inadequate (e.g. Peacock et al 2005, Love et al 2001, Andresen 1999, Irani et al 1999, Shank et al 1992). DeLone et al (1992) argues that commonly used benefit and cost analyses are often found lacking due to difficulty of quantifying intangible benefits. The lack of effective evaluation models does not only have an influence on individual projects but also, in the long run, the motivation to innovate and introduce new ICT tools in the construction industry.

The main purposes of using ICT in construction projects are to improve operational efficiency of an organization, to improve quality and to reduce project time and to increase profit levels (Gunasekaran et al 2001). Intangible effects could be sustainable competitive advantage (e.g. Barney 1991, Powell et al 1997, Henderson et al 1999), better project control and understanding, marketing, customer service, et cetera. Carefully evaluated and considered ICT investments with established objectives can boost an organization forward with the increased likelihood to achieve successful implementation and improved project performance while reducing costs. Equally, poor investments, those that are inadequately justified or whose costs, risks, and benefits are poorly managed can hinder and even restrict an organization's performance (GAO 1997). The effects associated with an ICT investment are uncertain and difficult to measure (Ekström et al 2003) and the benefits and value of IT investments are being questioned by researchers and practitioners (Dadayan 2006). However, a great number of researchers have shown the values of using ICT in construction projects (e.g. Dawood et al 2005, Bouchlaghem et al 2005, Fischer et al 2004, Björk 2001).

The process of investment justification has been identified as a major barrier to implementing ICT (Love et al 2000, Andresen et al 2000, CIRIA 1996, Enzweiler 1996) and because of the growing concern about the effectiveness of information systems expenditure there is an increasing need to re-think approaches to the evaluation of information systems in order to demonstrate business benefits from these investments (Remenyi et al 1999).

2. EVALUATING ICT INVESTMENTS

ICT systems are multidimensional constructs requiring multiple measures to evaluate (Etezadi-Amoli et al 1996, DeLone et al 1992). Any major ICT investment must be preceded by a careful evaluation of its direct and indirect benefits and costs (Gyampoh-Vidogah et al 1999). Farbey et al (1999a) defined the evaluation process as "a process that takes place at different points in time or continuously, for searching for and making explicit all impacts of an IT project." Willcocks et al (1996) define ICT investment evaluation as "Taking a management perspective, evaluation is about establishing by quantitative and/or qualitative means the worth of ICT to the organization." According to Farbey (1992), the evaluation is envisaged to serve different objectives, such as:

1. Being used as a part of the process of justification of a system;
2. To enable an organization to make comparisons between different projects competing for resources;
3. To provide a set of measures that enables the organization to exercise control over the project.

Moreover, evaluation and the subsequent measurement and comparison with actual achievements will provide the learning experience which is necessary if the organization is to improve its system evaluation procedures and development capability.

Evaluation and justification of ICT investments is a complicated process, not only in the construction industry but also in all major industries, since cost and benefits associated with the investment are uncertain and difficult to measure (Ekström et al 2003). Early estimates, in general, are typically plagued by limited scope definition and are often prepared under time pressure (Trost et al 2003). Traditionally, specialists in different areas have been engaged in the task of evaluating the benefits and costs of future ICT investments. Many times these specialists have little or no knowledge of the overall consequence of the investment. Andresen et al (2000) describe the IT managers' large influence on the selection of data management systems on which the senior management uses to support their decision making. Specialists such as IT managers have mostly poor understanding of the company's overall business goals and are often excluded from the decision-making process. The senior management on the other hand is well acquainted with the company's business but has little insight into the fast-changing ICT development and often lacks feedback from previous strategic ICT projects. Anandarajan et al (1999) pointed out the influence of the accountants in ICT investment decisions. They usually focus on analyses that can be measured in monitory terms but lack insight into the effects on the work processes. Instead of making the analysis of ICT investment the task of a specific profession, general methods and tools should be developed to assist the decision-making process. Even though substantial efforts have been made to develop such evaluation methods (e.g. Sacks 2004, Sethi et al 1994, Chismar et al 1985) there is still room for improvements.

There are several methods available for evaluating ICT investments spanning from simple computational formulas to complex techniques that comprise both quantitative and qualitative attributes. Traditional early investment appraisal methods, such as Cost Benefit Analysis (CBA), generates non-discounted estimate of benefits and costs, i.e. the cash flow, that the investment is expected to generate. Both the Discounted Cash Flow (DCF) and the Net Present Value (NPV) method calculate the net cost of the investment in monetary terms. The Internal Rate of Return (IRR) method calculates the discount rate where NPV is set to zero. NPV and IRR are basically used for the same purpose and can be viewed as complementary methods for the purpose of evaluation. Conducted correctly the IRR and NPV methods should give in an equal estimation of the effect of the investment. One of the most popular methods to use when comparing different ICT investments is the Return on Investment (ROI) method which measures how effectively a business uses its capital to generate profit – the higher the ROI the more profit.

The above-mentioned methods are well-established and relatively easy to use. However, many users argue that these methods are difficult to apply in estimations of ICT investment (Kumar 2000), probably due to an insufficient identification and evaluation process of benefits and costs (Powell 1992). Other criticism against these methods are that they fail to grasp the impact on the construction process and organization and fail to capture hidden costs, intangible benefits (Love 2006) and risks (Anandarajan, 1999). Andresen et al (2000) argues that more complex methods, such as Information Economics (IE) and Return On Management (ROM), have failed to be put into practice in the construction industry because of three main reasons: there is little awareness of the methods; the methods requires large operation requirements; and, the methods need to improve.

Despite the range of different evaluation alternatives little practical use has been made of these (Bannister et al 2000, Farbey et al, 1999b, Smithson et al 1998). Slow adoption can depend on several factors, e.g. inadequate methods – as discussed above; the methods are costly and require staff with special skills; or organizational culture (Brown 2005). Andresen et al (2000) and Marsh et al (2000) argue that the problems most likely are due to construction industry's structure and undercapitalization.

In order to address this above-mentioned deficiency, a new evaluation model is presented in the next section. The intention is to develop an easily-understandable and easily-comprehensible tool which would help the users understand the implications of an ICT investment in a construction project. To support a development towards practical applicability, the model has been applied to evaluate how Virtual Reality (VR) models have facilitated the design process in the large-scale construction project. Focus was on applicability, to establish whether or not it is a valid approach and, of course, to evaluate the implications from using VR models. The evaluation was carried out from a project perspective. The result was twofold. The evaluation model was considered highly applicable and valid approach and the net benefit from using VR in the design process was demonstrated.

3. THE ICT INVESTMENT EVALUATION MODEL

This paper presents a new evaluation model. The model is intended to provide for a structure and a work routine to be used by a multi-disciplinary working team throughout the process of assessing, planning for and managing the implementation, utilization and follow up of an ICT investment in a project organization. The evaluation presents a gross result. Benefit and cost variables are categorized, quantified in monetary terms and classified, depending on the likelihood of their happening. The model differs from most other financial evaluation tools since it is project-oriented and includes intangible benefits, such as process and information quality – which often provides a significant contribution to the final result. Other features include for example risk assessment. Besides presenting a monetary result, the process of carrying out the evaluation also helps the participants to obtain a clear insight into the characteristics and potential of the ICT tool in question as well as the processes and other tools of the project.

The predefined benefit category structure and variable list is an extension of DeLone's and McLean's theoretical framework ISS model from 1992 (Lindfors 2003, DeLone and McLean 1992). The proposed evaluation procedure and risk handling are inspired by the PENG model (Dahlgren et al. 1997). The PENG model has become a popular method in Sweden for evaluating IT investments in companies and organizations. The main difference is that the model proposed in this paper is project oriented and ICT investment "specific". In addition, in the PENG model, the benefit and cost variables and category structure are established by the evaluation group, which means that every evaluation is unique in its disposition, whereas the proposed model provides a predefined structure. I believe that the combination of a pragmatic evaluation procedure and a predefined category structure and variable list makes it easier for users to identify, evaluate and secure not only the tangible benefits and costs but also the intangible and hidden effects of realizing the investment proposal. I also believe that this combination facilitates the implementation process, follow-ups, the re-use of knowledge and the information process as a whole.

3.1 Basic assumptions

The proposed model is intended to be used in construction projects by multi-disciplinary evaluation teams before an ICT innovation is implemented, during its implementation and afterwards when the results can be assessed. The primary objectives for using the evaluation model are to:

- Facilitate for organizations to justify an ICT investment;
- Facilitate for managers and users to reach a better understanding of the impact of an ICT investment on organizational performance - which can help the organization utilize its resources better (Clemons 1991);
- Facilitate for managers and users to plan for, monitor and accomplish benefit realization as well as identify potential further benefits;
- Facilitate for managers and users to handle and restrict risk and costs associated with benefit realization; and
- Facilitate for managers and users to gather data for benchmarks that later can be used to provide a measure of the actual implementation success of the ICT investment (Farbey et al 1992).

The proposed model assumes that all benefits and costs – tangible as well as intangible – can be identified, categorized and measured in monetary terms and that all costs are incurred within the project and all returns (read: benefits) are received by the project.

The results from using the evaluation model will provide identification, categorized and classification of:

- Benefits that are expected to arise during and after the construction project life cycle. The benefit variables are predefined and structured into seven categories: 'System quality', 'Process quality', 'Information quality', 'System use', 'User satisfaction', 'Individual impact' and 'Project impact'; and
- Costs that are expected to arise during the construction project life cycle and that are generated as a result from the implementation and use of the ICT tool in the construction project. The cost variables are predefined and structured in two categories: 'Investment costs' and 'Operational costs'.

The model also assesses diffuse and intangible factors making them visible and traceable. However, many of these benefits or costs are hard to estimate and must be classified as risky.

As the costs and benefits associated with the ICT investment influence the project result, the decision to evaluate should involve the owner of the project and the affected stakeholders preferable prior to the procurement procedure.

4. THE EVALUATION MODEL FRAMEWORK AND PROCESS

The evaluation process is a joint effort between the project stakeholders which is characterized by a series of activities that vary in scope and intensity depending on the nature of the investment being evaluated. The activities are divided into three main phases:

1. Prepare
2. Analyze
3. Secure

4.1 Prepare

The first phase of the evaluation process – "Prepare" – includes identifying the scope of the evaluation, establishing a multidisciplinary evaluation team and getting the management involved. The preparation phase answer questions such as:

- What type of IC investment is to be evaluated?
- What is the purpose?
- Which stakeholders will be affected by the investment?

The preparation phase is necessary for establishing a multi-disciplinary group of people with a designated evaluation leader who possess the competence to assess the ICT investment – system functionality, effects on the multi-disciplinary work routines, et cetera. The first tasks for the evaluation team is to define scope and aim, describe the IT investment - its purpose and effect, collect knowledge of previous use, establish evaluation plan as well as setting up evaluation identification and history including (proposed guideline):

Evaluation ID - Set unique integer sequence number identifier, alt. use a hierarchical form: X.Y. Group related evaluations in the hierarchy.

Evaluation Name - State a concise and results-oriented name for the evaluation.

Evaluation History - Document created by; date created; last updated by; date last updated.

This phase also involves notifying the strategic, tactical and operational expectation of the ICT investment to the project organization's immediate stakeholders and to involve the decision-makers therein. A go/no-go decision is made by the project owner about whether to proceed with the evaluation or not (see Fig. 1).

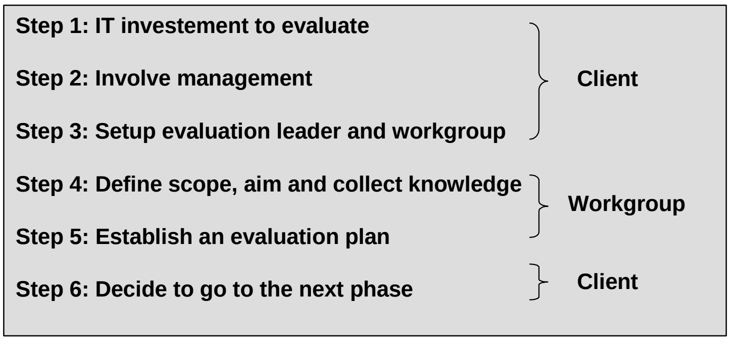

FIG. 1: Steps in the preparation phase.

4.2 Analyze

When a decision is taken to continue the evaluation process, the team proceeds to establish three sets of checklists in order to identify, quantify and classify benefits and cost as well as identify and handle the risks.

4.2.1 Benefit assessment

The expected project benefits from realizing an ICT investment are identified, structured and quantified using the theoretical framework Information System Success Model (ISSM) presented by Lindfors (2003), see Fig. 2. The proposed ISS model is an extension of the DeLone and McLean ISS model from 1992 (Lindfors 2003, DeLone et al 1992).

Benefits refer to all positive returns of an ICT investment.

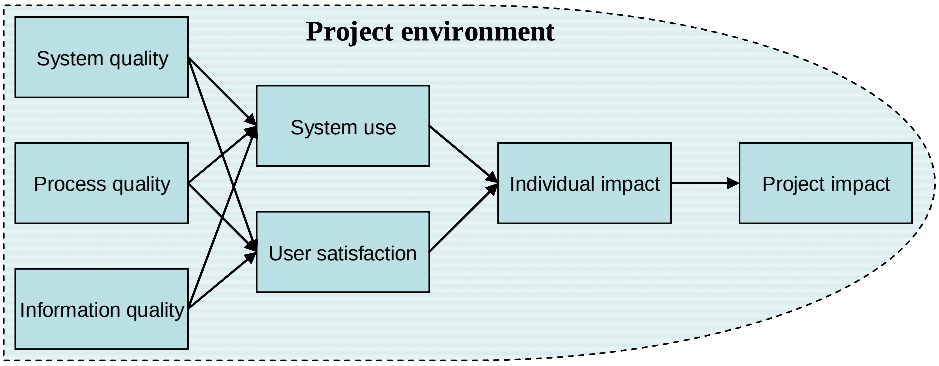

FIG. 2: The extended ISS model in a project environment (Lindfors 2003).

The DeLone and McLean ISS model from 1992 derives from Shannon's (1948) and Shannon and Weaver's (1949) initiative relating to the theory of communication and Mason's (1978) work on information influence theory (Lindfors 2003). It is basically a mathematical approach to the theory of communication where an information system acts as the information source that is sending information through a system to a recipient. It is divided into three basic levels; first, a technical level that represents the accuracy and efficiency of the system; second, a semantic level that addresses the success in conveying the message and, third, an effectiveness level which measures the effect the information has on the recipient, see Table 1.

Source	**Categories**						
Shannon and Weaver (1949)	Technical level		Semantic level	Effectiveness or influence			
Mason (1978)	Production		Product	Receipt	Influence on recipient		Influence on system
DeLone and McLean (1992)	System quality		Information quality	System use	User satisfaction	Individual impact	Project/organisational impact
Lindfors (2003)	System quality	Process quality	Informati on quality	System use	User satisfaction	Individual impact	Project/organisational impact

TABLE 1: Categories of Information System Success (Lindfors 2003, DeLone et al 1992).

Mason (1978) adopted this theory and revised it according to a product-oriented approach. Instead of effectiveness or influence, Mason presented the categories of receipt of information, influence on receipt and influence on system, also renaming the technical level and semantic level the product and production level (Lindfors 2003). Following the basic approach of assessing the value of a system, numerous researchers have created different models from various viewpoints. DeLone and McLean reviewed these previous studies and developed their taxonomy using six major dimensions of categories of information system success: System quality; Information quality; System use; User satisfaction; Individual impact and Project/organizational impact (DeLone and McLean 1992). Based on both process and causal considerations, it is proposed that these six dimensions of success are interrelated rather than independent (DeLone and McLean 2003). Lindfors (2003) extended this model to include measures for the perceived quality of the information management process (in Table 1). Each of the categories in Table 1 consists of a number of variables that recognize the effects according to (DeLone and McLean 1992).

- **System quality** – effect on the information system itself which produces the information
- **Information quality** – accuracy, meaningfulness and timeliness of the information produced
- **System use –** use of the information system
- **User satisfaction** – interaction of the information system with its recipients: users and project owner
- **Individual impact** – influence on management decisions
- **Project/organizational impact** – effect on organizational performance
- **Process quality** – effect on information management process quality (Lindfors 2003).

Lindfors (2003) argues that it is essential to adopt a more project- and process-oriented evaluation approach because of the nature of construction projects. By being able to link the impact of a future information system to a structure of predefined quality variables, Table 2, a deeper level of understanding can be brought to the evaluation process.

System quality variables	Process quality variables	Information quality variables	System use variables
Database content Ease of use Ease of learning Convenience of access Usefulness of system features and functions System flexibility System reliability Integration of systems System efficiency Response time	Information development Information acquisition Information identification Information preservation Information utilisation Information dissemination	Relevance of information Usefulness Usableness Understandability Clarity Format Content Accuracy Sufficiency Completeness Reliability Timeliness	Frequency of report request Appropriate use Purpose of use Number of reports generated Regulatory of use Amount of connect time Frequency of access
User satisfaction variables	Participant impact variables	Project impact variables	
Software satisfaction Decision-making satisfaction Satisfaction with specifics Information satisfaction Overall satisfaction	Information understanding Learning Information awareness Decision effectiveness Decision quality Improved decision analysis Correctness of decision Time to make decision Confidence of decision Improved individual. productivity Change in decision Task performance Personal valuation of IS Information management	Operating cost reduction Staff reductions Overall productivity gains Increased work volume Product quality Contribution to achieving goals Service effectiveness Time effectiveness Improved information management Increased profits	

TABLE 2: ISS categories with adjacent benefit variables (Lindfors 2003, DeLone et al 1992).

The process of assessing future benefits is carried out by exploiting the collective experiential knowledge of the multi-disciplinary evaluation group and data from earlier evaluations or any other relevant available information. Basically, the benefit evaluation procedure is a group activity that consists of four levels of benefit variable aggregation. First, the benefits are identified. The evaluation group proceeds methodically and uses the list of ISS categories and their adjacent variables in table 2 to establish project specific benefits and make sure that no intangible benefits are overlooked. One variable can include several different benefits and one benefit can be divided into several variables. Undoubtedly, it is difficult to ascertain all benefits at a given time, but using the “benefit variable structure” makes it easy for the evaluation group to include or change the input at a later stage. Secondly, the benefits are grouped into appropriate category (if not already done). In the third level, quantification of variables is performed in monetary terms. This is probably the most difficult part of the process and will surely lead to many discussions. Nevertheless, monetary assessment is essential and the discussions can be used in a positive way to exploit the collective knowledge and expertise of the group to bring about best possible result – assuming that the composition of the evaluation group promote collaboration and together strive to achieve best possible outcome. The quantitative variables are classified into one of three grades: 1 – ’Most likely’; 2 – ’Likely’; and 3 – ’Unlikely’, in the fourth level, depending on the likelihood of the benefit being realized.

Only those benefits that directly or indirectly affect the project are dealt with. The sum of the cumulated categories together with respective classifications represents the gross benefit for the evaluated investment. The prerequisites can be adjusted on all four levels, giving the users a maximum of flexibility to adapt the evaluation to new conditions.

4.2.2 Costs

The expected project cost from realizing an ICT investment are identified, structured and quantified using a theoretical framework developed from a project perspective. All costs are incurred and accounted for in the project. Costs can be defined as the expenditure necessary to achieve the benefits.

Table 3 illustrates how the project costs can be structured. The costs are divided into three categories, ‘Capital costs’, ‘Operational costs’ and ‘Indirect costs’. Each of the categories in table 3 consists of a number of variables that recognize the effects according to:

- **Capital costs –** Up front costs, e.g. software and hardware.
- **Operational costs** – Start-up and on-going costs, e.g. personnel and consultants.
- **Indirect costs** – Indirect expenses, e.g. support and productivity losses.

This structure intends to enable easier identifying, quantifying and grading of the costs and it also facilitates an easier management and follow-up of the results. The capital costs – including the up front costs that can be attributed to expenses such as acquisition of software and hardware - have been separated from the operational costs so that the project owner can readily calculate the depreciation time. Capital costs also include additional hardware accessories, such as increased processing performance, memory or similar. The operational costs - including the start-up and on-going costs, e.g. personnel and consultancy costs, are often underestimated and exceeding ‘obvious’ costs such as hardware and software costs. Operational costs also include the costs for carrying out the evaluation. Indirect costs are those expenses that are not classified as direct, e.g. support and productivity losses (e.g. when introducing a new ICT system or tool into an organization).

The process of assessing the costs is similar to that for analyzing benefits using the collective experiential knowledge of the multi-disciplinary evaluation group. The cost evaluation procedure consists of four levels of cost variable aggregation. First, the costs are identified. The evaluation group proceeds methodically and uses the list of cost categories and their adjacent variables to establish the costs, see table 3, and to ensure that no hidden costs are overlooked. Now, in practice, this is nearly impossible because the hidden costs are often related to future events which yet can not be anticipated, e.g. staff hours for maintaining the system, cost for communication, et cetera. However, additional input can be added in a later stage. Second and third level; the identified costs are grouped into appropriate category (variable) and quantified in monetary terms. And fourth level, the variables are classified into one of three grades: 1 – ’Most likely’, 2 – ’Likely’ and 3 – ’Unlikely’, depending on the likelihood of that happening. The structure and procedure facilitates for the users to identify individual costs – effect and size – as well as take in the overall result. It also facilitates pinpointing the most significant costs, which in an early stage could be enough in order to put together a preliminary budget.

Only those costs that directly or indirectly affect the project are dealt with. The sum of the cumulated categories together with respective classifications represents the total cost for the evaluated investment. The prerequisites can be adjusted on all four levels, giving the users a maximum of flexibility to adapt the evaluation to new conditions.

Capital costs	Operational costs		Indirect costs
Hardware and software	Personnel	Cost for evaluation	Support (network, data administration, etc.)
Compensation	Consultants	Education	Productivity losses
Acquisition	Travelling	Workplace	Other costs
Transition/changeover	Communication	Account	
Other costs	Administration	Security	
	Adaptation/converting	Other costs	
	Upgrading		

TABLE 3: Project cost categories with adjacent variables.

4.2.3 Risk management

The risk management process aims at anticipating uncertainties (read: defining Risks) in a potential ICT investment, assessing the degree of the risk, and identifying possible mitigation actions. The overall aim with the risk management process is to secure the project commitments.

Risks refer to exposure to such consequences as failure to obtain some, or all, of the anticipated benefits from utilizing an ICT investment. Risks also refer to consequences to the costs. Only those risks that directly or indirectly affect the project are considered. The risk management process helps managers and users to gain a better understanding about the consequences from the ICT investment and of the project as a whole. The risk management process also enables assessment of overall project risks and identifies and manages special risks. This could be general risks associated with ICT systems or applications (McFarlan 1981, Willcocks et al 1994), such as implementation costs; technical systems performance; or incompatibility of the system; et cetera or risks associated with using the systems or applications, such as functionality; compatibility; applicability; staff competence; et cetera.

The risk management process is a joint effort between project stakeholders represented in the evaluation group. The process, which is supported by a basic risk management structure, see table 4 (Dahlgren et al 1997), is carried out simultaneously to the benefit and cost assessment, before and during implementation of the ICT investment and when the ICT system or application is being used and for follow ups. The process is divided into three parts:

1. **Identifying and Assessing:** Identify and assess risks to the project's ability to obtain anticipated benefits and manage costs. Typically, these risks arise from lack of control or changes in the initial objectives.
2. **Mitigation actions:** Identify measures to mitigate risks and consolidate success. Estimated time schedule and cost for actions should be included, if possible.
3. **Monitoring and Follow up:** Gather information in a joint database – monitor and follow up in order to achieve best possible results.

The first part of the risk management process – "Identifying and Assessing" – aims at ensuring that every risk associated with the ICT investment are fully identified and assessed. Risks can be identified using a variety of approaches, e.g. continuously write down risks discovered during benefit and cost assessment; review previous evaluations; assess requirement specifications; interview users; brainstorming, et cetera. Identifying includes describing the risk and what benefit or cost variables it will affect. The next step is to assess them, i.e. appraise their significance for the project's outcome. The risks are assessed using a High-Medium-Low grading depending on whether they are more or less likely to occur, and whether the harm is more or less serious. The degree of significance given to any risk varies from situation to situation, thus every risk – new or existing – must be carefully considered/reconsidered by the evaluation team. This grading provides a list of priorities to future actions. Risks which could have a major effect on future benefits or impact critical tasks in the construction process should, as a suggestion, have highest priority. Other risks can be more difficult to appraise such as the life span of the ICT investment or factors that may lie outside the sphere of organizational control. Risks could also be external factors not directly related to the ICT investment, e.g. long time before a benefit occurs (Love et al 2005).

The second part – "Mitigation actions" – includes actions, time schedule and delegation of responsibilities to counteract identified risks, see table 4. The evaluation team can also consider alternative mitigation actions to address possible future changes of conditions and/or mitigation objectives. The risks/mitigation actions plan should be discussed and integrated with the overall project risk management to ensure accurate ranges are attached around benefits estimates affected by mitigation strategies.

The "Responsible person" is responsible for the third part – "Monitoring and Follow up": provide information to a joint database to see that all risk mitigation actions are carried out and all risks are acceptably mitigated. This information will also be used when performing follow ups.

Even though implementing a risk management process adds stability; risks and the risk assessment process will evolve over time. Risks may be added to the list and/or combined into others giving the users a maximum of flexibility to adapt the evaluation to new conditions.

Benefit/Cost	Risk/Obstacle	Priority	Measure	Time schedule	Responsibilities
Early quantity take off	Estimators/Purchasers not involved in project at this early stage	Medium	Look over project organisation and…	-month 0	Project leader
Hardware performance	Insufficient performance	High	Possible upgrading	-month 0	IT Manager
Etc.				-month n	

TABLE 4: Risk management structure (Dahlgren et al 1997).

Cooperation between the evaluation team and other project stakeholders in conjunction with transparency in the risk management process is vital in order to consolidate the foreseen benefits and avoid risks. Risk mitigation is important to the project as the odds of a future investment being successful are increased.

4.2.4 The evaluation results

The monetary result from using the evaluation model is presented as gross benefits and costs. The net benefit is calculated by subtracting the costs from the gross benefits. The decisions how to interpret and use the results is taken by the evaluation team or/and the project owner depending on the objectives with the evaluation. For example, the cash flow can be presented using illustrative and easily-understandable bar graphs where the benefits and costs are compiled and presented according to the classification grades, see Fig. 3. The colours represent here different levels of uncertainty. The results can also be further processed using methods such as DCF, NPV or IRR, mentioned earlier in the introduction, (see e.g. Ekström et al 2003, Andresen et al 2000). Other means to measure success could be to express the benefits as Key Performance Indicators (KPIs) and use the results for other evaluation purposes or for benchmarking.

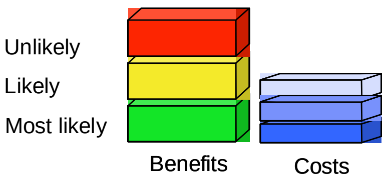

FIG. 3: Bar graph presentation of costs and benefits (Dahlgren et al 1997).

4.3 Secure

The process of securing benefits begins as soon as the decision to realize the ICT investment has been taken. However, while ICT investment evaluation is important, it is insufficient in terms of ensuring that the benefits identified and expected by the project organization are realized and delivered (Ward et al 1996a). ICT on its own does not deliver benefits (Ward et al 1996b). Active work throughout the project life cycle securing the benefits is required to achieve success. “Secure” includes a number of activities such as result estimation, planning before implementation- plan, secure, identify obstacles (obstacle analysis), preparation of follow-up, allocation of responsibility, etc. Typically, these activities fall short due to lack of insight about the importance of securing the realization of the benefits and uncertain allocation of responsibilities. However, securing the benefits are project activities subsequent to the evaluation process that lies beyond the scope of the proposed model.

A selection of methodologies for realizing ICT investments (Lin et al 2005) are listed below:

- Cranfield Process Model of Benefits Management (Ward et al 1996b);
- Active Benefit Realization (ABR) (Remenyi et al 1997);
- DMR’s Benefit Realization Model (Truax 1997);
- Model of Benefits Identification (Changchit et al 1998); and
- The IT Benefits Measurement Process (Andresen et al 2000).

5. IDENTIFYING AND STRUCTURING THE BENEFIT VARIABLES FROM USING VIRTUAL REALITY IN THE MK3 PROJECT – LESSONS FROM A CASE STUDY

The case is typical of constructing a large process plant: several companies jointly trying to comply to the basic needs of a client. The MK3 project was aimed at exploiting the potentials from growing market demands for iron pellets. Time was important in order to effectively take advantage of the market situation and achieve an edge over competitors. The purpose of the case study is to test the evaluation model presented in this article on a new ICT aid in used in the MK3 project. A short description of the case background follows. A more comprehensive description of the use of new ICT aids in the MK3 project can be found in Woksepp et al (2007), Jongeling et al (2007) and Woksepp et al (2006).

5.1 The MK3 project

5.1.1 Background

The Swedish state-owned mining company LKAB has recently increased their capacity by finishing the building of a new pelletizing plant (MK3) in Malmberget, northern Sweden. A workforce up to 250 people was employed by the constructors at the building site, while some 150 consultants and engineers were engaged in the design. The total expenditure was approximately EUR 280 M. The complexity of the project, the number of actors involved and the desire to involve the client and the end-users, such as industrial workers responsible for the plant operations, in the design work made Virtual Reality (VR) models excellent enriched sources of communications. Fig. 4 shows a screenshots from the VR models including an overview of the plant and a design review from the aspect of work environment.

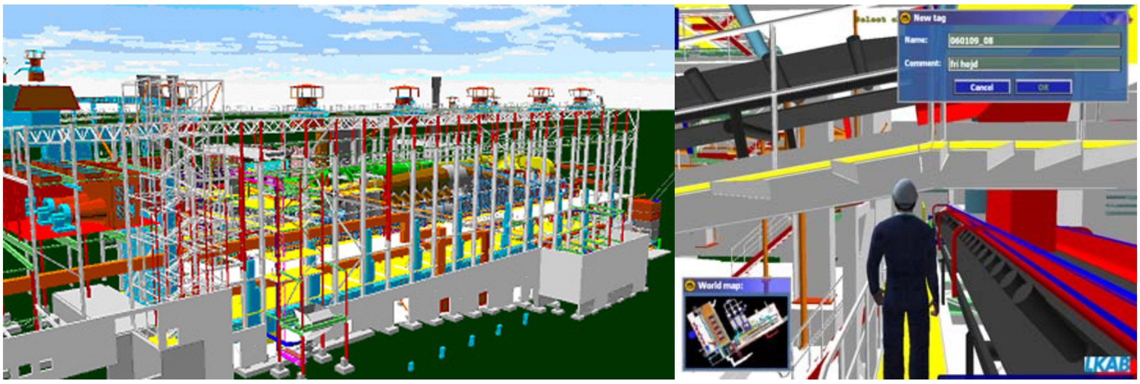

FIG. 4: Screenshots from the VR models of the MK3 project.

5.1.2 VR system and VR models

The technical equipment and VR platform used in the MK3 project was a low-cost approach that consisted of commercial software, PC computers and servers. The visualization tool Walkinside™, which was selected as VR platform in the project, can import most of the major CAD formats. All presentations of the VR models were interactive and done with computer monitors or 2D-projectors.

It was decided early in the project that most of the design should be in 3D and that the different 3D designs should be assembled and integrated in VR models for communication and coordination purposes. The client was responsible for the overall design process while the different design teams were responsible for the design of the subsystems, i.e. process equipment, building structure, installations, et cetera, and for providing correct and updated input data to the VR models. The design was carried out using a number of 3D CAD applications such as: Solidworks, Tekla Structures, AutoCAD, Microstation and Intergraph's PDS system. A VR consultant converted 3D models into VR format to produce different VR models for different purposes, e.g. design reviews, site planning, production, mounting, working environment for safety and maintenance. The VR models were also used for ocular clash detection, distance measuring, user positioning (XYZ coordinates or on an overview, updated in real-time), turning on/off objects layers, simulation of workforce and trucks using avatars, et cetera. The different design team exported updated 3D models to a FTP server every two weeks. Updated VR models were available on the FTP server to the design teams throughout the project. The total amount of information describing the VR models of the pelletizing plant is extensive, and includes the construction - prefabricated and cast in place concrete, the steel structure, the HVAC and electrical installations and machinery.

The VR models provided the design teams with structured and easy-to-understand design information continuously through the design process. The stakeholders could analyze the design both from a perspicuous as well as detailed perspective by navigating freely in the VR models. Moreover, using VR models made it easier to explain and discuss different design solutions with a larger group of stakeholders with different knowledge and experience. This facilitated the collecting of views from different perspectives that could be used to get a better and more production adapted design. The VR models were also used in the reviews meetings that occurred every two weeks. Here, design solutions were examined and discussed from the different perspectives and requirements on function, work environment and maintenance. Clashes between the different design disciplines was also discussed and resolved. It was concluded that one of the major benefits from using VR models to facilitate the design process was the increased level of understanding; especially within areas outside the scope of their own profession.

5.2 Case study procedures

The goal of the case study was to investigate the applicability of the evaluation model. This was done by using the model to assess the benefits and costs from utilizing VR models in the design process. The evaluation was carried out from a project perspective and the results were handled, analyzed and discussed with professionals with a thorough knowledge and experience of project management and technical engineering. The research objective was to support the development of the evaluation model.

No specific evaluation team was established; instead data from the case study were obtained from field investigations and informal interviews with 12 construction professionals involved in the design process. The interviews were conducted on one-to-one basis in conjunction to the participants' every day work at the construction site. This informal method helped us to obtain a deeper knowledge about using the VR models as well as capturing and understanding the benefits. Additional data was provided by a questionnaire which was sent out to additional professionals involved in the design process - thirty-one persons responded. The questionnaire was designed to investigate stakeholders' experiences working with VR models in the MK3 project. The interviewees and questionnaire respondents, all men, represented the client and a number of subcontractors with responsibilities within project management, design coordination, business management, technical engineering and model-based information handling. Only one had earlier experiences from working with VR models.

The data collected from field investigations, interviews and questionnaire were located into proposed benefit and cost structures in table 2 and 3. This procedure makes its also possible to capture benefits that does not belong to any specific stakeholder. Only the benefits belonging to the Project impact category are presented.

5.3 Case study results

The result presented here are a summary of the main identified benefits in the Project impact category and costs (all). An attempt is also made to quantify the results in monetary numbers on project impact level. The biggest values in the design process were:

- The VR models provided the stakeholders with design information in a way that is not possible using 2D CAD drawings. For example, large amount off complex interdisciplinary data could be gathered and presented in an easily-understandable way. The stakeholders could then analyze the design both from a perspicuous as well as detailed perspective by navigating freely in the virtual environment.
- Also, using VR models increased the level of coordination and understanding and made it easier to explain and discuss the overall design and different design solutions with a larger group of stakeholders with different knowledge and experience. The design teams could, interactively, in a virtual environment, explore different alternatives by predicting, understanding and evaluating the impact on the project as a whole in order to come up with the best solutions.

- VR was especially valuable in the conceptual design of the plant layout and in the detailed design phase which facilitated the collecting of views from other stakeholders that could be used get a better and more production adapted design.
- Also, a large number of collisions and design errors could be discovered and corrected in the design process which reduced re-work on-site.

However, the most important value for the client was to ensure to that needs and requirements were implemented in the design process. The time-pressure in the MK3 project and the ambition to enhance collaboration between the stakeholders, resulted in a concurrent design process where the VR models were used to coordinate and communicate the design to the client. Besides making it easier for the client to make crucial decisions, the VR models involved the client in the everyday design work. Being able to quickly sort out the information that is relevant for the moment and present it in an easy and comprehensible way have enabled the client to collect opinions from a wider audience and to focus on the actual decision making.

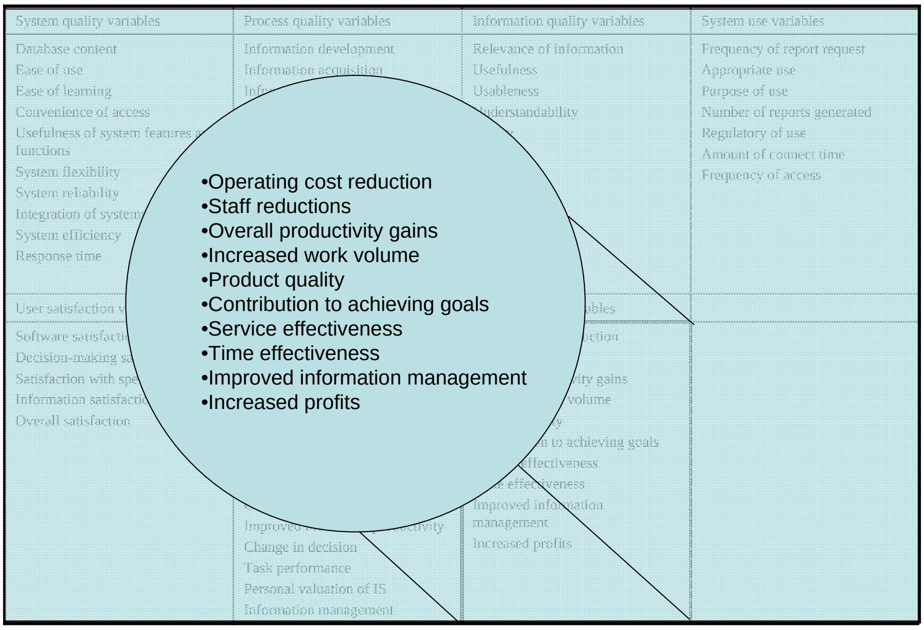

TABLE 5: Identified benefit variables in the Project impact category.

Table 5 shows the affected benefit variables in the Project impact category of using VR in the MK3 project (Project impact category). Most benefits are project specific and do not contribute specifically to any individual stakeholder. The major benefits came from the following variables in the category *Project impact variables*:

Staff reductions: Experience from a similar project using 2D drawings showed that staff devoted to design coordination was halved from 15 to 7 designers compared to the 2D design project. Nevertheless, the quality of the design coordination was considered to be higher in the MK3 project.

Product quality: The operation of a highly automated industrial process is to a large extent dependent on the maintainability of the process equipment. Measures to prevent production losses have high priority in such facilities due to the economical consequences. Therefore, to make sure that maintenance could be conducted, the maintenance personnel were asked to participate in a spatial analysis using avatars and VR models of the process machinery and layout.

Contributing to achieving goals: The design of the manufacturing process is of first priority for the client (before the plant layout and the construction of the plant). This leads to a situation where the focus is on the assembling and functionality of the machinery in the plant instead of the actual building. All separate design processes occur simultaneously in a concurrent design approach. The uses of VR models have facilitated the concurrent design process in the MK3 project. Especially in the design coordination process, the design review process and the capturing of client requirements on the final design.

Time effectiveness: The CE-marking procedure is normally carried out when the plant is finished. However, by using VR models the client could speed up the handling of CE-marking in order to get an earlier production start. Moreover, VR models were used to support planning and decision-making of prefabrication. For example, to speed up the production it was decided that larger parts of the belt conveyor system could be assembled off-site after it was checked in the VR model that these preassembled belt conveyor parts could safely be lifted in the plant.

Increased profits: Using VR models as a part of the partnering strategy in the project also including, e.g., concurrent working methods, facilitated the design, planning and construction processes thus advancing the date of completion. One of the project leader estimated that the coordination of the design and construction using VR in the project made it possible to advance the date of completion by at least two weeks (approximately 3% faster than planned).

To isolate the benefits from using VR is hard since it was part of an overall strategy also affecting the work processes (e.g. concurrent engineering). However, since all benefits and costs fall to the project (in this case due to the contractual arrangement – Partnering) we do not have to split these values between the stakeholders which makes it easier to quantify them. Also, in most cases it is not necessary to quantify all benefits. In this case study, we limited the quantification to a few variables where the project manager and the design coordinator estimated the benefits in quantifiable terms. If the estimated benefits are much higher than the costs of using the VR tool in the design process, it has been worthwhile. The estimated benefits are summarized in Table 6. The total benefits are estimated to EUR 10 630 K, including costs that are most likely, likely and unlikely to occur.

Project impact				
Benefit variable	**Benefit identified from…**	**Quantification**	**Likelihood to occur**	**Comment**
Staff reduction	Interview – Project manager	8 prs x 40 weeks x EUR 4K = EUR 1 280 K	**Most likely**	Well-supported figures
Clashes	Questionnaire/Interviews – Project manager	300 pcs x EUR 4 K = EUR 1 200 K	**Most likely**	Another project manager estimated the value to EUR 500. The number of clashes are estimated somewhere between 200 and 400 by the design coordinator
Earlier completion of project due to better coordinated shop drawings	Questionnaire – Project manager	2 weeks x EUR 3000 K = EUR 6 000 k	**Likely**	The plant's estimated profit per week when it has reached full capacity is EUR 3M!
Coordination montage	Questionnaire – Project manager	EUR 2 000 K	**Likely**	
Better information quality	Questionnaire – design coordinator	EUR 50 K	**Not likely**	Very difficult to confirm
Better insight into all aspects of the project	Questionnaire – design coordinator	EUR 100 K	**Not likely**	Very difficult to confirm

TABLE 6: Identified benefits in the Project impact category and their estimated values.

The operational cost to create the VR models in the design process can be estimated on the safe side to one person working fulltime during 60 weeks (the VR consultant), According to the design coordinator, this was only true in the beginning of the project and when the models become more complex, i.e. when the level of detailing increased. In between these periods in the project the VR consultant works approximately 8h/week on updates of the models. Also, the cost for doing the design in 3D was estimated to be the same as for 2D modelling, since much of the design made by the installation and machinery consultants are already delivered in 3D. Table 7, shows the estimated costs for the use of VR. The estimated costs are summarized in Table 7. The total costs are estimated to EUR 355 K, including the costs that are most likely, likely and unlikely to occur.

Project impact				
Cost variable	**Cost identified from…**	**Quantification**	**Likelihood to occur**	**Comment**
Capital cost	Interview – Project manager	EUR 15 K	**Most likely**	HW, SW
Operational cost	Interviews – Project manager, VR consultant	1 prs x 60 weeks x EUR 4 K = EUR 240 K	**Most likely**	VR consultants (Hög uppskatting)
Indirect costs	Interviews – project manager, VR consultant	EUR 100 K	**Likely**	Other costs – support, administration, personnel, training. Estimated sum.

TABLE 7: Identified costs and their values.

Comparing the benefits [in one category – the Project impact category] with all costs, see the bar graph presentation in Fig. 5, shows that the benefits are clearly higher than the costs, even if we only compare the most likely outcome. This conclusion is shared by the client, LKAB, who has decided to use the same working method provided by VR in the next project – the construction of a new pelletizing plant in Kiruna, Sweden, twice the size of the MK3 project. Even if the evaluation model is project-oriented, it is clear that the client is the main beneficiary.

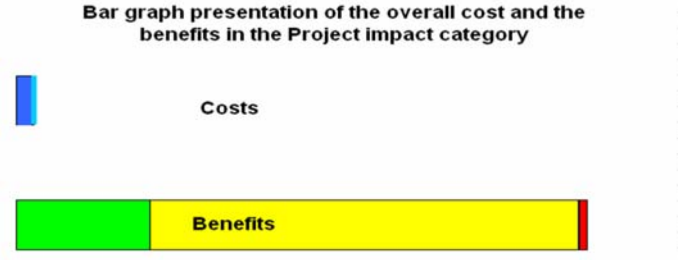

FIG. 5: Bar graph presentation of the overall costs and the benefits in the Project impact category.

A variety of inputs have been used to derive the findings presented in this paper, including data from interviews, observations and one questionnaire. The authors gathered this data during a period of one and a half year. Of course, things change during such a period: the project evolves, there is a turnover of staff, the users becomes more skilled at exploiting the VR models, new benefits emerges, "old" benefits changes, and so on. However, both performance and results feels nevertheless satisfactory. Even though a majority of the participant saw value in the use of VR models, still a few remained sceptical of the financial benefits of using VR. Since, the evaluation was made mainly based on interviews of a few key persons in the project the financial result is only a rough estimate. However, since most estimates are on the safe side and not all benefits have been finically estimated it is likely that the total benefits are much higher.

6. CONCLUSIONS

Modern ICT evaluation activities involve several multi-disciplinary measures that must balance each other if the evaluation is to be a success in terms of creating well-described understanding of the implications of ICT investment to a project organisation. However, literature review shows that the methods used today often fails to meet these requirements; hence, the relationships between the ICT investment and project impact remain unclear.

In order to address this above-mentioned deficiency, the overall research objective was to present a new project-oriented model for evaluating ICT investments in construction projects. Its applicability was validated in one case study. This research suggests that the proposed model can be applicable and give satisfactory result. As shown in the case study, both the evaluation as the presentation of results met the requirements for successfully identify and explain the impact of an ICT investment project level. However, it should be noted that this study was performed and evaluated by the authors themselves and an more comprehensive study based on objective data and evaluated by independent experts would be necessary in order to ensure a critical evaluation and detailed suggestions for further development.

As many ICT investment also involves changes in the process, the traditional construction processes has to be changed to take advantage of the benefits that the ICT tools can offer. In the case study, this was evident where the VR tool was an integral part of the concurrent engineering approach.

Given that the evaluation model is one of the results of the case study, the evaluation was not made according to the proposed strategy. Still, the shift in focus from individual stakeholders to benefits for the project gives a momentum to optimize the benefits in the use of a new ICT tools in construction. This will surely affect the processes and the contractual environment in the project, since it has to support sharing of information and achieved benefits and the costs of the investment in the project.

Nevertheless, the proposed model needs to be further developed and evaluated. Especially, how the individual variables in the different categories in Table 2 can be merged and measured at project level.

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