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ABSTRACT

Integrated operations in the petroleum industry adopt information technology, improve access to real-time data, integrate people and organizations, change work processes, and by doing so, enable better and faster decisions. Consequently, a set of associated business benefits is envisioned. However, the challenge is how to measure them. In this paper, we propose a pragmatic decision analytic method to assess monetary value of integrated operations. The proposed method builds on findings from contemporary literature that emphasizes the need to assess information technology in a broader context of organizational structures and work processes. The method therefore has a built in qualitative assessment of collaborative competence that provides indispensible insights to risks associated with a particular change management project. Yet, it allows for calculating monetary value by integrated formal decision analysis. Feasibility of the method is illustrated by an illustrative case from integrated and collaborative monitoring of offshore operations.

Keywords

Qualitative assessment, monetary value, business benefits, integrated operations, teamwork.

INTRODUCTION

The petroleum industry adopts Information and Communication Technology (ICT) and teamwork to implement Integrated Operations (IO). Key characteristics of IO are improved access to real-time data (sensors, aggregation and visualization techniques), integrated work processes, people and organizations. This creates more proactive and collaborative work practices, and enables better decisions to be made faster. Group decisions are of a better quality with the added value that groups are not using more time for decision-making (Blinder & Morgan, 2005). Serial work processes are replaced by simultaneous and parallel tasks, thereby reducing total time consumption, increasing many-to-many communications. From a decision-making perspective, parallel work execution means a more iterative process. Moreover, multi-disciplinary teamwork becomes more critical as the availability of real time data increases, and work is performed simultaneously, more or less independent of the physical location. Collaborative work brings intrinsic outcomes such as the quality of work-life or job satisfaction. These outcomes result in improved organizational performance (Cohen and Bailey, 1997; Delarue et al., 2008). While deploying ICT and related organizational changes, a wide range of costs should be taken into account (Irani et al., 2006). However, although the industry generally regards IO as highly beneficial, even rough numbers are seldom available.

Over the past decades, the contribution of ICT to organizational performance has been extensively examined by many researchers in operations and information systems research. Despite a large number of evaluation frameworks, improvement is still sought (Schubert and William, 2009), and evaluation of team performance and assessment of ICT business value remain challenging tasks (see (Delarue et al., 2008) and (Brynjolfsson et al., 2002), respectively).

Operations in the petroleum industry are characterized as decision-centric. However, information quality enhancement has value only if there is flexibility in operations; in other words, there must be potential to change the decision or additional information has no value (Bratvold et al., 2007; Pickering and Bickel, 2006). The decision-analytic view is based on explicitly representing decisions and is very different from qualitative approaches (Howard, 1970) that are dominant among methods for ICT business value assessment. Yet, decision maker quality needs to be included when investigating the ICT-performance relationships (Raghunathan, 1999).

We attempt to measure benefits from improved information quality and teamwork. The difficulty of putting a value on intangible means most studies in the ICT business value to focus on structural qualitative frameworks to plot where value is created, without any attempt to derive a monetary value. Our study has identified four types of direct impact on the decision-making process: (a) improved probabilities of outcome (value of information), (b) improved outcome (value of control), (c) changed decision scope/elements (value of flexibility), and (d) faster decisions.

The objective of developing a prospective method is therefore to construct a method that accounts for collaboration competency and relates the competency to formal decision analysis for monetary value assessment. The method builds upon existing studies and adapts techniques to the context of measuring IO value. Briefly, the proposed method consists of qualitative analysis that provides competency analysis along four IO dimensions: technology, teamwork, process and organization. This information is later used to provide better insights into a project under evaluation and to extract operational scenarios. Scenario analysis provides a means to connect qualitative assessment with changes in key performance indicators (KPIs), and focuses on relevant decisions. In turn, decision analysis provides a normative and quantitative approach to valuing information, flexibility and control. Consequently, the novelty of the proposal lies in its methodological guidelines of how to relate qualitative assessment of competence to quantitative decision analysis. At the same time the method is apt to provide insights into project, competency changes, and improved information quality.

The rest of the paper is organized as follows. We continue the paper with a brief synopsis of related work in the area of evaluating technology and intangible capital. We then discuss the proposed method, and finally we conclude the paper.

RELATED WORK

There are many studies on ICT benefits and their evaluation methods. Back in 2004, Melville et al. surveyed over 200 studies on ICT business value. Typically, the business value of ICT is defined as its ability to enhance the company's business performance (Parker et al., 1998). This broad definition is decomposed into three main categories that should be evaluated (Lech, 2007): support of the strategic and operational goals (value is created indirectly); contribution to positive or reduction of negative cash flows (value is created directly); and reduction of technological and organizational risks. However, ICT investments alone do not suffice to create value. Other assets such as organizational structure (Brynjolfsson et al., 2002), and work processes need to be correspondingly changed.

The body of knowledge is dominated by qualitative evaluations of intangible capital and ICT. For instance, Binney et al. (2007) develop a framework to measure intangible organizational resources. The framework is used to account for intangible capital value of ICT investments and is called the "tripartite model". The model assesses three factors: human capital constituted from skills, attitudes, abilities and competencies; structural capital refers to the structures and processes people develop and use to be productive, effective and innovative; and relational capital, concerning management of stakeholder relations and the creation of reciprocal information flows and learning opportunities for stakeholders. The model (Binney et al., 2007) considers a broader social, economic and environmental context: contributions and impacts on society and community, economics and environment. The TAPE (Technology, Accessibility, Psychology and Enforceability) framework (Sharif, 2008) concerns semiotic-symbiotic interaction in knowledge sharing (organizational learning) as a result of collaboration (socialization), technology transfer (combination), vision (externalization) and process (internalization). These frameworks provide essential building blocks for our purpose: teamwork (collaboration), technology adoption, and process dimensions.

The Balanced Scorecard (BSC) (Kaplan and Norton, 1992) method is most widely used. The method allows organizations to measure financial outputs and factors that influence financial outputs, like process performance, long-term learning and skills development. The analysis is based on four main analytical perspectives: financial, customer, internal process, and learning and innovation. The BSC method is applied in various evaluations, generic ICT evaluation (Stewart, 2008), or ERP system assessment (Chand et al., 2005).

In contrast, information economics (Parker et al., 1998) assesses value linking, value acceleration and job enrichment, value linking concerns the costs and benefits of organizational changes that result from of the new system, but that are not the immediate targets. Value acceleration accounts for the future effects of an investment. Job enrichment in information economic methods deal with individual and organizational learning and increased skills. Furthermore, the method assesses the risk of failing to implement the ICT investment by qualitative evaluation of the business domain (e.g. organizational risk and competitive advantage) and technological domain evaluation including strategic investment and risk assessment.

However, some approaches neglect qualitative evaluation and focus on technical component analysis of technology. For instance, vom Brocke et al. (2009) introduces an ontology-based approach to represent the relationships among business processes and IT infrastructure components. They use scenarios to simulate technology usage and assess needed capacity (costs) and resulting benefits. The proposed approach is entirely based on technical characteristics of process and technology. A somewhat simplified approach to the assessment of decision value is proposed by Phillips-Wren et al. (2009), whereby decision value of an intelligent decision support system is compared with a decision support system without an artificial intelligence method, i.e. comparing quality of output. Bratvold et al. (2007) and Pickering & Bickel (2006), however, formally analyze value of improved information in isolation from other influencing factors.

Other approaches decompose technology under evaluation and also model end-user behavior/characteristics. For instance, the techno-business assessment (TBA) framework (Zoric and Strasunskas, 2008) is designed to analyze and evaluate technological service platforms and their business value. The analysis starts from qualitative analysis and moves toward quantitative cash flow calculation. Four domain perspectives are analyzed: the user model describes services from the end-user perspective; the business model conveys a conceptual framework for the business logic; the system model provides complete details of the services from a system point-of-view; and the technical model exhibits technology and the specifics of implementation.

Despite the importance of quantitative evaluation, technology adoption should not be overlooked. These approaches focus on usability of technology and evaluate the end-user's acceptance of the technology. There are many evaluation frameworks that adopt the socio-technical evaluation perspective (e.g. by assessing perceived efficiency and effectiveness of the tools, intention to use, cf. Technology Acceptance Model (Davis, 1989), IS Success Model (DeLone and McLean, 2003), User Information Satisfaction (Kim, 1989)). Teamwork benefits are also assessed, although this is mainly done by qualitative measures (Delarue et al., 2008).

A PROSPECTIVE METHOD FOR VALUE ASSESSMENT

Given the above brief synopsis of related work, existing studies provide little insight on how to relate qualitative assessment of intangible capital to quantitative decision-making. Therefore, the research imperative is to extend current methods and develop a method that accounts for intangible capital (socio-technical change) and relates to a formal decision analysis.

In this section, we elaborate on the proposed method and illustrate using an exemplary application. The method presented here attempts to produce a monetary value. However, an additional significant outcome of the method yields enhanced insight on the success factors and risks of the project in question. The evaluation process is composed of three basic phases (Figure 1): preparation, analysis and value calculation. The method is created to account for both performance changes (analysis of KPIs when they are available) and future value estimation (future scenarios and decision analysis). Next, we elaborate the above-described phases and their steps.

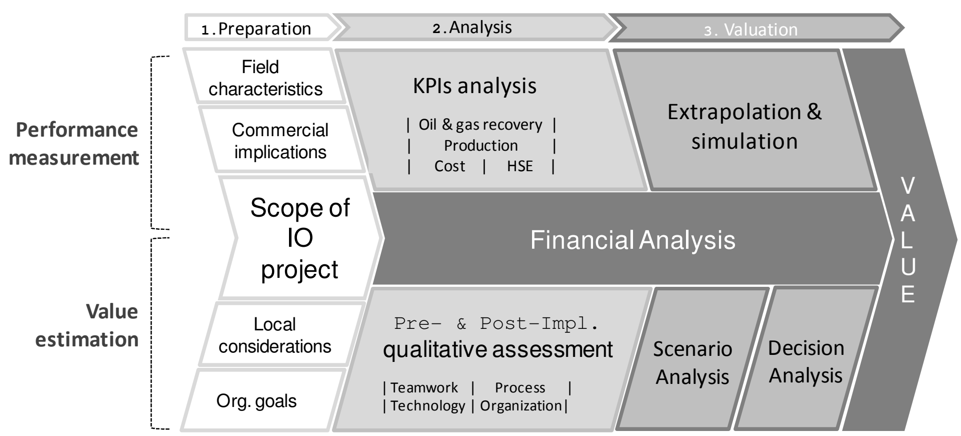


Figure 1. The proposed method

For illustration purposes, we use a case from the implementation of collaborative monitoring based on integrated visual information, where monitoring equipment (sensors, cameras, etc.) were installed to monitor rotating devices and similar equipment. All this monitored information has been integrated to observe the degradation of equipment. Correspondingly, work routines were changed to adopt teamwork, to use open landscape offices and to have regular meetings.

Preparation phase

We begin with the preparation for the evaluation exercise. This phase is basically homework before the second phase, which is conducted at a company's site. The preparation step includes collecting initial information about the scope of an IO project, related field characteristics (such as field production, number of wells, number of employees and their average wage rate);

local considerations (such as political and legal restrictions and incentives); commercial implications (cooperation on licenses, role of suppliers) and organisational goals. In order to maximize the benefits, technological advancements should be incorporated in the overall organizational infrastructure and related to the overall business goals.

Thus, in this phase, a boundary of the problem is investigated and the background information is collected in this phase. It is critical to collect detailed information about the IO scope in order to plot changes that IO will bring or has brought. The purpose of this step is to understand the scope of a particular IO implementation by decomposing the project into IO components. The analysis here provides information on what exactly has been implemented, e.g., installation of a collaboration room, downhole instrumentation, wireless sensors, or new software. A definition of the IO scope helps to investigate associated costs (Irani et al., 2006), narrow down qualitative analysis as well as to pre-select a set of relevant KPIs that will be analysed during a workshop. Organizational and human capital have crucial impacts on successful adoption (Rastogi, 2000) and, consequently, on the value of the solution. This leads to the next phase.

Analysis phase

Information technology is barely the catalyst; the main drivers of productivity are the organizational changes that complement ICT investment (Brynjolfsson et al., 2007). Therefore, we proceed towards the analysis phase that is partially conducted during the evaluation workshop with a company. A questionnaire is used for the initial qualitative analysis of intangible capital in pre- and post- implementation situations, using IO dimensions (i.e.s teamwork, process, technology and organization). This analysis is detailed in the course of the evaluation workshop. Main operational key performance indicators (KPIs) are also collected during the analysis phase.

The main purpose of this step is to analyze technological improvements and collaboration competency. First, a pre-IO level of intangible capital is assessed. Then, based on an IO project scope and boundaries set by an external environment, a post-implementation situation is analyzed. Comparison of these two states identifies IO dimensions that are most impacted, i.e. whether a particular IO project focuses on process, teamwork, organization or just technology change. For instance, the teamwork dimension is analyzed by team diversity, ability to adjust to incoming tasks, teamwork facilitation, sharing and understanding teamwork goals and supporting each other in the team's performance. The purpose is to measure teamwork competency, similar to Erden et al. (2008), where they identify four levels of the quality of group tacit knowledge: group as assemblages; collective action; phronesis (practical wisdom) and collective improvisation.

IO dimension	**Main categories**
Technology	Information quality
	Systems' robustness and accessibility to people both inside/outside the organization
	Technology novelty
	Technology maturity
Teamwork	Degree of diversity/heterogeneity of the team
	Team's ability to adjust to incoming tasks
	Degree of teamwork support
	Degree of a shared understanding of teamwork goals
Process	Degree of complexity of work process (low - routine tasks; high - new problem solving)
	Maturity (establishment) of work process
	Degree of collaboration in work process
	Degree is informal collaboration in the process
Organization	Degree of organization/unit commitment to common goals and objectives
	Innovativeness of organization in developing efficient methods and procedures
	Degree of the communication structures supporting collaboration across teams/units
	Degree of collaboration across disciplines, units and organizations

Table 1. Main categories of qualitative criteria

Teamwork performance, however, is not analyzed in isolation. Work design, task variety and interdependence are also important and organizational structure and processes are treated as the main means to enhance performance (Mueller et al., 2000). Therefore, competency is analyzed by three IO dimensions: process, teamwork and organization "learning". Work processes and working environment need to be changed with respect to new communication infrastructure and opportunities opened up by improved technology. Technology shall not be analyzed separately from human affairs (Orlikowski, 2007).

In Table 1, the four IO dimensions are listed with the main categories of qualitative criteria. The process dimension is assessed by its complexity, maturity, and level of collaboration required to execute a work process. Technology is analyzed with regards to systems accessibility, information quality, technology maintenance and novelty. Organization is analyzed in terms of commitment to common goals, innovativeness, and communication structures. Each category has a set of detailed parameters that are not elaborated here, due to space restrictions.

In Figure 2, the outcome of collaboration assessment of proactive monitoring and maintenance is visualized. We observe less complex work processes (result of lessened coordination), and improved collaboration and information communication resulting from work organization and more frequent and regular meetings. Information quality has significantly improved as the result of a single source of truth (integrated visual and sensor information). The teamwork competence has also been improved (e.g., workload and knowledge sharing in teams).

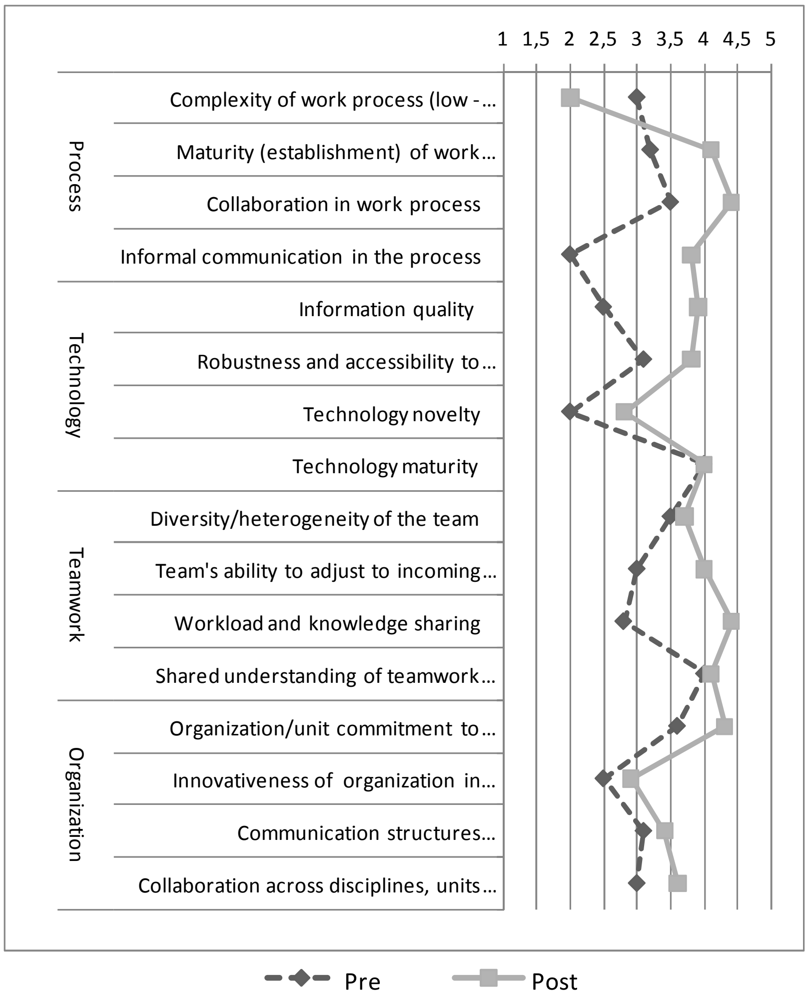


Figure 2. Change in intangible capital

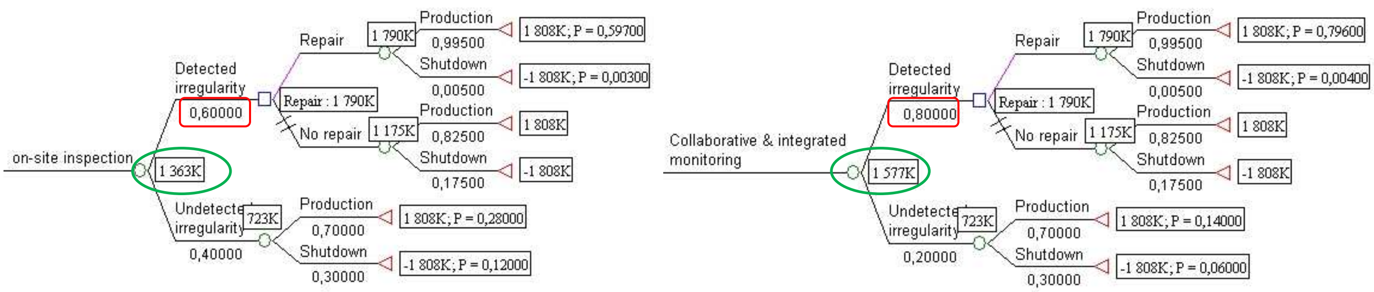
During the analysis phase, we collect relevant KPIs. The purpose of this step is to record (potential) changes in the KPI level. In the proactive monitoring case we may observe changes of KPIs as follows. Detecting equipment degradation in early stages helped to avoid some of unplanned decommissioning, while a single source of truth (no need to consult different information sources) and regular video meetings enabled efficient decisions and helped to reduce non-productive time for maintenance employees and even shorten planned downtime. KPIs are related to operational decisions, i.e. KPIs are treated as outcomes of decisions, then extrapolated and simulated. This is discussed in the following subsection (the value calculation phase).

Value calculation phase

We proceed to the value calculation phase during the workshop at the host company. Having discussed the key findings from the qualitative analysis, the focus group is broken down into smaller groups for scenario extraction (success/failure stories in *ex post* evaluation, or future scenarios in *ex ante* evaluation). The purpose is twofold: collect scenarios that will be detailed and used in decision analysis and examine how employees perceive value creation and whether these experiences (expectations) are in line with the changes in competences that were discovered in the previous phase.

Of course, the information gathered earlier is directly useful in this phase to guide and facilitate scenario generation. For instance, information about field characteristics or organizational goals, as well information displayed in Figure 2, can be used to facilitate story telling. Identified scenarios should be distinctive, and have influence on the value drivers. For scenarios to be useful in decision analysis, they must be “decision-focused”, i.e. scenario generation shall focus on a timeline, describing what may happen (event) and what decisions are typically made during the course of such events. For instance, analyzing the IO implementation rate, capital expenditures are spread in the time accounting for the sequence of IO-driven changes and uncertainties (i.e. magnitude of changes with respect to pre-IO state of operations). Analyzed decisions are of two types: strategic and operational. Analysis of strategic decisions mostly concerns project implementation (extrapolating costs with regards to discovered complexities of the project), whereas operational decisions are analyzed to account for changes in daily operations after collaborative monitoring is deployed.

In the later work session, scenarios are quantified and populated by relevant KPIs (as briefly described above). Key operational decisions related to scenarios are analyzed and formalized. The final value is calculated by extrapolating and simulating KPIs as well as by estimating value of information and control, related to decision making. Decisions are modeled using the decision tree / influence diagram technique.



(a) Decision tree for a traditional on-site inspection and monitoring

(b) Decision tree for integrated and collaborative monitoring

Figure 3. Decision analysis

Continuing our illustrative case in the monitoring, the qualitative analysis (recall Figure 2) allowed us posing a question: How did improved information quality and workload/knowledge sharing impact your daily activities and tasks in monitoring? One scenario brought up by the interviewees was improved detection of equipment degradation: visual information about rotating devices let production engineers notice unusual vibrations. Sitting in a collaboration room with other colleagues and with instant video conferencing between onshore and offshore employees, the engineers could easily confirm degradation of the tool and create a maintenance work order. Prior to this, the equipment check was performed by scheduled visual on-site inspections (requiring travelling offshore). This scenario is further analyzed and formalized using a decision tree (see Figure 3 displaying a simplified decision trees for the scenario). In an integrated and collaborative monitoring, equipment performance is closely monitored by a multi-disciplinary team increasing probability of detecting irregularities and degradation (compare Figures 3 (a) and (b) – probabilities of 0,6 and 0,8, respectively) and thus, allowing for the calculation of expected value of integrated and collaborative monitoring (i.e., from Figure 3, value equals 214 K (1,577-1,363)).

As mentioned, scenarios are further investigated to identify what KPIs they affect. In this particular case, we may see decreased downtime allowing us to calculate realized benefits in the form of production regularity, or in other words, more oil produced. Another realized benefit comes from a reduced number of offshore shuttling in relation to this scenario. Realized benefits are measured by the corresponding KPIs. Both values (realized benefits and expected value) are then extrapolated using a reoccurrence factor (one time scenarios vs. reoccurring) and frequency of scenarios (how often that happens).

CONCLUSIONS AND OUTLOOK

We have presented a method design for qualitative assessment and monetary value calculation of Integrated Operations (IO) in the petroleum industry. Improved access to information and integration of employees' competency in a collaborative teamwork are the main characteristics of IO. These improvements directly impact the decision-making process in the form of (a) improved probabilities of outcome (by more precise information), (b) improved outcome (by constant monitoring), (c) changed decision scope/elements (making decisions that were not possible before), and (d) faster decisions. Prerequisites for better decisions are the presence of the right competency; therefore, the proposed method includes a qualitative analysis of key IO dimensions: technology, teamwork, process and organization. The analysis identifies key competence changes along with the dimensions. The collected scenarios on how value is created or destroyed provide a means to formally conduct decision analysis to account for monetary value.

The objective of this paper is to introduce a practical evaluation method to put a value on information integration by integrated competence. The novelty of the method is in the proposed inter-linkage of the qualitative analysis of collaboration competence with a formal decision analysis that yields both qualitative insights into a project in question and quantitative (monetary) value. However, it is essential to continue with future case studies to validate and populate the method. The case studies will help to come up with heuristics to enable a smooth transition from qualitative competency analysis to quantitative decision analysis.

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