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Shared collaboration surfaces to support adequate team decision processes in an integrated operations setting

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ABSTRACT: This paper documents the outcome of a literature review as well as empirical findings related to how a shared collaboration surface may facilitate adequate team decision making in an Integrated Operations (IO) setting. In the review, we take a look at what decision support is, based on the two disciplines *decision systems* and *decision sciences.* There exist different needs for different organizations with regard to decision support. The paper will focus on IO settings, and in which situations such decision support would be useful in IO.

1 INTRODUCTION

The petroleum industry is undergoing a transition made possible by new and powerful information technology. Traditional work processes and organizational structures are challenged by more efficient and integrated approaches to offshore operations. Several companies on the Norwegian continental shelf have implemented integrated operations (IO) as a strategic tool to achieve safe, reliable and efficient operations (Ringstad & Andersen, 2007). In integrated operations, traditional work processes and organizational structures are challenged by more efficient and integrated approaches to offshore operations. The new approaches make it possible to reduce the impact of traditional obstacles—whether they are geographical, organizational or professional—to efficient decision-making (Ringstad & Andersen, 2007).

Integrated operations are both a technological and an organizational issue, and imply both the use of new technology and new work processes. The IO technology consists of high-quality video conferencing, shared workspaces and data sharing facilities and involve people in discussions both onshore and offshore.

Improved decision-making is in many definitions of IO highlighted as the main goal of integrated operations (e.g., Statoil, 2007). It is assumed that improved decision making processes in turn will lead to increased production, less downtime, fewer irregularities, a reduced number of HSE-related incidents, and in general a more efficient and streamlined operation.

There are some features of IO vis-á-vis traditional operations that are associated with improved decision-making, and some features that may challenge decision-making in an IO setting. One important feature for improved decision-making is the increased availability of real time data that make it possible for personnel at different locations to cooperate based on a shared and up-to-date description of the operational situation. Another important enabler of improved decision-making in IO is a shared collaboration surface. A shared collaboration surface can visualize a common and coherent representation of goals and activities and what the participants understand to be the agreed decision. Further, using such a collaboration surface, the participants can give their confirmation of the understanding of the decision, and it can be saved for future reference. This increases understanding and commitment within the team, and significantly reduces the risk of later, possibly wrong or vague, interpretations.

However, there are also challenges that are more visible in distributed teams than in teams interacting face-to-face. Ringstad & Andersen (2007) mention some potential obstacles and challenges that can influence decision processes and that can be faced by a company that is implementing IO. One such challenge is that the lines of command may be blurred in group-based and distributed decision making. Also, operation personnel and expert personnel who have to make sense of real time data streams might experience information overload. It might also be a risk that the understanding of installation specific factors of relevance to a decision might be lowered when decision makers work from locations not on the drilling and production facilities. In addition, increased complexity and interactivity can make it difficult for decision makers to maintain overview during an incident. IO collaboration technology seeks to meet such potential challenges.

The IO collaboration technology consists of high-quality video conferencing, shared workspaces and data sharing facilities. These arenas include so-called collaboration rooms (operation rooms) for rapid responses and decision-making. The design includes video walls to share information and involve people in discussions with each other both onshore and offshore.

In an operational context, a number of decisions are required, the decisions are interdependent, the environment changes, both autonomously and as a consequence of the actions taken by the decision maker; and the decisions are made in real time (Gonzales, 2005). Because decisions in dynamic environments must be made in real time, time constraints become an important determinant of performance (Brehmer, 1992). Also, dynamic decisions may involve time delays that positively or negatively influence one another in complicated ways over time (Diehl & Sterman, 1995).

Because the successful performance of many important tasks requires skillful decision-making, the identification of forms of decision support for dynamic decision-making has become a research priority. However, this identification process has proven to be very challenging (Lerch & Harter, 2001).

Personnel working in an IO setting will often benefit from decision support in different situations. In this review, we take a look at what decision support is, including examples from observing a dispersed team on a Norwegian oil field (Rindahl et al., 2005), with regard to how decisions may be facilitated through a shared collaboration surface. The literature review in this paper is based on a review of decision support (Kaarstad, 2009) performed within a larger research program (http://www.sintef.no/Projectweb/Building-Safety/). Knowledge obtained in this research program is currently carried on in a continuation research program where the obtained knowledge is used as support when advising on how distributed collaboration could be organized with regard to technical tools and collaboration skills in order to ensure resilience. The current paper focuses on IO settings, and in which situations decision support would be useful in IO.

2 WHAT IS DECISION SUPPORT

The term decision support contains the word "support", which refers to supporting people in making decisions. Thus, decision support is concerned with human decision-making. The definitions of decision support rarely mention this characteristic and rather assume it implicitly.

In the figure below, it is illustrated that the two disciplines that closely correspond to decision support, are *Decision Theory*, a broad discipline concerned with human decision making, and *Decision Systems*, which (primarily) deals with computer-based programs and technologies intended to make routine decisions, and monitor and control processes.

2.1 *Decision theory*

The human cognitive modes of comprehension, perception, representation and decision-making have been studied for decades. Analyses have been applied in particular to situations in which human operators are controlling and/ or supervising a technical plant.

Rasmussen (1986) has shown that an operator is supposed to execute certain activities, such as data monitoring, information seeking, pattern recognition, diagnosing, planning and acting on the system. Rasmussen's model is organized around three types of behavior: skill-based (direct mapping from observation to situation), rule-based (stereo-typed procedure to execute a task), and knowledge-based (decision making on a new situation). This division of behavior is often referred and used in the literature and has been used as basis for the development of several decision support systems.

A decision can be defined as the choice of one among a number of alternatives (Bohanec, 2003), and decision making refers to the whole process of making the choice, which includes: assessing the problem, collecting and verifying information, identifying alternatives, anticipating consequences of decisions, making the choice using sound and logical judgment based on available information, informing others of decision and rationale, and evaluation decisions (Bohanec, 2003). Research on decision theory has traditionally taken two complementary approaches; the *normative* and the *descriptive* approach.

Most decision theory is normative and concerned with identifying the best decision to take, assuming an ideal decision maker who is fully informed, able to compute with perfect accuracy, and fully

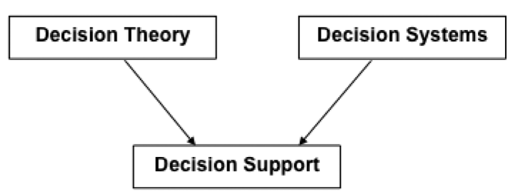

Figure 1. Decision support as impacted by decision theory.

rational. The normative approach uses abstract principles as a basis for good decision-making and discovers implications for how these principles can be applied in the real world. The practical application of this approach is called decision analysis, and aimed at finding tools, methodologies and software to help people make better decisions. The most systematic and comprehensive software tools developed in this way are called decision support systems (Wikipedia).

Since people usually do not behave in ways consistent with axiomatic rules, there is a related area of study, called a descriptive discipline, attempting to describe what people will actually do. The descriptive approach starts with observations of decision-making as it is done in the real world (or in a laboratory) and tries to derive a theoretical account that can be tested through additional observations, or that can assist in understanding what is happening. Since the normative, optimal decision often creates hypotheses for testing against actual behavior, the two fields are closely linked.

Simon (1960) described decision problems as existing on a continuum from programmed (routine, repetitive, well structured, easily solved) to non-programmed (new, novel, ill-structured, difficult to solve). According to Simon, the decision making process consists of three main stages. 1) Intelligence, which is a phase that is comprised of the search for problems, 2) Design, which involves the development of alternative solutions, and 3) Choice, which consists of analyzing the alternatives and choosing one for implementation.

A decision support system has usually been developed to deal with the structured portion of a decision problem, as we will see in the next paragraph.

2.2 *Decision systems*

Decision systems are computer technology solutions that can be used to support complex decision-making and problem solving. Decision support systems have evolved from two main areas of research—the theoretical studies of organizational decision-making (e.g., Cyert & March, 1968) and technical work.

Decision systems belong to multidisciplinary foundations, including (but not exclusively) database research, artificial intelligence, human- computer interaction, simulation methods, software engineering, and telecommunications. In the 1960s, researchers began systematically studying the use of computerized quantitative models to assist in decision making and planning (Raymond, 1966; Turban, 1967).

Decision support systems have evolved significantly since their early development in the 1970s. Research in this area has typically focused on how information technology can improve the efficiency with which a user makes a decision, and can improve the effectiveness of that decision. Characteristics of information needs and models differ in a decision support environment. The ill-defined nature of information leads to the requirement for different kinds of database systems like relational databases and flexible query languages. Similarly, the ill-structured nature of the decision process implies the need for flexible modeling environments.

Over the last two decades or so, decision support systems research has evolved to include several additional concepts and views. Group decision systems evolved to provide brainstorming, idea evaluation, and communications facilities to support team problem solving. Model management systems and knowledge-based decision support systems have used techniques from artificial intelligence and expert systems to provide smarter support for the decision maker.

In the 21st century, the Internet, the Web and tele-communications technology can be expected to result in organizational environments that will be increasingly more global, complex, and connected. Mitroff and Linstone (1993) argue that radically different thinking is required by managers of organizations facing such environments, which include consideration of much broader cultural, organizational, personal, ethical and aesthetic factors than has been the case in the past. Courtney (2001) suggests that decision support system researchers should take a much more comprehensive view of organizational decision making and develop decision support systems capable of handling much "softer" information and much broader concerns than the mathematical models and knowledge-based systems have been capable of handling in the past.

The mental models of stakeholders with various perspectives lie at the heart of the decision process, from defining what is a problem, to analyses of the results and trying to solve the problem. The organizational and personal perspectives are developed by discussing the problem with all affected stakeholders, to ensure that all relevant variables are either included in models, or in some way taken into account during the analysis. The need for broader forms of analysis, such as group sessions, may become more appropriate in the future.

There are numerous tools and techniques that help people in organizing data and thoughts. Some of these are technological systems like data storage, search and retrieval, visualization tools, expert modeling, communication technology and knowledge management systems. Rosness (2009) advised on how to improve decision-making processes, and listed different aids or tools for human decision-making support. One of these examples is technological:

- Tools to aid information handling in conjunction with decision-making, for instance computing tools and visualization tools.

Another is organizational:

- Systems for transfer or feedback of experience, e.g. investigation and reporting of accidents and near-accidents.

And the other tools he mentions are more procedures or guidance systems:

- A list of steps that are assumed to be necessary and sufficient to reach a rational decision, such as Janis and Mann's (1977) model of "vigilant decision-making" and various problem solving models (e.g. Hale et al., 1997).
- Logically consistent decision procedures, for instance based on expected utility theory (Keeney & Raiffa, 1993).
- "Political" advice on how to exert power, influence the outcome of decision processes and/or how to ensure commitment once the decision has been made (e.g., Machiavelli, 2003; Enderud, 1980).
- Advice on how to train decision-makers on an individual or group level.
- Advice on how to develop a culture that is conducive to "good" decision-making (e.g. Weick & Sutcliffe, 2001).
- Advice on how to create a setting for discourse that is conducive to dialogue and the accomplishment of informed consensus.

In summary, decision support may not solely be understood as a computer tool, but in a broader sense, it includes tools and techniques that help people in making a decision, like procedures, guidelines, advice, visualization tools, communication technology as well as training initiatives in decision making.

The reminder of this review will emphasize decision support tools that are designed to support the decision makers in an IO setting.

3 DECISION SUPPORT IN AN IO SETTING

The introduction of IO implies that the tasks involved in petroleum production are redefined and reorganized, and many tasks are relocated (typically from offshore to onshore). In addition, a range of new information and communication technology (ICT) systems, such as decision support systems and collaboration technologies, is being introduced.

In integrated operations, individuals often make decisions in small groups or in large organizational networks. Though one person is responsible for the decision made, the knowledge and competence of a group of people may be required to reach the best decision. The decision support tools that are designed are supposed to support different user groups and can be divided into individual, group, and organizational tools.

3.1 *Different user groups and decision support*

Individual decision support is most often concerned with operational decision support systems, designed to support optimal decision-making (Bohanec, 2003). They typically include expert systems and decision support systems for managers.

Group decision support is interactive computer-based systems that facilitate the solution of unstructured problems by a set of decision makers working together as a group. Typical applications include email, awareness and notification systems, videoconferencing, chat systems and mediation systems (Bohanec, 2003).

Organizational decision support systems focus on organization-wide issues rather than individual, group or departmental issues. They are general-purpose, multiple-user, large-scale systems that have a relatively definite, continuous and organized position in the planning and decision making processes of an organization and which are designed for a variety of organizational decisions. In an IO setting, it is most relevant to focus on decision support for individuals and groups, as these are the fundamental participants in integrated operations.

3.2 *IO teams and the impact of technology*

Many organizations are using integrated operations where distributed teams composed of individuals with complementary skills and knowledge collaborate on a variety of workplace tasks. Collaboration occurs within the context of cooperative work and is defined as "multiple individuals working together in a planned way in the same production process or in different but connected production processes" (Wilson, 1994). Because individuals who cooperate or perform tasks together share only partially overlapping goals, individual group members' activities must be coordinated to ensure that the disparate individuals come to share the same goals. Coordination involves actors working together harmoniously to accomplish a collective set of tasks (Van de Ven et al., 1976). A group decision results from interpersonal communication among group members (DeSanctis & Gallupe, 1987).

Collaboration support systems play a central role in facilitating communication among members of distributed teams. The technology may impose constraints in communication that are likely to affect a group's performance. In communication, people rely on multiple modes of communication in face-to- face conversation, such as para-verbal (tone of voice, inflection, voice volume) and nonverbal (eye movement, facial expression, hand gestures, and other body language) cues. These cues help regulate the flow of conversation, provide feedback and convey subtle meanings. Collaboration support systems alter the effectiveness of information exchange. It may take more time and effort by group members to achieve the same level of mutual understanding, and the communication constraint can sometimes affect the group's ability to reach a consensus decision (Daft & Lengel, 1986). Informal encounters create a common context and perspective that support planning and coordination of group work. Kraut et al., (1993) claim that without informal exchanges, "collaboration is less likely to start and less productive if it occurs". However, more recent research suggest that the use of collaboration technology may create the sense of being present in a place different from one's physical location—a sense of "being there" (Skarholt et al., 2009).

In IO-settings it will be important to leverage the beneficial differences inherent in computer-mediated communications and mitigate the negative differences when decision support systems and tools are selected.

3.3 *Different situations and decision support*

There are three distinct situations in integrated operations where decision support is assumed to be of particular importance. These situations can be divided into:

- Daily operation and planning
- Project work
- Risk situations and emergencies

Decisions support for the daily operation and planning include normal, real-time dynamic operation, day-to-day and long-time planning including e.g. production planning and planned maintenance, and will generally be used when there is sufficient time to think and plan ahead. Each organization will have separate needs for decision support in daily operation and planning. The main support tools that need to be in place for decision-making in IO are efficient collaboration tools for knowledge sharing and discussion, as equipment for video conferencing, wide screens for presentation, and mobile and wearable equipment. In general, a successful decision support system can generate a variety of benefits. It can provide information that is timely, accurate, relevant, concise, and in an attractive format.

In the concrete and task specific *project work*, tools that facilitate the sharing of information and expertise to improve the quality of team decision-making are needed. Given the distribution and diverse background of team members in integrated operations, multi-cultural issues may become prominent. Project planning and decision-making, therefore, becomes yet more complex and intricate. The modern organization, also an IO organization, can no longer be viewed as a group of loosely related departments with specific formal links, but as a series of highly interconnected business processes (Richardson et al., 2000).

The increased use of information technology, and the resulting interconnectivity, from local area networks, through intra-nets, has increased the capability for individuals and groups to exchange information rapidly. Project teams need processes and systems that are easy to set up and maintain over extended periods of time. Also, project teams may need to adopt group decision technologies in managing their projects. Some tools already exist to allow them to manage more effectively (Ringstad & Andersen, 2007).

The third situation where decision support is important is in risk situations and emergencies, and when a normal situation is developing into an emergency.

Risk is not a static and inherent characteristic with a given activity that is not possible to influence. Risk develops over time, together with the activities that is performed, the implementation of initiatives, learning from incidents, accidents, and success, use of new technology, development of work processes, and updating of procedures and guiding rules. Risk-informed decisions imply that one has to know whether the decision foundation is sufficient, and to evaluate the need and the possibility to further reduce the uncertainty before a decision is made (Walle & Turoff, 2008).

Teams must be encouraged and trained to handle emergencies. Emergencies often differ from situations operators normally are trained in, and often the solutions they are trained to take do not fit to the actions and decisions they need to take in an emergency. Therefore, training initiatives in collaboration and decision-making will be an important tool in risk and emergency situations.

4 OBSERVING AN IO SETTING

The method "Structured Observation and Feedback in Integrated Operations" (SOFIO) was developed in order to identify successful IO collaboration techniques (Rindahl et al., 2009; Kaarstad et al., 2009). The method is based on fundamental methodological principles for assessing virtual team effectiveness (i.e. Lurey & Raisingham, 2001). The method was developed in order to give feedback to teams working in an IO setting regarding how they collaborated. Feedback was given directly after sharp meetings and collaboration sessions. As seen in the literature review, decision support tools can be developed for *Individuals*, *Groups* and *Organizations*, and they may support people in different situations, as *Daily operation and planning*, *Project work* and *Risk situations and emergencies*. The observation study that applied the SOFIO methodology was focusing on *Groups* in *Daily operation and planning*.

One of the drivers for performing this study was that many groupware technology systems has been developed based on the assumptions that if the technology is excellent from the engineering point of view its excellence as groupware will follow. Tools like e-mail, video conferencing, and net meeting technology are examples of technology developed uniquely for interaction. Only rarely have human factors expertise and approaches been involved in the development. When IO collaboration tools started to get implemented it was frequently assumed that buying the best equipment would facilitate successful dispersed team interactions. This did often not happen, as the technology had a higher threshold than expected, because the established work processes did not require such tools, or that the equipment was not available for the right people at the right time (Larsen, 2008). Presently there seem to have been a change, and organizations ask themselves *What kind of work processes should our technology support and encourage?* (Rindahl et al., 2009).

Based on a theoretical foundation, four observation categories were selected in order to observe and emphasize successful techniques for team interaction, and to provide advice on how to become even better—both with regard to interaction skills, but also with regard to technological competence. The observation categories selected were: *Presentation techniques, Team, role and communication, Technological literacy,* and *Institutional language and culture* (Rindahl et al., 2009). Observation checklists were developed for each category. In this paper, the results from the category *Technological literacy* are most relevant. Technological literacy as introduced by Tyner (1998) is not necessarily a conscious competence—or incompetence. The so-called *digital native users* (the generation born into extensive use of digital tools) will have several advantages when collaborating in a high-end technology environment, as described by Prensky (2001) and Skraaning and Rindahl (2008).

The petroleum organization observed have the collaboration environments in place, the work processes have been analyzed and changed and even IO work practices have been established. The observing team was a third party in a video conference. During the meetings, the observers were typically observing several aspects simultaneously. One observer concentrated on oral presentation techniques, while another focused on the use of digital tools. A third observer particularly focused on body language, signals and expressions concerning the team and the interaction. After each observation, short direct feedback was given to the IO team. The next phase in the process was to write a short-reflection report. Each observer reported from the topic she or he was focusing on during the observations. These reports were sent to the participants after the meetings, and made a foundation for continuously evaluation of their distributed collaboration. Also, the short point reflection reports was working as a basis for a total evaluation and reporting at the end of the study. (Rindahl et al., 2009).

A simple but important insight to be achieved before good use of technology in IO interaction sessions can take place is that, in addition to verbal communication, the cursor and set of surfaces (video and visualizations) are the only tools the participants have available for expressing oneself.

In the observation study, it was found that technology literacy might vary in the team, but that it was an advantage for any meeting leader to know the video and audio technology well, including the procedures for what to do when something did not work as expected. A general finding was that for decision processes to work well, all participants should have access to the same information and visualizations. Further, interaction surfaces should be easily used during the session to visualize information, knowledge and ideas brought up by all participants (Rindahl et al., 2009). When sharing information on a screen, using the mouse cursor and surface shifts to focus attention and to support the ongoing verbal communication is recommended, in order for everyone to feel certain of what objects or topics were discussed. An over-elucidation was also found important when the surfaces was shifted, or the mouse was moved, in order to compensate for lag and allow all participants time to follow. The possibility to share data, process information and other relevant files, was seen as necessary in order to achieve good decisions. In safety critical work the repeat-back principle is often used in communication. In videoconferencing, there might sometimes bee disturbances in sound, and such oral repeat back might not always be enough. When the meeting made a decision, the decision was therefore often written down on the shared screen, and when consensus was reached, the decision was saved. With a highly technology literate meeting leader, pointing and changing surfaces could be used as a means to keep the discussions focused and efficient, and to summaries and conclude. It is not likely that the same focus would have been achieved without this shared surface channeling everybody´s attention in the same direction (Rindahl et al., 2009).

This paper has tried to demonstrate that decision support is not only computer-based support systems, but is a broad, generic term that encompasses all aspects related to supporting people in making decisions. Each organization will have separate needs for decision support, and different situations call for different solutions. In Table 1, some general recommendations are given concerning type of decision support that could be used in different situations. The table is not complete, but gives examples of some of the main ideas presented in this paper.

Overall, the main support tools that need to be in place for decision-making in IO are efficient collaboration tools for knowledge sharing and discussion. For daily operation and planning, systems for coordinating planning activities as well as operational support systems (like alarm systems) could be useful support tools. For project work, support systems to facilitate the management of project complexity and for sharing of information and expertise would be beneficial. For risk and emergency situations, decision support systems to detect risks could be a valuable tool. In addition, training programs could be developed to train individuals and teams in decision making in emergencies.

Teams, and in particular teams working in complex environments, such as an IO setting is, need to adopt the flexible, exploratory approaches necessitated by the complex environment they face. People must also be able to contact each other continuously, large amounts of data must be transferred when necessary, and the right decisions must be made in a timely fashion.

Table 1. Examples of possible decision support for different situations in IO.

Daily operation and planning	Project work	Risk and emergencies
Efficient collaboration tools for knowledge sharing and discussion	Efficient collaboration tools for knowledge sharing and discussion	Efficient collaboration tools for knowledge sharing and discussion
Alarm management systems to prevent alarm inflation so that alarm systems are effective and informative in daily operation	Group decision support systems to facilitate management of project complexity and for sharing of information and expertise to improve the quality of team decision making	Decision support systems for detecting risk Training initiatives for coping with emergencies

5 CONCLUDING REMARKS

In this paper we have seen that decision support is a broad, generic term that encompasses different aspects related to supporting people in making decisions.

Decision support for IO may not solely be understood as computer-based tools but in a broader sense, it includes tools and techniques that help people in making a decision, like procedures, guidelines, advice, visualization tools, communication technology as well as training initiatives. Different situations, like daily operation and planning, project work as well as emergencies; and different users, like individuals, teams, and organizations, call for different decision support. In the future, IO will imply that the people, tech nology and organization subsystems will be even stronger coupled and interdependent, and the boundaries between them will be blurred. Intercultural interaction, and even faster moving and more opaque technology, trust (both in technology and co-workers), and shared understanding among people at different locations are some of the issues that are likely to become even more important on the IO agenda in the next few years (Ringstad and Andersen, 2007).

Decision support practice, research and technology continue to evolve. Decision support research and development will continue to exploit many new technology developments and will benefit from progress in very large data bases, artificial intelligence, human-computer interaction, simulation and optimization, software engineering, telecommunications and from more basic research on behavioral topics like organizational decision making, planning, behavioral decision theory and organizational behavior (Power, 2007).

Organizations can benefit from the use of new and advanced technology in many ways. The challenge is not so much the technology in itself, but more the organizational aspects, such as developing clear roles and tasks, common goals, trust and knowledge and skills. These elements are essential for developing an efficient organization where highly motivated and skilled employees and managers can make safe and efficient decisions with adequate decision support.

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