**Application of Performance Measurement as an Early Warning System:** [**A Case Study in the Oil and Gas Industry**](http://researchonline.nd.edu.au/cgi/viewcontent.cgi?article=1011&context=theses)

**Abstract**

**Purpose –** The purpose of this paper is to present an overview of the concept of early warning signs in projects and explain how a performance measurement system can be utilized as a source of data for an early warning approach signaling that a project is about to experience problems at some stage in the future.

**Design/Methodology/Approach –** Combination ofaction research and semi-structured interviews and document analysis supplemented by a post-mortem analysis after project close-out

**Findings –** Detection of early warning signals in projects can be better enabled through the application of a performance measurement system with properly defined key performance indicators. Utilization of this tool can positively affect the overall success of the project.

**Research limitations/Implications –** The case study involved only one project from the oil and gas industry.

**Practical implications –** The empirical case study wasdeveloped to illustrate the usefulness of exploiting a performance measurement system in a project. This was done in order to provide early warning for possible problems that may arise and thus provides possibilities for taking initiatives for resolving them.

**Originality/Value –** This paperhighlights the gap in the literature concerning the link between early warning and project management and the link between early warning and performance measurement. It offers a new idea on how performance measurement can be used as an effective early warning system and is intended to be primarily of use to project management practitioners and practically-oriented academics who are interested in developing fresh insights into new approaches for better managing projects.

**Key words -** Early warning, Performance measurement, Key performance indicators, Project management

**Paper type** Technical paper

1. ***Introduction***

Although the utilization of project management tools and techniques has improved significantly in the recent years, still quite many projects fail. An approach to avoiding this is to attempt detecting possible signs of project failures at the early stages of a project, in order to take the necessary corrective measures. In retrospect, we are quite often able to point out a number of the most likely factors contributing to the project failure, and we can also see a number of signs of the failure. Those signals, often in the post project phase, appear obvious and it is hardly possible to understand why they were not taken into consideration at the time.

These signals, which can be seen as an expression, an indication, a proof, or a sign of the existence of some future negative issues, are defined by Nikander (2002) as “early warning signs”. A major challenge for the project managers will be of course the identification of these signs and attempting to respond to them in order to prevent the negative circumstances. Although it is not a proven fact that identification of early warning signals is a guarantee against project failure, there are a number of resources which consider paying attention to these signals and attempting responding to them as a contribution to project success.

According to Nikander (2002), which is consistent with our own findings, very little literature exists that deals explicitly with early warning in projects and project management. But the project management literature, according to Nikander (2002), does include some statements which are possible to interpret as examples of early warnings. For instance, Kerzner (1994), Cleland (1994) and Zeitoun & Oberlender (1993) have pointed to this phenomenon in their studies. Other authors have introduced in their research work different approaches which may be used as possible approaches for detecting early warning signs in projects. Some of these approaches include risk analysis (Niwa (1989); Nikander (2002)), project success/failure models (Pinto & Slevin (1987; 1988); Lewis (1993); Miller & Lessard (2001)), project assessment methods (Cooper et al. (1997); Cooper (2005); Wateridge (2002); Miller & Lessard (2000); Klakegg et al. (2010)), earned value management (Vanhoucke (2010)), decision support model of early warnings (Nikander & Eloranta, 2001) and performance measurement (Andersen & Fagerhaug, 2002). Although these methods have been mentioned as possible early warning sign identification approaches, we have not been able to find any amount of literature thoroughly discussing the link between project early warning and these methods.

This paper investigates the application of the well-known tool,\ performance measurement,\ as an early warning sign detection approach and examines its usability by presenting a case study from a real project in the oil and gas industry, where a performance measurement system for detecting early warning signs was implemented.

The reason we have chosen to set our focus on this specific industry is the fact that the oil and gas industry is the most important industry in Norway and influences virtually every aspect of the state and global economy. According to the Norwegian ministry of petroleum and energy, Norway is the fifth largest oil exporter in the world, with exports amounting to nearly 2.5 million barrels per day. Over the last ten years, oil production has been slightly higher than the level expected in the years to come. The future production level depends on a number of factors, such as technological development, oil price and whether new discoveries are made and developed. Norway is the second largest exporter of gas to Europe, with only Russia being larger. In 2006, Norway accounted for 30 percent of all gas production in Western Europe. On a world basis, Norway ranks as the fifth largest producer and the third largest exporter, despite the fact that the country only has 1.6 percent of the world’s proven gas reserves. There is a strong demand from the industry for improving its performance towards a path to reaching an even higher success rate.

This specific case and the process of applying performance measurement within this case will be reviewed and analyzed. The purpose is to illustrate the usefulness of utilizing a performance measurement system in a project as an early warning system that can give warning of possible future problems and allow taking initiatives for resolving them before they can lead to failure. The overall aim of this paper is to outline how performance indicators can be developed to detect problems in a project and how the application of performance measurement can contribute to project success.

The remainder of the paper comprises six sections. In the next section, the research purpose, scope, and methods are described. Next, a literature review covering the concepts of performance measurement, early warning, and the link to the project management field is presented. The case study is described in the subsequent two sections; the first of these sections includes information about the case project and a short history of the project, the second section comprises the findings and results from the action research and post-mortem analysis. The research conclusions are presented in the final section.

## Research Purpose, scope and methodology

The main research objective is to describe how implementing a performance measurement system can contribute to the identification of early warning signs in a project and outline the possible areas for improvement. It is also of interest to investigate how key performance indicators in projects can be developed, implemented and used, and which effects it might produce for the project.

With the principles of early warning already researched by different authors, the next phase of research is logically the development, implementation, and testing of more specific methods for identifying and acting on early warning signs, thus validating early warning as a feasible approach to improve project performance. For this type of research, the case study approach (as developed in detail by Yin (1994) lends itself naturally; it allows more in-depth development and testing of one specific approach, typically combined with action research where the researcher takes an active role in developing and implementing the changes to be validated (Greenwood & Levin, 2007). To fully research this field, a series of case studies applying different early warning sign detection methods in different project settings will be required; this is extensive work that will require contributions from many researchers. We have started the effort with this one case study utilizing performance measurement as the approach.

To select a case for action research, there are several criteria one can apply; variety in types of project and context, suitability for testing of the chosen approach, access to data, etc. In reality, a dominant criteria is the "convenience sample" (Marshall, 1996), i.e., the sample where the researchers is allowed suitable access. In our case, an oil company approached us and asked whether we would be able to undertake action research to implement an early warning system in a project being started. Assessing the project against criteria of suitability and relevance, we deemed the case project a good case for our research.

By limiting the sample to this case, the scope of the research was one case project executed in a Norwegian oil company and one of the world's largest suppliers of oil and gas. The case study was inductive, as a performance measurement system was implemented with the aim of problem prevention by detection of early warning signs, with the purpose of further developing the theory of early warning approaches in projects. Details of this case are provided in the subsequent section.

The methodology used for this research was a combination of action research and post-mortem analysis of the project. The action research was carried out between the years 2005, when the plan for operation and development of the project was submitted to the Norwegian ministry of petroleum and energy, and 2009, when oil the production was commenced. The action research involved the researchers working together with the project management team, parts of the project organization, and the project owner within the main company.

The action research included evolving stages, meaning that the stages were not fully defined at the outset of the action research; rather the findings in each stage led to the development of the next stages (Bassey, 1998). The first stage of the action research focused on outlining the early warning approach to be employed in the project and developing performance indicators. This was achieved through discussions with the project management team and conducting brainstorming sessions and interviews with representatives from the project management team and the project organization at large. The outcome was a model depicting the early warning approach and the initial performance indicators, approximately 40. During the second stage of the action research, further discussions and semi-structured interviews were performed to scope down the number of performance indicators and investigate whether the required data could be obtained. In the end, the set of performance indicators was reduced to eight key indicators, and these were implemented in the project’s performance measurement system. In the third phase of the action research, the performance measurement and early warning system was used to test the approach during the second half of the project. During this phase, the researchers were present in relevant meetings in the project, and also carried out interviews to learn how the project management team and project organization found the approach to support early warning detection.

The authors later interacted again with the project after the project was completed, and a post-mortem analysis was carried out in 2011. In general, a post-mortem analysis is ideally performed either soon after the most important milestones and events or at the end of a project. The benefit is that post-mortems can often reveal findings more frequently and differently than project completion reports alone (Myllyaho et al., 2004). The main reasons for carrying out this type of analysis is to clarify how the project turned out and to identify relevant lessons which can to be learned from it (Williams, 2004). In this case, the post-mortem analysis was done with the aim of evaluating the overall performance of the project, how the early warning system worked, and its effects on the project’s overall success. This was done through several interviews with the project manager and project control manager of the project. Table 1 shows the stages of the project between 2005 and 2011, alongside the time periods of different phases of our research involvement.

The conclusions from our research are built on the integrated results from these different methodological elements. These were integrated through triangulation of all the data sources, including interviews, observations, meeting minutes, and documents available from the project.

The results of this research are based on inductive reasoning, indicating that a similar outcome is likely to be achieved by applying this tool on other projects in the oil and gas industry.

Table 1. Case study phases throughout the project

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 |
| Submission of Plan for development and operation | Approval of plan by ministry of petroleum and energy | Installation of seabed templates on the field | Start of drilling | Production start-up | Start-up of operation of a subsea facility for injection of seawater for pressure support | Project finished |
| Action research | | | | |  | Post-mortem analysis |

## Literature review

The primary focus of this research is centered on early warning in projects and the specific approach of performance measurement as a tool for identifying these signals. The literature review specific to the two concepts of performance measurement and early warning signs, as well as their link, is presented in this section. The aim is to highlight the importance of early warning signs in projects and the effectiveness of performance measurement as a tool for identification of these signals and its contributions to project overall success.

## 3.1 The purpose of performance measurement

Many authors have investigated the purpose of performance measurement and how performance measures are used in different types of organizations. With some variations, a common theme in all these frameworks is the use of performance measurement as a means to improving performance. Sink and Tuttle (1989) posed the question “Why measure?” and answered by saying; measure to improve, to provide the management team with new insights into why the system performs the way it does, where it can be improved, and finally when the system is in control or out of control. According to Bond (1999), performance measures provide a mechanism for relating product or process improvement policies developed by senior management to action at a local organizational level. For the balanced scorecard, Kaplan and Norton (1996) linked the purpose of measurement more to strategic management aspects: 1) clarify and update strategy, 2) communicate strategy throughout the company, 3) align unit and individual goals with strategy, 4) Link strategic objectives to long term targets and annual budgets, 5) identify and align strategic initiatives, and 6) conduct periodic performance reviews to learn about and improve strategy.

This also seems valid in a project setting. Pillai et al. (2002) supported this idea by stating that performance measurement plays an important role in ensuring project success and its usefulness to the sponsoring organization. Toor and Ogunlana (2010) take a further step by identifying performance measurement as one of the most important aspects of project management, which strongly affects project success. Almahmoud et al. (2012) believe that performance measurement is the force that drives project management improvement.

Another popular approach in the recent years has been the development of different performance frameworks to explain what constitutes performance and how it should be measured. Prominent examples include the supportive performance measures matrix (Keegan et al., 1989), the SMART pyramid (Cross and Lynch, 1989), the results/determinants Matrix (Fitzgerald et al.,1991; Fitzgerald and Moon, 1996), the balanced scorecard (Kaplan and Norton, 1992), project health check (Jafari,2007), The earned value management approach as a performance measurement tool for cost control (Bower and Finegan, 2009), a multidimensional project performance measurement system to enable managers to deal with large volume of data (Marques et al., 2010), and the Swiss cheese performance management model (Almahmoud et al.,2012). Also Ika et al. (2010) in their study, mention several performance measurement tools such as cost benefit analysis (CBA), logframe, scoring techniques, etc.

Clearly, performance measurement is a versatile tool that has found a wide range of application areas in different sectors. However, from this brief review of some sources, a common pattern seems to be emerging; performance measures, in the capacity of representing a metric used to quantify the efficiency and/or effectiveness of action (Neely et al., 1995), is very much directed at performance improvement. Performance measurement links strategy to action, motivates employees, supports budgeting and control, allows benchmarking, etc., all of which are geared toward improved performance. As was explicitly stated by Behn (2003), the only real purpose is to improve performance; the others are simply means to achieving this ultimate purpose. It is crucial to note that recent findings show that in today's competitive, complex environment, the performance management approach that focuses only on traditional progress indicators can no longer be sustained and project managers need to manage project’s performance in a proactive rather than reactive manner (Almahmoud et al., 2012).

In the work done by Andersen and Fagerhaug (2001), a potential in performance measurement as a tool for early warning has been noticed. There are a few other references to early warning in literature, and these are discussed a little later in the paper. Early warning is also closely related to the concept of leading indicators, which will also be discussed later on. However, there seems to be a consistent difference in how early warning and leading indicators are perceived from what we think of in the context of projects. We will elaborate further on this point, but briefly explained; performance measurement is normally focused on detecting the presence of positive performance drivers, or alternatively, the absence of these, and as such constitutes some early warning that a negative development could be imminent. In a project setting, early warning should be more aimed at detecting predictors of negative events or crises, which is the inverse of how performance measurement usually works.

## 3.2 The Concept of early warning

The generic idea of early warning is a wide concept. It applies to almost any activity, sector, or area where it has value to obtain indications as early as possible of some development that in the future will become clearer, typically of a negative nature. The term early warning is applied in as diverse areas as meteorology, natural disasters, defense, and cost control. Before we go deeper into a discussion of early warning in a project setting, it is worthwhile to present some of the work that represents a platform for the little research that has been done on project early warning.

The first discussion about early warning in a management context was initiated by Ansoff (1975). This is supported by Nikander (2002) who dealt extensively with this literature in his doctoral dissertation. Ansoff suggested that strategic surprises, for example the oil crisis in the early 1970s, do not appear out of the blue, rather they may be detected by the aid of pre-emptive signs. These signs he called weak signals. A weak signal was defined as “…imprecise early indications about impending impactful events.” (Ansoff and McDonnell, 1990, p20). The core idea is thus that even unexpected discontinuities are heralded by some warning signals. In mid 1980s, Ansoff developed a management model based on the strategic management of companies applying the theory of weak signals. Ansoff’s theory can be divided into two parts. The first part deals with the actuality of the weak signals and the level of information they express and the second part includes the utilization of weak signals in the form of a weak signal’s strategic issue management systems (WSSIMS).

The theory of weak signals has not been uncontroversial. Critics include Webb (1987) who claimed such messages or information about the future could not be obtained and that Ansoff's work had no earlier foundation to confirm the claims of such weak signals. He believed that these signals only provide weak knowledge of the final threat or opportunity. Ashley (1989) turned the discussion around, saying that such discontinuities are only seen after they have occurred and possible precursors of their arrival only identified with the benefit of hindsight. Makridakis and Heáu (1987) stated that the concept of weak signals had remained a purely academic idea. Åberg (1993) stated that weak signals are usually so vague that they are easily missed, and that it is difficult to believe in them; in fact they are uncertain, irrational and not credible. But on the other hand, several other authors have described the same core idea using slightly different terms, for example symptoms, early indicators, soft form of information, and early warnings (see for example Mintzberg, 1994; King, 1987; Juran, 1995). Leidecker and Bruno (1987) and Pinto and Slevin (1988) have also done some studies which can be regarded as research in support of the existence of weak signals.

We also question whether the term *discontinuities* is the best one, or at least the only one, to describe the kind of problems normally encountered in projects. Ansoff’s work is very much focused on the kind of fundamental changes in a company’s surroundings that traditional strategic planning based on extrapolating current knowledge cannot detect. The aforementioned oil crisis is one example, but others mentioned include the success of smaller cars and the invention of the transistor. Such events would certainly have impacted, and caused problems, for many on-going projects at the time they occurred, particularly if they depended on oil as an energy source or were projects to develop new car models or pre-transistor technology electronic devices. As we will return to later in the paper, there are other, and less fundamental external changes, that constitute problems for projects; loss of key personnel, poor alignment of goals among key stakeholders, quality problems in physical deliveries from subcontractors, etc. In fact, projects seem to fall victim to both such fundamental discontinuities, to more slowly evolving problems displaying a trend, as well as problems that appear at the end of a cause-and-effect chain. Each of these probably requires a different approach for early detection.

Expanding the view beyond management literature, the belief in early warnings seems more profound. Whereas detecting minor behavioral changes in competing industrial enterprises that eventually lead to the introduction of profoundly new technologies can be challenging, identifying physical changes like the formation of a low pressure system or an increased concentration of a certain type of algae could be easier. Not surprisingly, there is an abundance of articles, reports, and web pages dedicated to or dealing with early warning in many different sectors. Let us move on based on the premise that early warning signals do exist, also in projects. In Nikander’s words (2002) “an early warning is an observation, a signal, a message or some other item that is or can be seen as an expression, an indication, a proof, or a sign of the existence of some future or incipient positive or negative issue. It is a signal, omen, or indication of future developments”.

## 3.3 Early warning approaches in project management and performance measurement

To conclude the review of literature, we will look at some approaches that deal with early warning inside the core fields of project management and performance measurement. According to Nikander (2002), which is consistent with our own findings, very little literature exists that deals explicitly with early warning in projects and project management. But the project management literature, according to Nikander (2002), does include some statements which are possible to be interpreted as examples of early warnings. For instance, Kerzner (1994), Cleland (1994) and Zeitoun and Oberlender (1993) have pointed to this phenomenon in their studies.

A broad range of the project management literature points deals with risk management as one important part of the field’s toolbox. The body of work on risk management is too large to review here, so it is sufficient to say that various authors have mentioned terms like *risk symptoms* and the *occurrence of symptoms and issues*. According to Nikander (2002), since early warning refers to a problem that may arise in the future, the relation between the early warning phenomenon and risk management is rather obvious. Kappelman et al. (2006) also linked these two concepts by stating that early warning signs provide an indication of evident risks and thereby an assessment of a project’s propensity to future problems and failure.

Another large body of literature in the project management field deals with so-called project success factors, or sometimes their inverse, project pitfalls. This topic was also extensively researched by Nikander (2002), who listed a number of key publications on the topic. Important work includes Baker et al., (1983), Pinto and Slevin (1987; 1988), Pinto and Kharbanda (1995), Lewis (1993), Cleland (1994), Harrison (1993), Lim (1987), and Miller and Lessard (2001). Similarly, on project problems or pitfalls, some relevant material can be found in Nikander and Eloranta (2001) and Nikander (2002), where compilations of typical project problems were presented, while both Kerzner (1995) and Lientz, Bennet, and Rea (1995) discussed cause-and-effect (cause-and-problem) chains in projects.

When it comes to converting the knowledge of the likely existence of both relatively generic project success factors and pitfalls into practices that can be employed in project management, there is much literature outlining ways to ensure that success factors are promoted or pitfalls avoided. The recommendations range from specific tools like project planning and stakeholder analysis to good advice about communication, leadership, and other soft management skills. However, very little seems to focus on the early warning aspect of trying to detect either the absence of success factors or movement toward pitfalls. To the extent that the different empirical studies of successful or failed projects have been able to identify truly generic issues, these should represent a suitable platform for developing early warnings. Thus, it is perhaps a little surprising that little work has been done pursuing this idea. We have only been able to find four approaches described in literature.

First, Niwa (1989) outlined an approach based on the use of computer-based expert systems. The concept of *risk alarms* was introduced, which are meant to be advance warnings of emerging problems. A knowledge transfer system was proposed as a solution to recurring risks in project, a system that would partly collect and store large amounts of experience from relevant projects, analyze risk causes and mechanisms, and establishing these risk alarms. The book deals with how such a system could be developed and implemented, but does not elaborate further on the risk alarm approach.

The second approach is based on the use of regression analysis to identify signals that indicate that a project will become distressed (Hanna and Gunduz, 2005). This work was limited to construction projects and attempted to link certain factors of the project in its pre-construction phase, especially during the bidding stage, to probability of distress in the construction phase. Through the analysis, a number of variables were found that together represented a success ratio of more than 70%. These were owner and/or contractor experience, design issues (percentages complete before awarding of contract and start construction), and management related issues, typically the amount of experience with this type and size of projects. The authors claimed that the model could be used to define the early warning signs in the bidding stage, but gave no explanation about how these issues should be measured or acted upon.

Another approach was proposed by Liu et al. (2003). It relied on the use of fuzzy logic to determine early warnings, and was limited to software development projects. In contrast with the other approaches described in this paper, this one is based on metrics, i.e., performance measurements, collected from the project. These include for example metrics for requirements quality, customer involvement, group productivity, etc. Through the application of fuzzy logic, calculations are made based on the metrics, and the results appear as diagrams portraying risk levels for quality, schedule, and cost for the modules of the software to be developed. In that it relies on project metrics, the approach is relevant for our discussion, even though the paper focused very little on how to collect the metrics and which metrics were most relevant. The main contribution was the demonstration that fuzzy logic could be used as an alternative analysis method once performance measurements had been collected.

The final approach is the key contribution from the doctoral dissertation of Nikander (2002), whose precursor was also described in Nikander and Eloranta (2001), a decision support model of early warnings. In this model, the flow of events in the project forms the main source of information, of which observations are made by persons inside the project organization. Some of these observations can represent an early warning, most observations do not. This is determined through an analysis of the observations and knowledge about the project. For observations deemed to constitute signals of future problems, the rest of the process follows more or less a traditional risk management procedure of analyzing possible effects of the problem and developing different types of responses. The model says very little about how to make the required observations of the flow of project events. However, the model is accompanied by an extensive set of typical early warnings of different problems, derived from empirical and literature studies performed by the authors. This is perhaps the most helpful piece of information to practitioners attempting to implement an early warning system. Still, in our view, the weak part of this model is the lack of discussion about how to collect observations that will allow detection of early warnings, and this is the function we believe performance measurement can fill.

Within the area of performance measurement, at least one specific application of early warning, in the area of product development processes, has been found. However, we also believe the concepts of leading and lagging indicators need to be included here, as there seems to be a link to early warning. Syamil et al. (2002) presented a paper on performance measures in product development processes that also discussed briefly the potential of such measures as early warning signals. The idea is that measurements can be taken both at the end of a process, in this case a product development process, and during the process. Such measurements, the authors claimed, have been ignored, but could be very useful. If measured early enough, they could predict later problems that would only show up after-the-fact in traditional end-result measurements.

This view, however, is really not different from the gradually prevailing view in the field of performance measurement; performance indicators must be balanced, both with regard to performance dimensions covered and the time of measurement. When introducing the balanced scorecard approach, Kaplan and Norton (1996) emphasized both these aspects and also referred to this time balance as a matter of leading and lagging indicators. Lagging means they are measured at a late stage in a process or a chain of processes, thus presenting management with a rear-view mirror assessment of events that have happened and can no longer be influenced. Such indicators show up too late to have any value in early warning. Leading indicators, contrary to what seems to be a common belief, are not able to measure “before the fact”. Also leading indicators need to measure an event or status after they have occurred. What sets them apart from lagging indicators is what they measure. Typically, when designing leading indicators, the objective is to capture events or developments in an early stage of a cause-and-effect chain, thus being able to predict future performance. In support of this idea, Keil and Montealegre (2000) recommended that managers need to ask themselves in the earliest possible stage of the project if there are any “red flags” serious enough to lead to project termination or remarkable redirection. Paying attention to these signs earlier in the project increases the probability of successful outcomes.

Future knowledge can be impacted, but not the current, so the prediction ability of the leading indicator lies in its location in the cause-and-effect chain. This is equal to the thinking of Ansoff (1974), Nikander (2002) and others who have discussed early warning and project early warning, i.e., the crucial issue is to be able to interpret signals that appear early in a chain of events. The answer of performance measurement is to define performance indicators or metrics that track these signals, thus allowing management to respond to them early enough. This is the main premise of this paper and the thinking we believe needs to be pursued to bring project early warning further. Performance measurement seems to have the capacity to close the gap not addressed by other authors discussing project early warning, where it is assumed that weak signals will be detected and interpreted correctly.

1. ***Description of the case project***

The specific case project studied in this research was carried out by a Norwegian oil company, which is an international energy company with operations in 36 countries. This project is an oil field consisting of a subsea development attached to existing installations and infrastructure in the Norwegian Sea. The field is a gas and natural liquid gas field with a thin oil zone. The recoverable reservoirs are 186 million barrels of oil and condensate and 41.5 billion standard cubic meters of gas. The field was discovered in 1982/1983 and the plan for development and operation was submitted in 2005 and approved by the ministry of petroleum and energy in February 2006. The subsea templates were installed on the field in the spring 2007. The drilling began in 2008 and production was initiated the next year. The expected plateau production from the project in 2016-2017 is 96,000 barrels of oil equivalent per day. A number of success criteria were defined for this project, including cooperation and communication, technology qualification, and improvement activities. The project had a budget of 14.5 billion Norwegian kroner and the subsea production system has a life cycle of 20 years.

## Application of performance measurement as an early warning in the case project

## 5.1 Development of a performance measurement system

During years 2005 and 2006, a performance measurement system was developed in cooperation with the case project. At first, 5 brainstorming sessions were held, one session for each technical discipline in the project, and one session with the entire project management team. The participants were asked to brainstorm possible problems that could show up during the project. This was followed by a semi-structured risk analysis, evaluating and prioritizing each risk according to its probability and severity. The same process was carried out once more involving more people, 85 persons, the maximum number of project organization members which was possible to gather at the time, in order to expand the view on possible problems. The last activity consisted of a thorough review of risk registers from past projects in order to learn from similar undertakings.

The result was the development of 40 indicators; too many and later reduced to 18, and finally down to 8 key indicators, through a prioritization of areas of importance. The procedure of reducing the number of indicators was done through a two-stage approach: First, the reduction from 40 to 18 was based on filtering the indicators according to their perceived importance for this specific case project. The resulting 18 indicators were then brought forward for implementation in the management information system, MIS, of the company. After starting this effort, it was realized that each indicator required much work and for some of them, data was difficult to obtain. Thus, based on data availability and the effort required to implement each indicator, the final set ended up being the 8 most relevant ones.. The required data needed to feed these indicators were partly collected from the MIS and partly from the project’s various records as well as through surveys of personnel. The early warning system was also implemented in the MIS; measurements could be retrieved from the system and various diagrams and graphs produced to display the data.

For the final 8 early warning indicators, the purpose of measuring each, how they were portrayed, and how measurement of each indicator contributed to the detection of early warning signs is discussed next. Figure 1 shows an overview of the areas covered by measurement.



Figure 1. Various areas covered by measurement

1. Competence and staffing

Access to sufficient competence and capacity was, together with the contentment of the project team members, seen as a foundation for the success of the project. The purpose of this indicator was to provide the project management with a notification of whether the project at any given time had the necessary expertise and capacity, as well as some time ahead. From experience, it was known that people are ordered to move to new projects, themselves seek new challenges in other projects or companies, and that the project owner often fails to realize how much resources are required during different periods of a project. So instead of waiting for a crisis to materialize when the project became understaffed, this was meant to detect such situations early enough to ensure continuous sufficient staff levels. However, it turned out that the indicator was utilized only during the ramp-up phase after sanctioning of the project. Partly, it had served its purpose when the project had reached full staffing levels, and partly it proved unable to give much information about the future. It is possible that the indicator could have been angled toward assessments of the likelihood of loss of people in the future, but this was not attempted.

1. Employee satisfaction

A consensus among a large majority of the experienced people involved in this project was that "happy people" was a prerequisite for a good project, and that brewing discontentment would be representing the beginning of a negative development. It was therefore seen as essential to be able to "keep a finger on the pulse" of the project team's well-being and levels of contentment.

In the case project, this was achieved through the use of a questionnaire, administered online quarterly to all the project participants. The survey contained 13 questions and was developed in collaboration between the research team and the project team. Respondents were asked to rate statements on a scale from 1 – 6, with a higher value indicating higher levels of agreement with the statement. The purpose for selecting this scale was to force the respondents away from a mid-point. The results were compiled into spider charts, see Figure 2, for the whole project team as well as for sub-disciplines. The response rate stayed quite consistently at 70-80%, with the remaining 20-30% probably having too low involvement in the project to find it relevant to respond (some worked only part-time on the project, others were located geographically quite far away from the rest of the team).

The experience from the case project is that this indicator worked well as a warning of poor performance and allowing improvement action to be taken, e.g., increasing communication, hosting social events, etc.

Figure 2. Level of employee satisfaction in the project

1. Interface actions

The case project had a specific process in place called interface management, whose purpose was to facilitate smooth handling of all kinds of interfaces in the project, e.g., technical integration of components or sub-systems, providing documentation required by other actors, etc. With 80% of the budget spent on purchased systems from a large number of suppliers, the subsea system to be hooked up to an already operational platform installation, and with the project team split into several technical disciplines, the number of such interfaces was vast. And past projects had shown that such interfaces provided excellent opportunities for problems, so there was a clear need for future-looking monitoring of this issue. The purpose of the interface management process was the early identification of issues at interfaces with potential to impact cost or schedule, and then to minimize or eliminate their impact as well as promote clear, accurate, timely, and consistent communication with other organizations for exchanging interface information. When such an interface issue was identified, a so-called *interface action* was defined, meaning action must be taken to investigate the issue until it can be closed.

In terms of measurement of this, the indicator focused on the ratios between defined interface actions that had been identified but still remained open, interface actions deemed critical, and closed interface actions. Depending on how these rations would develop, warning would be obtained that no new interfaces were being identified, identified actions were not followed up and closed, or only non-critical actions are being closed, all of which could lead to serious problems. The indicator was presented in the form of a chart, shown in Figure 3, and the data was made available to all project members and suppliers through a web-based system used for sharing information. In the chart, there is an acceptable balance among the three types of interface issues over time, and the number of closed issues increases simultaneously as the number of open and critical issues decrease.

In the case project, this indicator was the one that received the most attention and focus from the project team, and interface meetings were held every 2 weeks. With the system providing a clear picture of the detailed connections between all stakeholders, especially contractors, and the interface status, including problems, delays, and slippages, it worked well as an early warning system by providing conditions for taking preventive actions. The project management indeed saw the interface management system of the project as a very helpful tool contributing to the success of the project. He believed that lack of interface management can be a cause of major problems.

Figure 3. Illustration of Interface actions in a specific period of time throughout the project

1. Supervision actions

This indicator was a “sibling” of the interface actions, but with a focus on quality. By scrutinizing the project plan and deliverables planned throughout the project, critical items were identified and targeted for so-called supervision actions, a planned check of the quality and timeliness of the deliverable. Like the interface actions, these planned checks would be recorded in the MIS and classified as open, overdue, or closed, depending on whether they had been implemented and the quality deemed acceptable. Figure 4 illustrates the number of active and overdue supervision actions over time. The overdue actions are the ones which have already passed their deadlines and the active ones are related to tasks which are being followed up. Several trends in the graph would represent a warning signal; phasing out of new supervision actions being defined, increase in overdue actions, etc.

While quality is difficult to measure, this at least showed whether critical components and systems had been checked and cleared for delivery. Delayed or failed supervision actions would represent a warning that slippages were building and action must be taken.

Figure 4. Illustration of supervision actions in a specific period of time throughout the project

1. Risks/uncertainties

The area of risks, or in the company’s vocabulary uncertainties, was an obvious one to cover by an indicator. Traditionally, risk management is biased toward the identification of risks, with the active follow-up and mitigation of the risks receiving less attention. Through a similar logic to the monitoring of supervision actions, keeping track of the status of identified risks could both direct more attention to these as well as provide early warning about the development of risks. Risks are both identified in an early phase of the planning, but new risks are seen throughout the project and added to the risk register. A risk would only be closed after the project had taken the necessary precautions to minimize the likelihood of the unwanted event happening or reducing the consequences of it. Figure depicts how this data was communicated internally in the project. Tracking these trends could reveal, e.g., that no new risks emerge, too many go unhandled, etc.

Figure 5. Illustration of uncertainties in a specific period of time throughout the project

1. Growth in contracts

With 80% of the project budget being directed to a long list of suppliers, growth in these contracts could quickly accumulate to large overruns. This is certainly not unheard of in projects, with many contractors pursuing a strategy of increasing the work and profits through change orders or addition work. The purpose of this indicator was therefore to keep track of such growth and the economic impact on the project.

In addition to just looking at the original contract value and growth, this indicator measured the evolution of both forecasts and actually billed value by the contractors. By measuring this indicator with a certain frequency, a better basis for predicting the development of the costs was provided, as shown in Figure 6. Although this indicator is more lagging in nature, it still represented a source of early warning through providing a cost prognosis. Another effect is that it has provided a good basis for forecasting and estimation in subsequent projects.

Figure 6. Illustration of the level of contract growth in a specific period of time throughout the project

1. Cost-related modifications

Like the previous indicator, this indicator also recorded changes, but to a greater extent. The purpose was to measure how much a change in project scope would cost the project. The indicator was based on the number of internal or external design changes and the corresponding changes in costs, and thus illustrates to the project team the effects of making changes and the costs of errors or omissions made during the planning and design phases. If the costs of such modifications showed an upward trend, see Figure 7 for an illustration, chances were these would keep growing throughout the project and thus provide an early warning to either be prepared for higher costs, renegotiate contracts, or review the design before entering into new contracts. However, this is a lagging indicator recording changes already made that have cost consequences, and therefore not a very strong indicator in terms of early warning.

1. Float

This final indicator was developed to monitor schedule progress, based on collection of data about activities run by contractors and internally by the project team. *Float* is a measure of how much dependent contracts and activities can be delayed without influencing the completion of milestones or the total project. Its usage is to assess whether a delay, be it caused by a supplier of parts or materials, a contractor of sub-systems, design consultants, or internal resources, is critical or not for the rest of the chain of activities. Keeping track of the available float would provide the project continuous insight into the remaining flexibility and the speed at which the float was diminishing, thus giving rise to a need for action. An even earlier warning could be obtained by reviewing the percentage completeness of a delivery and comparing the necessary estimated remaining time to the available float.

Figure 7. Illustration of development in change related costs in a specific period of time throughout the project (DCP = design change, DDP = design development proposal, PBS = change in plan, budget or strategy)

After having developed these indicators, including understanding the data required and how they should be presented, they were implemented into the MIS. Using internal programming resources, links were established to automatically collect the data already available in MIS or in other systems, and for data that needed to be collected manually, online surveys were created. The project management team put the system to use, making a review of the indicators a topic at weekly or semi-weekly management meetings. In addition, discipline managers shared and discussed the measurements with their sub-teams, and relevant indicators were also discussed with contractors and suppliers. A subsequent evaluation of the system and its use showed that the project management team found it practical to use and helped to both raise the awareness of many different issues and give warnings about potential problems.

In the next section we will discuss the results of implementation of this system for the project and how it affected the overall success.

***5.2 Performance measurement system implementation results***

Our findings from the post-mortem analysis of the project and its use of the performance measurement system show two main messages; 1) the case project turned out to be highly successful measured against all success criteria and 2) the use of the performance measurement system for early warning seems to have led to early detection of future problems and thereby contributed to the project success.

According to the project control manager, this project, despite being a complex project from both a technological and organizational point of view, is considered a clear success, being completed on budget, on time, and with the specified quality. The realized oil production has exceeded what was planned, and the health and safety performance was very good.

Determining how much, if any, of these results were caused by the early warning system is inherently difficult; attribution of effect is impossible to calculate, and running studies with a control group is also virtually impossible. We therefore have to rely on assessments made by the people who were involved in the management of the project, even though these can be biased toward optimistic assessments, especially since these people were the ones to initiate the development of this system.

In any case, the view is that the performance measurement system helped the management team, especially the top project management team, to put more focus and attention to aspects of the project otherwise easily overlooked. It provided a clear picture of the project as a whole and it definitely worked as an early warning system in many situations, alerting the project to future issues and allowing these to be resolved. In total, it is claimed that it strongly contributed to the overall success of the case project. A further testament to the benefits of the system is the fact that another four projects have used the same system, albeit with some additional indicators. An evaluation of these altogether five pilot projects has shown the need for performance measurement and verification capabilities.

When reviewing the 8 indicators ex post, they can be categorized in terms of their usefulness as an early warning source, determined to a large extent by their nature as a lagging or leading indicator, see Table 2. Employee satisfaction, interface actions and risks are the most useful indicators in this respect. Supervision actions and float are two indicators that, despite being leading, are considered only to be of medium contribution to identification of early warning signs. The reason is that although they both display delays and progress obstacles, these are in fact the result of a cause and effect chain that the indicators fail to detect the start of. The source of the problems should ideally have been identified even earlier, and often were by means of the indicators for interface actions and risks. The two least contributing indicators were growth in contract and cost-related modifications. As has been mentioned, these are truly lagging indicators which are measured after the fact and provide little basis for detection of early warning signs.

Table 2. Type of indicators in the designed performance measurement system

|  |  |  |  |
| --- | --- | --- | --- |
| Indicator | Type of indicator | Duration of measurement | Level of efficiency as an EW source |
| Competence and staffing | Leading | Until sanction of the project | Low |
| Employee satisfaction | Leading | Whole project | High |
| Interface actions | Leading | Whole project | High |
| Supervision actions | Leading | Whole project | Medium |
| Risks | Leading | Whole project | High |
| Growth in contracts | Lagging | After sanction | Low |
| Cost-related modifications | Lagging | After sanction | Low |
| Float | Leading | Whole project | Medium |

As mentioned earlier in the paper, there is a strong demand from the oil and gas industry for improving its performance toward the path to reaching even higher success rates. We believe the results of this research is a proof that application of early warning systems, besides its positive impact on the specific case studied, can have a positive impact on the performance of projects in the entire oil and gas industry. This is due to a standardized procedure which all projects in this industry follow. Also, this tool being closely linked to risk management practices, can aid project managers in effectively detecting problems in advance and taking corrective actions on time.

## Conclusions

Through this paper we have tried to demonstrate the link between the two concepts of early warning and performance measurement, and indicate how the implementation of performance measurement as an early warning system in a project can contribute to the improvement of overall project performance. According to Almahmoud (2012), in today’s complex and competitive environment, there is a need for managing project performance in a proactive rather than a reactive manner. Performance measurement of early warning indicators is a direct response to this; the leading indicators can actively contribute to taking proactive action to prevent imminent problems. Lagging indicators, on the other hand, provide information about issues after the fact and can represent a basis for learning, but not as a tool for early warning.

In the case project, according to neutral measurements of success and the project management team, early warning based on performance measurement contributed very positively to the success of the project. This does not prove that use of a performance measurement system can guarantee success in any type of project, but represents a promising result. In the future, broader investigations of such systems should be carried out. Testing this approach in different projects, in various organizations and environments, can provide further insight into the potential of the approach and how such a system should be designed and used.

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