Identifying Early Warnings in Drilling Projects and Finding their Relationships with the Outcomes and Problems of these Projects in Some Real Cases in Iran

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ARTICLE INFO

Keywords:
EARLY WARNING,
DRILLING PROJECTS,
PROJECT OUTCOMES,
PROJECT PROBLEMS,
CASE STUDY
INTRODUCTION

Received: 2 Mar. 2018
Received in revised: 26 Apr. 2018
Accepted: 11 May. 2018

ABSTRACT

As projects increase in size and complexity, they become more difficult to handle; one of these large and complex projects is oil and gas projects. The current controlling processes of projects are not able to detect the problems in early phases of the project and are rather delayed, which leads to extra time and cost. One solution is to find the symptoms of problems in the early phases. Due to the importance of drilling projects in upstream sector, the main objective of this research is to identify the early warning symptoms of problems in drilling projects and to find the relationships between the selected early warnings and the outcomes and problems of these projects. To this end, the early warnings have been recognized through literature review and interviews with experts. Then, a case study analysis is performed to find the relationships between early warnings and project outcomes. All the cases have been selected from previously completed drilling projects in one of the oil fields of Iran. The findings show that there is a relationship between early warnings, project outcomes, and project problems.

1.Introduction

The performance of a project highly depends on the determining precision of the predictive factors of performance in the early stages of a project. In this regard, projects are usually revised over their running life depending on their prediction precision and complexity. Increasing complexity in projects and rapid changes make the governance of projects increasingly challenging (Williams, Jonny Klakegg, Walker, Andersen, & Morten Magnussen, 2012). They require quick and successful responses to a whole extent of different alerts (Ansoff, 1975). In light of the financial weights and turbulence in the professional workplace, modern development projects must be executed at a less cost and less time. One of the most important and complex projects in many countries is oil and gas projects. The economy, especially in industrialized nations, relies upon oil and natural gas (Postali & Picchetti, 2006; Weijermars, 2009), and, with a specific end goal to take care of this demand, the oil industry works at high power levels around the world (Salazar-Aramayo, Rodrigues-da-Silveira, Rodrigues-de-Almeida, & de Castro-Dantas, 2013). Project managers must have the capacity to adjust changes occurred during the execution of projects and must have the ability to respond to them quickly. Moreover, managers should be able to predict the future of project based on these changes and take corrective actions (Kaushik, 2013).

The control in project execution is based on estimation and considering the difference between "what was planned" with "what is being done", i.e. calculating the deviation between the planned and the actual states. Conventional systems for project management cannot suitably address the problems of the projects. McKenna, Wilczynski, and VanderSchee (2006) estimated that about 30-40% of projects in oil and gas industry suffer from budget and/or schedule

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overrun larger than 10%. Furthermore, Earnest Young (EY) Company investigated data from 365 projects all over the world, including upstream, liquefied natural gas (LNG), pipelines, and refining segments. Their study showed that the majority of the projects are facing delays and/or cost overruns, and these overruns are common in all of the segments and geographies; 64% of the projects are facing cost overruns, and 73% of the projects are reporting schedule delays (Preis, Burcham, & Farrell, 2014).

Exactly when cumulated deviations in the project are recognizable and considered as critical, it suggests that there should be a problem with the project execution. If that problems are not rapidly and successfully solved, the unsolved problems may develop into clashes and debate between project parties (Bower, 2003). As a result, projects often suffer from weak performance such as rework, low productivity, schedule delays, cost overruns, and quality defects (Love & Smith, 2003; Rahman & Kumaraswamy, 2004). Having recognized deviations, usually a backward analysis is performed to examine the issues and procedures to manage the impacts of the problem(s). The delayed identification of the problems leads to additional cost called as "cost of reactive approach", which could be significant based on the nature of the problem and the timing of problem detection. Generally, this cost of reactive approach contributes significantly to the cost overrun on projects (Kaushik, 2013).

The above paragraphs obviously showed that despite the use of project management tools in recent years, a lot of projects face time delay and cost overrun yet. Many oil and gas projects in Iran, including drilling projects, have been terminated with a lot of delays and cost overruns. This is because techniques used for controlling the projects are based on deviation management, and, often after finding a significant deviation, a backward analysis is performed to find the problem. This adds extra time and cost respectively to the final actual finishing time and the actual cost of the project. Thus, a proactive approach can be use instead; one way to prevent failure or deviation from the main objective is to identify possible signs of project failure during the early stages of a project in order to take the necessary corrective measures. Therefore, the main objective of this study is to find early signs of problems in drilling projects in the early phases of the projects and so as to find the relationship between them and project outcomes and problems and finally take the necessary proactive actions.

2. Literature Review

Conventional systems for project management cannot suitably address the problems of the projects. The conventional techniques for project control rely upon what really happened, i.e. historical data. They use patterns to predict future events; it is hard to see unforeseeable changes or conditions which are outside the extent of project environment by using patterns. The execution control of oil and gas projects could be seen in a comparable way except for the variables which are to be measured, and tools could vary in accordance with oil and gas projects. The current controlling and execution management practices are not able to distinguish the problems adequately early and are constantly to some extent late. It is clear that projects do not result in total failure in a relatively short period of time (Walley, 2013). One way to stay away from project failure or deviation from the first objectives is to endeavor to recognize conceivable indications of project failure during the early phases of a project, keeping in mind the end goal of the project to take the essential corrective measures (Haji-Kazemi & Andersen, 2014). The concept of early warning (EW) in a management context was first discussed by Ansoff (1975) and was later supported by Nikander (2002) in projects. According to Nikander (2002), "an EW is an observation, a signal, a message or some other items which 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 issues. It is a signal, omen, or indication of future developments." He devised a preliminary model outlining the character of the EW's perceptions (Figure 1), which sees project occasions as a period bound sequential stream of occasions. Data about the stream can be acquired at any given time (e.g., EW's of potential future project problems). Such information can then be processed and responses will be required in order to influence the flow of the project.

Few authors have mentioned in their studies about the exact time at which the early warning sign identification should begin in the project life cycle. According to Lewis (1993), the prerequisites of project success are the things that must be in order before the project is initiated. Haji-Kazemi, Andersen, Eleftheriadis, and Capellan (2015) believe that

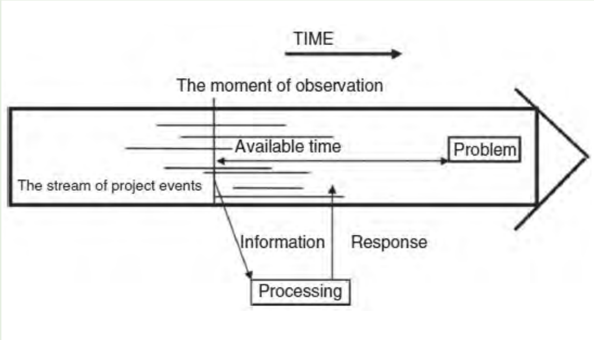

Figure 1 : Preliminary model of early warnings devised by Nikander (2002)

when early warning signs are recognized in the early phases of a project, the accessible time will be fairly sufficiently long for project managers to take correcting measures in the consequent phases of the project. For example, in the case that some warning signals related to cost and time limitation are identified in the early stages, budget estimating in the initiation phase can be performed more accurately. An expansive scope of the project management focuses on early warning signs through the treatment of risk management as one vital piece of the field's toolbox. According to Nikander (2002), because 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, McKeeman, and Zhang (2007) also link these two concepts by stating that early warning signs provide an indication of evident risks, and thus an assessment of a project exposition to future problems and failure. Both Kerzner (2013) and Lientz and Rea (2007) discussed cause-and-effect (cause-and-problem) chains in projects. Haji-Kazemi and Andersen (2013) also believe the concepts of leading, and lagging indicators need to be included here since there seems to be a link to early warnings. In support of this idea, Keil and Montealegre (2000) recommended that managers should need to ask themselves in the earliest possible stages of the project if there are any "red flags" seriously enough to lead to project termination or remarkable redirection. Paying attention to these signs earlier in the project increases the probability of successful outcomes.

In recent years, various empirical studies discussed early warnings in different projects. Kappelman et al. (2007) identified a list of early warning signs of IT project failure. Spjelkavik, Andersen, Onsøyen, Fagerhaug, and Marheim (2008) introduced a conceptual framework for early warnings in projects as a tool for contribution to project success in their studies. Williams et al. (2010) investigated why methods fail to pick up early warning signals, how current project assessment methods try to uncover early warning signs of problems, and how successful current project assessment methods are trying to uncover early warning signs of problems. Haji-Kazemi, Andersen, and Krane (2013) provided an overview of the full extent of early warning detection approaches which can aid project managers in taking corrective actions timely enough for preventing failures. Their study showed that the choice of the most effective approach for identifying early warnings is arguably dependent on the type of project, organizational culture, and the project environment. Haji-Kazemi and Andersen (2013) presented an overview of the concept of early warning signs in oil and gas projects and explained 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. Derakhshanalavijeh and Teixeira (2017) identified and evaluated the relative importance of the significant factors contributing to the gas-oil construction industry of Iran as a case study for developing countries. The results of their survey revealed that the main causes of cost overrun in this industry include inaccurate cost estimations, improper planning, frequent design changes, inadequate labor/skill availability, and inflation of costs of machinery, labor, raw material, and transportation prices.

Having reviewed recent literature on early warnings, it was found out that most of the previous literature identified early warnings in different projects, but none of them investigated the relationships between them and project performance with the data from previous projects. In this study, we identify the early warnings in drilling projects and investigate the effect of these identified early warnings on projects success or failure via case studies and quantitative analysis.

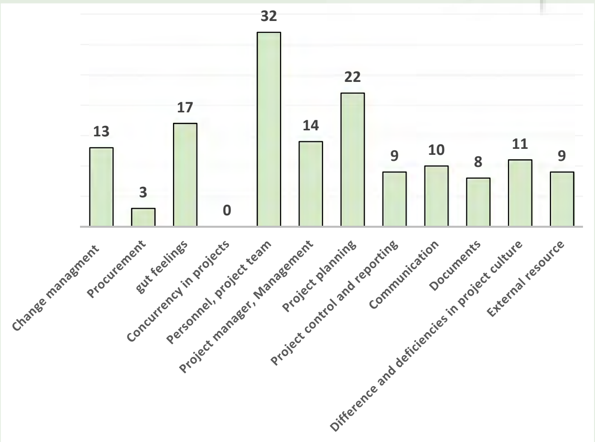

Figure 2 : Classification of early warnings into some subcategories based on literature survey.

3. Research Methodology

As the main objective of this study is to identify the early warnings of drilling projects and to find the relationship between the identified early warnings and project outcomes, the methodology of this research includes four steps. The first step is to identify the early warnings related to drilling projects. In this step, we selected early warnings from two sources, namely literature review and experts interviews. The second step is to select project performance indicators. Menches and Hanna (2006) developed a performance measurement index with the following six project outcomes: percentage of budget overrun, percentage of schedule overrun, actual percentage of profit, change in work hours, number of change orders, and communication among the project team. In this study, project performance indicators should be selected based on the features of drilling projects and the availability of data. The third step is to study the relationships between the selected early warnings and performance indicators via case studies to find out whether or not early warnings differ in successful and partially (un) successful projects. Finally, after finding the relationships between early warnings and project performance in the previous step, the quantitative analysis was performed to find the correlations between early warnings and project performance indicators.

4. Early Warnings Identified by Literature Review and Interview with Experts

Recent works on risk management and early warnings in project management were studied; most of them identified early warnings in oil and gas projects and some of them could refer to drilling projects. Having reviewed the literature of early warnings in projects, 148 early warnings were identified in projects. According to the kind of early warnings found by reviewing the literature, it was confirmed that the main early warnings found are qualitative (78 out of 148, i.e., 53 %). Moreover, 54 early warnings found were quantitative, and 16 early warnings were categorized in gut feelings. In addition, EW's can be categorized into classes, many of which include early warnings that have the same meaning and are relevant to that class. Subcategories in this thesis are change management, procurement, gut feelings, concurrency in projects, personnel and project team, project management, project planning, project control and reporting, communication, documents, difference and deficiencies in project culture, and external resource. As Figure 2 shows, most of the early warnings are classified into personnel and project team (22%) and project planning (15%).

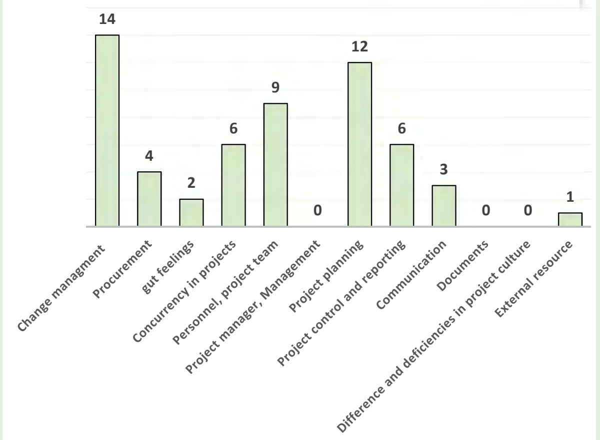

Figure 3 : Classification of early warnings from experts' interview into subcategories.

Since academic papers investigated early warnings in general for oil and gas projects, expert interview is the most valuable source in this step for identifying the early warnings. In this step, experts from drilling projects were asked to share their experience. Since there were not many studies conducted about early warnings, the expert interview was selected as a suitable method for this research. Finally, having investigated the experts' interviews, fifty-seven early warnings in drilling projects were identified. Early warnings identified by interviews are listed in the appendix. According to the kind of early warnings found by reviewing literature, it was revealed that most of the recognized early warnings were quantitative (41 out of 57, which equals 72%), and the remaining (16) were qualitative. The classification of early warnings into subcategories is shown in Figure 3.

As Figure 3 shows, the majority of the early warning

Table 1 : Early warnings from literature and experts' interview selected for further analysis.

Early Warning from Literature	Early Warning from Experts' Interview
Major changes in performance level for a team or individual members reflect problems.	Delay in receiving drilling fluid
Significant project scope items are omitted from bid packages.	Late scope change
The project team is lacking in the necessary expertise and experience to successfully execute the project	Delay in drilling because of rig repair
Low skill or a project manager with little experience	A lot of claims between contractors and employer
The project team is experiencing a high turnover rates and instability in team membership.	Delay in the process of procurement
Significant changes in project at late phases of project	Delay in receiving critical equipment and materials
Project team members are overscheduled.	Delay in process engineering
Early project delays are ignored- no revision to the overall project schedule	High variation in drilling quantities and original estimates
Project resources have been assigned to a higher priority project.	
Inaccurate cost estimating.	
Fluctuation of raw construction material prices.	

indicators were related to the "change management" and "project planning" by 25% and 21% respectively.

Since the aim of the study is to find the relationship between early warnings and project outcomes, only early warnings which are measureable, which happen early in the project, and which provide available data are selected. Based on such criteria, the following early warnings are selected from the literature and experts' interviews for further analysis (Table 1).

5. Early Warning Indicators

After analyzing early warnings from literature and experts interview, it became evident that many of them were identical and could be integrated into one early warning. As a result, six early warnings were finally selected and summarized in Table 2.

6. Project Performance Indicators

According to the availability of data, two performance indicators, namely mechanical completion index (MCI) and total cost index (TCI) of the project are selected for this research. These two indicators show the variance of time and cost respectively.

Mechanical Completion Index: MCI in drilling projects is described as checking and testing equipment and construction to confirm that the installation is in accordance with drawings and specifications and ready for commissioning in a safe manner and in compliance with project requirement. MCI includes all drilling and completion phases and all the testes needed just before handing over the well to the exploiter. If mechanical completion (MC) is confronted with time delay, the finish time of the project will be delayed (Choi, 2007).

Total Cost Index: TCI means the total cost of drilling well. It includes all the costs related to engineering, drilling, equipment, materials, and other costs. If projects are executed at the lowest cost, they are cost effective. A high variation compared to the planned cost could lead to the project failure. Thus, TCI is used as another project performance indicator.

7. Data Collection

To study the relationships between early warnings and

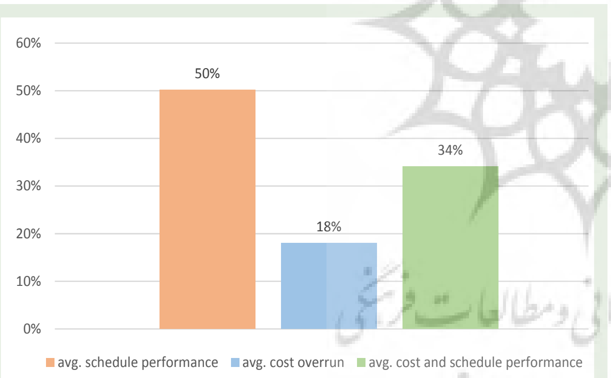

Figure 4 : Project performance.

Table 3 : Results of the case studies.

Early Warning	Project Cases			
	1	2	3	4
NCO	●	X	●	○
CCO	●	X	●	X
DF	○	X	●	○
PS	●	○	●	X
RR	○	X	○	X
PROC	●	○	●	○

Table 2 : Early warnings selected for performance prediction model.

ID	Early Warning Indicator (EWI)	Measurability
Number of Change Orders (NCO)	Number of change orders	Number of changes in project
Cost of Change Orders (CCO)	Cost impact of changes	(Actual cost-planned cost)/Planned cost
Drilling Fluid (DF)	Delay in receiving drilling fluid	Time waiting for receiving drilling fluid
Process Schedule (PS)	Delay in process schedule	Actual duration-planned duration
Rig Repair (RR)	Delay for rig repairing	Time that drilling process stopped because of rig repairing
Procurement (PROC)	Delay in issuance of purchase orders	Actual procurement progress-planned procurement progress

project outcomes, the data related to six early warnings (NCO, CCO, DF, PS, RR, and PROC) and two project outcomes (MCI and TCI) are collected from the past drilling projects. Data from 39 wells in one of the oil fields in the south of Iran are selected for further analysis. All the projects were performed between 2015-2017. The dataset selected for this research contains nearly identical projects in type, size, and cost, and the data are collected at 7 phases from the beginning to the end of projects. The phases of the wells were Hole 26”, Hole 17”, Hole 12 1/4”, Hole 8 1/2”, Hole 6 1/8”, completion, and demobilization.

For classifying projects into successful and less than successful cases in this research, projects with either a 10% growth in total cost index (TCI) or a schedule delay of more than 10% in the completion of project (MCI) or in both indexes are categorized in less than successful projects. Having reviewed the data, it was found out that most of the projects had schedule overrun and cost overrun. By the criteria set for determining successful and less than successful projects, only six projects (15%) were successful regarding the schedule performance, but 23 projects (59%) were successful considering the cost performance. The average schedule overrun and cost overrun of all the projects were 50% and 18% respectively.

8. Case Study Analysis

Based on analyzing literature about early warnings, a hypothesis is made that the EWI does behave differently in case of successful and less than successful projects. To achieve the above goal, each early warning was studied over the drilling duration of the projects via case studies. In this section, multiple cases, including completed projects are studied. All documents consist of project close out reports and monthly and weekly reports; the documents related to the risk of drilling projects are also reviewed. The performance of the project is defined in terms of meeting their schedule and cost estimates. The cases selected cover both successful and less than successful projects. We expect that early warnings in less than successful projects should be clearly visible. Cases 1 and 3 were less than successful projects, and cases 2 and 4 were successful projects. Having analyzed the case projects, it was discovered that a higher number of early warnings was detected in less than successful projects as compared to the successful projects. Furthermore, the early warnings detected in less than successful projects contributed to major project problems. The summary of case study analysis is tabulated in Table 3.

It should be noted that “●” means a warning was detected and contributed to a major problem, but “○” represents that a warning was detected but did not contribute to a major problem; “X” means no warning was detected.

9. Quantitative Analysis

After finding that EWI’s differ in successful and less than

Table 4 : Meaningful correlations between EWI and MCI at each phase of the project.

EWI	MCI					
	26"	17"	12 1/4"	8 1/2"	6 1/8"	Completion
PS		-0.650		-0.656	-0.710	-0.842
CCO						
DF	-0.704	-0.669	-0.607	-0.656	-0.718	-0.749
PROC	-0.765	-0.863	-0.859	-0.858	-0.781	-0.842
RR	0.694	0.655	0.708	0.639	0.702	0.747
NCO	0.579	0.716	0.683	0.693	0.605	0.713

Table 5 : Meaningful correlations between EWI and TCI at each phase of the project.

EWI	MCI					
	26"	17"	12 1/4"	8 1/2"	6 1/8"	Completion
PS	-0.695				-0.594	-0.774
CCO	0.550	0.681	0.673	0.761	0.775	0.838
DF	-0.619	-0.566	-0.573		-0.555	-0.722
PROC	-0.587	-0.740	-0.723	-0.700	-0.731	-0.726
RR			0.576		0.567	0.596
NCO	0.577	0.551		0.764	0.730	0.767

successful projects, a quantitative analysis will be performed to derive the relationship between EWI's and project performance indicators; in this step, a correlation analysis is performed. Since data contained abnormal variables, Spearman's rho correlation was used. The following tables show the correlation analysis between EWI's and project performance indicators (see Tables 4-5).

The correlation results presented in the above tables confirms that as the projects progress, the number of indicators correlated with the project performance indicators increases. Furthermore, NCO, DF, and PROC do affect the project performance indicators clearly. It is seen that procurement and drilling fluid are important for these projects, and a higher NCO causes a delay and cost overrun in the projects.

Project Problems Associated with EWI's and Performance of Projects

The quantitative analysis and case study analysis confirm that there is a relationship between early warnings and project problems and project outcomes. After reviewing the past drilling projects, the problems they had faced, and the correlations analyzed in the previous part, we could categorize the projects problems associated with EWI's as listed in Table 6:

10. Conclusion

The delayed identification of project problems leads to additional final costs. This research showed that reactive management adds additional costs to the final actual cost of projects. Thus, we could shift from reactive project management to proactive project management. One way to prevent projects from delay and cost overrun is to identify the symptoms of problems in the early phases of the projects. The main objective of this study was to identify the early warnings of drilling projects and to develop the relationship between early warnings and project outcomes and project problems. Early warnings were identified through literature review and experts' analysis and selected based on a criteria set. For deriving the relationship between EW's and project performance, a case study analysis and a quantitative analysis were performed. The case study analysis confirmed that some early warnings were seen in less than successful projects, and most of them led to critical problems as the project proceeded. Furthermore, the quantitative analysis showed that the number of correlations increases during the execution of project, which means paying attention to EWI's at the early phases of the project can help managers to take

Table 6 : Problems relevant to EWI's.

EWI	Potential Problems
NCO	Performing activities out of planned sequence causes problems for the project
	Changing orders leads to executing some activities again, which causes delay and adds extra cost to the project
	Changing orders causes contractor's claim on their time and cost of the projects
CCO	- Variation from estimated cost
	- Contractors claim on their cost of contract
	- Rework activities affected by NCO add extra cost to the project
RR	- Time waiting for repairing the rig causes delay in drilling process
PROC	- Delay in receiving main equipment and materials, especially in completion phase, causes cost and schedule problems
	Using low quality materials and equipment (usually responds after tray 2 or 3) causes delay in the projects
	Because of sanction, contractors had to manufacture some equipment they needed, which caused delay in the project.
DF	Drilling fluid is one of the most important parts in drilling. Time waiting to receive drilling fluid causes schedule delay in drilling projects.

corrective actions before confronting a major problem. Our research shows that a lot of EW's are qualitative, and we have very poor documentation about them. The majority of the early signs of problems stayed in the brain of the project team. We could develop a system that the warnings of the past projects could be stored for future projects, and experts can use them and learn how to deal with warnings. In addition, reviewing past drilling projects showed that the project performance was not good. Thus, NIOC and clients can assess and rank the contractors before holding tender to assign the project to quality contractors. Moreover, companies in oil and gas can be aware of the importance of EWI's. Finally, for future research, a quantitative model can be developed to predict the future of the projects using early warnings.

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