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Ranking and sensitivity analysis of key factors for successful project management performance: An application of AHP for oil and gas sector

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***Abstract*- Complexities faced by oil and gas projects due to uncertainty and risk, demand the implementation of project management techniques for their successful completion. Therefore, this is made by using analytical hierarchy process, to identify and prioritize the key factors for successful project management performance of oil and gas projects. These factors are categorized into three groups which include attributes of project staff, project planning process and assessment of project quality. Using Expert Choice, a hierarchy is developed followed by pairwise comparison based upon data collection from industrial experts of oil and gas sector. Results of analytical hierarchy process (AHP) concluded that, project completion within estimated time and budget, clarity of objectives and involvement of top management are most crucial elements for improvement in project management performance of oil and gas projects. Whereas sensitivity analysis being carried out according to three different scenarios highlighted factors according to their relative importance.**

Keywords: Oil and Gas sector, Project Management, Analytical Hierarchy Process and Sensitivity Analysis.

I. INTRODUCTION

Oil and gas sector is considered as major contributor of nation's economy and infrastructural development [1]. This sector has two major divisions i.e. upstream and downstream. Upstream sector is concerned with exploration and production of oil and gas and downstream sector deals with refining, transportation and marketing [2]. Oil and gas sector is known by certain characteristics such as huge investments, environmental effects, multi discipline workforce, global influence and high rewards. Many times oil and gas projects face complexities due to unstable political situation, increased market demand, fluctuations in price and tough schedule [3]. These issues sometimes lead oil and gas projects towards cost and schedule overrun as well. The reasons behind cost and schedule overrun are unavailability of skilled staff, unclear definition of projects scope, inappropriate planning, poor project control, lack of competent leadership and inexperienced project management personnel [4]. Besides this, these projects face issues like lack of trained staff, unfavorable market conditions and environmental concerns. Project of oil and gas industry are usually risky, uncertain and provide intangible benefits. These risk also exists due to uncertain cash flow and irreversibility of these projects incorporating economic risks as well [5].

Project management tools and techniques are highly important to handle complex projects within estimated time and budget [6]. It is used by organizations to handle frequent customer needs with in allocated timeframes along with fast decision making. A study based in UAE has concluded that project management practices have positive influence on project success [7]. Organizations use project management tools and techniques to achieve organizational goals in a focused manner. It is also used to predict crisis while handling uncertainties to make a project successful [8]. The success of project management process is analyzed by defined criteria based on cost, time and quality, whereas project success is measured by its objectives [9]. A project which is executed in right direction has an ability to be successful but successful project management always enhance success of projects [10]. Project management practices not only enhance the performance of project manager who is using it, but it also improves project performance. It improves project

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performance by proper budget control and time utilization as estimated [11]. Project management tools and techniques helps to complete projects with in estimated budget and time while meeting desired quality level [12]. Its tools and techniques (DMAIC, PDCA, risk map, decision tree, sensitivity analysis, SWOT analysis, cause and effect diagram) are also used by oil and gas sectors for successful completion of projects [13].

According to the literature, AHP is widely used for many purposes relevant to project and project management. It is one of the most promising technique used for multi criteria decision making [14]. In a study AHP has been used for the selection of investment project of solar thermal based power plant [15]. The application of AHP also exists for construction projects to access safety risk during planning and budgeting phase [16]. A study carried out in Italy used AHP for the assessment of hydropower projects by incorporating stakeholders [17]. AHP also has its application for identification and evaluation of critical success factors for projects of construction industry [18]. The performance measurement of green supply chain of a manufacturing organization is also made using AHP [19]. In Table 1, studies applying AHP for different projects is given.

Project management performance is directly associated with success of oil and gas projects. The knowledge of factors essential for improvement in project management process is helpful for project managers for execution and successful completion of oil and gas projects. Therefore, keeping in view, issues faced by oil and gas sector, this study is made using AHP to identify and prioritize the factors, which are essential for the successful project management performance of oil and gas projects.

II. Analytical Hierarchy Process

AHP is a multi-criteria decision making process which helps organizations to deal with complex and multiple conflicting objectives. It is widely used in many fields like engineering, manufacturing, management and social sciences. It uses pairwise comparison to rank alternatives subject to particular goals [20]. Analytical hierarchical process is a systematic way to prioritize and weight all the objectives. It is assumed that all the objectives of a particular problem are represented in a hierarchy. This technique has ability to deal with complex phenomena of real life by producing most consistent results. Analytical hierarchical process also has a potential for linking with linear programming and expert's systems. It also facilitates decision makers to tradeoff between criteria. It has following basic steps:

I) A hierarchy based structure is defined for identified problem by decomposing it into goal, criteria and sub criteria. It is most important and fundamental step of decision making process. Basically hierarchy based structure is used to link elements of one level to next associated level.

*II)*After the development of hierarchy, pair wise comparison is made between all the alternatives by expert's / decision makers. This comparison is made based on a scale, according to which decision maker's rate elements [14, 26]. Description of scale is given in Table 2.

*III)*Pairwise comparisons of previous step are synthesized to get result of overall priorities and weights of elements with respect to the goals.

TABLE 1
STUDIES USING AHP FOR DIFFERENT PROJECTS

Reference	Topic Addressed
[15]	Selection of investment project of solar thermal based power plant
[16]	Assessment of safety risk during planning and budgeting phase of construction project
[17]	Assessment of hydropower projects by incorporating stakeholders
[18]	Identification and evaluation of critical success factors for projects of construction industry
[19]	Performance measurement of green supply chain of a manufacturing organization
[21]	Evaluation of complexity of projects
[22]	Selection of a renewable energy project in Spain
[23]	Management of project risk for construction projects in India
[24]	Project selection process for six sigma deployment
[25]	Risk assessment for construction projects in China

AHP is developed using a software known as "Expert Choice". It allows group decision making to solve complex phenomena by sharing experience and knowledge. There are certain benefits of Expert Choice, which are explained below.

I) It helps to minimize the influence of dominant group member or groupthink.

*II)*Overall structure of hierarchy is based upon agreement of whole group by considering their concerns. With group discussion, modifications can be made to cover all the aspects.

*III)*In a situation where it becomes difficult to reach a conclusion, it may be decided through voting or average of judgments may be taken.

*IV)*It synthesizes the objectives with respect to goal to get overall priorities.

*V)*Sensitivity analysis is performed using Expert Choice to observe the result of change in objectives.

*VI)*It is an ideal tool for group decisions through cohesive and rigorous process.

TABLE 2
SCALE FOR PAIRWISE COMPARISON BETWEEN FACTORS

Level of Importance	Definition	Interpretation
1	Equally preferred	Two activities contribute equally to the objective
3	Moderately	Experience and judgment slightly favor one activity over another
5	Strongly	Experience and judgment strongly or essentially favor one activity over another
7	Very strongly	An activity is strongly favored over another and its dominance demonstrated in practice
9	Extremely	The evidence favoring one activity over another is of the highest degree possible for affirmation
2,4,6,8	Intermediate values	Used to represent a compromise between preferences listed above
Reciprocals	Reciprocals for inverse comparison	

III. METHODOLOGY

Key factors for successful project performance are identified with the help of literature review and discussion with experts of oil and gas sector. After which a hierarchy is developed based upon three level. Data collection is made by pair wise comparison of one factor with other factor according to their relative importance using scale ranging from 0 to 9. Then based on this data collection, key factors are prioritized according to their importance. After which sensitivity analysis is carried out considering different scenarios to help project managers to deal with varying conditions of oil and gas projects.

A. Key Factors of Successful Project Management Performance

There are many factors which influence project management performance to various extent. These indicators are identified with the help of literature and expert opinion. In this study, these factors are grouped into three categories which include attributes of project staff, project planning process and assessment of project quality.

Several studies indicates that technical knowledge, collaboration between technical and non-technical staff, training of staff and leaderships skills of team are important indicators of workforce's attributes [1, 2, 27, 28]. Clarity of objectives, project completion with in estimated time and budget, work norms and standards and involvement of top management are most important factors for project planning [2, 27-30]. Several investigations concluded that project quality assessment is based upon implementation of quality control programs, ability to respond quickly and adequate risk analysis [2, 27, 30-32]. All these variables are also given in Table 3.

B. Development of AHP Model

Hierarchy model being developed by AHP must meet the goal behind it. The model developed for this study is based on three levels as shown in Figure 1. First level is representing the goal of designed hierarchy i.e. key variables for successful project management performance. Objectives / criteria for achieving goal are represented by second level of hierarchy i.e. project staff, project planning process, project quality measures. Whereas sub criteria's for objectives are defined at level three. Sub criteria for project staff include staff's expertise, collaboration, training and leadership skills, whereas project planning process is sub categorized into project completion with in estimated time and budget, involvement of top management, project objectives clarity and its norms and standards. Sub criteria for project quality measures include quality control programs, quick response of queries, implementation of ISO standards and risk analysis.

TABLE 3
ESSENTIAL FACTOR FOR IMPROVEMENT IN PROJECT MANAGEMENT PERFORMANCE

Main	Sub Categories	Notation	References
Attributes of project staff (PS)	Technical knowledge	PS1	[1, 2, 27, 28]
	Collaboration	PS2	
	Leadership skills	PS3	
	Training	PS4	
Project planning process (PP)	Project completion with in estimated time and budget	PP1	[2, 27-30]
		PP2	
	Work norms and standards	PP3	
	Clarity of objectives	PP4	

	Top management involvement		
Assessment of project quality (PQ)	Quality control programs	PQ1	[2, 27, 30-32]
	Ability to respond quickly	PQ2	
	Risk analysis	PQ3	
	Implementation of ISO standards	PQ4	

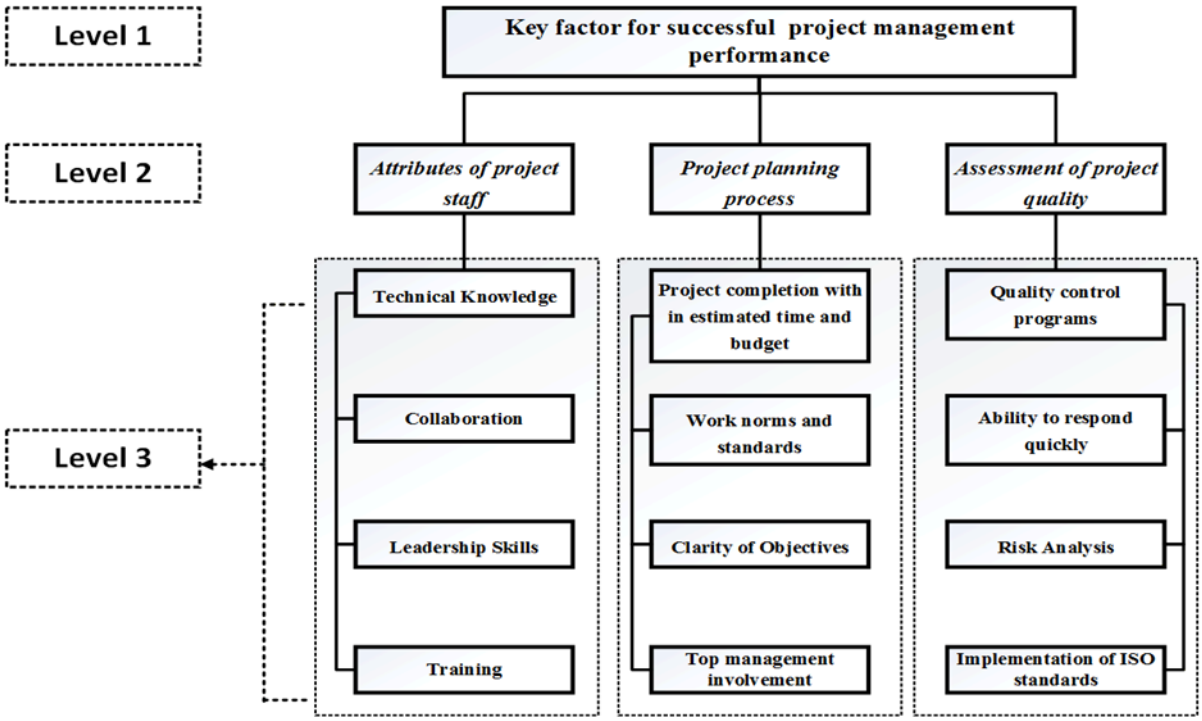


Figure 1. Hierarchy developed for essential factors of project management performance

C. Data Collection

A questionnaire based survey is carried out by industrial experts of oil and gas sector to determine the relative importance of each factor with respect to other. This questionnaire is based upon pair wise comparison between factors using a scale of 0 to 9. Each element is compared with other element to evaluate its relative importance based on some goal / criteria [33]. This method also allows cross checking and consistency between elements. First, a pairwise comparison is made between elements of second level according to the goal of this study. Attributes of project team, project planning process and assessment of project quality are compared with each other. After which, at third level three pairwise comparisons are made for each element of first level according to their respective sub criteria. Pairwise comparison between factors of first level is given in Table 4. Whereas comparisons between attributes of project staff, project planning process, and assessment of project quality are given in Table 5, 6 and 7 respectively.

TABLE 4
PAIRWISE COMPARISON BETWEEN FACTORS OF FIRS LEVEL

	PS	PP	QP	Priorities
PS		0.5	2	0.327
PP			1	0.413
QP				0.260

TABLE 5
PAIRWISE COMPARISON BETWEEN SUB CATEGORIES OF "ATTRIBUTES OF PROJECT STAFF"

	PS1	PS2	PS3	PS4	Priorities
PS1		0.67	1.47	1.58	0.281
PS2			0.70	0.86	0.249
PS3				1.18	0.254
PS4					0.216

TABLE 6
PAIRWISE COMPARISON BETWEEN SUB CATEGORIES OF "PROJECT PLANNING PROCESS"

	PP1	PP2	PP3	PP4	Priorities
PP1		1.29	1.33	1.58	0.286
PP2			0.69	0.97	0.204
PP3				.90	0.277
PP4					0.233

TABLE 7
PAIRWISE COMPARISON BETWEEN SUB CATEGORIES OF "ASSESSMENT OF PROJECT QUALITY"

	QP1	QP2	QP3	QP4	Priorities
QP1		1.09	2.31	1.59	0.344
QP2			1.40	1.37	0.278
QP3				0.97	0.179
QP4					0.200

D. Ranking of Key Factors using AHP

Pairwise comparison between factors is synthesized to get overall ranking of variables. For attributes of project staff, technical expertise of workforce is the most important element followed by leadership skills, collaboration and training respectively as shown in Figure 2. Whereas for project planning process, the most important attribute is project completion within estimated budget and time followed by clarity of objectives, involvement of top management and work norms and standards respectively as indicated by Figure 3. Assessment of project quality is based upon quality control programs, quick response of queries, implementation of ISO standards and risk analysis respectively as shown in Figure 4. Overall consistency of all measures is less than cut off value of 0.20 [34].

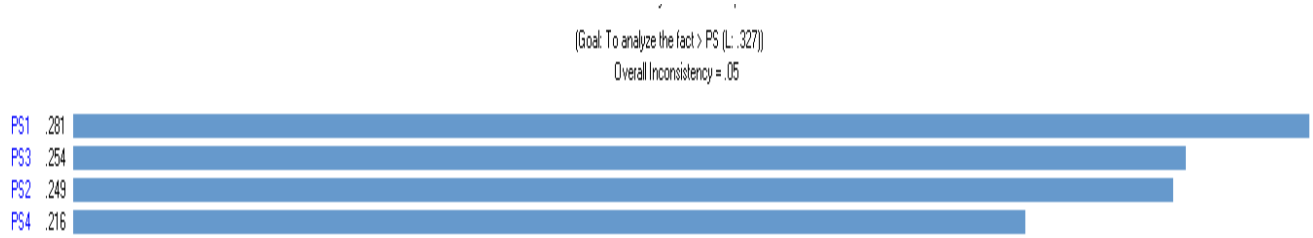


Figure 2: Prioritization of factors of "attributes of project staff"

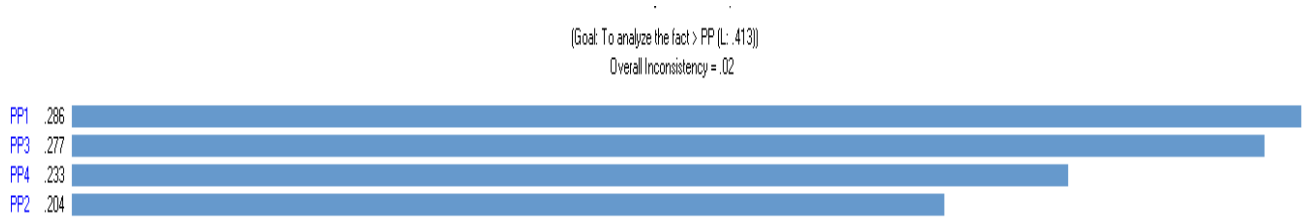


Figure 3: Prioritization of factors of "project planning process"

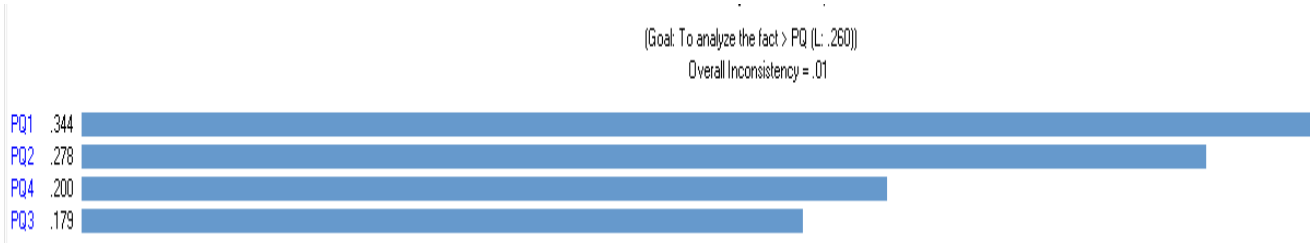


Figure 4: Prioritization of factors of “assessment of project quality”

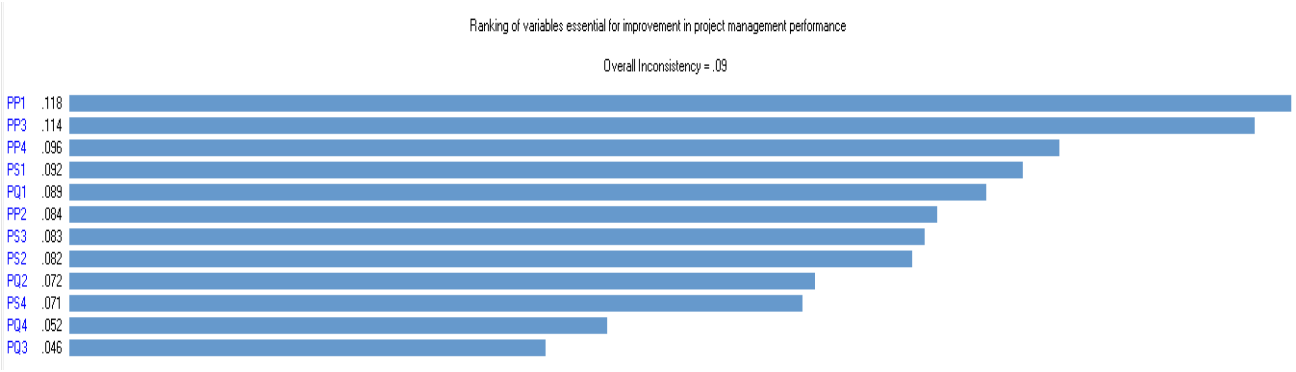


Figure 5: Overall Prioritization of factors for successful project management performance

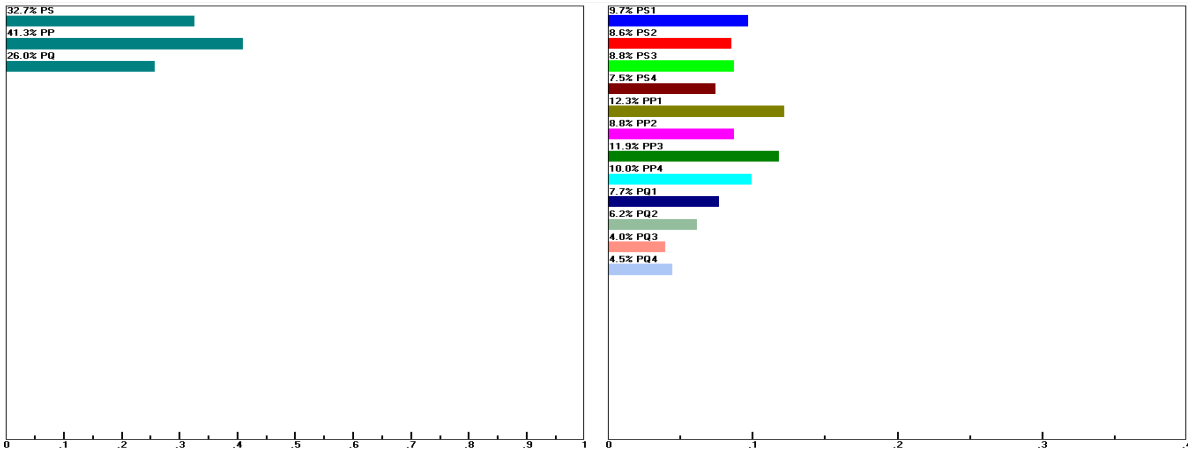
According to the results produced by analytical hierarchical process, most essential element for successful performance of project management process is project completion within expected time and budget followed by clarity of objectives and involvement of top management. Whereas least significant contributors for successful project management process are training of staff, implementation of ISO standards and risk analysis respectively. In Figure 5, all the factors contributing for better project management performance are shown in a sequence with consistency less than 0.1. All variables are ranked according to their priority level in Table 8.

TABLE 8
RANKING OF ALL FACTORS ESSENTIAL FOR PROJECT MANAGEMENT PERFORMANCE

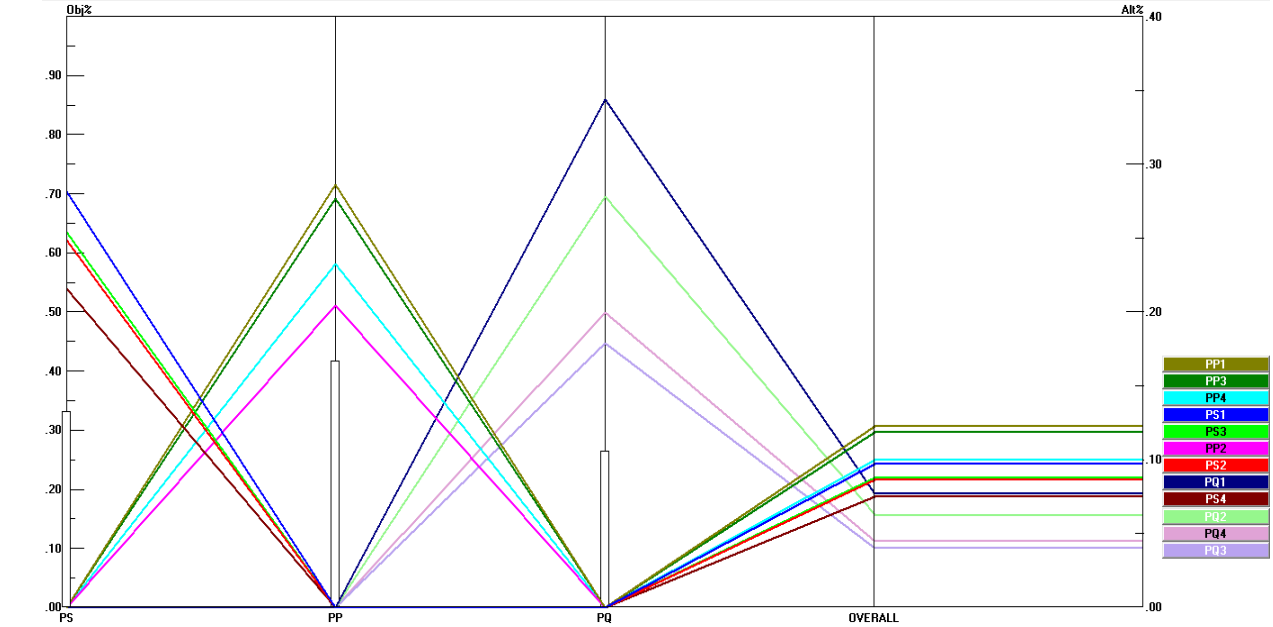
Main Factors	Sub Categories	*Notation*	Rank
Attributes of project staff (PS)	Technical knowledge	PS1	4
	Collaboration	PS2	8
	Leadership skills	PS3	7
	Training	PS4	10
Project planning process (PP)	Project completion with in estimated time and budget	PP1	1
	Work norms and standards	PP2	6
	Clarity of objectives	PP3	2
	Top management involvement	PP4	3
Assessment of project quality (PQ)	Quality control programs	PQ1	5
	Ability to respond quickly	PQ2	9
	Risk analysis	PQ3	12
	Implementation of ISO standards	PQ4	11

E. Sensitivity Analysis

The last step of AHP based decision making is sensitivity, where input data is slightly changed to observe effect on overall results [35]. It is best performed with graphical interface to help decision makers. Sensitivity analysis of AHP based model is shown in Figure 6 (a&b) with overall ranking of all elements. In figure 6a, percentage contribution of each main factor and sub categories is also shown. Besides this, three additional scenarios are discussed by rearranging overall priority structure of model. Analysis of model with different priorities structure, helps experts to evaluate different policies before making a final decision.



(a)



(b)

Figure 6 (a & b): Sensitivity analysis of AHP Model

I. Sensitivity Analysis w.r.t "attributes of project staff"

For first scenario, "attributes of project team" is given highest priority followed by planning process and quality assessment as shown in Figure 7. For this scenario, technical expertise of team is ranked at one followed leadership skills, collaboration and training respectively. Whereas least contributor for this scenario are quick response of queries, implementation of ISO standards and risk analysis. When factor "attributes of project staff" is dragged down by giving priority to other two factors, it is observed that project completion within estimated time and budget and clarity of objectives become dominant factors.

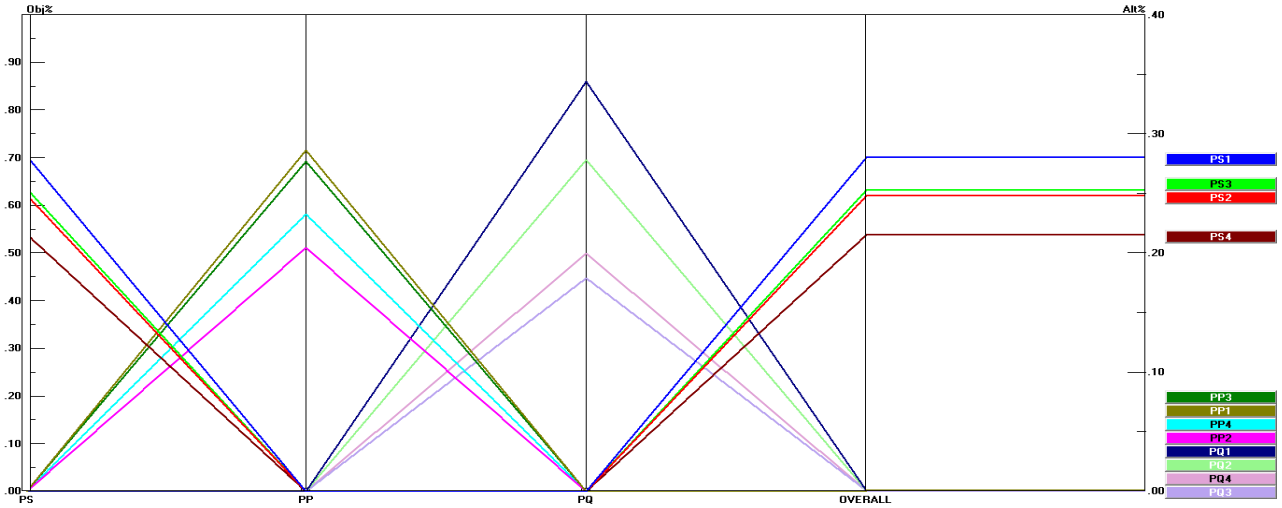


Figure 7: Sensitivity Analysis with priority to "attributes of project team"

II. Sensitivity Analysis w.r.t "project planning process"

In this scenario, project planning process is given highest priority followed by attributes of project staff and assessment of project quality as indicated in Figure 8. According to this scenario, most significant contributor for project management performance are project completion within expected budget and time followed by clarity of objectives, top management involvement and work norms and standards. The least contributor for this scenario are training of team, quick response of queries, implementation of ISO standards and risk analysis. When factor "project planning process" is dragged down by giving priority to other two factors, it is concluded that staff's knowledge and leadership skills become dominant factors.

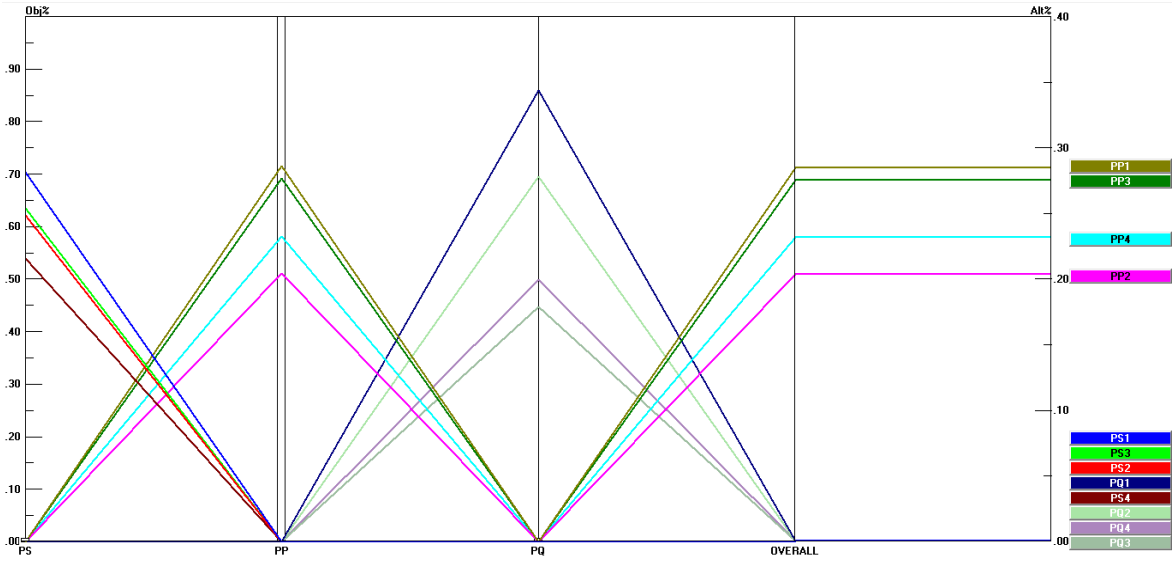


Figure 8: Sensitivity Analysis with priority to "project planning process"

III. Sensitivity Analysis w.r.t "assessment of project quality"

For third scenario, assessment of project quality is given highest priority followed by attributes of staff and project planning process as shown in Figure 9. Most important factors for this scenario are quality control programs, quick response of queries, implementation of ISO standards and risk analysis respectively. Whereas least significant contributor are work norms and standards, leadership skills, collaboration and training of project staff. Whereas, when assessment of project quality is less prioritized with respect to other two factors then project completion within forecasted time and budget and technical knowledge of team becomes most dominant factors.

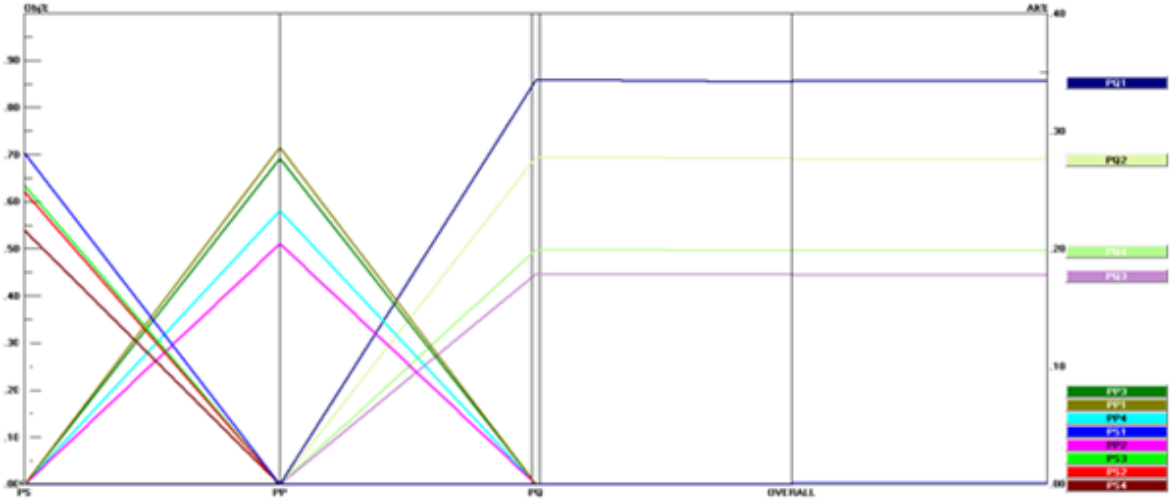


Figure 9: Sensitivity Analysis with priority to “assessment of project quality"

IV. Conclusion And Recommendations

Oil and gas project face many difficulties due to inappropriate planning, tight schedule and uncertainties. Therefore, this study is made using AHP to help project managers by ranking the key factors for successful project management performance. With the help of literature review and expert’s opinion, key factors are selected. After which an analytical hierarchy based model is developed using these factors to facilitate oil and gas industrial experts for decision making in different scenarios. Data collection is made from oil and gas experts using a scale ranging from zero to nine. Based upon pair wise comparison on Expert Choice, collected data is synthesized to get overall results of hierarchy. After which it is found that

1. Project completion within expected time and budget followed by clarity of objectives and involvement of top management are most crucial elements for better project management performance of Oil and Gas projects.
2. Least significant factors for improvement in project management process are quick response of queries, implementation of ISO standards and risk analysis.
3. Three different scenarios are also analyzed in this study by sensitivity analysis to help project managers in varying conditions. Each scenario has different dominant and least contributing factors.

Therefore, project managers should focus on highlighted factors of this study, to achieve success for oil and gas project management process while handling all uncertainties. It will help project managers to minimize difficulties faced during execution of oil and gas projects. Data collection for this study is made from oil and gas sector of Pakistan, whereas for more generic results, data collection can also be made from oil and gas companies of other countries as well.

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