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Risk Matrix for Exploration Portfolio Analysis and Management

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Summary

Exploration Risk Analysis attempts to assess the merits of an individual prospect whereas Exploration Portfolio Analysis expands the vision to include the effects and contributions of individual prospects on the entire portfolio. The portfolio optimization models in E & P industry are extensions of the classic Markowitz' Efficient Frontier Theory which many companies attempt to model. The emphasis of such portfolio models is on (i) economic indicators such as NPV, IRR (ii) risk indicators such as Expected Value, risked IRR (iii) the impact of individual prospect on the entire portfolio. The intent of this paper is (i) to demonstrate the value of treating each geological play as a portfolio which could then be rolled up to the Basin Level (ii) to demonstrate the use of "Uncertainty Web" to address the uncertainty issue of quantification of Probability of Success (POS) and (iii) design a portfolio risk matrix.

Krishna-Godavari Basin hosts a number of plays ranging in age from Permian to Pliocene. The objectives of the different prospects drilled in KG Basin Onland are analyzed in the ambit of Exploration Portfolio Analysis. More number of exploratory wells is required to realize the YTF potential of Cretaceous and deeper syn-rift / rift fill plays.

All portfolio analysis techniques and efficient frontier models presume that the risk associated with a prospect is conveyed in no uncertain terms and begin to use the POS to build Expected Value models. The impact on the Expected Value of a Portfolio due to uncertainty in quantification of risk is demonstrated by analyzing a hypothetical portfolio consisting of five prospects, two in Proven Petroliferous Province, one in Known Petroliferous Province and two in Frontier Petroliferous Province. The analysis is carried out by constructing an "Uncertainty Web" which enables the Exploration Management to identify the parameters which affect the POS the most, and hence the EMV of the portfolio. Ranking of prospects thus based on a single parameter like NPV, IRR or EMV would be misleading and would eventually lead to opportunity loss.

These exercises have been utilized to design a Portfolio Risk Matrix. The Risk Matrix consists of three segments (i) Technical: comprising of parameters like envisaged IOEIP, POS and Upside Potential (ii) Commercial: consisting of parameters like NPV, IRR, EMV, Pay back and a concept called "Comfort" and (iii) Technical Bias. Weightages are assigned to each segment and marks are assigned in a range for each parameter. The Portfolio Risk Matrix could be used to analyze, optimize and manage the Exploration Portfolio.

Introduction

Many E & P companies have discovered the value of managing their assets as blended collection or portfolio, taking into account interdependence of projects rather than considering investments on a project-by-project basis. The "Portfolio Management" approach capitalizes on the fact that all projects interact, whether they involve exploration, development, production or acquisition. Portfolio analysis, like risk analysis, attempts to assess projects based upon the expected return on investment and its perceived risk and uncertainty. While risk analysis limits its perspective to the merits of an individual prospect, portfolio analysis expands the vision to include the effects and contributions of individual prospect on the entire portfolio. In effect,

portfolio analysis broadens the restricted and isolated view of selecting prospects based solely on individual merits and allows the E & P Company to determine how the potential prospects will affect the overall goals, objectives and the risked return of the entire portfolio. Though the basic concepts behind portfolio optimization and asset diversification are widely recognized and understood, application of these ideas in petroleum exploration has proven to be a bit more complicated. The intent of this paper is to design a risk matrix which could be used for exploration portfolio analysis and management.

Portfolio Analysis in Hydrocarbon Exploration

The basic tenets of portfolio analysis in petroleum exploration are extensions of two fundamental concepts propounded by Harry Markowitz. (i) The first concept is that a rational investor is not indifferent to risk, and will seek an optimal balance between risk and return. Thus, when this is applied to petroleum industry, focusing on return alone is not sufficient to determine the value of either a prospect or a portfolio. Most oil companies are not only risk averse but they are also inconsistent in risk aversion. In other words, the same company may invest one day in a high-risk project with a moderate expected return and the next day farm out a low-risk project with a similar return. (ii) The second fundamental concept of modern portfolio theory is that the only way to evaluate the acceptability or value of any project is by considering its contribution to the portfolio as a whole. Individual projects can impact portfolios in many ways. They can diversify or increase risk; they can help companies reach short-term goals or make them fumble in the long term, or vice versa. Often, the implications are not intuitively obvious until projects are evaluated in the context of portfolios.

In the context of petroleum exploration, a prospect portfolio is selected from an inventory of exploration prospects. Inventory is a list of prospects that the management is "considering" while portfolio represents the prospects that would actually be drilled. The probability of success (POS), estimated reserves in case of success, the costs, the preferred economic measures such as NPV, IRR along with risk indicators like EMV are included in the inventory and portfolio listing. By this process each of the prospects in the inventory are effectively compared and ranked. Additional G & G work is carried out to reduce the uncertainties and perception about risk leading to enhancement of POS. As prospects pass through internal hurdle rates of return and there is an improvement in EMV, they mature from prospect inventory to prospect portfolio.
Diversification in terms of exploration of different plays provides an opportunity to realize the potential of the operative plays in a basin. Another important advantage of diversification is that the number of scenarios or the resultant events that are possible in a portfolio increases as the number of component projects in a portfolio increases. The number of possible scenarios in a portfolio with "n" number of prospects is 2^n i.e. the number of scenarios possible in a portfolio consisting of 1, 2, 3, 4, 5, …, n prospects would be 2, 4, 8, 16, 32, … 2^n.

KG Basin Play Portfolio

Krishna Godavari basin, a peri-cratonic basin, is located along the East Coast of the Indian peninsula. It is one of the few basins which host petroleum occurrences in a variety of geological plays. Hydrocarbon occurrence has been established in sediments ranging in age from Permian to Pliocene. The first wild cat exploratory well, Narsapur-1 was drilled on Narsapur structure in 1978, which blew out at a depth of 4035 m., with heavy flow of gas from the well, thereby establishing the presence of hydrocarbon in the basin. Commercial flow of gas was established in 1983 in the well drilled on the Razole structure. Exploratory efforts in the basin since then have resulted in discovery of a number of oil and gas fields, notably Pasarlapudi, Tatipaka, Ponnamanda, Mandapeta, Mori, Kesanapalli-West, Adavipalem, Kesavadasupalem, Gopavaram, Kaikalur and Lingala, Mandapeta, Endamuru etc.

The sustained and relentless exploratory efforts made in Onland part of Krishna Godavari Basin since more than two decades, have generated rich knowledge base with respect to hydrocarbon generation, migration and entrapment. As on 01-04-2007, 382 exploratory wells have been drilled and 43 oil and gas discoveries have been made by ONGC leading to establishment of more than 123 MMt (O+ OEG) initially in-place hydrocarbons in KG onland basin. Integration of all the available information has established presence of five Petroleum systems in Krishna Godavari Basin viz. (i) Kommugudem Mandapeta / Golapalli (ii) Gajulapadu – Kanakollu (iii) Ragahavapuram – Tirupati (iv) Palakollu - Pasarlapudi and (v) Vadaparru – Ravva / Godavari Clay. Important and effective plays targeted for exploration in different areas are Tertiary sequences in Narsapur-Island-Amalapuram, Gollapalli & Mandapeta in Mandapeta-Kommugudem, Kanakollu in Kaikalur-Lingala, and Tirupati in Penumadam-Bhimavaram areas. Ragahavapuram play has been pursued in the northern part of the basin covering Kaza - Kaikalur-Nandigama in the west to Mandapeta in the east.

An attempt has been made to analyze the milestones of exploration in KG Basin Onland with special reference to established and potential plays, their prospectivity perception in the realm of portfolio analysis and management. The targeted plays are divided in to three groups: (i) Tertiary plays (ii) Cretaceous plays (Tirupati &

Ragahavapuram equivalents) and (iii) Deeper plays (Aptian & older i.e. Gollapalli equivalents & older).The drilled wells have been grouped into these three categories based on the primary objective for which they were originally drilled. Similarly successes met in the wells have been studied and placed in respective groups. A well is deemed to be drilled for the deepest objective where multiple objectives have been targets.

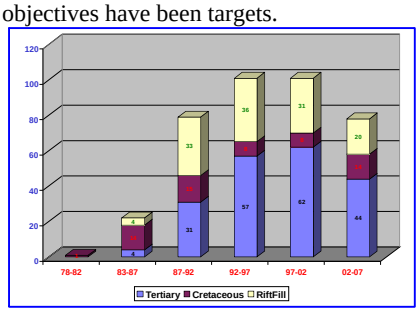

Fig.1 Play wise no. of wells drilled.

The study has brought out certain interesting trends. Exploration started in the Basin with Cretaceous as focus. The thrust shifted to Tertiary Plays in 1986-87 and after discovery of Tatipaka-Pasarlapudi fileds gained further momentum and is being continued to date. Exploration for deeper synrift / rift fill plays has been given importance since the beginning. However, though there have been successes in Cretaceous and synrift/rift fill plays, the number of wells drilled for Tertiary targets has outnumbered all the other targets put together largely due to the continued commercial success in Tertiary Plays. Drilling for deeper plays to larger target depths is also constrained by availability of drilling resources capable of handling HP-HT conditions and higher risk money. The thrust in exploration in any basin is normally guided and driven by past successes and commerciality of such successes.

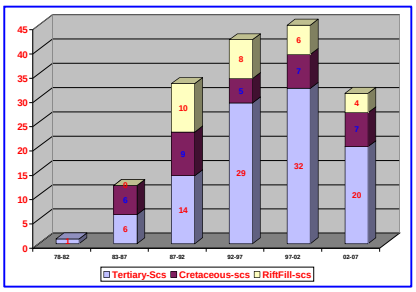

Fig.2 Play wise no. of wells successes.

The Mesozoic sequences are estimated to hold 390 MMT out of the estimated 575 MMT resource potential of KG Basin Onland against which only 60 MMT could be established as initially inplace volume.

An exploration strategy with playwise inventory & portfolio and an even mix of all the plays would help in achieving a better resource to reserve conversion. Such a model should be on a dynamic scale with mid-term corrections provided by risk – reward realization which could be on a three year moving average.

Analysis of a hypothetical portfolio

A hypothetical portfolio consisting of five prospects in varied geological setup that had passed the internal hurdle rates was studied. Two prospects in proven petroliferous province, one in a known petroliferous province and two in frontier petroliferous province were assumed with different levels of risk and reward. The description of the prospects in terms of critical elements is as follows:

(i) Prospect A: Proven Petroliferous Province. Known Petroleum System (!). Main Risk Factor: Identifying a potential entrapment situation. Play peaked out. YTF Field Sizes anticipated to be marginal – medium, the larger ones having been discovered.

(ii) Prospect B: Proven Petroliferous Province. Known Petroleum System (!). Prospect located outside proven geographical limit of the system. Postulated extension of Reservoir and Fairways.

(iii) Prospect C: Known Petroliferous Province. Hypothetical Petroleum System (.). Presence of Source Rock Confirmed. But Correlations not established. Reservoir Facies Model based on Geological Model only. Entrapment model based on good seismic data. Limited well data.

(iv) Prospect D: Frontier Petroliferous Province. Speculative Petroleum System (?). Presence of Source Rock and Reservoir Facies based on Geological Model only.

(v) Prospect E: Frontier Petroliferous Province. Deepwater prospect in 1500 m WD. Play not yet established. Speculative Petroleum System (?). Presence of Source Rock and Reservoir Facies based on Geological Model only.

The estimated mean reserves, Risk Money, Mean NPV and IRR are as under:

Table 1

	A	B	C	D	E
Mean Reserves	10	20	50	100	300
Risk Money	4.3	4.92	17.47	20.36	66.17
NPV @ 0%	82.80	212.64	680.59	1,353.45	3,810.98
NPV @ 10%	5.49	46.87	124.92	247.97	613.31
IRR	11.52%	18.20%	16.85%	16.97%	16.17%

The most widely used economic indicators to accept, reject or compare investment proposals, are NPV, IRR, Payout, ROI. These traditional measures of profitability convey "no risk" in the context of petroleum exploration as these do not account for risk and uncertainty that are inherent to oil exploration in terms of probability of discovering producible hydrocarbons. Historically, the Oil and Gas Industry has made investment decisions based on expected monetary value (EMV) or risk weighted economics. EMV is a function of NPV, Risk Capital and Probability of Success (POS) at a given prospect. The parameter which is difficult to be assessed quantitatively and hence affects EMV the most is the POS. Expert judgments about the POS are classic examples of subjective probability estimates. Single value estimates of uncertain parameters predict an outcome that is possible, usually optimistic, and nearly always wrong. It is a fact that many explorationists multiplying a series of subjective probabilities to estimate the chance of success for the same prospect from the same data produce astonishingly wide range of answers.

The probability of each parameter for all these five prospects such as Source (Presence, Potential, Prospect Location vis-à-vis Migration Fairway), Reservoir (Presence, Continuity, Quality), Entrapment (Trap-Closure – Structural – Stratigraphic, Seismic Data Quality, Integrity and Seal, Top / Lateral Seal, Retention Capacity) and Play Dynamics (Timing of Trap Formation, Timing of Hydrocarbon Generation / Migration).), was assigned by individual members of the prospect appraisal team independently. A range of probabilities that emerged were used to run a Monte Carlo simulation for forecasting the range of distribution of Probability of Success and in turn the Expected Monetary Value.

Table 2

	A	B	C	D	E
Range of POS	17.27% to 32.27%	6.12% to 16.02%	11.31% to 25.49%	5.10% 13.96%	1.94% to 5.92%
Range of EMV	10.84 – 23.81	8.40 – 29.93	61.45 – 160.49	49.70 – 171.45	9.23 – 163.33

Table-2: Range of POS and EMV of prospects due to uncertainty

A sensitivity analysis carried out during the Monte-Carlo simulation procedure, enables to identify the parameters that affect the forecast values most, in this case the POS and the EMV. The Sensitivity analysis provides the ability to quickly and easily judge the influence of each assumption on the forecast. The influence of the different parameters on the POS for each of the five prospects analyzed and pictorially depicted in the Portfolio Uncertainty Web which aids in visually identifying the most sensitive parameters that influence the POS of a particular prospect and in turn the EMV.

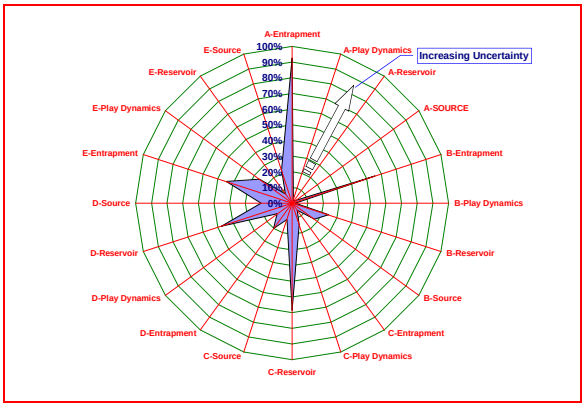

Fig.3 Portfolio Uncertainty Web

The prospect appraisal teams might want to review the entrapment at Prospects A and B, reservoir models at Prospects C & D, play dynamics, source and entrapment at Prospect E in order to reduce the uncertainty about these parameters.

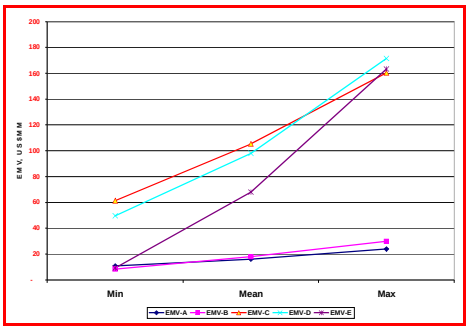

Fig.4 Portfolio Range of EMV

The "Uncertainty Web" only indicates the uncertainty in assessing a particular parameter, its impact on the POS and the relative risk to the other parameters and not the relative riskiness amongst prospects.

The computed EMVs at the portfolio level through a decision tree with minimum, mean and maximum POS for

each prospect are US $ 139.46 MM, 306.03 MM and 548.99 MM and the risked IRR at the portfolio level are 5.54%, 8.59% and 10.90% respectively. The effect of uncertainty in assessment of POS can thus be perceived and it should be endeavor of the appraisal teams to reduce this range the minimum levels possible. This can be addressed by developing robust risk matrices at the prospect and portfolio level.

Portfolio Risk Matrix

Any E & P company intending to perform rigorous portfolio analysis needs to prioritize the parameters that form part of such an analysis procedure. A risk matrix has been designed (Table-3) that could prove useful in an E & P company's portfolio analysis and management endeavors for effectively assessing, ranking and building a robust exploration portfolio model. The risk matrix is divided into three segments Technical, Commercial and Strategy with a weightage of 50%, 40% and 10% respectively.

Three factors, IOEIP, POS and Field Growth Prospects have been included under ***Technical Parameters*** as these encapsulate the geo-technical strengths of a prospect. A weightage of 40%, 40% and 20% is assigned to these parameters respectively.

Under Commercial Parameters, traditional factors such as NPV, IRR, Payback, Risk Money, EMV and a factor called "Comfort" are included with weightages of 30%, 10%, 10%, 20%, 25% and 5% respectively. "Comfort" is the difference between the actual POS assigned by the geoscientists and the POS at which the EMV becomes zero and below which the EMV @ 0% becomes negative. This could serve as a measure of comfort that would enable the management to assess the relative riskiness in commercial terms.

Strategy and Bias: It is a fact that a personal bias operates in decision making, which however cannot be quantified. Two factors (i) strategy and (ii) technical / personal bias are included with 60% and 40% weightages respectively.

Conclusions

The portfolio optimization models in E & P industry are extensions of the classic Markowitz' Efficient Frontier Theory. Though the basic concepts behind portfolio optimization and asset diversification are widely recognized and understood, the application of these ideas has proven to be complicated particularly in exploration. Play analysis should be included in Portfolio Management methodologies so as to keep an even mix of risk and reward. A play wise inventory and portfolio of prospects with details of POS assessed through a "Prospect Risk Matrix", economic indicators and risk indicators needs to be maintained. This would help the exploration management in systematically building a risk-reward model for each play in the Basin. Analysis of exploratory endeavors in KG Basin Onland indicates that the Cretaceous and older plays require much more input to realize the YTF potential.

The concept of Uncertainty Web would help companies in listening to the explorer and encourage the prospect appraisal teams to voice and document the uncertainties in a range. This in turn would help in identifying the parameters which affect the POS of an individual prospect and consequently the EMV of the entire portfolio. The exploration management might wish to direct the team to revisit such parameters and investigate the assumptions further, in the hopes of reducing its uncertainty, and therefore its effect on the portfolio EMV.

The E & P companies world over endeavor to design risk matrices for each level of investigation viz. Petroleum Province, Petroleum System, Play or Prospect. The "Portfolio Risk Matrix" designed and presented in the paper would help in analysis and management of the portfolio of prospects with the Technical, Commercial and Personal parameters and the internal priorities can be set up and reorganized periodically. Such a matrix needs to be created for each play and then rolled up to the Basin level. This would enable the companies to have a consistency in risk analysis and portfolio management procedures and also a periodical reality check.

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Table 3

RISK MATRIX FOR EXPLORATION PORTFOLIO ANALYSIS AND MANAGEMENT																	
TECHNICAL PARAMETERS : WEIGHTAGE = 50%																	
Parameter	**UNIT**	**Weightage**	**0-5**	**5-10**	**10-15**	**15-20**	**20-25**	**25-30**	**30-35**	**35-40**	**40-45**	**45-50**	**50-60**	**60-70**	**70-80**	**80-90**	**90-100**
IOEIP	**MMB**	**40%**	**<0.5**	**0.5-1.0**	**1-2**	**2-5**	**5-8**	**8-10**	**10-20**	**20-30**	**30-40**	**40-50**	**50-75**	**75-100**	**100-200**	**200-500**	**>500**
Discovery Probability.	**%**	**40%**	**<3%**	**3-5%**	**5-6%**	**6-7%**	**7-8%**	**8-9%**	**9-10%**	**10-12%**	**12-15%**	**15-20%**	**20-25%**	**25-30%**	**30-35%**	**35-50%**	**>50%**
Upside Potential / Field Growth Prospects	**as a % of IOEIP of the propsect under consideration.**	**20%**	**<10%**	**10-20%**	**20-30%**	**30-40%**	**40-50%**	**50-60%**	**60-70%**	**70-80%**	**80-90%**	**90-100%**	**100-125%**	**125-150%**	**150-200%**	**200-500%**	**>500%**
COMMERCIAL PARAMETERS : WEIGHTAGE = 40%																	
Parameter	**UNIT**	**Weightage**	**0-5**	**5-10**	**10-15**	**15-20**	**20-25**	**25-30**	**30-35**	**35-40**	**40-45**	**45-50**	**50-60**	**60-70**	**70-80**	**80-90**	**90-100**
NPV @ 0%	**US $ MM**	**10%**	**0-5**	**5-10**	**10-15**	**15-20**	**20-25**	**25-40**	**40-50**	**50-60**	**60-100**	**100-200**	**200-300**	**300-400**	**400-500**	**500-1000**	**>1000**
NPV @ 10%	**US $ MM**	**20%**	**<0.5**	**0.5-1.0**	**1-2**	**2-5**	**5-8**	**8-10**	**10-20**	**20-30**	**30-40**	**40-50**	**50-75**	**75-100**	**100-200**	**200-500**	**>500**
IRR	**%**	**10%**	**<3%**	**3-5%**	**5 - 8**	**8 - 10**	**10 - 13**	**13 - 15**	**15 - 18**	**18 - 20**	**20 - 23**	**23-25**	**25-28**	**28-30**	**30-35**	**35-40**	**>40**
Pay Back	**Years**	**10%**	**>15**	**11-14**				**8-10**					**5-8**		**3**	**2**	**1**
Risk Money	**US $ MM**	**20%**	**> 75**	**60-70**		**50-60**		**40-50**		**30-40**		**20-30**		**10-20**		**3-10**	**<3**
EMV @ 0% DCF.	**US $ MM**	**15%**	**0-2**	**2-4**	**4-6**	**6-8**	**8-10**	**10-12**	**12-15**	**15-18**	**18-20**	**20-25**	**25-40**	**40-50**	**50-100**	**100-200**	**>200**
EMV @ 10% DCF.	**US $ MM**	**10%**	**<0.5**	**<0.5**	**0.5-1.0**	**1-2**	**2-4**	**4-6**	**6-8**	**8-10**	**10-12**	**12-15**	**15-20**	**20-25**	**25-50**	**50-100**	**>100**
Comfort	**%**	**5%**	**0-5%**		**5-8%**		**8-10%**		**10-12%**		**12-15%**		**15-20%**		**20-40%**		**>40%**
TECHNICAL / PERSONAL BIAS, STRATEGY : WEIGHTAGE = 10%																	
			0-5	**5-10**	**10-15**	**15-20**	**20-25**	**25-30**	**30-35**	**35-40**	**40-45**	**45-50**	**50-60**	**60-70**	**70-80**	**80-90**	**90-100**
TECHNICAL / PERSONAL BIAS	**%**	**50%**	**Unquantified.** **Depends on the perception of the Exploration Manager of the Company.**														
STRATEGY	**%**	**50%**	**Unquantified.** **Depends on the exploration strategy of the company. Could relate to geological objective / new play or geographical domain.** **Prerogative of the Exploration Manager of the Company.**														