Managing Dynamics in the Global Oil & Gas Industry: Past Applications & Emerging Trends

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Abstract

The global oil and gas industry is among the world's largest and most complex, and billions of consumers around the world experience the consequences of its dynamics every day as inventories wax and wane and prices fall and rise. The industry has a long history of System Dynamics applications in three main areas: 1) market dynamics, the interactive movements of capacity, supply, demand, and prices; 2) business dynamics, the performance-driving interactions of corporations and their business units with suppliers, customers, competitors and other stakeholder groups; and 3) project dynamics, the interactions driving cost and schedule performance on the complex projects that develop new reserves and production/distribution capacity.

System Dynamics has a bright future in the oil & gas industry, being in a unique position to contribute to more systematic management that will drive faster and more consistent growth of shareholder value. The future will see a blending of market, business and project dynamics, reflected in models that integrate the commoditized marketplace and asset portfolio management. These models will be the analysis engines for management systems that are fully integrated into the strategy-forming, planning and decision-making processes of the major oil and gas companies.

Keywords: Project dynamics, market dynamics, business dynamics, oil & gas, commodities, supply & demand.

Introduction

The global oil and gas industry is among the world's largest and most complex, and billions of consumers around the world experience the consequences of its dynamics every day as inventories wax and wane and prices fall and rise. The industry has a long history of System Dynamics applications in three main areas: 1) market dynamics, the interactive movements of capacity, supply, demand and prices; 2) business dynamics, the performance-driving interactions of corporations and their business units with suppliers, customers and competitors; and 3) project dynamics, the interactions driving cost and schedule performance on the complex exploration and development projects.

This paper is a summary view of business dynamics issues and System Dynamics applications in the global oil and gas industry from the vantage point of PA Consulting Group and its clients. It is not an exhaustive survey of such applications, although we have cited relevant journal articles for those who are interested.

1) Market Dynamics

In California, weather conditions in the Summer of 2000 coupled with decades of little capacity growth caused wholesale electricity prices to soar well over $100 per megawatt-hour. Yet just two years later long-term supply contracts are being signed below $20 per megawatt-hour. The electricity market did not move alone – oil prices sank below $18 per barrel from $34 in 2000 and in May of this year rose again to over $30, and natural gas prices hover below $2.00 per mcf down from over $5.00 last year.

The deregulated markets for energy are driven by the same laws of economics that operate in other agricultural and mineral commodities. Most commodities follow a recurring demand/price pattern of boom succeeded by bust. Prices are high when the supplies are tight, and prices are low when capacity is abundant and demand is relatively scarce. Many markets have excess capacity, and substantial fixed costs in these strongly interlinked industries make for volatile pricing.

Although it is common knowledge that oil, gas and power are volatile commodities, big bets are made every day and many of them go wrong. Enron (for example) apparently thought they were adequately hedged, yet falling energy prices contributed significantly to their downfall. The State of California "solved" its electricity crisis by entering into long term supply contracts at $40-$50 per megawatt-hour, well above current wholesale prices.

For centuries economists have been trying to reduce business risk by understanding and predicting commodity capacity/supply/demand/price movements. The advent of the digital computer initiated a steady stream commodity price forecasting models of various types, including some System Dynamics models. Yet it is widely acknowledged that the models in common usage do a poor job of predicting commodity capacity/supply/ demand/price movements beyond the very short term, and require significant judgmental inputs even for short-term forecasting. As a result, in the oil and gas business (as in other parts of the energy industry) it is widely believed that reliable price forecasting is a pipe dream, and investment and other management decisions are often made based on forward price curves.

The presumption in this trading-based approach is that forward curves represent the best available information. But forward curves embody two substantial and well-known shortcomings as decision-support tools: 1) they are poor predictors of price movements in volatile markets; and 2) many management decisions involve risk-bearing commitments that extend well beyond the liquidity tenor of the commodities involved – that is, beyond the point where markets become illiquid and forward curves cease to be available. The inadequacy of conventional oil and gas models is likely to increase as markets are increasingly connected dynamically – the oil and gas markets are more tightly coupled now than in the past, and gas and electric power markets are rapidly becoming more coupled as well.

Given the industry's huge cash flows, risky high-stakes decisions and history of price volatility, a more reliable capacity/supply/demand/price forecasting capability would be worth a great deal.

In our experience there are two fundamental reasons why most oil-industry price forecasting is chronically unreliable beyond the very short term. The first is that most forecasting efforts rely on static, open-loop models that, in effect, seek to replace missing feedback loops with exogenous data inputs. Models with a useful breadth of industry detail will involve far too many such inputs for those inputs ever to be internally consistent over time, and this inconsistency is a built-in source of forecast unreliability. System Dynamics modeling helps to reduce this source of forecasting unreliability – by making it possible to replicate real-world feedback loops in the computer, it dramatically reduces the number of required data inputs and thus the potential for significant inconsistencies between them.

The second reason for forecast unreliability is what we term The Scenario Problem, a forecasting by-product of model boundary issues. In a nutshell, a forecast is only as good as the business scenario on which it is based. That's true even for a theoretical perfect model, but in assessing forecast reliability most skeptics do not differentiate between the reliability of the model and that of the modeled scenario. System Dynamics helps to reduce this source of forecasting unreliability as well because of its speed advantage against static, open-loop models. All other things being equal, a dynamic model will require only about one-tenth of the input data needed for an open-loop model covering equivalent organizational or industry scope – this gives a roughly proportionate reduction in the turn-around time for scenario analyses. It makes it possible to simulate and analyze many more scenarios, including Fit-Constrained Monte Carlo analyses requiring hundreds or thousands of simulation runs. If approximate probabilities can be attached across a range of such scenarios, the entire scenario spectrum can serve as the basis for multiple Monte Carlo simulations and for the design and testing of management decisions and policies. In this way System Dynamics modeling can provide a solution to The Scenario Problem and its effects on the reliability of oil & gas market forecasts.

Some in the oil and gas industry will wonder why we do not include the policies and actions of the OPEC cartel as a perhaps insurmountable barrier to oil & gas market forecasting reliability. That is because, like other organizations, cartels have dynamics that can be reliably simulated – OPEC is no exception. Those dynamics have a great deal to do with the internal politics and shifting balance of power between OPEC members and with the balance of capacity, supply and demand between OPEC and non-OPEC nations. These tend to shift systemically in normal times based on supply, demand and price movements in the marketplace. That they can be reliably simulated is evidenced by a model of global oil market dynamics PA built and operated for a major oil company. The consequences of non-systemic OPEC actions (another Arab oil embargo, for example) are readily simulated using scenarios inputs to the model, inputs which can be the basis for Monte Carlo simulation.

Today the main barrier to development and application of such market models in the oil & gas industry is not technical, rather, it is the skepticism of many in the industry that such models are feasible or that they can be reliable. But given that it has been done already, and that comparably complex models of global markets are in use in other industries, such skepticism is likely to influence the rate at which dynamic market models are employed in the oil and gas industry and not whether they are so employed.

PA Models	**Description**	**Client engagements**
Natural gas upstream market model	Simulates the supply, demand and pricing dynamics of a regional natural gas market	Several with major oil, gas and gas transmisión firms in North America
Crude Oil Supply and Demand Model	Simulates Global upstream production and Refinery Capacity; Shows the drivers of the cyclical price differential between heavy and light crude oil.	With two major oil and gas firms

<u>References:</u>

Armstrong, J. (1985) Long Range Forecasting: From Crystal Ball to Computer. New York: John Wiley.

Davidsen, P., J. Sterman, and G. Richardson (1990) A petroleum life cycle model for the United States with endogenous technology, exploration, recovery, and demand, System Dynamics Review 6(1), 66-93.

Ford, A. (1997) System dynamics and the electric power industry. System Dynamics Review 13(1), 57-85.

Meadows, D.L. (1970) Dynamics of Commodity Production Cycles. Waltham, MA: Pegasus Communications.

Paich, M. and J. Sterman (1993) Boom, bust, and failures to learn in experimental markets, Management Science 39(12), 1439-1458.

Sterman, J. (1998b) Modeling the formation of expectations : The history of energy demand forecasts, International Journal of Forecasting 4, 243-259.

Weymar, H. (1968) Dynamics of the World Cocoa Market. Cambridge, MA: MIT Press.

2) Business Dynamics

The upstream oil and gas industry is highly capital intensive even when overall capacity is not being expanded. Production volumes from a portfolio of producing assets will decline rapidly without significant new capital investment each year. Worldwide the industry spends over $100 Billion annually on exploration and production capital projects, and this rises significantly in periodic waves of capacity expansion.

Oil & gas producers face hard investment decisions because it is difficult to know whether a given project will ever pay off. They place big bets on capital projects with a thirty-year lifespan in a market where prices fluctuate widely and frequently. System Dynamics has helped managers understand the interconnections and tradeoffs between exploration and development projects, reserve additions, production profiles, expected revenue and cash flows.

Recently there has been a strong move towards an "asset-light" business model in the energy industry. Enron's spectacular demise masks the fact that more conservative trading firms seem to succeeding with this new business model. Older capital-intensive energy firms are establishing trading arms and trying to decide on the right mix of asset-heavy and asset-light businesses. There are many unanswered questions about how to manage these new businesses both alone and alongside their more capital-intensive cousins.

The future of energy business simulation is being driven by this new and broader view of the assets on which the industry is built. Many new risks are associated with financial rather than physical assets, in the form of new types of supply contracts between players at different points in the industry supply chain. Awareness is growing that physical and financial assets cannot be adequately managed as stand-alone entities, that risks and management decisions alike ripple through each company's whole portfolio of assets and must be understood and managed at the portfolio level.

This represents a significant challenge for oil and gas companies, because the data, information systems and models to quantify and manage portfolio risk have not yet been integrated. The large number of active business elements (both physical and financial), the many connections between such elements, and the pronounced effects of market volatility on the performance of those elements make this a dynamically complex problem. We are convinced that System Dynamics is an essential element of solutions that will emerge during the next decade. We expect that application of System Dynamics will bring about a significant change in how the oil & gas industry defines, measures and manages risk. At present risk management is fragmentary and incomplete: System Dynamics will help to make it comprehensive and integrated.

PA Models	Description	Client engagements
Upstream Oil & Gas Exploration and Production	Business Unit Model of E&P sector evaluates strategies for increasing production and cash flow	Múltiple oil & gas companies
Business Dynamics of the Exploration Process	Simulates the consequences of various strategies for entering a new area to explore for oil and gas.	Multiple oil & gas companies
Gas Pipeline Utility De-Regulation Model	Simulates the monopoly utility provider and evaluates the consequences of strategies for moving toward a deregulated environment.	Gas transmission company
Reputation Strategy	Simulates impact of company's "green" investment (including interactions with stakeholder & special interest groups) on reputation and shareholder value	Multinational oil & gas company.

References:

Bunn, D. and E. Larsen (eds.) (1997) Systems Modelling for Energy Policy. Chichester, England: John Wiley and Sons.

Forrester, J.W. (1964) Modeling the dynamic processes of corporate growth. Proceedings of the IBM Scientific Computing Symposium on Simulation Models and Gaming. Reprinted in Forrester, J.W. (1975a) Collected Papers of Jay W. Forrester. Waltham, MA: Pegasus Communications.

Genta P, et al (1994) How to Use System Dynamics to Create Your Own Future: A Case Study of a Worldwide Oil and Gas Exploration Group, proceedings from the International System Dynamics Conference.

Genta, P. and N. Sokol (1993) Applying a Systems Thinking Approach to Business Process Re-Engineering: A Case Study of a Canadian Oil and Gas Producer, proceedings from the International System Dynamics Conference.

Lyneis, J. (1980) Corporate Planning and Policy Design. Waltham, MA: Pegasus Communications.

Naill, R. (1973) The discovery life cycle of a finite resource : A case study of U.S. natural gas, in Meadows, D.L. and D.H. Meadows (eds.), Toward Global Equilibrium: Collected Papers. Waltham, MA: Pegasus Communications, 213-256.

Packer, D. (1964) Resource Acquisition in Corporate Growth. Cambridge, MA: MIT Press.

Vennix, J. (1996) Group Model Building: Facilitating Team Learning Using System Dynamics. Chichester, England: John Wiley and Sons.

Project Dynamics

Include project portfolios both for exploration and for development.

Because the oil and gas industry is so capital intensive, growth of shareholder value depends greatly on the return it can secure on that capital. The industry record is not good – it routinely averages 8-9% ROE, well under the overall market average ROE of 12-13% for publicly held companies. This underperformance is a result of the high complexity and capital cost of individual projects in the oil and gas industry, and of the great difficulty the industry has in avoiding cost and schedule overruns on those projects. While projects have been growing steadily in complexity and risk, the project analysis tools and management methods in regular use have not advanced significantly.

A deepwater production platform usually costs between $200 million and $1 Billion and take several years to design and build. A recent study by the Norwegian government of 13 deepwater projects costing a total of $ 9.5 Billion found that development costs averaged 27% over budget. Cost overruns of that magnitude make the difference between a project generating 12% ROE and one returning 9%. In addition, significant delays in first oil or gas production and revenues are also commonplace on such projects. In the next few years the stock price of more than one major oil company will be sharply affected by the rate at which new oil and gas production come on line from deepwater fields. For such companies, project performance will directly affect shareholder value.

It is the dynamics of complex projects and project portfolios that make them so prone to cost and schedule overruns. Since the late 1970s System Dynamics models have been a highly effective means of improving performance of complex projects in the aerospace, shipbuilding, computer software, civil construction and automotive industries. The oil & gas industry has lagged behind these other industries in making use of System Dynamics to facilitate the management of complex-project management. For these other industries complex projects are the primary source of revenue, which probably explains why they are ahead of the oil industry in employing System Dynamics as a project management tool. But the oil industry in beginning to realize that, although complex projects are not themselves a source of revenue, without new management methods they have the potential to destroy increasing amounts of shareholder value.

Increasingly the oil & gas industry is launching mega-projects that consist of several large, interdependent field development projects. As a result, there is an increasing need for tools that support the management of entire portfolios of multiple complex projects with strong interdependencies. The automotive industry is the leader in applying System Dynamics to better manage portfolios of projects, and this technology is expected to spread into the oil and gas industry.

PA Models	Description	Client engagements
The Project Management Modeling System (PMMS)	Simulates the dynamics of complex projects and portfolios of such projects	Multiple firms managing onshore & offshore development projects

References:

Cooper, K. (1980) Naval ship production: A claim settled and a framework built, *Interfaces* 10(6), 20-36.

Cooper, K. (1993a) The rework cycle: Why projects are mismanaged, *PM Network* (Feb), Project Management Institute, Newtown Square, PA 19073, 5-7.

Cooper, K. (1993b) The rework cycle: How it really works…and reworks…, *PM Network* (Feb), Project Management Institute, Newtown Square, PA 19073, 25-28.

Cooper, K. (1993c) The rework cycle: Benchmarks for the project manager, *Project Management Journal* 24(1), 17-21.

Cooper, K. (1994) The $2,000 hour: How managers influence project performance through the rework cycle, *Project Management Journal* 25(1), 11-24.

Cooper, K. and T. Mullen (1993) Swords and plowshares: The rework cycles of defense and commercial software development projects, *American Programmer*, 6(5), 41-51.

Conclusions

System Dynamics has a bright future in the oil & gas industry, being in a unique position to contribute to more systematic management that will drive faster and more consistent growth of shareholder value. The future will see a blending of market, business and project dynamics, reflected in models that integrate the commoditized marketplace and asset portfolio management. We expect that these models will be the analysis engines for management systems that are fully integrated into the strategy-forming, planning and decision-making processes of the major oil and gas companies.

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