A CASE STUDY IN BUSINESS VENTURE RISK ANALYSIS

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ABSTRACT

In the present day business environment companies are faced with ever increasing investment risks and a smaller margin of error and are forced to take a more holistic view of the risks associated with large investments.

Business Venture Risk Analysis (BVRA) is the strategic application of risk management tools including process engineering, RAM, qualitative / quantitative risk analysis, economic analysis at key points in the senior level decision making process in a business venture to ensure risk concerns are appropriately identified and cost effectively managed to promote the highest likelihood of strategic business objectives being met.

At KBC Advanced Technologies we have developed a business venture risk analysis methodology for the oil, gas and petrochemical industries which effectively marries the use of Clockwork Solutions proprietary advanced simulation technology with our other proprietary tools and domain knowledge and expertise in the RAM, Risk, Process and Marketing arenas.

This paper will present an approach to evaluate the risk for a business venture in planning a multi-billion dollar capital investment. A large international petroleum refining company was considering modifying an existing refinery to exploit new upstream opportunities, but before proceeding, wanted to determine if, in fact, the upgraded refinery would meet future product specifications and production requirements to justify the investment. The company commissioned KBC and Clockwork Solutions to evaluate the risks associated with the investment in achieving the objectives and then to optimize the investment by focusing on performance improvements to deliver the best possible ROI. KBC provided the domain knowledge of the particular processing environment while Clockwork provided the predictive modeling and simulation expertise. As a part of the business venture risk analysis, KBC/Clockwork built a detailed reliability-centered asset model to simulate and quantify expected performance in terms of products delivered to the market. Discrete event simulation software, enhanced with the capacity to model networks of units and tanks, was used to build an accurate model in the design phase to compute throughput efficiency. Individual component models were used and integrated into a final model to optimize the value of the venture by assessing volumes of product produced and processed and volumes of refined product delivered to the market.

The model outputs enabled decision makers during the design phase to quantitatively determine the best and most cost effective solution to meet project objectives, including maximization of the final product over the system’s life cycle.

"All business proceeds on beliefs, on judgements of probabilities, and not on certainties." Charles William Eliot

INTRODUCTION

The decision to build or upgrade large petrochemical or refinery facilities demands a detailed and accurate economic/technical analysis to justify investment. Risk is an inherent element in any business operation. With each new endeavor, a company’s approach to risk and the understanding of the level of exposure will ultimately determine the venture’s likelihood of delivering its projected returns. The business venture risk (BVR) analysis process involves bench testing the design, operations, maintenance programs and all market and other external influencing factors against the companies stated business plan objectives.

Results of a BVR analysis include the following:

- Identification of all elements of design, operations, maintenance and external influencing factors that will adversely influence business plan objectives
- Optimization of planned design, operations & maintenance to avoid majority of above
- Input to operations plan that will manage and control residual risks to business plan objectives
- All translated into economic impact to the project

A business venture risk analysis involves reliability modeling, process modeling, market forecasting, and risk assessment. This paper focuses on the reliability modeling aspect of the BVR process.

The SPAR reliability model tool is one of the vehicles for the Business Venture Risk Analysis (BVR) providing:

- A model to review and confirm base-line system design and operating parameters
- Identify and modify areas of design and operation that may adversely effect the criteria
- An engine for "what if" scenario modeling / analysis to develop cost effective design and contingency planning options

High-fidelity, discrete event simulation can be used to generate quantitative predictions about future behavior and performance of the contemplated system(s). The simulations use stochastic methods to compute productivity (i.e., the potential revenue stream) of proposed systems while also computing key contributors to system unavailability over a given system life span. Reliability modeling software, enhanced with the ability to model networks of units and tanks, enables rigorous comparisons between different design, cost, operation, staffing, and maintenance alternatives of petrochemical or refining facilities. Accurate predictions of system productivity and operating costs are more important now due to globalization which has enhanced competition in the marketplace with a much smaller margin of error.

Once a model is built to represent the performance of a system over time, it can be used to go beyond performance assessment and focus on performance improvement. Performance improvement scenarios define the impact of changing individual components in the system, operating strategies, adding intermediate storage, etc. on the system performance. These "what-if" scenarios can be used to compare the results to the base case system performance and determine how to most cost effectively improve system performance. Performance improvement scenarios are especially useful and cost effective early in the design phase of a project to improve the reliability in design of the system before project sanction or design freeze.

Why Simulation

Discrete event simulation, sometimes called Monte Carlo simulation, offers strong advantages as a tool for investment decision making in complex systems with significant elements of uncertainty and variability. The primary reasons are:

- Accuracy unequaled by analytic models (closed form mathematical treatments)
- Explicit treatment of variability and uncertainty
- Support for changes of key parameters over time
- Explicit consideration of interaction and coupling
- Flexibility in accommodating case-specific rules and constraints

Discrete event simulation is a method for modeling behavior of complex systems using statistical representations and conditional rules to define behavior of the system's components. Behavior of the larger system results from behaviors of constituent components and from interactions among those components. The life history of a system of such components is represented in the simulation (as in real life) by intervals of operation and repair/maintenance.

An essential capability of reliability modeling software is a way to represent and customize system-specific operating and contingency rules. Most complex systems have rules or constraints unique to that system, therefore; a generic or predefined model is not likely to have system specific logic or operating rules already incorporated. Our experience dictates that it is almost always necessary to construct a customized model for each situation.

Typical metrics generated from the simulation include:

- time dependent system throughput and/or availability,
- optimized spare parts allocations,
- optimized maintenance and inspection intervals,
- equipment redundancy levels, etc.
- number, duration, and consequences of unplanned down time events,
- equipment repair counts and costs,
- spare parts usage,
- accounting of lost production due to each component type
- optimized tank storage sizes
- average throughput over time of units that make up a system with storage buffers

Performance and cost metrics generated from these analyses can be customized to address case-specific issues.

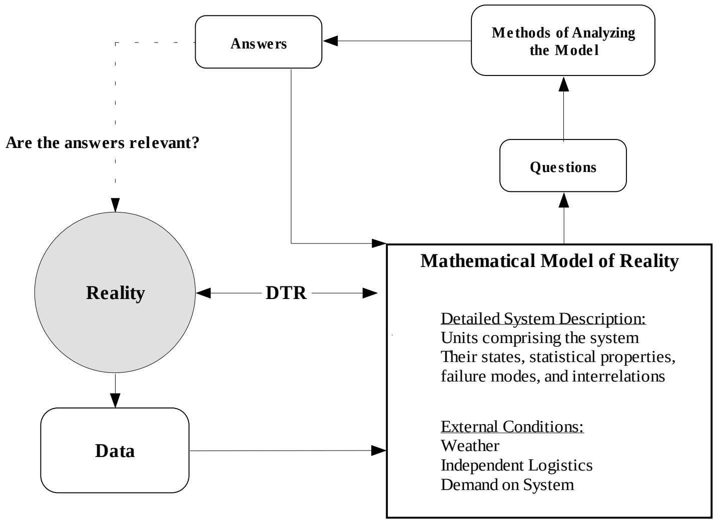

Figure 1: Distance to Reality

DISTANCE TO REALITY

A mathematical model of reality must incorporate all of the relevant factors that will have an impact on the system performance. The predictive modeling experts at Clockwork Solutions and the petrochemical and refinery process experts at KBC work together during a BVR study to accurately model the system. In effect, the joint efforts of KBC and Clockwork Solutions working with the petrochemical or refinery customer significantly minimize the distance to reality to ensure model accuracy.

CASE STUDY

The rest of this discussion is an overview of an actual modeling effort KBC Advanced Technologies and Clockwork Solutions are currently working on The synergetic alliance of KBC and Clockwork Solutions allows for the successful integration of the petrochemical and refinery domain knowledge of KBC and the predictive modeling expertise of Clockwork Solutions. The customer has decided to embark on a new business venture which will allow for the exploitation of new technology to recover petroleum resources. A major refinery upgrade of existing facilities is under consideration as part of the overall project which includes upstream and downstream developments. The customer must also decide whether to buy power, hydrogen and steam from an outside source or build the appropriate hydrogen and cogeneration plants. It is necessary to ensure that the projected throughput availability and product specifications will justify the large capital investment required and meet corporate financial hurdle rates. In addition, it is important to determine whether the system has the flexibility to handle alternate feedstocks to deal with upset conditions. Given the size and risk associated with this investment, KBC and Clockwork have been contracted to help identify and quantify any risk associated with this venture and suggest cost effective means to mitigate against and / or minimize those risks in order to increase the probability of achievement of the business venture objectives. The purposes of presenting the following case study are to illustrate:

- The customer's objectives and requirements of solution
- Project Background
- How reliability modeling software enhanced with buffer storage capability is used to model entire supply chain from upstream to downstream facilities and beyond
- How reliability modeling is used to go beyond performance assessment and focus on performance improvement (reliability in design)
- Clockwork Solution's Role
- KBC's Role
- Initial Results

This case study presents an illustrative, not exhaustive, picture of the possibilities.

In this effort, SPAR models were used to calculate end-to-end throughput predictions for a large refining project. The project consists of integrating well drilling schedules and oil forecasts into upstream processing models, modeling steam cogeneration facilities and steam/water requirements, pipeline transport, storage capacity, and downstream processing units for product delivery to a dispersed market. All sub models will be integrated into a high level model to simulate the performance of the entire system with intermediate tankage and predict the average throughput produced during the system's economic life cycle. In-depth details of this project have been withheld to respect customer-proprietary information.

These results were critical inputs to a financial model the project team used to evaluate investment decisions. The objective of the integrated high level flow model was to quantify and maximize performance impacts of design and operations tradeoffs of each individual unit in the model with different levels of intermediate tankage. The modeling software used for this analysis was SPAR and STORM by Clockwork Solutions, Inc.

The engineering and management teams used the models to quantify combined effects of reliability, maintenance, operating practices and constraints, capacity limits (or bottlenecks), reservoir performance projections, and business objectives. Historically, these concerns have been analyzed independently or with only cursory accounting for the complex interactions among them due to the difficulties involved in an accurate treatment. With SPAR/STORM, realistic models were created which provided accurate treatment of all these concerns and complex interactions.

Customer Objectives

The main objectives of the customer is to perform a basecase assessment of the proposed system, identify options for system improvement and be able to quantify improvement and weigh it against capital and operating cost in an economics model. This objective must be met within the context of meeting the economic goals over the system's economic life. The reliability model results must be used to determine in advance if proposed changes are cost effective to implement. In addition, an analysis on intermediate storage in the system from production to market must be done to determine the best tank sizes to use to give the system flexibility and an opportunity to buffer reliability issues. Because of high capital investment, it is imperative that high unit availability is maintained. The overriding goal is to maximize final product over the system's life cycle.

Role of the Clients

The joint partnership of KBC and Clockwork Solutions provided the customer with an opportunity to perform Business Venture Risk analysis to increase the likelihood of meeting their business objectives. The partnership provided an opportunity for external experts in petrochemical and refinery processes with experts in reliability modeling to combine their strengths in a unique product to meet customer objectives and expectations.

KBC's role is to:

- Provide relevant global operating experience to validate assumptions and operating policies of the specific situation being modeled
- Help create realistic models for the way process equipment operates by providing realistic component failure and repair frequencies based on domain knowledge
- Provide accurate estimations on component failure on system impact
- Use knowledge and experience of domain specific technology and RAM assessments to propose new changes to make to the system and work with Clockwork modelers to determine the system performance impact of these changes allowing quantified cost benefit analysis being performed

Clockwork Solution's role is to:

- Serve as a customer interface to explain how a complex petrochemical/refinery system is modeled using SPAR/STORM
- Develop, build, and execute the throughput availability model
- Generate model results to determine the performance of the system and alternate systems, and other metrics needed by the customer including top contributors to downtime
- Use KBC's domain specific knowledge of petrochemical and refinery operations and processes to validate model assumptions and reduce the "Distance to Reality"

Throughput availability, consisting of mechanical and operational availability, was used as the primary performance metric. Throughput considers system productivity even during turndown and partial outages (both planned and unplanned). This is in contrast to conventional availability, which, as often defined and interpreted, may not account for operation at reduced output levels.

$$\textbf{System Efficiency} = \frac{\textit{Ratio of Achieved Production*}}{\textit{Production Potential}}$$

*model output

The Modeling Process

Modeling was initiated during conceptual engineering design and extended the early phases of detailed design. The basic steps in bringing the modeling effort into the broader systems engineering process were:

- Define targets of analysis
- Construct models using a granularity that provides reasonable fidelity.
- Review and validate assumptions and constraints embodied in the models
- Perform simulations
- Interpret results to identify issues and opportunities
- Present results to design, operations, and management teams
- Refine models as necessary to incorporate new understandings or to address new issues
- Create variants of baseline models to evaluate alternatives for cost effective performance improvement
- Iterate through these steps as needed to support decision making

Results

The project team used the models to:

- Gain an understanding of the facility bottlenecks:

For example, the model showed the residual hydrocracker capacity to be the bottleneck. A detailed modeling analysis on the residual hydrocracker system resulted in the finding that there was a great disparity between the licensor's statement of what the availability of the system could be and what the availability of the system actually might be. KBC experts validated the model results. The large disparity also created a need for the customer to work with KBC and determine operating practices and system configuration changes in the residual hydrocracker that would help meet the economic goals of the entire venture. The residual hydrocracker unit model was then updated to reflect these changes and predict the new, higher throughput efficiency. An integrated refinery model, using Clockwork's in-house STORM modeling software, was used to determine the impact of the residual hydrocracker operation on the final refinery system throughput using intermediate storage. Subsequent scenarios were created to determine the availability of the residual hydrocracker needed to meet project objectives. See Figure 2. (Note: numbers have been changed to respect customer proprietary information). In addition to helping meet system objectives, the modeling process using Clockwork and KBC resources showed that the expected throughput efficiency of the system was very much more aligned with historical system performance of similar units, thus the model was producing realistic results.

- Use upstream facilities reliability models to determine if the upstream can produce the amount of feedstock needed for input to the refinery per year given the system design throughput constraints:

The upstream processing site models were used to determine the average barrels of feedstock produced per year according to the calculated production potential.

Production Potential = minimum of reservoir deliverability or system capacity (Capped)

To determine the production potential per year for the upstream production sites, it was necessary to incorporate the well drilling schedules, expected oil rates per well, well to flow station allocations, well production deferment rules, utility requirements per well, and the cogeneration system into the upstream site reliability model. All of these factors were built into the SPAR model using SPAR's flexible event driven logic maker. For example, logic was created to keep track of the production loss due to failed system equipment. This equipment modeled consisted of down-hole and wellhead equipment for several wells, flow station equipment, and the main processing site equipment. The production deferral algorithm used in SPAR kept track of production loss due to equipment failures so that all potential production from a given well could be added back to the system.

In effect, the upstream production site models were useful for both finding cost effecting reliability improvements and helping identify areas where the well drilling schedule could be modified to meet throughput objectives.

- Identify and optimize the design of specific elements in the individual units.

For example, an extensive model of one of the upstream processing sites indicated that buying an additional centrifuge to serve as a redundant backup to the centrifuge currently in the design would save in excess of $1 million US dollars per year due to lost production. The cost of the centrifuge was small compared to the cost savings it will generate.

- Quantify the impact of logistics on production or system cost.

For example, an in-depth model of the waste discharge system from one of the upstream processing sites quantified the expected magnitude and frequency of overflows due to unscheduled system outages. Although this system did not prove to be critical to system production, this in-depth analysis indicated a potential significant operating cost impact as alternative disposal options had to be considered.

- Assess sensitivity of system performance to data used as input:

Performance predictions were done using inputs from several different reliability data sets. Mean data was chosen as the baseline for most equipment. In some models, low 10% and high 10% confidence data was used to assess sensitivity.

- Quantify impact of adding differing sizes of intermediate tankage on system and individual unit availability over time:

Clockwork's in-house STORM software gives SPAR the capability of modeling tanks as reliability buffers with the units of a petrochemical or refinery model in a reliability based flow model. STORM is used to dynamically model product levels in intermediate and final product buffers and the consequences of these becoming full or empty. STORM is being used to determine the storage size of certain intermediate tanks in the refinery to maximize the unit availability of the bottleneck of the system and the production of the entire system. This storage optimization must consider the size and cost constraints of available tankage.

Model Highlights

Each model consisted of:

- The unit configuration showing the critical equipment in the unit (compressors, turbines, pumps, heat exchangers, columns, etc.), their dependencies, and redundancies, if any. In a reliability model, equipment is considered critical if, upon failure, there is an impact on system performance. Over 2000 major components were included in both upstream production site models.
- The unit operating procedures describing various operating contingencies, turndown modes, etc.
- The equipment characteristics including capacity, reliability (failure rate and failure characteristics), maintenance requirements, and repair times.
- The integrated model abstracted results from the individual component models to gain a big picture understanding of how the entire system will perform during the economic life cycle.

Most equipment was represented at the level of detail consistent with process flow diagrams and P&IDs. KBC worked with these documents to determine critical equipment, reliability data, and the impact of individual component failure on the system being modeled.

The stand-alone models were maintained and used in parallel with the integrated model. The individual unit models helped the design teams in identifying weak points in each of the units. Also, results of the separate unit models served as sanity checks on results of the integrated model.

Once the separate models were validated with KBC process experts and the customer, they were abstracted and then combined into a separate, integrated model. However, the integrated model was more than just the separate models lumped together. Most significantly, rules and constraints governing the interactions among the units were added. Also, intermediate storage between the upstream and downstream plants was modeled to assess potential benefits over a range of possible capacities, ranging from zero up to many hours of production. The final model will serve as a deliverable to the customer to use and modify over the life cycle of the entire system.

The following are examples of other enhancements added to assure fidelity:

- Logic to affect consequential outages or curtailments in any part of the system due to problems in another part of the system.
- Critical shutdown/restart resulting from both intrinsic failures and from induced outages due to problems elsewhere.
- Production boosting of certain units during periods of partial capacity reductions in any part of the system.
- Effect of utility failures on well production and hence on system throughput.

REPRESENTATIVE OUTPUTS

Tables 1, 2, and 3, and Figures 3 and 4 are examples of metrics computed for each design configuration studied. Several dozen alternatives were analyzed. The values in the figures are from the base case design configuration. Later configurations showed improved performance. The tables shown here are for only the upstream plant. Outputs specific to other units were tabulated for all the major elements of the system.

Table 1: Upstream Plant Mean Performance Metrics

Average production over life with production deferment
Average production over life without production deferment
Average throughput efficiency over life
Average production per year
Average production over life from flow stations
Utility deficiency contribution to system throughput loss

Table 2: Equipment Criticality

Equipment Type	Percent Contribution to Throughput Loss
Equip. Type 1	16.8%
Equip. Type 2	8.4%
Equip. Type 3	4.6%
Equip. Type 4	3.8%

Table 3: Unit Criticality

Unit Type	Percent Contribution to Throughput Loss
Unit 1	29.8%
Unit 2	16.0%
Unit 3	9.3%
Unit 4	4.8%

Tables such as these when coupled with capital and operating costs provide the detailed basis for design or operations revisions. Alternate configurations can be modeled by modifying the base case and comparing the new resulting outputs to that of the base case.

The value of providing a distribution of production outcomes like in Figure 4 is that it quantifies the probability of not reaching production objectives. An average value of expected production is difficult to evaluate without knowing the variance.

A result such as in Figure 4 can be input into a financial analysis by selecting a statistical confidence level and extracting the corresponding production level. Whether this level of risk is acceptable has to be determined by financial criteria for acceptable rates of return. This risk level should be used to determine if changes need to be made to the system, and hence additional scenarios need to be run to mitigate the risk of falling below economic objectives.

REFERENCES

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Stream Flows (Throughput Efficiency)	Crude	Gasoline	Distillate
Design Expectations	95%	96%	97%
Base - Initial system configuration without unit boosting and storage	61%	66%	69%
Base - With unit boosting and storage	70%	78%	81%
Bottleneck (75% available)	74%	80%	83%
Bottleneck (80% available)	79%	82%	86%
Bottleneck (85% available)	83%	85%	88%
Bottleneck (87% available)	87%	89%	90%

Figure 2:
Scenario Outputs Determine Impact of Bottleneck on Product Streams*

*This is a work in progress, not all options for mitigation have been explored

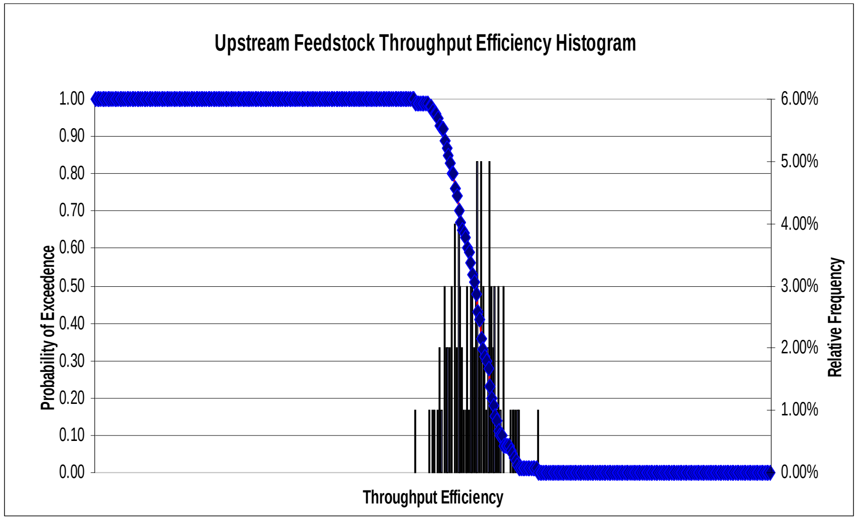

Figure 4:
Upstream Throughput Efficiency Histogram

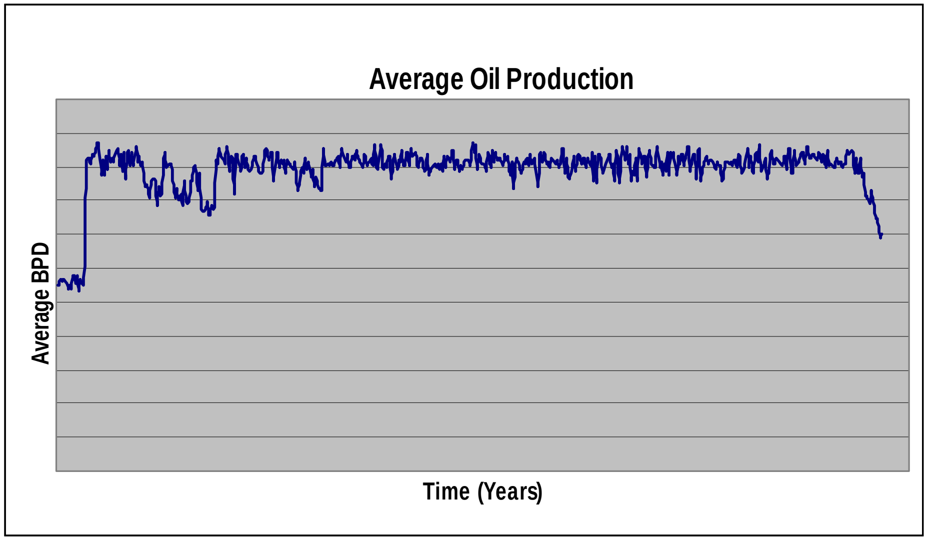

Figure 3:
Upstream Average Oil Production Over Time