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# Buy-back Contract Risk Modeling Using System Dynamics

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## Abstract

*In this paper ContractSim is presented. ContractSim is a Windows program based on a combination of system dynamics and Monte Carlo simulation techniques that can be used to perform risk assessments. A user-friendly interface has been built around a basic risk model. Before the simulator is put to use in a given project, it must be validated by experts in risk analysis to reflect the specific risk elements and dependencies in the project. The first version of ContractSim was designed to evaluate so-called Buy-back contracts, which is being used by NIOC, the Iranian national oil company when foreign companies are contracted to develop oil fields in Iran. When ContractSim has been tailored for a specific oil field development project, project management can perform risk assessments without the continuous support from risk analysts.*

## Introduction

In recent years, it has become common to require uncertainty analyses as part of the evaluation and approval process of large projects in both the private and public sector. An uncertainty analysis implies the construction of a model where uncertain elements are identified and their dependencies defined. The elements are characterized with probability distributions, and the results of the outcome variables of the stochastic model are simulated using the Monte Carlo method. Outcome variables are typically the Net Present Value (NPV) of the project, the total cost, or the time it takes to complete the deliveries. The results can be used for a range of complex decision tasks, like to select the best development strategy, technical concept or contractual conditions.

Although the use of uncertainty analysis is increasing, it has far from reached its potential. Major reasons for this are probably that the theory is difficult to understand and communicate, and that there are few available experts. Whenever there are changes concerning the uncertainty model or the assumptions underlying the analysis, the risk model needs to be updated and re-simulated. This requires the same expertise that did the risk modeling in the first place. Such changes are an almost every day experience. Experts in quantitative risk assessment are a rare resource, and they are expensive. One intriguing question should therefore be asked: Is it possible to reduce the need for experts, and hand over the power of uncertainty analysis knowledge to the (project) people?

In this paper ContractSim is presented as a possible solution to the problem described above. ContractSim is a Windows program based on a combination of system dynamics and Monte Carlo simulation techniques that can be used to build risk models. A user-friendly interface has been built around the model, making it possible for non-experts in risk analysis to do model updates. There is however one important condition for this approach to be successful. *It must be possible to foresee what kind of changes that is likely to be needed*. End user domain knowledge is thus as important as knowledge in modeling and simulator design. In the simulator, conditions that are expected to change become variables in the model. Any new combination of variable values can then be evaluated without any change in the actual model structure. In other words, the need for risk experts may be reduced because the project (management) can now do most of the 'what-if' tasks themselves.

In the first version of ContractSim, the so-called Buy-back contract regime was chosen. The reason for selecting Buy-back contracts was because the cash-flow uncertainty and the complexity of such contracts made it difficult to capture the risk dynamics using ordinary spreadsheet models.

## Buy-back contracts

The National Iranian Oil Company (NIOC) uses the Buy-back contract concept towards foreign oil companies in oilfield development projects in Iran. The oil company has two roles. He finances the investment, and he acts as a total contractor, organizing the development of the oil field, including the construction of a turnkey process plant which is to be operated by NIOC. The dynamics of the buy-back contract is illustrated in figure 1 below.

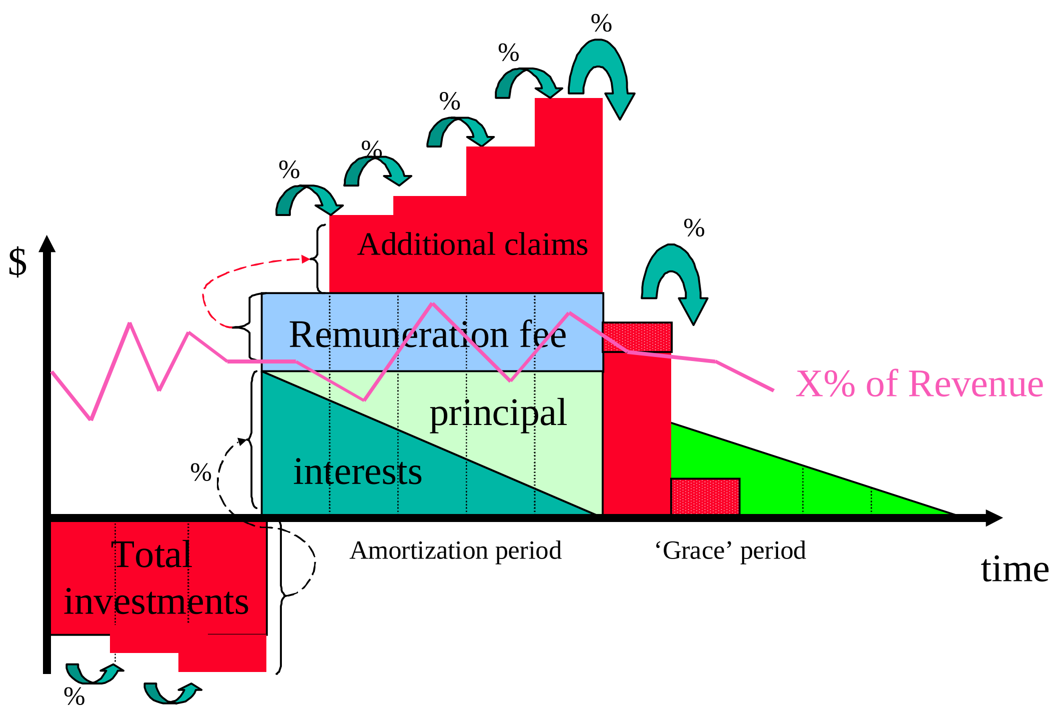



*Figure 1: Buy-back contract cash-flow dynamics*

In the Buy-back contract regime, the investments are converted to a loan (annuity), which is to be paid back by the revenue generated from a percentage of the oil produced. The interest is normally defined as the Libor bank rate. In order to achieve an investment return reflecting the risks involved, a so-called Remuneration Fee (RF) is added to the annuity. The size of the RF is typically an item to be negotiated, not only because it will directly influence the return on investment for the oil company, but also the cost efficiency, a measure used by NIOC to evaluate proposals from foreign oil companies or contractors.

Cost efficiency is defined as the total cost divided by production capacity. If the oil produced in a given period is not sufficient to generate revenue that will cover the annuity and the RF, a corresponding claim is transferred to the subsequent period, adjusted with the Libor rate. A claim remaining at the end of the amortization period is likewise transferred to a so-called Grace period. Whenever a claim is moved to a subsequent period, profitability is reduced because transferred claims are only adjusted by the Libor rate. The oil company therefore has a strong incentive to deliver a low cost and efficient facility.

## Description of ContractSim

ContractSim was originally developed for *Saga Petroleum ASA* in 1999 for assessing risks related to oil field projects in Iran.

The simulator is made up of two interconnected components:
- A dynamic simulation model, built in Vensim (© Ventana Systems Inc.), and
- A stand-alone MS-Windows application program with a tailor-made graphical user interface, enabling end-users to communicate with the underlying simulation model and perform simulation runs and uncertainty analyses.

### *Basic input*

The user can freely set or adjust the parameters before running a simulation, like:

- Start time for investments
- Investment period length
- Amortization period length
- Grace period length
- Yearly investments, subdivided into capital expenditures (CAPEX) and drilling expenditures (DRILLEX)
- Interest rate used in annuity
- Remuneration fee
- Oil price scenarios
- Oil production profiles

In addition, conditions defining start of operations (i.e. start of amortization) can be defined in different ways, e.g. contingent upon the achievement of a certain production capacity or simply (as a certain time period) after the investments.

### *Basic output*

Result variables tabulated or plotted in graphs over time include:
- Investment, grouped as CAPEX, DRILLEX, and total investments with or without interest

- Operating expenditures (OPEX)
- Production volumes
- Income from production
- Net present value (NPV) of investment
- Cost efficiency of the oil field facility
- Client outcome, i.e. the client's economic result (discounted values or as cash flows)

### *Basic model structure*

A brief overview of the causal connections represented in the model is shown below:

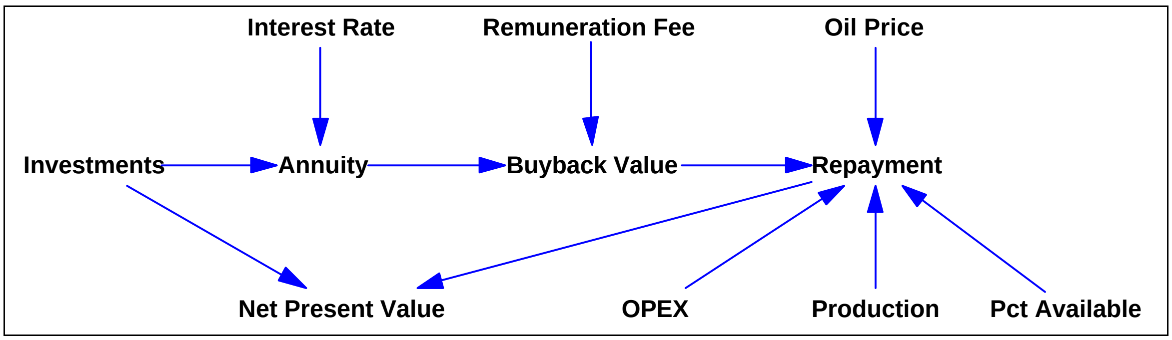



*Figure 2: Buy-back contract model causal relationshops*

In short, the above figure expresses the following relationships:
The *Investments* made in the project together with the *Interest Rate* determines the *Annuity*. The *Buyback Value*, which is the amount of money payable to the contractor provided that there is sufficient income available from production, is dependent on the *Annuity* and the negotiated *Remuneration Fee*.

The *Repayment*, however, which is the amount actually paid back to the contractor, is not only determined by the *Buyback Value*. The *Repayment* is also highly dependent on the available income from the oil field, which is made up of the *Production*, the production *Pct Available* parameter, the *Oil Price*, and the *OPEX*, which could be deductible from the income when the actual *Repayment* is to be calculated.

The *Net Present Value* of the net cash flows is determined by the accumulated *Investments* as compared to the accumulated *Repayment* over the contract lifetime. This is, of course, an extremely simplified view of the model structure, which consists of more than one hundred variables and constants and an extensive set of formulas defining how the variables are interrelated.

### *Production sector*

In the model overview we see that *Repayment* is influenced by *Production*. The model contains a production sector where *Production* is simulated based on a number of essential parameters, as shown below:

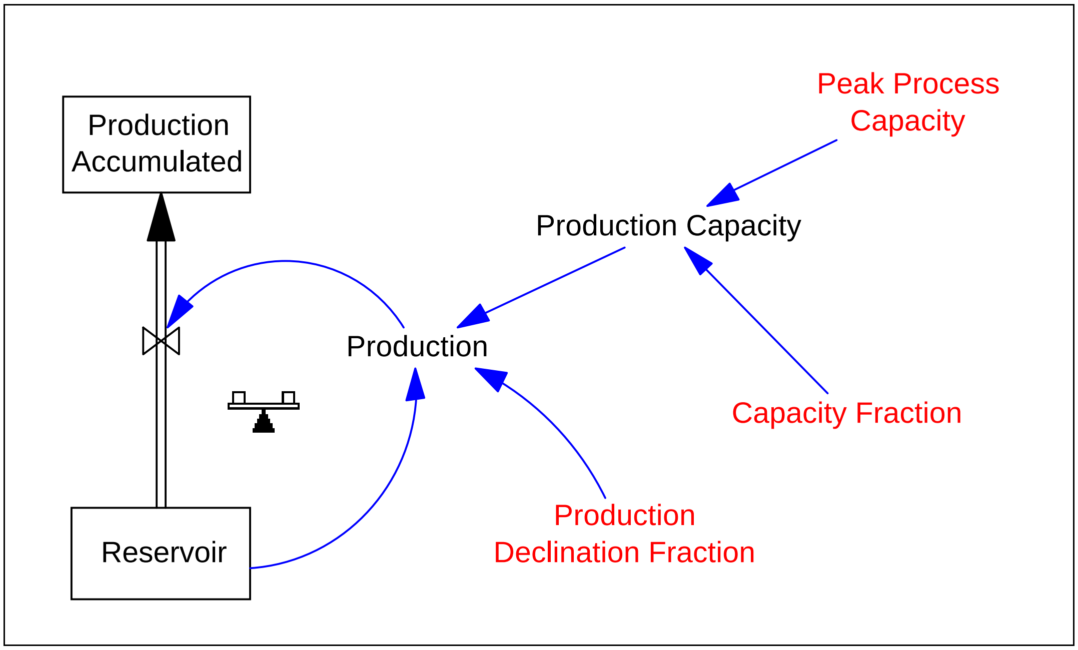



*Figure 3: Buy-back contract production model*

The initial *Reservoir* level is set by the user together with a *Production Declination Fraction (PDF)* constant, which determines a fraction of the remaining reservoir that is produced per time unit. The PDF constant is a measure derived from the reservoir simulations and is used as input parameter. The production rate is also limited by the actual *Production Capacity*, which in turn is determined by a *Peak Process Capacity* constant and a *Capacity Fraction*. The *Peak Process Capacity* expresses the maximum production capacity of the oil field installations, while *Capacity Fraction* is a lookup function over time, reflecting the development of the installations and at which time the oil field reaches full capacity.

When running simulations the user may choose between a self-defined *Production* time series and a simulated *Production* based on the underlying causal model. In the setting shown in the figure 4 below, *Simulated* production profile is chosen and the parameter values specified within the *Simulated profile* group will take effect. If *Predefined* production profile were chosen the selected time series icon in the *Predefined profile* would fully determine the production rate each year of the simulation.

By clicking on the time series icon, the user may draw a production curve over time or import production data from the clipboard.

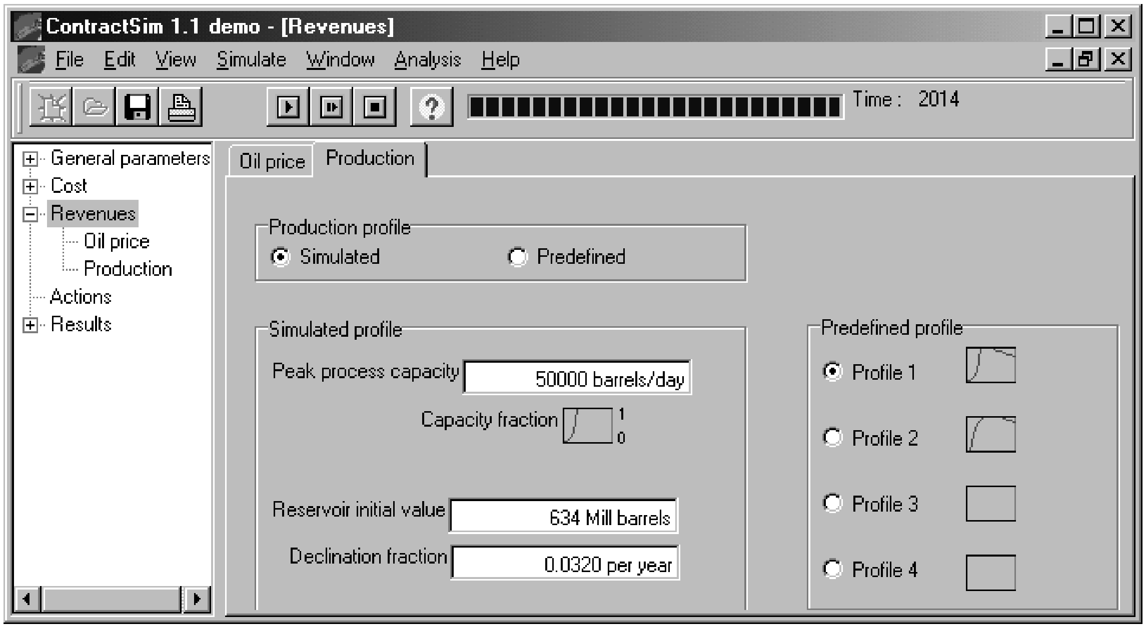



*Figure 4: Buy-back contract model production profile alternatives*

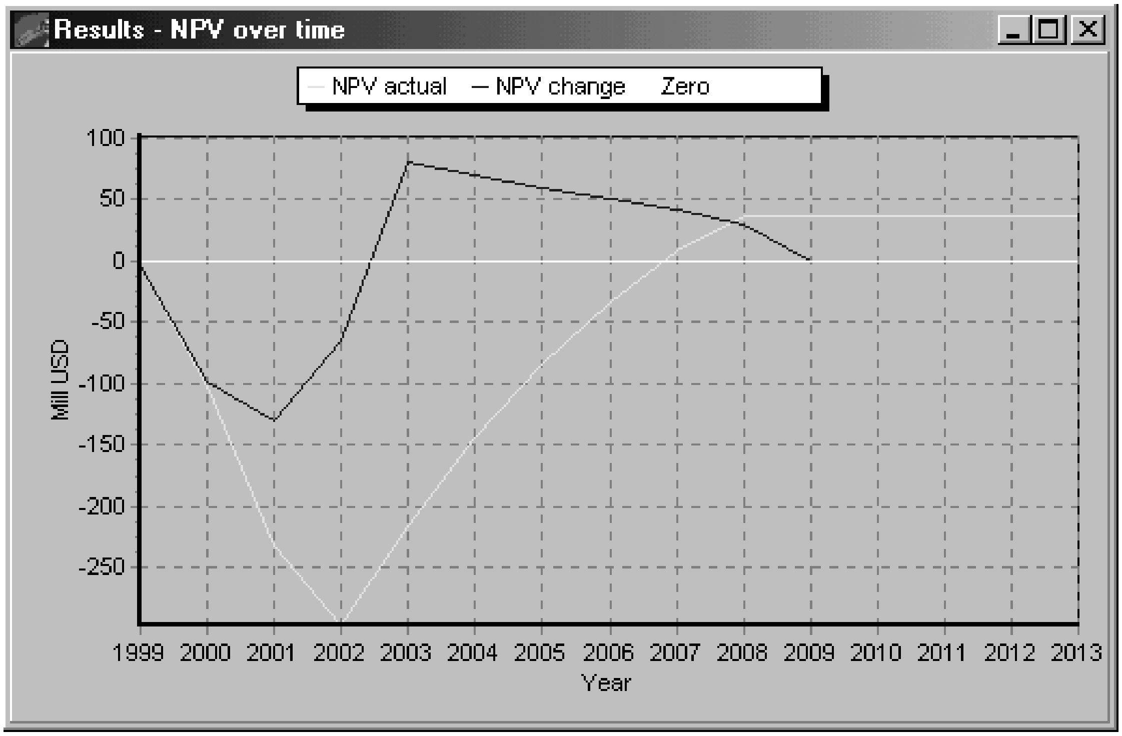
## *Simulated vs. predefined time series*

The ability to choose between predefined time series specified by the user before running a simulation; and simulated behavior determined by a causal model, is a design principle used in ContractSim for a number of essential parameters. This allows a model user to override parts of the causal model and replace simulated behavior with own assumptions, prognoses, or results from other models. It also provides a standard method for stepwise model decomposition: 1) Identify a model parameter or constant, 2) Provide time series values for the parameter, and 3) Identify a possible causal structure governing the parameter, which has now become an endogenous variable.

However, by providing switch boxes for choosing between simulated and predefined time series, we leave it up to the end-user to accept or reject a certain model sector when using the simulator. Let's say we had a causal model simulating oil price over time. Some users might object to the idea that the oil price could actually be simulated with a sufficient degree of credibility, but still find the remainder of the ContractSim model valid. Such users would then typically select a predefined oil price and use their own expectations to determine the oil price to be used in the calculations.

## *Scenario analysis*

ContractSim lets you generate simulated scenarios based on your own parameter settings. When using ContractSim in 'single simulation' mode, a deterministic result is generated, presented as graph plots of selected variables over time or tabulated time series, as shown in figure 5 below.




NPV over time

| | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 20 |
|---|---|---|---|---|---|---|---|---|
| NPV actual | -84.54 | -34.12 | 7.73 | 36.73 | 36.73 | 36.73 | 36.73 | 36. |
| NPV change | 60.00 | 50.43 | 41.85 | 29.00 | 0.00 | 0.00 | 0.00 | 0.0 |

Figure 5: ContractSim NPV graph plots and tabulated results

## *Uncertainty analysis capabilities*

ContractSim also takes advantage of Vensim's built in sensitivity analysis capabilities. It lets you perform risk analysis by allowing you to specify stochastic properties for virtually all model parameters, and running Monte Carlo simulations (multiple runs) generating spread plots visualizing probability distributions for selected result variables.

An example of a spread plot is shown in figure 6 below. The solid line of this plot indicates the mean value. The different color sectors stands for different probability percentiles. In other words, it may give users a fairly good and visual image of the upsides and downsides of a certain oil field development contract, given the specified input uncertainties and dependencies described in the model. The risk exposure at any point in time can thus be visualised.

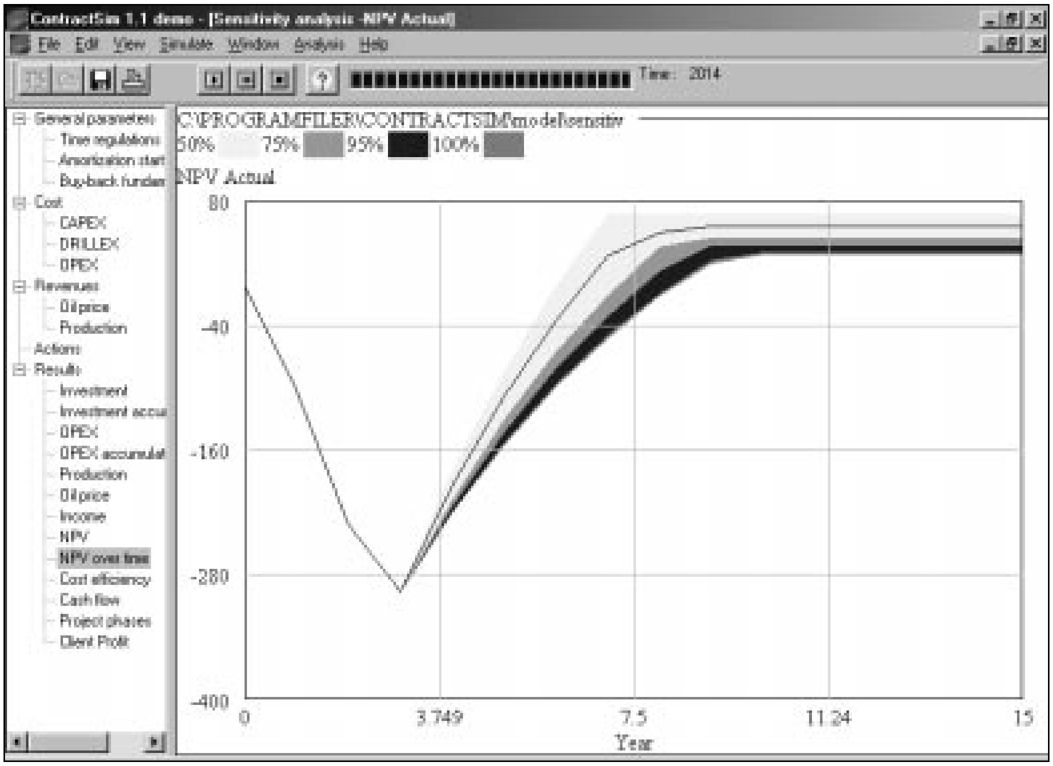



*Figure 6: ContractSim Monte Carlo simulation NPV graph plot*

For the buy-back contract simulated here, and as seen from the oil company's point of view, it is clear from the graph that the downside risk is much larger than the upside. It is also easy to see what the worst-case scenario is, should the project be terminated at any point in time, e.g. due to political intervention.

## Conclusion

By using ContractSim, the risk exposures of a Buy-back contract can be investigated and the involved parties can discuss and define what they mutually agree as fair risk allocation, which is an extremely valuable knowledge when a Buy-back contract is to be finalized. It is however necessary that the contractual parties have confidence in the risk model, and it must therefore be based on a well-proven, realistic and valid representation of the actual oil field reservoir and development project in question. Risk analysts should therefore do the construction of the uncertainty model in close co-operation with reservoir, process and field development professionals. The project management can then do the risk evaluation of different contractual arrangements in ContractSim once a valid model has been implemented.

## References

A.B. Huseby, et.al. *Value Chain Analysis in an offshore field development project*. Nordnet '99: 'Managing Business by Projects', Helsinki, September 1999.

J. Wright. *Incentive Contract Risk*. World Congress on Project Management, 22-25 May 2000, London