Proceedings of the 2002 Winter Simulation Conference
E. Yücesan, C.-H. Chen, J. L. Snowdon, and J. M. Charnes, eds.

DISCRETE EVENT SIMULATION FOR THE RISK OF DEVELOPMENT OF AN OIL FIELD

Carlos Magno C. Jacinto

CENPES – Well Technology Engineering
PETROBRAS SA
Avenida Hum, Quadra 7
Ilha do Fundão
Rio de Janeiro, RJ, 21949-900, BRAZIL

ABSTRACT

The present work focuses on the development of a simulation method which provides an engineering tool for managing the risks associated with the development of an oil field. The developed method consists of performing discrete simulation based on data from field operations. The paper reports and discusses the simulation results of a real field development which lead to the following highlights: The operations that present the highest level of risk are emphasized and studied for defining their impact on costs. The consequences of some deviations from the preplanned schedule are evaluated in terms of increasing the total amount of the investment. The possible gains and risks associated with the use of some emerging technologies are analyzed. This study shows that this methodology is an useful tool for providing relevant information to contracts negotiation with suppliers and drilling contractors.

1 INTRODUCTION

The development of an oil field is involves an enormous number of issues and the risk associated to them. The limited knowledge about the characteristics of the geological formation , technical facilities, and human behavior, results in considerable uncertainty about the oil and gas wells drilling operations.

Oil and gas companies (energy companies) need extensive studies to evaluate their projects before spending money, and to quantify the benefits of proposed projects, prior to their implementation.

For the evaluation of an oil field, under uncertainty, the use of discrete event simulation technique is proposed.

2 RISK ANALYSIS

Although the term risk means " possibility of loss ", the theory defines risk as "dispersion of the unexpected results, due to oscillations in the variables of the model" (Jorion 1997).

- The risk can be defined, in general, as the uncertainty in relation to results and can be understood in probabilistic terms.
- The risk management includes the processes involved in the identification, analysis and answer to the risks, incluinding maximization of the positive event results and minimization of the consequences of negative event.
- The identification of the risks refers to the determination of which risks possess larger probability of affecting the project and its characteristics.
- The quantification of the risks corresponds to the evaluation of the risks and their interaction, besides possible consequences.
- The development of the answers to the risks defines the necessary improvements for the use of opportunities and answers to the menaces.
- The control of the answers to the risks has an objective to observe the changes in the risks during the project.
- In this work we focus on the quantification of the risk of development of a petroleum and gas field, generating a histogram of the total costs of the project (close to Value at Risk methodology).

3 DISCRETE EVENT SIMULATION

The fundamental concept of discrete event simulation is associated to the occurrence of events in the time. An event is defined as an instantaneous occurrence that changes the state of a system and, if each variable of state of the system can only move in a countable number of discrete points in the time; the simulation of this system is called discrete (Kelton et al 1998).

The modifications happen continuously in a real system but just a part of these modifications will be considered important and monitored in the discrete simulation.

A variable time then is defined as the one that supplies the value of the simulate time (clock), and the values can be attributed to this variable of two ways: progress of time by fixed increment (the clock is advanced in increments and some alteration is verified in the system) and for progress of time for event (the clock points for the instant of occurrence of each event of the model).

4 PROBLEM

The following field development strategy was proposed by the specialists team:

1. Two DP (dynamic positioning) rigs to the project, with capacity to accomplish the drilling and completion of any of the wells.
2. Sequence of the wells prioritizes the wells producing of larger productivity wells, being inserted among them the closest injector wells.
3. The critical resources are BAP (adapting base of production) and ANM (wet christmas tree) of production and the groups of injector wells. The first production group will be available on a defined date, the three following every sixty days. For the injection group, the first available on a defined date and the others every forty five days.
4. The drilling and completion of the wells will be accomplished in the following way:
   a. Drilling until the beginning of the horizontal well (phase 1),
   b. BAP installation (phase 2) ,
   c. Drilling of the horizontal well (phase 3)
   d. Completion until TH (tubing hanger) (phase 4),
   e. ANM installation, (phase 5).

5 THE SOLUTION

For the creation the simulation model ,the software Arena 5.0 professional version, a widely accepted language, popular in industry and academic settings was used. This software has been used to modeling many general applications but had never been used to modeling risk development of an oil field.

The logics block was create (Figure 1) to assist the problem formulation , taking into account its complexity. The Table 1 shows the collection of pre-processed data model about the well phases time (Rockwell Software 2000).

6 SIMULATION

The initial screen for data entry in the simulation model, is shown in Figure 2, and required the following input parameters:

-MTBF (Mean Time Between Failures), represents the mean time among successive rig failures.
-MTTR (Mean Time To Repair), indicates the mean time requires for rig repair.
-R $ Daily rental rates of each rig, in Real.
-Technical limit (C3) Minimum time to drilling and completion of a well.
-**Learning speed (C2)** $0.25 \leq C_2 \leq 0.45$ represents a low learning speed; $0.45 \leq C_2 \leq 0.8$ represents a good learning speed; $C_2 \geq 0.8$ represents an excellent learning speed.
-Drilling and completion times These inputs can assume any value, as constant as probabilistic and it can be any probability distribution that can be used in Arena 5.0 (Table 2).

7 RESULTS

Once the model is validated, the simulation is executed with the data showed in data entry screen. We simulate a replication number of the model that generates more representative results for decision making. The model was simulated, considering the development of the whole field, a four year period, in just some minutes. Here we can analyze the impact of the use of additional rig, or fail or accident in some well, etc...

The following results were obtained:

1. Utilization rate of the rigs around 98%.
2. End of the chronogram thirty days before the scheduled.
3. Risk of the field development given by the total cost histogram in FIGURE 3 taking 300 replications of the model.

8 CONCLUSIONS AND RECOMMENDATIONS

The use of the simulation technique in studies where the dynamics of the productive systems has relative operational complexity , difficulty of modeling or cause upset to the users, can be applied and will reproduce with reasonable fidelity the reality of the scenery in subject.

In this aspect it is important to emphasize that for certain real systems, due to the high involved costs, high complexity, besides excessive time of answers to the formulated subjects, they will be prohibitive or impossible of they be obtained, in case those are fruit of the own operational reality.

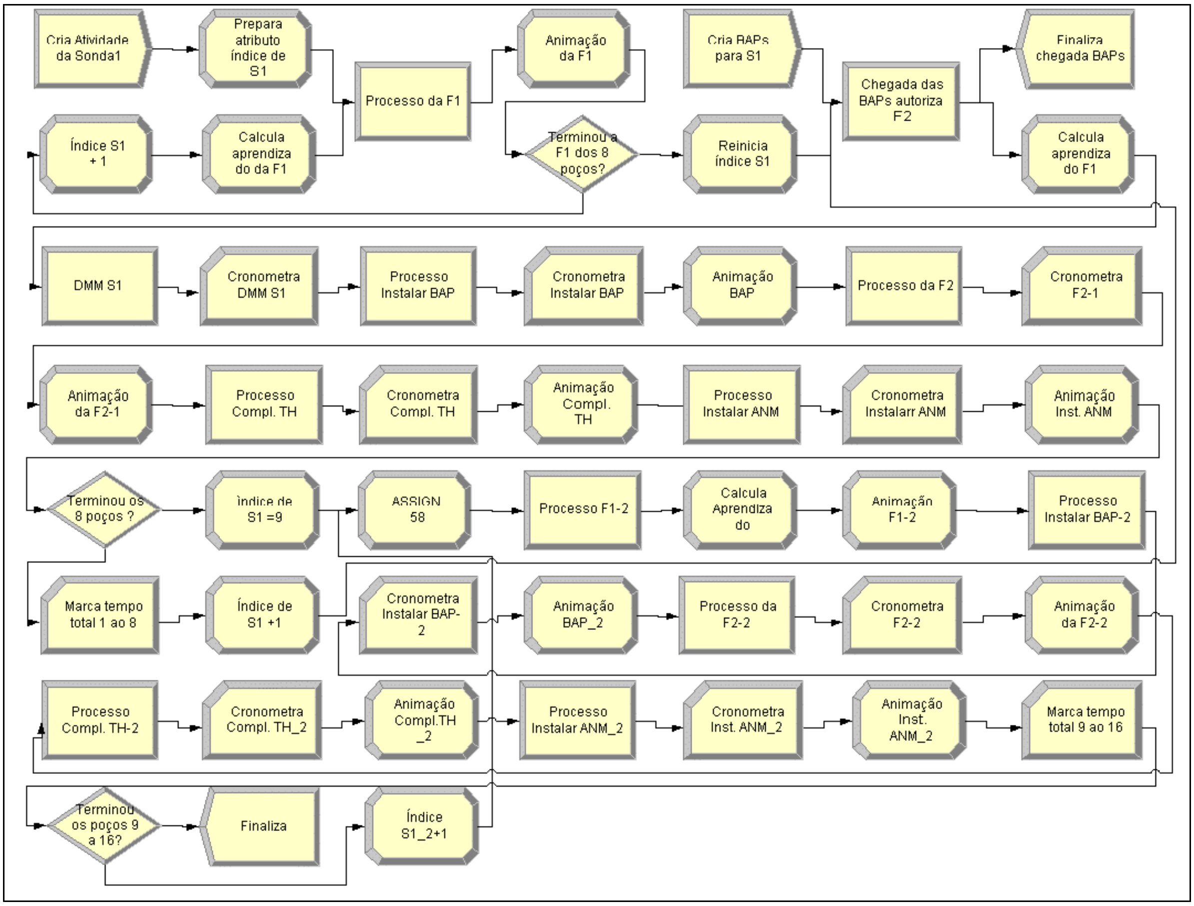


Figure 1: Logic and Animation Set

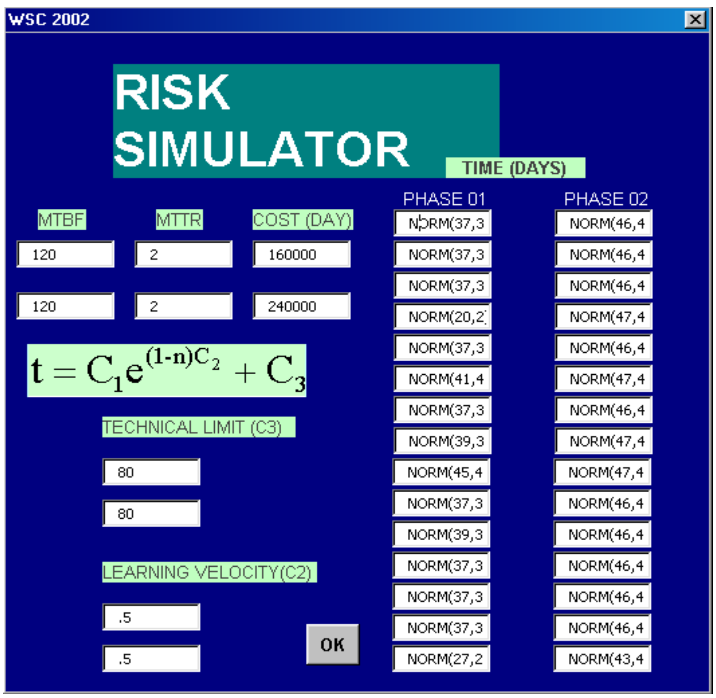
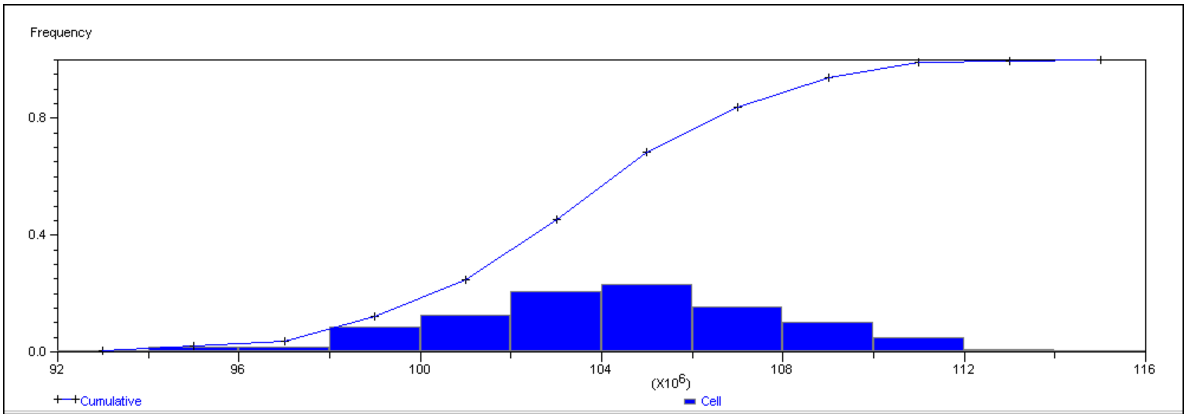


Figure 2: Data Entry Set



Histogram Summary
EXPOSIÇÃO AO RISCO DE DESENVOLVIMENTO

	Cell Limits		Abs. Freq. (Time)		Rel. Freq.	
Cell	From	To	Cell	Cumul.	Cell	Cumul.
1	-Infinity	9.4e+007	1	1	0.003344	0.003344
2	9.4e+007	9.6e+007	5	6	0.01672	0.02007
3	9.6e+007	9.8e+007	5	11	0.01672	0.03679
4	9.8e+007	1e+008	25	36	0.08361	0.1204
5	1e+008	1.02e+008	38	74	0.1271	0.2475
6	1.02e+008	1.04e+008	62	136	0.2074	0.4548
7	1.04e+008	1.06e+008	69	205	0.2308	0.6856
8	1.06e+008	1.08e+008	46	251	0.1538	0.8395
9	1.08e+008	1.1e+008	30	281	0.1003	0.9398
10	1.1e+008	1.12e+008	15	296	0.05017	0.99
11	1.12e+008	1.14e+008	2	298	0.006689	0.9967
12	1.14e+008	+Infinity	1	299	0.003344	1

Figure 3: Histogram of the Risk of the Oil Field Development (R$) in 300 Model Replications

Table 1: Well Phase Model

	Well 1	Well 2	Well 3	Well 4	…	Well 15
PHASE 1	Function	Function	Function	Function	…	Function
PHASE 2	Function	Function	Function	Function	…	Function
PHASE 3	Function	Function	Function	Function	…	Function
PHASE 4	Function	Function	Function	Function	…	Function
PHASE 5	Function	Function	Function	Function	…	Function

Table 2: Probabilistic Distributions Used in Arena Software Version 5

Distribution	
Exponential	EXPO
Gamma	GAMM
Johnson	JOHN
Lognormal	LOGN
Normal	NORM
Poisson	POIS
Triangular	TRIA
Uniform	UNIF
Weibull	WEIB
Discrete	DISC
Erlang	ERLA
Continuous	CONT
Beta	BETA

The simulation allows agile information to give support to decision taking processes, without disturbing the real system. The costs involved in simulation studies for evaluation of performance of productive operating systems, are minimum if compared to the benefits that these can bring.

This simulation technique, if used in the economic evaluation studies can help a lot on defining efficient strategies, minimizing costs and enabled the positive economical evaluation of fields which were considered non-economical when evaluated through conservative approaches

REFERENCES

Jorion, P., 1997.*Value at Risk: The New Benchmark for Controlling Derivatives Risk*. U.S.A.: McGraw Hill.

Kelton, W.D., R. Sadowski, and D. Sadowski, 1998. *Simulation with Arena*. New York, NY: WCB/MacGraw-Hill.

Rockwell Software, *2000. ARENA Professional Edition Reference Guide*, U.S.A.

AUTHOR BIOGRAPHY

CARLOS MAGNO C. JACINTO is a Petrobras SA (Brazilian Energy Company) employee about 15 years. He is a doctorate candidate in COPPE – UFRJ. His research interests include risk modeling and simulation, performance improvement, failure prediction and artificial intelligence; all applied in Well Technology Engineering. Email: <magno@cenpes.petrobras.com.br>