Expert Systems with Applications 39 (2012) 10821–10831

Contents lists available at SciVerse ScienceDirect

Expert Systems with Applications

journal homepage: www.elsevier.com/locate/eswa

Using fuzzy NPV evaluation to justify the acquisition of business interruption insurance

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ARTICLE INFO

Keywords:
Fuzzy net present value (FNPV)
Quantitative risk assessment (QRA)
Reinsurance
Business interruption insurance (BIC)
Oil and gas

ABSTRACT

Offshore platforms oil and gas day to day operations themselves involve an undeterminable list of risk. Some of them can be prevent or at least mitigate as a result of an experience of a former disaster. Indeed, although computational mathematical technologies grows so fast helping the engineers to estimate and mitigate the risk much uncertainties remains in a way of vagueness, which is many times impossible to measure precisely due to the imprecision and the lake of data. In such cases fuzzy logic is the mathematical treatment indicated to deal with these problems. As insurance is one of the most important economic form to mitigate risk the purpose of this paper is to verify the viability of purchasing a business interruption cover (BIC) for an offshore production unit using the fuzzy net present value (FNPV) that results of the discounted cash flow (DFC) involving much vagueness and uncertainties in these available information.

1. Introduction

The main goal of this paper is to evaluate the decision of buying an insurance cover for business interruption (BI) events that could arise from an offshore rig accident caused by a material damaged covered by energy policy wordings, during E&P (exploration and production) activities. In such case, these facilities maintain their production stopped for a long time, generating extreme financial losses. In contracting the insurance policy, another difficulty is determining the deductible level and the sum assured. The latter point is not an obvious thing because, generally in these accidents the physical reserves of oil remain almost in the same level, although the principal loss is the opportunity cost of selling the oil in the present time against selling this production after the facility replacement. This period could last more than 3 years and the delay period could match the market in a hard cycle where the prices are lower than in an accident time. Facing these features could be a problematic question and the Contractors managers should decide what is the sum assured and deductible for the policy. Thus, after showing these points, they look for a methodology that could express mathematically the managers' decision making structure regarding the insurance purchasing option.

In order to accomplish this objective a fuzzy net present value (FNPV) methodology was applied to evaluated the a simplified cash flow of an Oil Company that has suffered an total loss claim that caused the business interruption during a unknown period, because the replacement of a such structure delays at least 3 years. In the present simulation, using FPNV concept, it was obtained a positive response for 3 hypothetical study cases:

(a) Total Loss with BIC and waiting period transformed an a deductible value of 10% of the covered damage;
(b) Total Loss with BIC and waiting period of 6 weeks (45 days);
(c) Total Loss without BIC.

The final results obtained showed the options B is the best alternative followed by option C (both include buying BIC with certain level of self retention) were ever superior there no buy insurance cover for business interruption risk.

2. The fundamentals and the main purpose of insurance

Insurance is one of the most important tools of transfer risks mechanisms available to individuals, companies and governments. It can mitigate risk in order to allow the continuity of the normal operation of large corporations, individual's property recovery after big nature catastrophe disaster occurrence and so on, e.g., in many instances it guarantees the perfect economic equilibrium during crisis period. According to Contador (2007), the insurance not only allow the risk mitigation but enhance and stimulate the growing of the internal capital market, arise the ratio of savings and investments and to increase the GDP potential growth – as a

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http://dx.doi.org/10.1016/j.eswa.2012.03.011

aftermath the insurance market works decreases the investor' uncertainty therefore increasing his trend to invest.

The theoretic definition of insurance is important to understand its necessity and its main characteristics. The formalization of a technical definition of insurance is necessary to understand its importance and basic characteristics. Regarding the Insurance Brazilian Institute – IRB (IRB, XXXX), it can be stated:

"Insurance is a contract where one of the parts involved obligates itself, by the collection of the premium, to indemnify the other part in the case of the occurrence of determinate events or eventual damages. Individuals are looking for economic protection in order to prevent themselves against random necessities. It is an operation by which the payment of an appropriate remuneration one person promises to protect itself or other person in the case of the materialization of a determinate event, using the service of a third person, the Insurer, which undertake the set of defined events, compensating them according to the statistics law and Principle of Mutualism. This compensation of the accidental effects is shared by mutual following the statistics laws. The insurance contract is a randomness, bilateral, onerous, and presupposes the narrow ultimate good faith being essential to it formation the existence of the insured, the insurer, the risk, the risk object, the Premium and indemnization".

According Shyng and alii (Shyng, Wang, Tzeng, & Kun-Shan, 2007) in them relevant paper insurance is not a easy market to understand, because it demands "face-to-face contact with customers in order to provide services that satisfy customer's needs".

The main characteristics of the insurance are:

(a) Utmost good faith – when applying for a possible insurance contract (policy) the insured should supply all the data that could affect the risk. If he does not obey the full disclosure principle during the proposal time a claim could be denied by the insurer;
(b) Insurable interest – only a person or firm which can be suffer a loss or be responsible for it can apply for policy;
(c) Indemnity – the principle aim of the insurance contract is to restore the insurance object exactly like it was immediately before the claim, preventing any insured gain from the claim payment. In order to guarantee this principle 2 rules are in force:
    (c_1) Rule of Subrogation: Insurance Company will become owner of the damaged object (salvage value) after the indemnization payment;
    (c_2) Rule of Contribution: Considering only the non-life branches, if the Insured has more than one policy for the same risk, each policy will contribute proportionally with the maximum indemnization value according to its responsible in the risk, and the indemnization will never overcome the maximum sum assured among these policies.
(d) Proximate Cause: is the cause that generates the claim. In other words is the root cause. If this cause is not state in the policy wordings the will be denied.

Varian (Varian, 2003), shows an example that clarifies the definition presented below explaining the economic protection against random events the individuals are looking for, according IRB definition. In order to adequate the example to present paper imagine that an Oil company has a fleet of 70 offshore platform evaluated in US$ 7,000,000,000,000 (this value represents the total Equity of the Oil Company) – all of them operating in the Gulf of Mexico (GoM).

Supposing that next hurricane season would have a potential total loss for offshore platform in the GoM of 2% the Oil Company probably will lose US$ 140,000,000,000. The probability distribution is a 2% of a US$ 140,000,000,000 loss and 98% of nothing happens, e.g., the Total Equity remains the same US$ 700,000,000,000,000.

Assuming, hypothetically that there is a policy for this offshore fleet available costing US$ 2,000,000,000. Should this loss materialize the Oil Company the Total Equity resulting after the indemnization will be US$ 6,998,000,000,000 (Initial Total Equity less the insurance premium). The insurance does not modifies the probability of hurricanes seasons neither its disasters severity capacity but protect the individuals and firms properties and lives. Following the mutualism principle and law of large numbers for a relative small amount the insured can protect itself against a possible severe damage that could cause serious financial problems to recovery and even, in the case of enterprise in the worst scenario, the final insolvency.

In a general manner, if the Oil Company decides to buy the insurance with a Sum assured of US$ X which a charged premium of zX, the company will be presented to the following gamble or lottery:

(a) First scenario (claim occurrence): 2% of probability to obtain US$ 140,000,000,000 + X – zX
(b) Second Scenario (no claim):
    98% of chance to obtain US$ 7,000,000,000,000 – zX

How much insurance to buy depends on attitudes towards risks. As describes by Levy and Sarnat (1984), persons or companies can be classified regarding the Expected Utility Theory (EUT) in 3 main subdivisions:

(a) Risk averse: for this kind of individuals or firms when exposing to a lottery involving a speculating risk (with a chance w of a gain and a chance 100% – w of a loss) the loosing of more US$1.00 is more impacting than the possible earning of more US$ 1.00. Mathematically speaking, their Utility function is marginally decreasing, although is absolutely increasing. The shape of their Utility function is concave His risk aversion [R(x)] coefficient Levy and Sarnat (1984) defined by de equation bellow is positive:

$$R(x) = \frac{-U''(x)}{U'(x)} \tag{2.1}$$

where:
X: is de wealth of the individual or firm
U"(x): utility function second derivative
U'(x): utility function first derivative

(a) Indifferent to risk: following the reasoning developed in above this kind of individuals or firms in the same situation do not matter about to gamble or not to gamble. Therefore, their Utility function is linear and their R(x) is zero.
(b) Risk lovers: for this kind of individuals or firms when exposing to a lottery involving a speculating risk (with a chance w of a gain and a chance 100% – w of a loss) the possible earning of more US$1.00 is more impacting than the possible loosing of more US$ 1.00. The shape of their Utility function is convex. His risk aversion coefficient is negative.

It is possible to think in the different results as random events as they are different nature estates, like loss or no loss. Therefore, it could be considered a consuming contingency plan as a specification to what should be consumed in each nature estate. In this sense, the Best option for the insured is to choice the plain appropriate to its budget.

According to Varian (Varian, 2003), it is possible to describe the insurance buying process in terms of indifference curve analysis. In the example above there are 2 possibilities: the loss of US$ 140,000,000,000 (contingent estate – the worst situation when the claim does materialize) and Total Equity remains the same of US$ 700,000,000,000,000 (no claim – the Best situation). The essence of insurance is to offer one way to obtain this point financial capacity to insured in order to buy the amount US$ X of insurance (the value of Sum Assured) paying a premium US$ zX for this Sum Assured protecting itself against the worst scenario that could collapse it financial situation. This tradeoff, e.g., the initial payment of US$ zX will allow the final insured Equity to be equivalent of US$ X – zX, where z is a small, if the claim materialize. Therefore, the consumption in the good situation (no claim), divided, by the increment *f* the additional consumption in the worst scenario is:

$$\frac{-zX}{X - zX} \tag{2.2}$$

The ratio above represents the slope of the budget constraint line. Therefore, given the consumption indifference curves in each nature stage it is possible to observe the amount of insurance would be bought which is equivalent to the marginal rate of substitution between the tangency of consumption in each nature estate that must be equal to the price that allow the consumption Exchange in the 2 stages mentioned above. Furthermore, as estate by Henderson and Quandt (1990), in the case of optimal choice, as the price varies the demand for insurance alters.

Consider the following premises:

1. The consumer is rational and has a limit budget and desires to buy a mix of products (one of them being the insurance for his house – Q_1 and the other the loan for his car – Q_2). The combination from which results in degree of satisfaction. As mentioned above, he has a budget constrained that can be expressed as:

$$y^0 = p_1 q_1 + p_2 q_2 \tag{2.3}$$

where:
y^0 = fixed income
p_1 = price of Q_1
p_2 = price of Q_2

It is important to remark that the level of utility generate by these products can be expressed in terms of Henderson and Quandt (1990):

$$U^0 = f(q_1, q_2) \tag{2.4}$$

Using the Lagrange Multiplier Utility function it is possible to solve this problem. Consider the Utility function gives by Eq. (2.4) and budget constrain (2.3). Therefore, we can be written:

$$V = f(q_1, q_2) + \lambda(y^0 - p_1 q_1 - p_2 q_2) \tag{2.5}$$

where:
λ = Lagrange multiplier
V = function of λ, p_1 and p_2

Henderson and Quandt (Henderson and Quandt, 1990) states that it can said V is equivalent to U for values q1 and q2 that turn valid the constrain budget, since

$$y^0 - p_1 q_1 - p_2 q_2 = 0 \tag{2.6}$$

In order to maximize V is necessary to calculate de partial derivatives and turn they equal to zero forming the following equation system:

$$\frac{\partial V}{\partial q_1} = f_1 - \lambda p_1 = 0 \tag{2.7}$$

$$\frac{\partial V}{\partial q_2} = f_2 - \lambda p_2 = 0 \tag{2.8}$$

$$\frac{\partial V}{\partial \lambda} = y^0 - p_1 q_1 - p_2 q_2 = 0 \tag{2.9}$$

The Hessian determinant has to be positive so:

$$\begin{vmatrix} f_{11} & f_{12} & -p_1 \\ f_{21} & f_{22} & -p_2 \\ -p_1 & -p_2 & 0 \end{vmatrix} > 0$$

Using the relations $p_1 = f_1/\lambda$ and $p_2 = f_2/\lambda$ and multiplying the determinant product by $\lambda_2 > 0$, results:

$$2f_{12} f_1 f_2 - f_{11} f_2^2 - f_{22} f_1^2 > 0 \tag{2.10}$$

where:

It is remarkable to note, otherwise, that for a one commodity, this is strictly convex, if and only if its second derivative is positive.

This demonstration was developed in order to show that the insurance purchasing process many times follows rational mechanism, limited by the personal budget.

Concluding, this example shown that insurance is a form of risk mitigation both the own assets as for third part involved.

3. The general business interruption coverage (BIC) for commercial lines

When a firm suffers an accident, the owner would be indemnified by the material damage cover, since, obviously, the root cause, is embraced in policy wordings. However, it will delay some time to the enterprise to return to its normal activities. If the claim was to severe that stopped it production process, causing serious losses to the employer, since there fixed expenses like wages, equipments rent and so on that do not stop with the production interruption. For an example, a total loss occurring an offshore platform caused by a capsized, would means severe losses of earnings since a construction of a new offshore structure would delay 3 or 4 years an average, which means a typical case of business interruption damage. More than money, it is difficult to evaluate precisely the actual value of the claim because the oil quotation fluctuates during the time and suffers with market volatility and other factors of speculation and shortfalls. In chapter 5 it is pointed out how can be settled out the sum assured for offshore platform production unit, mainly in the situation when the oil prices are increasing.

Following this reasoning, the BIC was created to minimize cash flow impact during business interruption period. One of its characteristics is that addressed exclusively to firms, with main function to maintain insured business movement, keeping its operation ability and consequently its return level prior to claim occurrence. Furthermore, depending on the insured interest it can contract another additional coverage like: fixed expenses, reimbursement for the services of the expert expenses, Net Profit, Over head and other additional cover depending on the companies and the market. However, this kind of insurance cannot be bought in separate: this cover is only available if the insured by the material damage for the firm.

Regarding Swiss Reinsurance Company Report 2004 (Swiss, 2004), BIC aims to protect the financial wealthy of the firm against whatever relevant event that could cause a business interruption of the enterprise. This report highlights the importance of the BIC making an analysis of an industrial organization. In fact, the Fig. 1 extracted from this report, shows that any events that affect negatively the energy supply or the raw material, or yet, the occurrence of any accident that could interfere in the production process, committing the production therefore affecting the Company's cash flow and the shareholder profitability. In this sense, this report advocates the BIC as a tool to guarantee the financial return against any event that could interfere in all the Company supply chain.

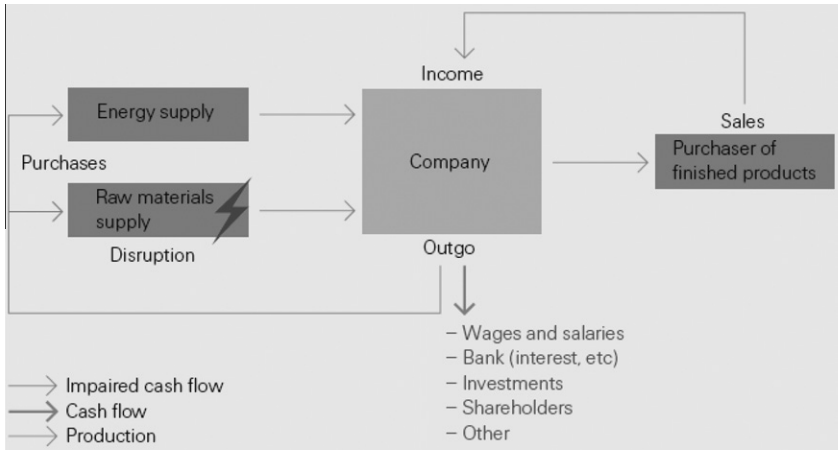


Fig. 1. BIC Framework explaining the features of the operations' coverage (source: Swiss Reinsurance Company Report – 2004).

Furthermore, the kind of production and the goods' manufacturing conditions determine how sensible is the Company in relation to business interruption event. According to mentioned report, one industry that has a scheduling production will present big financial losses when an accident occur in any stage or machine belong to the manufacturing process, as shows Fig. 2. As a consequence, when the production is organized in a sequential to buy the BIC is highly recommended since any failure can commit the production and consequently the Company earnings. Notwithstanding in the case of industry is organized in parallel production the BIC is not a good financial protection option since the business interruption is more difficult to happens.

The BIC basic cover embraces three main points, regarding Swiss Re Report (2004):

(1) Fixed expenses, since many of these remain at the same level after the claim, independently to the production level;
(2) Net profit, which would be a result from insured operation;
(3) Overheads, embracing expenses done with the specific purpose to the insured to avoid the business shortfall, as for an example, rent another machines to substitute the damaged ones.

One of the main characteristics of the BIC is the indemnity period (IP). According to Azevedo (2008), the IP is the time delaying between the date that the insured initiated to suffer the with production shortfall consequences, consuming or servicing offered due to the claim and the date of the normal restoration of the Company's activities. This period cannot overcome a limit fixed in the BIC policy, which is determined by the insured that cannot be superior to 36 months. However, this period can overcome the policy period since if an annual policy that coverage began in January with an IP of 6 months suffer an accident in December. In this particular case, the insured under the BIC if there is no deductible relative to time (waiting period) would be cover till June of the next year. The main point in this case, is the occurrence of the material damage claim under the Material Damage Policy period which normally is the as BIC policy. Notwithstanding, if actual IP overcome the IP fixed in the policy limit, the financial losses due to business interruption will be limit to 6 months.

For better understanding matters of a BIC issues, supposes an example that considers the following policy data:

- Policy period: from 01/01/2006 to 01/01/2007
- Data of Loss (DoL): 05/01/2006 (1st May 2006)
- Repairs Conclusion: 07/01/2006
- Normal Activities Restoration: 09/01/2006
- IP fixed in the Policy: 6 months

Since the IP begins at DoL and will last till the normal restoration of the activities or the fixed IP (the least of the 2 values), it is possible to conclude:

- If the root cause of claim was covered by Material Damage policy wordings, the insured will indemnified by financial losses due to business interruption caused by the claim since the accident occurred during the policy period.
- Although the IP was fixed in 6 months, the indemnization will be limit by 4 months (the time for restoration).
- If the activities restoration occurred only in 12/01/2006 – 7 months after the claim – the indemnization would be limit by 6 months.
- The BIC rate is applied under Gross Profit, which is denominated Gross Profit Assured (GPA) that has a different meaning from the normal accounting use – which express the difference between Sales Received minus Cost of goods (or cost of manufactured products).
- Obviously, the variables expenses are excluded since with the paralization they will not occur.

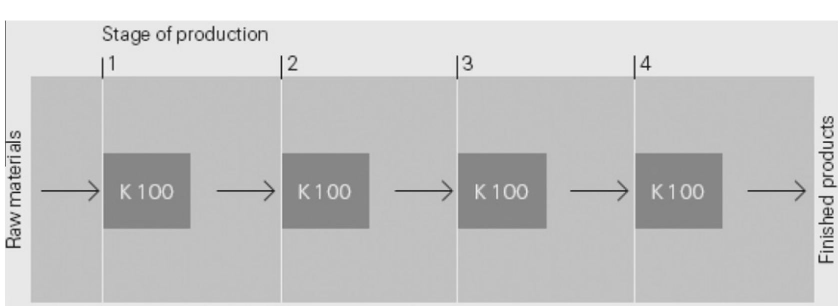


Fig. 2. Sequential production example of an industrial plant – Source: Swiss Reinsurance Company Report – 2004.

One important characteristic noted followed in example the above is that how bigger the IP more will be the GPA or the Sum Assured. The premium is obtained multiplying the GPA by the damage average rate. By one side, the increase of the IP causes the premium increment, however there is a possibility that the firm turns back to operates before the fixed IP forecasted, this happens because the insured is the most interest part in restoring its business. To avoid that insurer benefit with this fact there is a correction factor applied in the premium rate.

3.1. The role of reinsurance companies

Notwithstanding insurance Companies they don't have the financial capacity to underwrite risk above their limits without espousing themselves and their clients to big financial losses if claim catastrophic scenarios materialize. For this purpose there are some special company called reinsurance that has expertise in risk underwriting of insurance companies.

This kind of firm in majority are big financial conglomerate trading worldwide basis, with a very higher degree of capital internalization, strong expertise in underwriting risk in many branches around the world and most of all they have capacity to pay, if risk were accepted in a reasonable way and worst PML do not materialize in conjunction in many areas around the world at the same time, higher values of indemnization.

The main function of reinsurance is:

(a) To proportionate economic financial stability to Insurance company;
(b) To avoid accumulations losses due to catastrophic events like hurricanes, earthquakes, tsunamis and other nature perils that could affect an area where the insurance company has accepted many risks of the similar type;
(c) To create a structure that allows the Pooling the risks mechanism sharing big losses or the great frequency o losses of certain kind during a certain period for a number of number as bigger as possible. This issue will be better understood in the Fig. 3;
(d) To allow insurance companies grow their capacity of underwriting risks;
(e) To transfer the underwriting knowledge to the insurance companies.

Note: when contracting any insurance cover, not only the BIC, is important to define mainly for property, liability and energy branches two parameters (based on ERC Francona Re, 1996):

(a) The EML is an estimate of the maximum loss which could be sustained by the insurers as a result of any occurrence considered by the underwriter to be within the realms of probability. This ignores such coincidence and catastrophes as may be possibilities, but which remain higher unlikely.
(b) The PML is the largest loss that may be expected from a single fire (or other peril when another peril may be the controlling factor) equal to any given risk when the most unfavorable circumstances are more or less exceptionally combined and when, as a consequence, the fire is unsatisfactorily fought against and therefore is only stopped by impassable obstacles or lack of sustenance.

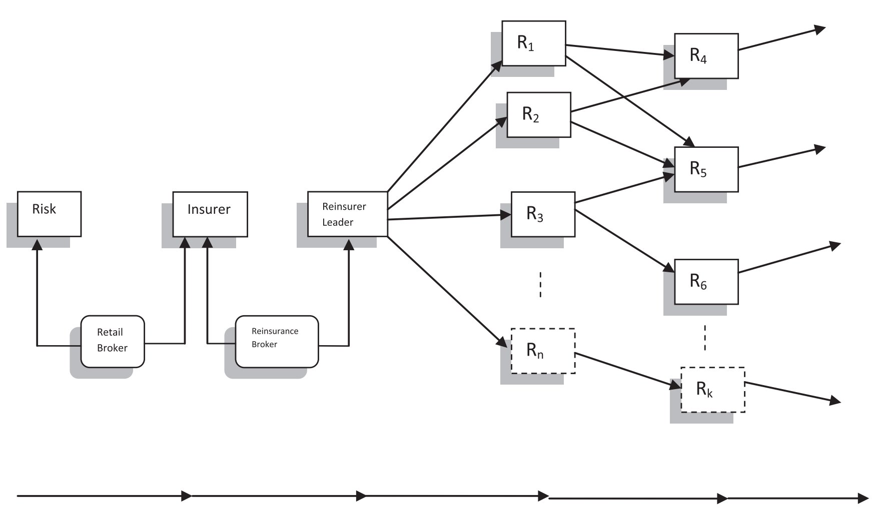
Reinsurance companies can accept risks using to basic forms:

(d) Treaty – a kind of package that presupposes a automatic acceptation if a particular risk is such that accomplishes all the underwriting conditions and limits. This is a big advantage because it decreases the administrative expenses and the rates to be applied were previously established;
(e) Facultative: the risk to be submitted to reinsurer analysis involves a great value at risk and or has a big potential that big disasters should happens. In such situations, it will involve too much technical underwriting background to analyze possible PML (Possible Maximum Loss) scenario damages and to determinate the appropriate ratemaking.

Below, Fig. 3 presents a brief description of the placement of main types of reinsurances. First of all, it is important to remark that main classification of reinsurance is Life and non-Life branches (which include Property, Marine, Liability, Credit and many other types of risks).

Regarding the sharing of responsibilities of risks and premiums, reinsurances can be contracted both a proportional basis and non proportional basis:

(a) Proportional:



Where: R_i = Reinsurance Company

Fig. 3. The pooling risk mechanism comprising insurance, reinsurance and retrocession.

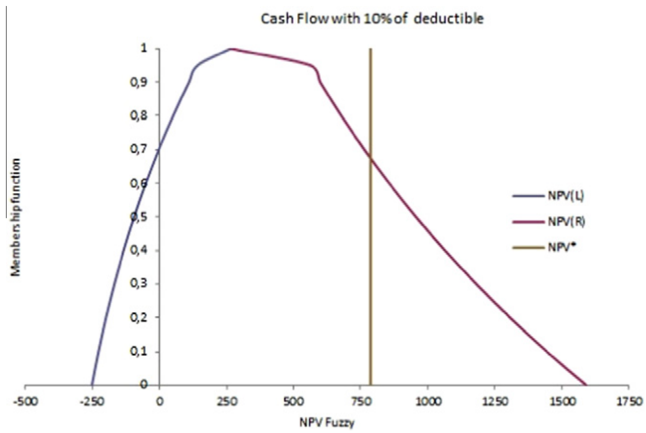


Fig. 4. Numerical results of study case A.

(a_1) Quota Share – The cession (the responsibility to be transferred to reinsurance is a fixed percentage). As a result, the retention of the Cedent (the insurance or the so called reinsured) will 100% less the cession part.

(a_2) Surplus – The retention will be proportional to the ratio between the desired sum assured (that could lower than the value at risk) and available reinsured limit for a specific coverage for a single risk. Therefore, the cession will be obtained from 100% less retention. Once calculated these percentages, they will be used when sharing the premiums and the responsibilities in the claims' payments.

(b) Non-Proportional (Excess of Loss Reinsurance) – instead of sharing proportionally the premiums and the claims according to the responsibilities assumed per risk, this kind of reinsurance will be based in the loss limit, which means a financial value payable for the ceding company (insurance) – like a deductible. There are 3 kinds of Excess of Loss reinsurance:

(b_1) Per Risk – every recuperation is made risk by risk basis.

(b_2) Per Occurrence or Catastrophe – as Kiln and Kiln (Kiln & Kiln, 2001) says:

"The protection of an insurance account by means of excess of loss is now worldwide significance and there is hardly an insurance Underwriter in the world who does not use or write such reinsurance. Like all important and successful operations the basic concepts is simple. If an insurance company or Underwriter is unfortunate to suffer a very large loss then catastrophe Reinsurers will reimburse him to for that proportion of his loss which exceeds an agreed value (the deductible) up to an agreed limit. Simple though the concept is, many difficult arise in practice. Through the years considerable thought has had to be given to defining more precisely the terms of contracts to eliminate these difficulties"

(b_3) Stop Loss – Again Kiln and Kiln (Kiln & Kiln, 2001) states:

"The Sop Loss reinsurance indemnifies the reassured against sustaining an aggregation of losses during a period of time. Normally the losses would be those occurring during the term of period of the contract as they are finally settled. However, where the settlement is unduly prolonged, the contract may make provision for outstanding losses to be commuted or settled on basis laid down in the contract. A typical example of this in the case of a reinsurance of long-tail business. The term of contract is normally annual one as this coincides with accounting period of most Underwriters".

After this general explanation, below is presented the most common form mechanism of Pooling Risk:

4. Offshore oil and gas platform industry background

The offshore oil and gas industry is continuing improving its oil offshore production, taking into account its sedimentary basin areas around the coast. After the severe damage that occurred since 1988, the Energy Line insurance underwriting tasks became more and more selective and restrictive regarding E&P offshore activities.

In order to evaluate and to analyze the biggest claims in this specific market, including offshore and onshore explorations, we show above the main losses occurred until 2001 around the world (see Table 1 based on Smith (Smith, 2002)).

Recently, one of the Marsh's Company Report (Marsh Company, 2001) presented a picture showing a relation between the majors claims and their timing relating the E&P activities. It represents a total of a 91 severe claims in E&P offshore fields, from 1970 to 1999 (categorizing the events by equipment – Table 2 – and by event – Table 3):

Recently, the Willis Energy Market Review from March 2009 (Willis, 2009) exposure a figure of the 10 most expensive insured losses between 1999 and 2008, as they are listed at the Table 4.

If we only consider the hurricanes as the main losses bellow that destroyed or damaged many offshore platform and other vessels, pipelines and all others upstream auxiliary structures, the maximum indemnization, during the period 1999 to 2008 that could affect the offshore industry should be US$ 136.127 billion – in other words the summation of the hurricanes' indemnizations. Even if the Global PML market scenario was half the Hurricane Katrina Loss Value this is US$ 35 billion probably there would be no capacity in the energy insurance and reinsurance market and the Oil Companies would self retain a big portion of their own risks. This figure means that there is no space for small participants without a big level of capitalization to survive in Oil and Gas offshore market.

According the practice in London market (*apud in* reference number (Willis, 2006), Lloyd's mainly, many insurers and underwriters had been using the Saffir Simpson as a rule of thumb to guide them when analyzing potential hurricane damage risk in order to build their ratemaking manual for offshore and marine

Table 1
Source: Smith, Terry (February 2002).

Enterprise	Claims payment (1000 US Dollars)	Nature of the peril
Total France	1,200,000,00	Refinery
Petrobras P36	500,000,00	Semi-submersible
Citgo USA	380,000,00	Refinery
El Paso Aruba	350,000,00	Refinery
Conoco Refinery UK	260,000.00	Refinery
BASF	119.000,00	
SASOL	104.000,00	Refinery
G.D.M.	100.000,00	
Tosco USA	99.000,00	Refinery
Citgo USA	85.000,00	Refinery
Tosco USA	51.000.00	Refinery
Total	**2.937.000,00**	

Table 2
Claims by type/equipment. Source: Marsh (2001).

Equipment	Number of accidents	Average Loss[a] (US$ 1000)	Percentage (%)
Transport	4	402,000	29
Jacket	10	100,000	18
Production	5	67,400	6
FPSO[b]	3	53,200	3
Drilling	741	40,400	30
Others	28	28,100	14

[a] Average loss considering values above US$ 10 million.
[b] Floating production, storage and off-loading vessel.

Table 3
Number of Claims by peril nature. Source: Marsh (2001).

Events	Number of accidents	Average loss[a] (US$ 1000)	Percentage (%)
Explosion	7	266,900	25
Fire	10	37,500	5
Vapor cloud	1	113,400	2
Mechanical defects	45	84,300	51
Others	28	47,600	18

[a] Average loss per accident.

Table 4
The ten most expensive insured losses (Source: Willis Energy Market Review (March 2009)).

Loss	US$ Billions	Date
Hurricane Katrina	68.515	2005
(9/11) September Eleven	23.654	2001
Hurricane Ike	15.000	2008
Hurricane Ivan	14.115	2004
Hurricane Wilma	13.339	2005
Hurricane Rita	10.704	2005
Hurricane Charley	8.804	2004
Winter Storm Lothar	7.223	1999
Winter Storm Kyrill	6.097	2007
Hurricane Frances	5.650	2004

Table 5
Hurricane potential damage loss severity.

Hurricane	Ivan	Katrina	Rita	Hurricane
Saffir Simpson	Cat 4	Cat 5	Cat 4	Cat 2
Hurricane severity index	33	47	42	36
Integrated kinetic energy	4.4	5.1	4.3	5.2
Number of platform destroyed	7	46	69	54
Number of platform damaged	24	20	32	95
Commercial market Loss (US$ Billion)	1.25	3.0	3.5	3.0

structures that operates in these areas. However, as shown by Watkins Syndicate statistics (*apud in* reference number (Willis, 2006), the guidelines turned out to be a poor tool for underwriter tasks, that compared the big four recent hurricanes like is showed at Table 5.

As Willis Energy Market Report (March 2009) remarks:

> "Perhaps both direct and reinsurance markets will pay more attention to the Integrated Kinetic Energy of a given windstorm than simply rely on the Saffir Simpson scale in the future".

As the main object of this paper are the BIC claim, to give an idea of the losses magnitude we extracted an estimated damaged picture of Katrina and Rita, regarding offshore platform damages losses, from Willis Energy Market Report, May 2006 (Willis, 2006)(Table 6).

Kaiser (Kaiser, Yu, & Jablonowski, 2009) in his relevant paper confirms these estimations.

5. BIC in the offshore industry

5.1. Introduction

It is very important to state that a BI Claim payment is due only if the peril that caused a production interruption is covered under the wordings of Material Damage policy.

The Business Interruption risks which include Oil and Gas Exploration and Production (E&P) activities are comprised in the Energy line insurance. This Business Insurance Clause (BIC) is very expensive, turning out its price prohibitive for the Oil Companies. As can be certified in the insurance market, a Material Damage (MD) coverage including a BIC could be acquired for approximately 2.0% or 2.5%, which is a very high and unusual ratio.

Another option in order to decrease the price is to adopt higher deductibles. Notwithstanding this measure could drive the oil company in bad situation since the coverage does not include a big part of its damages.

BIC covers accidents that could cause a loss of earnings after the initial commercial date due a claim covered in the MD insurance policy.

Following the historic costs of this kind of policies (MD including a BIC), the price becomes a big obstacle to contract them. Nevertheless, after the big claims occurred in 1988 (Exxon Valdez accident that causes the production interruption for a long time period, directed the Oil companies to consider the possibility of buying a BIC.

Without insurance, who could support these economic losses including long-term penalizations? A loss like that could drive the oil company to bankruptcy situation.

Studying the possibility of the acquisition of a BIC, Sharp (1994) highlights most important things that have to be observed:

(a) The maximum period of time necessary to restart the production. Commonly the Insurance Companies offer indemnity periods between 12 or 18 months. This time of cover could be insufficient to cover all the paralization time in cases like Total Loss (TL) of the structure;
(b) The maximum deductible period, measured in days or months, known as Waiting Period (WP), establishes that the BIC will only begin to work after the WP;
(c) The determination of the Insurance amount contracted for BIC. This question does not has an elementary answer once it is very difficult to set a correct amount that will be sufficient to cover all the paralization costs;
(d) To verify if the causing circumstances of the MD event costs are comprised in the covered perils of the MD policy. If the MD event cause is excluded of the covered perils, no payment is due for the financial loss caused from the BIC.

5.2. Main characteristics of the BI policy

5.2.1. Indemnity basis

It is a hard task to determine the correct amount sufficient to comprise the economical damages occurred. However these calcu-

Table 6
Katrina and Rita Energy Loss Estimates (Source: Willis Energy Market Review, May 2006).

	Physical damage (US$)	Operators extra expense (US$)	Business interruption (US$)	Total (US$)
Katrina				
Upstream excluding Rigs	4,137,312,000	1,228,225,000	831,686,000	6,197,123,000
Rigs	474,100,000		58,285,000	532,385,000
Downstream	1,791,205,000		628,500,000	2,419,705,000
	6,402,617,000	**1,228,125,000**	**1,518,471,000**	**9,149,213,000**
Rita				
Upstream excluding Rigs	2,762,756,000	870,478,000	853,260,000	4,486,494,000
Rigs	497,750,000		49,995,000	547,745,000
Downstream	481,635,000		364,565,000	846,200,000
	3,742,141,000	**870,478,000**	**1,267,820,000**	**5,880,439,000**

Notes to the table:
(1) These loss estimates are for the energy industry as a whole and are not necessarily insured amounts.
(2) Where no Business Interruption and Operators Extra expenses are available BI/OEE has been included in Physical material damage number.

lus proceedings are based in the BIC for the commercial insurance lines.

In the case that there is no pattern of wordings for BIC, the cover scope will vary according to:

(a) Insured necessities;
(b) Reinsurer's financial capacity and
(c) Reinsurer and Insurers willingness to underwrite such kind of risks. These risks comprised claims with a high degree of severity but a small probability of occurrence. This fact means that if there is a claim it will impact in a bad way the reinsures and insurers cash flow for this specific branch.

In the past, the basis of the indemnities allowed the insured to get some financial benefit from the insurance once the indemnity amount could overcame the real loss. In order to avoid such situation, insures started to contract external financial auditors to criticize the indemnity values.

There are many factors that influence the final calculus of the agreed amount due. Therefore, there are many ways to focus this problem if an oil company wishes to protect its net financial capacity to generate earnings (the gross value minus taxes, tariffs and royalties). However it seems to us that the most proper solution is to make a financial damage agreement that should avoid court litigations, although this is not the way to eliminate indemnities distortions. Nevertheless, we consider besides the distortions cited above, which is inherent to insurance matters, the agreement proceeding is the best way to finish this question once is very difficult to calculate the actual damage value.

As stated by Sharp (1994), another way to solve this question is to set a Net Operational Loss (NOL) that would be reimbursed to the insured, since the claim is comprised in the cover scope, limited to a maximum indemnity value fixed in the policy. This type of indemnity should take in account costs and expenses that should be excluded in a long run stoppage, such as royalties, tariffs, another taxes, transport, oil processing in the rig topside in the onshore terminals, Petroleum Tax Revenue, additional costs and maintenance. This is not an exhaustive list but is very complete.

Another form of indemnity evaluation is to set a Net Profit lost per barrel (NPLB) in production activities. Taking into account that it is not a hard task for the oil company to set the NPLB, this method is the most preferred for the majority of the firms.

Another possible solution could be to set the loss based in the Annual Value of Contract (AVC). This method is appropriated when there is a Contract Supply of Oil or Gas with annual fixed prices. Although there are various methods inserted in the policies to evaluate the offshore platform BI losses, some policies simplify this process assuming a maximum limited for extraordinary expenses known in the insurance market as oil extra expenses (OEE). This expression means that the cost incurred with the loss mitigation objective or with the purpose to decrease sue and labor (SL) costs are considered minimization measures. Generally such measures are comprised in the policy as obligations.

5.2.2. Indemnity period

The Indemnity Period is the time period in days that the BIC is valid. After this fixed time, even if the BIC damages still continuing the insurer or the reinsurer has no liability for such monetary values.

The Indemnity Period will take in account the earnings and expenses incurred in the previously years at the same time considered avoiding possible distortions.

As in the DSUC, Sharp affirms that the biggest BI time periods results from the big MD claims which include total loss events. The average time to build a new facility is around 3 or 4 years.

Nevertheless, in general the insurers and reinsurers do not wish to offer an Indemnity period of 3 or 4 years. In the most common situations the adopted period will be 12 or 18 months.

Adversary of the DSUC ordinary works where the occurrence probability of a big claim increases as the construction time pass the probability of a MD severe claim decreases as the time pass. This figure is justified because the oil and gas reserves fall down during the production period.

5.2.3. Scope of cover

Sharp (1994) says that the perils against which the market is able to offer an insurance cover are similar to those embraced in the DSUC:

"The coverage is similarly geared to perils insured under specific policy forms, in particular the physical damage and control of well policies effected on the facility. Insures are rarely prepared to include other risks, but may be prepared to include others facilities on which throughput from the insured platform are dependant. The market term for such coverage is Contingent Business Interruption which has come under much sharper focus in recent years following Piper Alpha loss".

It is worthwhile to mention that is too difficult to fix a fair indemnization amount regarding BIC cover for an offshore platform affect by a severe claim that cause a long term business interruption period. An outsider observer all can point out: but what about the reservoir volume? Was it affected? The best way to save time and is ways to fix a NPLB or AVC as previously mentioned in this paper.

6. Fuzzy mathematics and economic analysis

6.1. Fuzzy number

The Fuzzy Set Theory is a generalization of classical, called crisp, set theory and was developed by Zadeh (1965). Fuzziness describes sets that function characteristic allows various degrees of membership of a given set of elements.

Let X be a collection of elements denoted generically by x.

Definition 1. A fuzzy set $\tilde{A}$ in X is a set of ordered pairs,

$$\widetilde{A} = \{x, \mu_{\tilde{A}}(x) | x \in X\} \tag{6.1}$$

where $\mu_{\tilde{A}}(x)$ is the membership (or grade of membership) function of x in $\tilde{A}$, which maps X to the membership space M, $M \in [0, \alpha]$, $\alpha \leqslant 1$. If M is the closed interval [0,1], then $\tilde{A}$ is called a normal fuzzy set.

Definition 2. A generalized trapezoidal fuzzy number $\tilde{A}$ as $\tilde{A}$ = {a, b, c, d; h}, where the set elements are the vertex of real numbers denoting the smallest possible value, the most promising interval value and the largest possible value of a fuzzy event, respectively, with membership function demonstrated by Definition 3. For a triangular fuzzy number $b = c$.

Definition 3. The membership degree h, $0 \leqslant h \leqslant 1$, represents the confidence level of the fuzzy number, and can be considered to indicate the degree of confidence of the decision-makers' opinion. The support of $\tilde{A}$ is the crisp set that contains all the elements have a nonzero membership grade in $\tilde{A}$, i.e., the interval $[a, d]$ (6.1),

$$\mu_{\tilde{A}}(x) = \begin{cases} \mu_{\tilde{A}L}(x) = \frac{h(x-a)}{(b-a)}, & a \leqslant x \leqslant b \\ h, & b \leqslant x \leqslant c \\ \mu_{\tilde{A}R}(x) = \frac{h(d-x)}{(d-c)}, & c \leqslant x \leqslant d \end{cases} \tag{6.2}$$

The membership function given in Eq. (6.2) represents the mapping of any given value of x to its corresponding grade of membership, μ. Thus a fuzzy triangular number (TFN) can be defined by its corresponding left and right representation of each degree of membership.

The TFN represents the rational basis for quantifying the vague knowledge about most decision problems, e.g., the estimate of cost, revenue, interest rates, and so forth, specially using these TFN to model cash flows and perform economic decision analysis by calculating the net present value (NPV), as state by Gutierrez (1989) for an investment project.

6.2. Arithmetic

Algebraic operations for triangular fuzzy numbers (TFN) which are used on present worth calculations $p = (\bar{x}, \bar{x} + \propto_l, \bar{x} + \propto_r) = (a, b, c)$ are given by Eqs. (6.3)–(6.6):

$$(a, b, c) + (d, e, f) \cong (a + d, b + e, c + f) \tag{6.3}$$

$$(a, b, c) - (d, e, f) \cong (a - f, b - e, c - d) \tag{6.4}$$

$$(a, b, c) \otimes (d, e, f) \cong \begin{cases} (ad, be, cf), & (a, b, c) \geqslant 0, (d, e, f \geqslant 0 \\ (af, be, cd), \quad \textit{if} & (a, b, c) \leqslant 0, (d, e, f \geqslant 0 \\ (cf, be, ad), & (a, b, c) \leqslant 0, (d, e, f \leqslant 0 \end{cases} \tag{6.5}$$

$$(a, b, c) \div (d, e, f) \cong \begin{cases} \left(\frac{a}{f}, \frac{b}{e}, \frac{c}{d}\right), & (a, b, c) \geqslant 0, (d, e, f \geqslant 0 \\ \left(\frac{c}{f}, \frac{b}{e}, \frac{a}{d}\right), \quad \textit{if} & (a, b, c) \leqslant 0, (d, e, f \geqslant 0 \\ \left(\frac{c}{d}, \frac{b}{e}, \frac{a}{f}\right), & (a, b, c) \leqslant 0, (d, e, f \leqslant 0 \end{cases} \tag{6.6}$$

$$\lambda \otimes (a, b, c) \cong \begin{cases} (\lambda a, \lambda b, \lambda c), & \lambda \geqslant 0 \\ (\lambda c, \lambda b, \lambda a), & \lambda \leqslant 0 \end{cases}, \quad \forall \lambda \in \Re \tag{6.7}$$

6.3. Fuzzy net present value

Chio and Park (1994) and Kuchta (2008) are among those authors who developed net present value formula for fuzzy numbers. The cash flow at the time period t is defined by the triangular fuzzy number $P_t = (p_{t_0}, p_{t_1}, p_{t_2})$ and the interest rate is defined by the triangular fuzzy number $R_t = (r_{t_0}, r_{t_1}, r_{t_2})$ where $\forall r \geqslant 0$. In Eq. (6.8) the α level interval of the cash flow is given.

$$P_t = [p_t^{l(\alpha)}, p_t^{r(\alpha)}] = [p_{t_0} + (p_{t_1} - p_{t_0})\alpha, p_{t_2} + (p_{t_1} - p_{t_2})\alpha], \quad \forall \alpha \in [0, 1] \tag{6.8}$$

In Eq. (6.9) the fuzzy net present value of the cash flows is given:

$$NPV = \left[\sum_{t=0}^{n} \left(\frac{\max(P_t^{l(\alpha)}, 0)}{\prod_{t'}^{t}(1 + R_{t'}^{r(\alpha)})} + \frac{\max(P_t^{l(\alpha)}, 0)}{\prod_{t'}^{t}(1 + R_{t'}^{l(\alpha)})}\right), \sum_{t=0}^{n} \left(\frac{\max(P_t^{r(\alpha)}, 0)}{\prod_{t'}^{t}(1 + R_{t'}^{l(\alpha)})} + \frac{\max(P_t^{r(\alpha)}, 0)}{\prod_{t'}^{t}(1 + R_{t'}^{r(\alpha))})}\right)\right] \tag{6.9}$$

Sorenson and Lavelle (2008) express the triangular membership function for the fuzzy net present value of a single cash flow occurring in period t in Eq. (6.9) to simplify the evaluation of the fuzzy net present value. The cash flow at the time period t is defined by the triangular fuzzy number $S = (S_i^P, S_i^M, S_i^O)$ and the interest rate is defined by the triangular fuzzy number $r = (r_i^P, r_i^M, r_i^O)$ where $\forall r \geqslant 0$.

$$NPV = \left(\frac{S_i^P}{(1 + r_i^P)^t}, \frac{S_i^M}{(1 + r_i^M)^t}, \frac{S_i^O}{(1 + r_i^O)^t}\right) \tag{6.10}$$

The fuzzy net present value of cash flows occurring in n-year project period is defined in Eq. (6.11) where interest rate $r = (r_i^P, r_i^M, r_i^O)$ is same for all years, $S = (I_i^P, I_i^M, I_i^O)$ denotes the initial investment cash flow and $A = (A_i^P, A_i^M, A_i^O)$ denotes the uniform annual cash flows.

$$NPV = \left(I_i^P + \frac{A_i^P((1 + r_i^P)^t - 1)}{r_i^P(1 + r_i^P)^t}, I_i^M + \frac{A_i^M((1 + r_i^M)^t - 1)}{r_i^M(1 + r_i^M)^t}, I_i^O + \frac{A_i^O((1 + r_i^O)^t - 1)}{r_i^O(1 + r_i^O)^t}\right) \tag{6.11}$$

In order to compare the NPV fuzzy presented in Eq. (6.11) with the traditional deterministic NPV that not include the uncertain and risk in their cash flows, Chio and Park (1994) proposed a defuzzyfied NPV obtained using the center of area concept as follows (see also Ross, 2010):

$$NPV^* = \left(\frac{\sum_{j=1}^{N} NPVfuzzyj.X\mu(NPVfuzzy)}{\sum_{j=1}^{N} \mu(NPVfuzzy)}\right) \tag{6.12}$$

where $N = n^\circ$of interactions and μ(NPV) fuzzy = pertinency function of fuzzy NPV.

To proceed with all the calculations that will be necessary in the following case study, Excel spreadsheets were developed to facilitate the task.

7. Oil platform insurance case study

Before presenting the assumptions of a Natural catastrophic claim, we should look the Oil Company Cash Flow considered in our simulation. Instead of exhaustively describe the accounts, we simplify the cash flow as follows:

Production (bbl)
(x) Oil Price (US$ per bbl)

(=) Gross Revenues (GR)
(−) Revenues Taxes (% GR)
(−) Cost of Selling Goods
(=) Gross Profit (GP)
(−) Depreciation (5% GP-fixed value)
(−) Overheads (%GP)
(−) Insurance
(−) Cost of Material Damage
(−) Cost of Business Interruption
(=) Earnings before Taxes (EBT)
(−) Taxes (% EBT)
(=) Net Profit (NP)

This cash flow structure showed below is deterministic, although embraces much vagueness in almost index exhibited. In order to incorporate the uncertainty – which is considered vague because not random (Sorenson & Lavelle, 2008) – it was improved the Fuzzy Set Theory (Sharp, 1994), more specifically the FNPV (Gutierrez, 1989) to obtain this value for the four study cases:

(A) Total Loss with BIC and waiting period transformed an a deductible value of 10% of the covered damage;
(B) Total Loss with BIC and waiting period of 6 weeks (45 days);
(C) Total Loss without BIC

This cash flow structure will be repeated in the analysis for the 20 years life cycle of the platform (first assumption). Bellow we show other suppositions, which will be use in the fuzzy NPV analysis:

1. Claim Occurrence is fixed on the 6th operation year;
2. Platform Life cycle = 20 years;
3. Insurance ratio will be represented by a Triangular Fuzzy Number equals to (0.7%, 1.0%, 1.5%);
4. Waiting Period will be fixed on 90 days after claim;
5. Production follows an exponential production curve initiated in 80,000 bbl per day in the first year, following a negative exponential curve during the life the of the campus basis;
6. Overheads will be represented by a Triangular Fuzzy Number = (12%, 18%, and 24%);
7. The interest rate will be represented by a triangular fuzzy number = (12%, 16%, 24%);
8. Barrel Price will be stated as $99.33 per bbl, varying in the range of −0.5% and +0.5% as a TFN, in accordance with the recent quotations of July 20th;
9. Production Costs per bbl will be represented considering a range of ($30, $40, $50) per bbl;
10. Taxes under revenues will a fixed amount of 25% from the Gross Revenue;
11. The Insured Amount will be the equipment price ($1.500.000.000) discounted of the five initial operation years depreciation (5% per annum);
12. It was assumed that a Total Loss occurred in the end of year six and the platform only returning to operate at the beginning of the tenth year. This is a deterministic assumption of the model and also a limitation of it. The way to deal of this kind of situation was to construct a possibility vector treating the vagueness of claim occurrence.

The proposed algorithm follows the above procedure:

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a. For i = 0.05, for all $\mu \epsilon [0;1]$;
b. For t $\epsilon [1;15]$;
c. If t = claim period;
d. Production level for each period;
 (a) (x) Oil Price (US$ per bbl)
 (b) (=) Gross Revenues (GR)
 (c) (−) Revenues Taxes (% GR)
 (d) (−) Cost of Selling Goods
 (e) (=) Gross Profit (GP)
 (f) (−) Depreciation (5% GP-fixed value)
 (g) (−) Overheads (%GP)
 (h) (−) Insurance
 (i) (−) Specific Deductible (10% of initial investment or 6 weeks deductible)
 (j)(−) Cost of Material Damage
 (k) (−) Cost of Business Interruption
 (l)(=) Earnings before Taxes (EBT)
 (m)(−) Taxes (% EBT)
 (n)(=) Net Profit (NP)
5. For t $\epsilon 1;15[]$;
6. Sum all of NPL(α) and NPR(α);
7. Compute $\sum_i NOL(\alpha)_t/(1+r)$, for all μ;
8. Compute NPV*

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8. Numerical results and conclusions

Take into account the data showed previously, some interesting results were obtained. Notwithstanding, it requires very carefully interpretation to not extrapolate the possibilities of the model.

First of all, looking at the four alternatives, considering the BIC purchasing option performed a better solution than not buy the

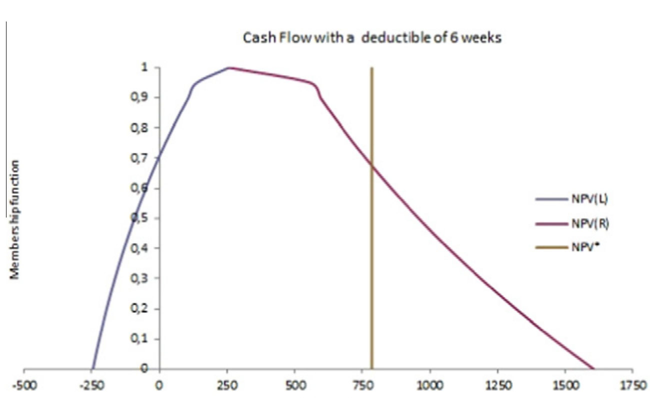

Fig. 5. Numerical results of study case B.

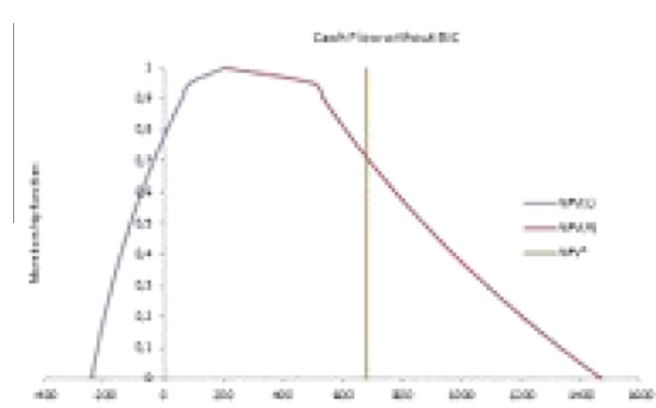

Fig. 6. Numerical results of study case C.

Table 7
Table of results.

	NPV L(α)	NPV (α = 1)	NPV R(α)	NPV defuzzyfied
Case A	−251.254.156,65	265.047.282,81	1.591.455.283,53	787.031.843,35
Case B	−245.926.230,20	257.346.609,36	1.605.989.223,77	784.952.146,49
Case C (worst)	−242.208.039,02	204.746.602,18	1.471.781.027,60	680.800.801,97

Case A: Cash Flow with BIC and a 10% deductible of the initial investment.
Case B: Cash Flow with BIC and a 6 weeks of deductible after the event.
Case C: Cash Flow without BIC.

insurance cover to business interruption risk, which sounds a great robust output of the papers' model.

However, case A (the best alternative – see Fig. 5) and case B (the second best alternative – see Fig. 6) show that the best option is mixing buying the BIC and certain level of self retention (waiting period in time or deductible in value) (Table 7). Therefore, it seems that the alternative of purchasing the BIC mixing with certain degree of self retention became attractive and increases the NPV of the Oil Company.

Another great advantage of the Fuzzy NPV value compared with deterministic NPV is that the former always consider no delays in the production, no volatility in oil prices and other variables that do affects in a remarkable way the Oil company cash flow, conducing it to big financial problems. As these kind of project have a long payback period they are exposed to market volatility prices that sometimes turns out a project economic viable into an uneconomic one.

Perhaps another highlight result was that the NPV was only positive for fifteen years period. The last 5 years the Oil Company experienced an economical damage, although it has contract the BIC cover. It seems reasonable in some way, considering that Oil and Gas is a riskier activity and many FPSO are resulted from the transformation of the old big vessels which implies the increase of the construction cost. And as time passes the reservoir volume decreases and the recuperation of the oil and gas became more difficult and expensive. Such kind of results can be viewed in Fig. 4.

This paper present a new methodology for oil risk managers how they in an economical point of view, including geological and economical uncertainties always presents during exploration and production oil and gas projects, the purchasing of a BIC cover. It seems to the authors, although the higher price it is a good decision considering the recent great hurricane accidents, such Katrina that caused the production paralization losses to the majority of the oil companies.

These results above mentioned confirmed the main objectives outlined in the abstract of this paper showing how important is to the Oil company risk manager elaborate a hedging policy to mitigate severe business interruptions losses that could cause even in the midterm the financial collapse of the Oil Company.

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