

# USING REAL OPTION VALUATION THEORY TO MEASURE BENEFITS FROM UNCERTAIN COSTS REDUCTIONS

Carlos Alexandre C. de Abreu<sup>1</sup> and J.P. Barros Neto<sup>2</sup>

## ABSTRACT

The aim of this paper is to make an investment evaluation using a Real Option model and demonstrate the differences in investment decision – making process using traditional and Real Option valuation in a construction project. The main objective is to show how the incorporation of cost uncertainty in the economic analysis influences the final result of the evaluation. Financial data of cash flows from a residential building project before construction and other market data are used as inputs for the economic analysis of the project. First we estimate the project's value using traditional valuation indicator Net Present Value (NPV) with no cost reduction. After that we estimate the NPV simulating possible costs reductions resulting from better internal processes towards a lean construction. The same financial and market data used to estimate the NPV are used in the Real Option Valuation model as inputs. The model's uncertain variable is the total operational costs which will be considered a random variable governed by a stochastic process. Other variables as income, taxes and market variables remain deterministic in the model.

## KEY WORDS

economic evaluation, uncertainty, real options, cost reduction, lean construction

## INTRODUCTION

Research in lean construction has been on for a while, but it's hard to find papers approaching the economic evaluations of projects based on lean construction and its benefits on the financial bottom line, which this approach in construction management can lead.

This paper intends to discuss aspects of cost reductions and uncertainty in the economic evaluation of a construction project and apply the Real Options Theory to an investment analysis of a residence building

project, simulating cost reductions. Our main goal is to exemplify a methodology of economic evaluation of the benefits from uncertain lower costs, which projects based on lean construction principles can offer.

The model presented here includes the managerial flexibilities, main characteristic of a real option model, resulted from the unknown future of the construction cost variable. Real options theory has been used as a tool for evaluation of projects in economic sectors where investment projects have a long time ahead in the future until the end of its cash flow.

---

<sup>1</sup> Researcher, Department of Structural Engineering and Civil Constructions, Ceará Federal University; Brazil. Phone +55 85 33969607 (30); calexabreu@yahoo.com.br

<sup>2</sup> Professor, Department of Structural Engineering and Civil Constructions, Ceará Federal University; Brazil. Phone +55 85 33669600; jpbarros@ufc.br

The oil & gas industry has been the main field of real options analysis due to the great uncertainty in oil prices and as observed in Tourinho (1979), Meyer and Majd (1983), Dias and Rocha (1999) and Costa Lima and Suslick (2001). Pharmaceutical industry is also an important field of application of real options models, since new products need a long time, subject to all kinds of uncertainties, between developing a new drug until the total approval by the health agencies and commercialization. Loch and Breude-Greuel (2001) and Rogers et al (2002) focus on the uncertainties of markets and R&D processes in new drug development and use real option to value pharmaceutical projects.

Construction projects have characteristics that suggest using real option valuation models. Projects and the whole industry are affected by all kind of uncertainties creating flexibilities that cannot be evaluated by traditional methods, construction projects take a long time to build (uncertainty is greater in longer periods) and at least part of the investments needed in this sort of project is irreversible. Lima and Heineck (2007) used real option valuation to identify the best strategy to develop a residential building considering uncertainty in demand of apartments. Buttimer and Ott (2007) evaluated a commercial building project, subject to uncertainty on the value of the future rent value.

The paper starts with a discussion of cost reduction and uncertainty in lean construction projects, continues with the arguments on real option theory and ends with the research methodology, evaluation model developed, results and main conclusions.

## **COST REDUCTION AND UNCERTAINTY IN LEAN CONSTRUCTION**

Construction projects have as final products residential apartments, commercial offices or other type of constructions which are in a class of products of high values. A client's decision –making process considers the price of an apartment, for example, as a very important variable when considering the acquisition of this kind of product. One of the most relevant aspects in the final price of a construction product is the total cost of the built structure. The greatest part of those costs comes from the production sector as direct costs of construction material and construction worker's wages.

The production sector of a construction project or firm has a primary task of controlling and reducing costs aiming in a more competitive price for its final products. Project's costs are a fundamental aspect for a company to engage competition in the construction market, and the best way of doing it is by always producing more using less resources. Forzberg and Saukkoriipi (2007) consider that production costs can be reduced in two ways: rising productivity and reducing wastes. These two types of cost reductions efforts need to be measured so it can be used as input parameters in an economic evaluation.

Koskela (1993) defined the 11 principles on which is based the lean construction thinking. Most of these have at least a partial connection with the costs reductions objectives of the production sector of a construction firm or project. Actions related to the extinction of activities that do not add value to a project will eliminate

unnecessary expenditures. In the same way, reduction on cycle time turns possible the presence more cycles with the same level of investment, increasing productivity and lowering unitary costs. Simplification, control and continuous improvement of flow and conversion processes are also conducts that lead to a reduction of construction costs.

Lean construction principles infer that a stable environment leads to gains in production. The variability in the whole production process and, consequently, on products developed, causes increases on cycle times and on the portion of activities witch do not add value, leaving an increase in production costs and loss of value of the product. Melles (1994) puts that, in this context managers need to reduce variability of the production process and increase reliability on production planning.

Is it possible to make a production process planning 100% certain? Will the initial plans be totally applied when executed? Conte (2002) argues that a project needs a baseline defined but it's difficult to keep the plan during the production cycles because of the presence of uncertainty in the different stages of constructions.

Tommelein (1997) considers the complexity in planning and controlling a construction project in reason of the existence of a variety of different uncertainties in a project. The first step to have success in planning a production process is to consider the uncertainties. Tommelein (1997) simulated a lean construction process with the occurrence of some types of uncertainties observed in this sort of project: scope of work, duration and timing, quantity, quality, resource

assignment and flow path and sequencing.

Reduction of uncertainty to 0% is very improbable. In this context the production costs from a planned project will also have some uncertainty, taking costs to a higher or a lower level if the process has a worst or better performance as initially planned, respectively. In this case an economic evaluation based on deterministic parameters may lead to under estimation of a project's value. The real options valuation theory is a methodology which accounts uncertainty in the analysis of investment projects.

#### REAL OPTIONS VALUATION THEORY

Companies have traditionally used static indicators and methodologies for economic valuation of projects based on discounted cash flows resulting in measures as net present value (NPV) and internal rate of return (IRR). These types of approach are based on the fact that company's managers will follow a planned budget and schedule from the beginning to the end of the investment project, with its incomes, costs and taxes remaining with no change. In this context the managers have a passive role, which does not reflect reality in an uncertain environment.

Investment projects are normally connected to some kinds of flexibilities which offer decision options to a manager during the operational life of a project. Trigeorgis (1996) shows that these flexibilities are different from flexibilities in production processes, since the first are concentrated on the decision making process of a manager, that is, the options to delay an investment, abandon an investment, change scale or expand level of production. These options occur

accordingly to market variables (for example, price of an apartment), cost's level, cost reduction rates, macroeconomic environment and other relevant variables in decision-making.

The Real option Valuation theory is based on the concepts of the options traded in stock markets applied to real projects, where those are considered options of investment. The methodology enables the valuation of a manager's flexibility to adapt and review his estimates for investment decisions if market or project's processes have any change. Real Option Valuation considers flexibility caused by uncertainties as a key point of an economic analysis of an investment.

The basis of real options valuation models is that a project's value has a behavior similar to a financial option in derivatives market. A real project is an option of investment, not an obligation where the investment can be made at any time until its expiration. Paddock et al (1988) make an analogy between variables used to determine the value of a financial option with a real project.

In a real option model the asset on which the option will be valued is the real projects discounted cash flows. As it happens on future markets, real options also have an exercise price representing the value that an investor has to pay to acquire an option. In the "real markets" that will be the value of investment costs necessary to build the project.

Considering construction projects these costs can be represented by the discounted costs of the production process. Uncertainty is represented by the volatility of the project's value due to market oscillations (on price or costs), internal processes variation

(lowering or increasing costs), technological changes (reducing costs) and political shifts influencing prices or costs and other relevant uncertainty. A financial option has an expiring moment defined in contract. Real option maturity is the time to build a construction or other type of projects. In the case of companies operating with concessions, the real option will expire at the final date of concession contract.

The main types of option are the European and American. The first can be exercised only at the end of its expiration while the second can be exercised at any time until expiration (Cox and Rubinstein, 1985). Real projects are closer to American options since they can be delayed, expanded or stopped if conditions are not favorable and its value is not being optimized.

#### DATA ACQUISITION AND METHODOLOGY

Data used as input parameters in the real option valuation model developed for this paper were obtained as results from a research through construction companies participants of the Inovacon program in Fortaleza – CE, Brazil. The economic data from projects were acquired through internal documental analysis and interviews with employees responsible for the data and cash flow construction. Three types of residential buildings projects were gathered and analyzed: projects concluded projects in construction and projects not started. To better fit the objectives of this paper was chosen one project of the third type.

The data collected to build cash flows and make the economic analysis of projects were: estimates of future revenues based on a scenario of sales conditions on a monthly basis, estimates of future expenditures

(project's costs, production costs, marketing costs, office costs, land costs, brokerage and taxes).

After the cash flow construction we estimated the project's value using traditional valuation indicator Net Present Value (NPV) with no cost reduction. The next step was the estimation of the NPV, simulating possible costs reductions resulting from better internal processes towards a lean construction.

Since the future cost reduction is our uncertain variable we developed a mathematical real option model where that uncertainty is incorporated. The same financial and market data used to estimate the NPV are used in the Real Option Valuation model as inputs. A comparison is made between results from NPV and real option model demonstrating the effects of including the cost uncertainty in the economic analysis.

## REAL OPTION MODEL

The first step in a real option valuation model is the definition of the uncertainty that will have influence on project's values. This model is a one uncertainty model and the variable which will not be deterministic is the rate of costs reductions launched by possible gains from lean construction.

Varian (2006) divides costs for a company in two types: fixed costs and variable costs. The first are the costs which are independent of the production level and the second are the costs that oscillate with production. Since we are dealing with an individual building and, consequently, only with its costs instead of the firm's aggregate expenditures and production, we considered that the project's costs are defined and do not vary with production. This model

assumes that lean construction will have a positive impact on the fixed costs reductions efforts. It does not consider that costs can turn the opposite way.

This is a real options continuous time model based on the one developed by Mc Donald and Siegel (1986) considered the basic real option model. The model's main idea is the definition the trigger investment decision point which the returns obtained from the residential building's construction have an optimal value (V), which compensates making a high investment expenditures (I) (building's production costs). Value (V) is subject to the rate of cost reduction (c) which has a random behavior governed by the Geometric Brownian Motion stochastic process observed in equation (1).

$$d(Vc) = \alpha(Vc) dt + \sigma(Vc) dz; \quad (1)$$

Where,  $d(Vc)$  is the variation of the project's value subject to oscillation on rate of cost reductions,  $\alpha$  is the expected growth rate of returns of the project attached to cost reduction rates,  $\sigma$  is the volatility in costs reductions rates and  $dz$  is the Wiener increment in charge of defining the oscillation's tendency. Estimation of (Vc) is in equation (2).

$$Vc = \Sigma (\text{Rev} - \text{tax} - \text{opex}) + I_c / (1 + r)^n; \quad (2)$$

Where, Rev are the revenues resulted from apartment sales, tax are all payments made to the government, opex is the summation of all other costs excluding production costs (treated here as the capital investment cost),  $I_c$  are the monetary benefits to the returns resulted from lean construction's costs reductions,  $r$  is the rate which the monthly returns in the cash flow are discounted and  $n$  is the

number of periods discounted. We can see that (Vc) will change if benefits (Ic), with c as the uncertain variable, also shifts.

Real option value in continuous time is estimated through a differential equation which can be obtained by two methods: ideas of dynamic programming and option pricing. In this case it was used the first, since we have as our uncertain variable an asset that is not traded on markets nor has at least an asset or portfolio on markets that could replicate its volatility, as a proxy. Construction project's volatility can use for a proxy the volatility of construction companies in the stock market. But in this case the projects analyzed are managed by small construction firms.

The use of dynamic programming as a tool for optimization of project's value is based on the idea that this tool breaks the chain of decisions surrounding an uncertain investment into two components. They are the immediate decision of investing and a valuation function that captures the subsequent decisions of investing in some time in the future (Dixit and Pindyck, 1994).

To find the optimal sequence of decisions the work is done backwards from the last moment that investment could be made to the beginning. At each future decision point the manager will compare payoff for immediate investment (represented by the present value of the project at any future point) to continuation and make the decision of investing or delaying based on the applied in finance and to this model are based on Neftci (2000), Dixit and Pindyck (1994).

$$\frac{1}{2} \sigma^2 (Vc)^2 \frac{\partial^2 F(Vc)}{\partial (Vc)^2} + \alpha (Vc) \frac{\partial F(Vc)}{\partial (Vc)} - rF = 0 \quad (4)$$

highest value. Equation (3) is known as the fundamental equation of dynamic optimization or Bellman equation in continuous time and represents the maximization of project's value in future periods.

$$r F(Vc,t) = \max \{ \pi(Vc,t) + (1/dt) E [dF(Vc,t)]; \quad (3)$$

Where in the left side of equation (3) is the return that a decision maker requires for holding the asset or delay the construction project using a discount rate. On the right side there is the immediate flow of profits or dividends from the project represented in the first term and the second term is the expected capital gain from oscillation in project's value in the future. The summation of both terms is the total expected returns for delaying the investment. Considering that the project will produce profit flows only when decision to invest is taken ( $\pi(Vc,t) = 0$ ) the return for delaying the project will be only the gains from oscillations of stochastic variable, rate of cost reduction.

Using Ito's Lema (mathematical theorem used to calculate derivatives in stochastic calculus (Similar to the chain rule in traditional calculus) we get the differential equation which estimates project's option value presented in equation (4). Since the prime objective here is to apply real option theory in a construction projects we won't get in the math details of the algebra and explanation of Ito's Lema. The details in stochastic calculus

where  $\frac{\partial^2 F(Vc)}{\partial (Vc)^2}$  is the second derivative,  $\frac{\partial F(Vc)}{\partial (Vc)}$  the first derivative, F is the option value, r is the discount rate,  $\sigma$  is the volatility of cost reduction rate and  $\alpha$  is the expected

growth rate of returns of the project attached to cost reduction rates.

In this paper we define the discount rate as 12% in a yearly basis. That is close to the value obtained in safe capital application in Brazilian financial markets. That is the minimum return which a firm requires for its project. With lower rates return on a project investor prefers financial markets applications. Expected growth and volatility rates of cost reductions on lean construction is a type of data not measured in the companies visited. For these parameters it was set values of 1% for the first and 10% for the second, both yearly.

Resolution of equation (4) needs three boundary conditions which are determined accordingly to the particular economic dilemma being analyzed. This model looks for the maximization of returns  $V_c$  under a total production cost or investment cost  $I$ . Resolution is going to define an optimal value  $V_c$  and, consequently, a value of  $c$  for optimization. The boundary conditions delineate an option curve separating region where investment is optimal from where waiting is the best decision. Conditions are in the following equations:

$$F(0) = 0 \quad (5)$$

$$F(V_c^*) = V_c^* \quad (6)$$

$$F'(V_c^*) = 1 \quad (7)$$

First boundary condition defines that the option value is zero when the project reaches that value. The second condition is called the value matching condition. At the optimal moment of investing option value and termination payoff are equal. The last is the smooth pasting condition which determines that the derivatives termination payoff and option value are the same at the optimum.

Solution format which satisfies (4) is equation (8). Dixit and Pindyck (1994) consider this equation format as the predominant in real option valuation models following stochastic processes in continuous time. It estimates the delaying option value of the project. Simplifying and doing some algebraic manipulations of equation 8 and the three boundary conditions we estimate constant  $A$ , which is used in the calculation of option value and the optimum value of project's return linked to the uncertain cost reduction rates from lean construction philosophy.  $A$  and  $V_c^*$  are defined in equations (9) and (10). Equation (11) is the positive root of the second order differential equation of the option valuation.

$$F(V_c) = (V_c)^{B1} \quad (8)$$

$$A = (V_c^* - I) / (V_c^*)^{B1} \quad (9)$$

$$V_c^* = (B1/B1-1) I \quad (10)$$

$$B1 = \frac{1}{2} - \alpha/\sigma^2 + \sqrt{[\alpha/\sigma^2 - \frac{1}{2}]^2 + 2r/\sigma^2} \quad (11)$$

## ECONOMIC ANALYSIS

Using traditional discounted cash flow based NPV methodology to analyze this residential building project and considering no cost reductions, the project would not be economically viable. The traditional rule of investment requires that the net present value of the project needs to be higher than zero, in that way presenting a positive monetary return (in Brazilian currency – Real) from the project. Since the project in analysis has a NPV of R\$ -2.113.240,28, the decision following traditional deterministic methodology would be not take the investment. Still with the NPV valuation but now allowing cost reductions in simulated scenarios of possible effects of lean construction on costs. Project would be economically

viable only if cost reductions were above 37,6% of total production costs which is called the NPV trigger investment point when it surpasses zero. Reductions inferior to that rate do not turn the NPV to positive values as it can be seen in table 1.

Using the real option valuation model presented in the previous section to evaluate the same project, the results and the rule of investment decision won't be the same. Observing table 1 its possible to see that at cost reduction rates of 37,6% and below the

option has a positive return value for the investment.

Its also possible to see that the optimal investment or the option trigger point where investment decision should be taken is at a 65% cost reduction rate for this project and an option value of R\$ 1.549.088,53, showing a trigger point superior to the one obtained using NPV. Why is the option trigger point higher? Why negative NPV values are positive using the real option approach.

Table 1 – NPV analysis in cost reduction scenarios

| Cost reduction rate(%) | Option value (R\$)  | NPV (R\$)       |
|------------------------|---------------------|-----------------|
| 0                      | 57.332,24           | (2.113.240,28)  |
| 5                      | 81.837,70           | (1.831.514,60)  |
| 10                     | 113.881,33          | (1.549.798,39)  |
| 15                     | 155.016,12          | (1.268.082,19)  |
| 20                     | 206.978,20          | (986.365,99)    |
| 25                     | 271.695,38          | (704.649,78)    |
| 30                     | 351.294,73          | (422.933,58)    |
| 35                     | 448.110,07          | (141.217,37)    |
| 37,6                   | 506.094,89          | <b>5.275,05</b> |
| 40                     | 564.689,26          | 140.498,83      |
| 45                     | 703.801,31          | 422.215,03      |
| 50                     | 868.443,43          | 703.931,24      |
| 55                     | 1.061.847,87        | 985.647,44      |
| 60                     | 1.287.488,72        | 1.267.363,65    |
| <b>65</b>              | <b>1.549.088,53</b> | 1.549.079,85    |
| 70                     | 1.850.624,85        | 1.830.796,05    |
| 75                     | 2.196.336,71        | 2.112.512,26    |
| 80                     | 2.590.730,90        | 2.394.228,46    |

These different values are due to the presence of the input parameters of the real options model, expected growth of cost reduction rates and, mostly, the uncertain variable's volatility. What happens is that considering a non deterministic future, the current estimate of project's value is uncertain, that is, it can assume higher values with possible future cost reductions.

If cost reductions aren't sufficient to make the project viable the manager

has the flexibility to delay the investment and wait for better conditions towards efforts of lean construction philosophy for cost reductions. In that way an option value will never go below zero as it's demonstrated on figure 1 and accordingly to equation (5).

In figure 1 we have the non linear option curve and the linear NPV values for different cost reduction rates. The NPV trigger point is at the



point where the straight line crosses the horizontal axis (37,6%). Below that, as discussed previously, there are only negative values of NPV. Option trigger point follows the value matching and smooth pasting boundary conditions. So it is optimal to undertake the investment at the point where the values of NPV and Option are equal (65% cost reduction). Cost reduction rates between the

37,6% and 65% have positive npv values but aren't the optimal investment since there is a possibility of increase in cost reduction rates. The optimal trigger point is the only value where both curves will meet. Values above that should always be to take the investment, or else, the investment will never be taken because the waiting value is going to be higher than the immediate investment.

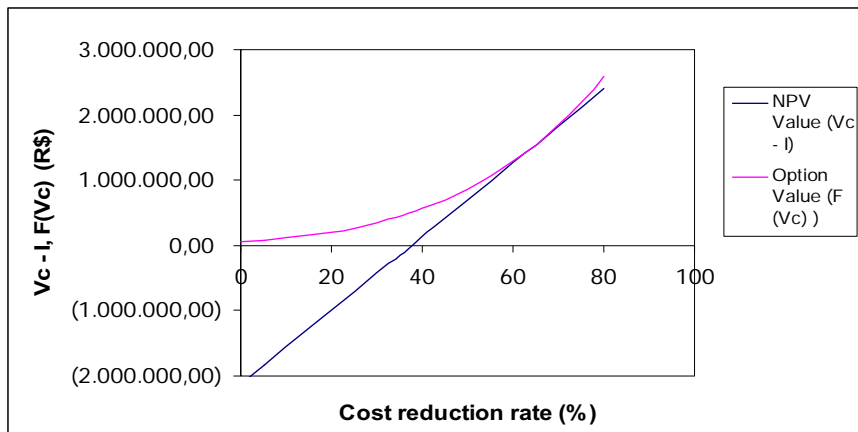


Figure 1 – NPV and value x cost reduction rates

## CONCLUSIONS

Real option models are valuable tools to be used in economic evaluation of projects in the construction industry especially on environments in which uncertainty is a key characteristic. The methodology fits lean construction philosophy at one of the main objectives of the lean construction thinking, that is, costs reductions. The tool allows a manager to measure economic impacts on project's values from probabilistic gains from the application of lean construction ideas to a whole firm or individual projects. In this paper we did not have more detailed data on benefits from more specific points in lean construction (for example, use of less material, gains in

productivity of workers). So we simulated some values for cost reductions, volatility and expected growth of rates. In future works the more detailed impacts could be measured.

Real Option valuation does not exclude traditional NPV and other methodology based on discounted cash flow since the last is part of the real option models. The methodology can be described as the estimation of the expanded NPV, that is, in addition to the traditional estimates of project's return, this tool estimates the flexibility value of a manager. Option decision rules are very sensitive to variation on volatility levels and expected growth of costs reduction rates.

## REFERENCES

- Buttimer, R., Ott, S. "Commercial Real Estate Valuation, Development and Occupancy Under Leasing Uncertainty". *Real Estate Economics*, Vol 35, p 21-56, 2007.
- Conte, A.S.I. (2002). "Lean Construction: From Theory To Practice". 10th Annual Conference of the International Group for Lean Construction (IGLC-10) Proceedings. Gramado, Brazil.
- Costa Lima, G.A.; Suslick, S.B. (2001). "Quantification of Investment Moment in Mineral Assets Using Real Options Theory". *Ouro Preto Mining School Journal*, Ouro Preto, v. 54, n. 2, p. 149-154.
- Cox, J., Rubinstein, M. (1985). "Option Markets". Prentice Hall. 498 pp.
- Dias, M. A., Rocha, K. (1999). "Petroleum Concessions With Extendible Options Using Mean Reversion With Jumps to Model Oil Prices". In: 3rd International Conference on Real Options, The Netherlands, 1999, June 6-8, p. 1-27.
- Dixit, A.K., Pindyck, R.S. (1994). "Investment Under Uncertainty". Princeton: Princeton University Press, 468 pp.
- Forsberg, A., Saukkoriipi, L. (2007). "Measurement of Waste and Productivity in Relation to Lean Thinking". 15th Annual Conference of the International Group for Lean Construction (IGLC-15) Proceedings. Michigan, USA.
- Koskela, L. (1993). "Application of the New Production Philosophy to Construction". Technical Report n.72. Center for Integrated Facility Engineering. Department of Civil Engineering, Stanford University, 75pp.
- Lima, G., Heineck, L.F. (2007). "Evaluation of Resource Allocation Strategies in Real Estate Projects – A Real Option Theory Approach". Proceedings of XXVII Production Engineering National Meeting. Foz do Iguaçu, Brazil.
- Loch, C. H.; Bode-Greuel, K. (2001). "Evaluating Growth Options as Sources of Value for Pharmaceutical Research Projects". *R&D Management*, 31, 231.
- McDonald R. and Siegel, D. (1986) "The Value of Waiting to Invest". *Quarterly Journal of Economics*, 101, 707-728.
- Melles, Bert. (1994). "What do We Mean by Lean Production in Construction?". 2nd Annual Meeting of the International Group for Lean Construction (IGLC-2) Proceedings. Santiago, Chile.
- Meyers, S., Majd, S. (1983). "Calculating the Abandonment Value Using Option Pricing Theory". MIT Sloan School of Management working paper No. 1462-83.
- Neftci, S., 2000. "An Introduction to the Mathematics of Financial Derivatives". New York, NY, USA, Academic Press. 430 pp.
- Paddock, J.L., Siegel, D.R., Smith, J.L. (1988). "Option Valuation of Claims on Real Assets: The Case of Offshore Petroleum Leases". *Quarterly Journal of Economics*, p. 479-508.
- Rogers M.J., Gupta A. and Maranas C.D. (2002). "Real options Based Analysis of Optimal Pharmaceutical R&D Portfolios". *Ind. Eng. Chem. Res.* 41, 6607–6620.
- Tommelein, I.D. (1997). "Discrete – Event Simulation of Lean Construction Process". 5th Annual Conference of the International Group for Lean Construction (IGLC-5) Proceedings. Gold Coast, Queensland, Australia.
- Tourinho, O.A. (1979). "The Valuation of Reserves of Natural Resources: an Option Pricing Approach". PhD. Dissertation, Berkeley: University of California.
- Trigeorgis, L. (1996). "Real Options – Managerial Flexibility and Strategy in Resource Allocation". Cambridge (EUA): MIT Press, 427 pp.
- Varian, H. (2006). "Microeconomics: Basic Principles". Rio de Janeiro: Elsevier. 850pp.