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Dynamic Investment Decision: Financial Modeling with Real Options vs. NPV

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Abstract. In this paper we apply real options theory to sequential investment. Based on two case studies, we examine the value of options of investment that will be made in many interdependent stages. We develop a combined approach of decision tree and real option. Then we compare our approach to the results given by the traditional Net Present Value. First, we show that applying real options to sequential investment projects incites operators to modify their behavior in relation to the uncertainty by taking into account potential benefits, namely the ability to strongly provide positive results associated with risky projects. Second, we show how real options lead to enhance flexibility and to identify opportunities that were not previously validated.

Introduction

Investment projects generally consist of several phases of development characterized by uncertainty. For example, the development of a new high speed train depends on the success of research and development phases, the estimated market potential, the reaction of competitors and projects, etc. For drugs, development phases prior to launch involve the search for new molecules, obtaining a patent, clinical trials and the approval by regulators. Marketing of products or services is also often a step-by-step process. For example, the successful launch of a basic service (e.g. mobile telephone SMS) may possibly offer the opportunity to market more advanced services (such as mobile telephone MMS). Each phase involves one or more decisions made in the context prevailing at the time of the decision. In addition, decisions depend on each other. The abandonment of the project from any phase does not allow its development. Indeed, if one phase of research and development (R&D) ends in failure, the product or service would never be launched. The capital already invested would therefore be lost. On the other hand, stopping the project at this phase avoids the loss of more capital. The notion of risk is fundamental in analyzing sequential projects and leads us to distinguish two main sources of uncertainty:

- Market uncertainty: Does the market accept the product or service? This uncertainty depends on the ability of the product or service to meet the needs and expectations of consumers. In this case, the probability of success or failure can be understood in a risk-neutral framework as in financial option pricing models of Black and Scholes (1973) or Cox, Ross and Rubinstein (1979).
- The uncertainty of events: Does R&D business lead to innovation? Will the clinical trials of a new drug be successful? Will the regulatory authority allow the selling of this drug?

To deal with these questions, managers have to assign subjective probabilities to estimate the chances of success of such events based on their knowledge and experience.

In this paper, we seek to better understand these two types of uncertainties through two case studies. In the case study of Servocal, we are only interested in the market uncertainties of a sequential project launch of services for the mobile telephone. While in the case of Medicat, using the development project of a drug, we integrate the uncertainty associated with the events of this project. In the literature, few studies have examined the impact of sequential investment projects and interdependence on the value of a portfolio of real options. Trigeorgis (1993) was among the first to study the implications of interdependence and to establish the non-additivity of real option values. His analysis is based on a series of options written on the same underlying asset, but the reality applications request different assets for each option in the portfolio.

Vishwanath (1992) derived sufficient conditions for the application of relatively simple rules to solve the problem of optimal sequential investing in a collection of investment projects. She considers projects that must be exercised, and the benefits of which are mutually independent. She highlights the limitations inherent in the application of dynamic programming which is a complex task and brings only small economic overview.

Childs, Ott and Triantis (1998) proposed a more comprehensive study of the interdependence between the valuation of real options and investment sequence. They described problems where the form of interdependence between projects ranges from mutual exclusivity to perfect complementarities. However, their analysis is limited to projects "mutually exclusive". Their results show that it is not always desirable to exercise first the more expensive option.

Smith and Thompson (2006) study the impact of sequential investment and active management on the value of a portfolio of real options. The options are assumed interdependent, so that the exercise of an option is supposed to produce, in addition to its intrinsic value based on an underlying asset determined, additional information on the values of other options based on related assets. By making an application in the field of oil exploration, they conclude that dependence increases the variance of potential outcomes; it also increases the expected value of the integrated portfolio of options and increases the cost of an optimal management. They suggest that the stochastic dynamic programming techniques can be used to determine the optimal sequence of investments. Given some plausible restrictions on the structure of information, they show that the optimal dynamic program can be identified and implemented through policies relatively simple to execute. In their work, they were able to deduce exact analytical expressions for the implied value of the portfolio, which allows the value of active management to be assessed directly.

One of the larger problems faced by managers is the correct evaluation of sequential investment opportunities. In this context, Costa et al. (2007) suggests that the traditional method of evaluation and decision-making is to calculate the expected value of future scenarios mapped out using a decision tree. Its major drawback is that the appropriate discount rate is difficult to estimate because it changes continuously over the nodes of the tree. They propose an approach for evaluating investment options for sequential study of an integrated project of conventional oil. The sequence of decisions found differs from those provided by the traditional net present value (NPV). They conclude that increased volatility increases the value of flexibility necessary to adapt the project to the new environment and that the strategy of the project in phases can increase its value.

Leiblein and Ziedonis (2007) examine the application of real options theory of investment decision sequence. To develop criteria of decision, they discriminate between investments that provide growth options from those that confer deferral options. They also introduce a conceptual model that explains the adoption of technology as a sequence of embedded options. During the introduction of each successive generation of technology, the company may either defer investment and wait for future generations or invest immediately for an experience that offers a claim on the adoption of subsequent generations. Their results show that the deferral and the option value growth depend on the magnitude, frequency and uncertainty of change and inter-generational nature of rivalry.

Stoverink and Madlener (2011) studied the economic feasibility of building a power plant in Turkey using the real options theory. Their objective was to determine the value of real options sequential nature of the power station project in question. To this end, they developed an investment model based on sequential binomial tree model of Cox et al. (1979). Considering a four-step analysis, they found that the application of real options analysis can be very useful, especially for strategic planning projects. The relatively high value of the option relative to the net present value (NPV) of the project indicates that the flexibility of reaction during the project, depending on market developments, can be ascribed substantial value. Another advantage of applying real options to sequential investments is that they also provide, in addition to the option value of investment, the optimal strategy for exercising the option. The revelation of the possibilities of action and examination allows a rethinking of the conventional calculation of the NPV of such projects.

Tamada and Tsai (2007) consider a sequential investment problem in two steps where the manager desires to cancel the project if it fails in its first stage. They assume that they cannot, at first, observe the result of the first stage. They propose two approaches to investment procedure. First, the integration procedure where just one agent is responsible for the investment in two stages. Second, a separation, where two different agents are responsible for the two stages of investment. The integration results in lower wage costs and a significant effort in both stages to get the correct information to cancel the project. The separation may have some advantage in terms of cost information. They show that when the cost of effort in the first stage is sufficiently low, the leader prefers the separation because the agents first step has less incentive to lie about the results.

In this paper, we apply real options theory to sequential investment. Based on two case studies, we examine the value of options of investment that will be made in many interdependent stages. We develop a combined approach, decision tree and real option. Then, we compare our approach to the results given by the traditional Net Present Value. In the first section we propose the case of “Servocal”. In the next, we present the case of “Medica”. The last section concludes.

1. “ Servocal” case

The company Servocal plans to offer voice services to mobile operators in an emerging country, the Bodistan via a multiservice platform (denoted MS). This investment includes a server (SER), systems for voice (SV), the cost of installing and operating license. Currently, three operators (Astral, GlobalTel and Bluesia) have expressed interest in marketing the services of Servocal.
After analyzing the needs of each of its potential customers, it defined the structure of service prices of its platform as follows: bills for customers will be developed using a simple matrix that applies a fixed price for each type of service.

A market study has set the initial prices and has predicted traffic patterns. In order to stimulate demand and prevent the entry of competitors in this market, Servocal will decrease the selling price of 15% per year from the second year.

Tariffs / min in euros

Type	**Tariff**	**Pourcentage**
Service 1	0,02	2%
Service 2	0,08	23%
Service 3	0,1	17%
Service 4	0,06	48%
Service 5	0,04	10%

Traffic forecasts (million minutes)

Year	**1**	**2**	**3**	**4**	**5**
Traffic	48,00	100,00	320,00	450,00	470,00

Capital expenditures (CAPEX) include:
- A server (8 800 K €)
- 2 vocal servers (each VS of 2 500 K €) the first year, an additional VS in the second year and 3 SV in the third year,
- The cost of installation, programming and server configuration (500 K €),
- The cost of the license granted by the local authority control for a period of five years, is 1 200 K €.

Investments are amortized linearly over the remaining life of the project because as there is no second-hand market for this type of very specific investment, they cannot be resold. The residual value is zero.

Operational costs (OPEX), selling and general break down as follows:

- Maintenance costs (k € 8 for each VS),
- Technical personnel costs (K € 5 per month),
- Billing costs of 0.25% of gross revenues,
- Overhead: 5,000 K € plus 3% of gross revenues,
- Commissions on sales is 6.5% of gross revenues.

We retained for analytical purposes, an average tax rate on profits of 35%. The risk-free rate is 5%. The cost of debt before tax is 8% and on equity is 17%. 45% of the business is financed by debt. The profitability of this project is evaluated by reporting eventual deficits on the tax base of the following year.

1.1. Determination of project revenue

We first calculate an average price per minute for all services according to their price and consumption patterns that we consider (for simplicity) stable for 5 years.

Calculate the price / minute

Type	Weight	Price/minute	Price/min ajusted
Service 1	2%	0,02	0,0004
Service 2	23%	0,08	0,0184
Service 3	17%	0,1	0,017
Service 4	48%	0,06	0,0288
Service 5	10%	0,04	0,004
Average Price / Minute			0,0686 €

The turnover is obtained by multiplying traffic (volume in million minutes) by the average price per minute which declined 15% per year from the second year.

Turnover (in millions)

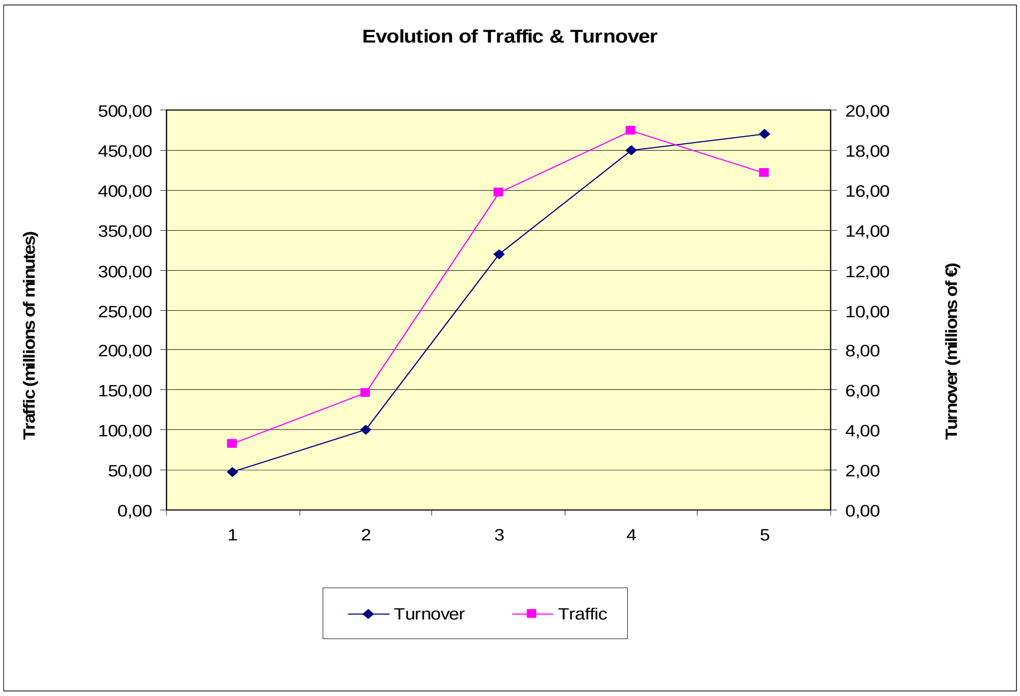
Year	1	2	3	4	5
Traffic (million minutes)	48,00	100,00	320,00	450,00	470,00
Price	0,0686	0,0583	0,0496	0,0421	0,0358
Turnover	3,29	5,83	15,86	18,96	16,83

The traffic curve has an "S" shape characteristic of the diffusion of services subject to network externalities (or effects). Indeed, when a product or service characterized by such effects is launched, market penetration is characterized by a diffusion function with an S-shape which outlines the various stages of the adoption process (Goolsbee, 2005). At first, the number of users is low. It slowly increases to a point where it takes off (inflection point), then reaches a maximum speed of diffusion. The rate of diffusion decreases then because the potential development of the population is becoming less important. When the entire target population adopted the innovation, the market is at saturation.

As a result, the financial evaluation of investment projects subject to such effects is particularly difficult with conventional methods of evaluation, such as NPV, given the large uncertainties on the number of future users, and therefore sales. If the company manages to exploit these effects, the number of users actually grows exponentially, otherwise the project fails.

Investment projects with network effects are particularly risky because they require reaching a critical mass of users so that their cash flows are seen to be positive without guaranteeing their profitability.

Given the continued decline in prices, increasing the number of minutes sold can no longer counterbalance at period 5, and therefore sales decline.



1.2. Investment and operational costs

Investments in K€

Year	0	1	2
Server	8 800		
VS	5 000	2 500	7 500
Patent	1 200		
Installation	500		
Total investments	15 500	2 500	7 500

The depreciation is linear in the remaining life of the project given the inability to resell the equipment.

Amortization (K€)

Year	1	2	3	4	5
I 1	3 100	3 100	3 100	3 100	3 100
I 2		625	625	625	625
I 3			2 500	2 500	2 500
Total	3 100	3 725	6 225	6 225	6 225

Io: investment made at date 0.

Maintenance costs are proportional to the number of VS while technical personal expenses are fixed.

Operational costs in K€

Year	1	2	3	4	5
Nember of VS	2	3	6	6	6
Maintenance costs	16	24	48	48	48
Personnel expenses	60	60	60	60	60
Total operating costs	76	84	108	108	108

1.3. Income statement

Year	1	2	3	4	5
Turnover	3 293	5 831	15 860	18 958	16 831
Operation costs	76	84	108	108	108
Amortization	3 100	3 725	6 225	6 225	6 225
Operating Income	**117**	**2 022**	**9 527**	**12 625**	**10 498**
Operating Margin (%)	3,5%	34,7%	60,1%	66,6%	62,4%

Distribution costs	214	379	1 031	1 232	1 094
Billing costs	8	15	40	47	42
General and administrative costs	5 099	5 175	5 476	5 569	5 505
Subtotal	5 321	5 569	6 546	6 848	6 641
Earning before interest and taxes (EBIT)	**-5 204**	**-3 547**	**2 981**	**5 777**	**3 857**
Exploitation Margin (%)	-158%	-61%	19%	30%	23%

This gives an operating loss in the first two years, which is the necessary time to reach a critical consumption level of minutes. Then it increases strongly before bending under the impact of price reductions.

The carriage of deficits consists of reducing the tax base of the following year when operating income is negative. This report contributes to improving the profitability of this project, since at period 4, the firm pays almost no taxes despite the exceptional level of operating income (5777).

Taxation	1	2	3	4	5
Tax Base	-5 204	-8 751	-5 770	7	3 857
Corporate taxes	0	0	0	2	1 350

Earnings Before Interest After Taxes (EBIAT)	**-5 204**	**-3 547**	**2 981**	**5 774**	**2 507**
Net income margin (%)	-158%	-61%	19%	30%	15%

1.4. Weighted average cost of capital (WACC)

In order to provide updated cash flows, it is necessary to determine first the weighted average cost of capital of the firm. When the project is on the same level of economic risk as the company, it can be calculated from the cost of equity and corporate debt weighted by the share of each element in the total. This method leads to two remarks:
• The project must be within the same industry as the firm or, more generally, the evolution of its gross operating surplus (GOS) should be roughly constant,
• The choice of the average cost of capital assumes that the project is funded in the same proportion as the firm or that it is funded differently but its impact negligible. Mathematically, the average cost of funding sources (with the inclusion of tax benefits for corporate debt) weighted by the financing structure (respective percentage of equity and debt financing in the total Company):

Determine the WACC	
Cost of debt before tax	8%
Cost of debt after tax	5,20%
Cost of Equity	17%
% of Debt	45%
% of Equity	55%
WACC	**11,69%**

1.5. Cash flows and NPV

Cash flows are calculated from net income (EBIAT) to which we add Amortization. Cash flows are discounted at WACC, while investments are discounted at risk free rate account. Deferring the payment of the expenditure investment in time, gives the company the opportunity to invest those funds at the Risk-free interest rate (Luehrman, 1998).

Cash flows and investment form the free cash flows. The cumulative free cash flows are the NPV. As the NPV is negative, the project should not be initiated under this criterion.

WACC	11,69%					
Year	**0**	**1**	**2**	**3**	**4**	**5**
EBIAT		-5 204	-3 547	2 981	5 774	2 507
Amortization		3 100	3 725	6 225	6 225	6 225
Cash Flows		-2 104	178	9 206	11 999	8 732
Cash Flows discounted		-1 884	143	6 607	7 711	5 024
Investment	-15 500	-2 500	-7 500			
Investment discounted	-15 500	-2 381	-6 803			
Free cash flows discounted	-15 500	-4 265	-6 660	6 607	7 711	5 024
Cumulative free cash flows discounted	-15 500	-19 765	-26 425	-19 817	-12 107	-7 083

Cash Flows discounted	17 601 K€
Investment	-24 684 K€
NPV	**-7 083 K€**

1.6. Integration of other development phases

The project of the company "Servocal" includes two additional phases. In three years, the company will have the opportunity to make an additional investment for data services because of its position already acquired on the market. Then, in 5 years, it will sell multimedia services to market (numbers in millions of euros):

	Inv.	Inv. dis. in 0	CF dis. in. 0	PNV
1st Phase	24,68	24,68	17,601	-7,08
2sc Phase in 3 years	80	69,11	70	0,89
3rd Phase in 5 years	140	109,69	115	5,31
Total	244,68	203,48	202,60	-0,88

Inv. dis.. : Investment discounted at risk free rate of 5%. We discount investments by the risk-free rate because by delaying discharge of capital expenditure over time, the company has the opportunity to invest those funds at the risk free interest rate (Luehrman, 1998).
FC dis. in 0: discounted cash flows at date 0.

These two additional projects have a positive NPV but these do not offset the NPV of the first phase, and do not result in an overall positive NPV (-0.88). This criterion should lead to reject this project.

This evaluation by the overall NPV does not account for the flexibility offered by the different project phases. Indeed, if the state of nature is unfavorable in 3 years (5 years, respectively) the second (resp. third) phase will not be realized.

So there are two calls (growth option), with maturities 3 and 5 years respectively, which may be exercised by making additional investments. It is in fact a composed option as the launch of the third phase will be undertaken if the second phase has been previously implemented.

It is therefore necessary to evaluate this compound growth option in order to check how it affects the overall NPV of the project, called Adjusted NPV (ANPV).

In this context the NPV of the investment proposal is:

ANPV = NPV (active phase 1) + value of the call made for phases 2 and 3.

We propose to evaluate this call by the binomial model of Cox, Ross and Rubinstein (1979). First, we develop the tree of the project cash flows for the two phases. For simplification, the number of periods chosen equals to the maturities of options.

The parameters of the binomial model are:

Variable	Description	$2^{ème}$ Phase	$3^{ème}$ Phase
S	Present value of cash flows	70	115
T	maturityof option (years)	3	5
σ	Standard deviation of cash flows (volatility)	40%	40%
r	Risk free rate	5%	5%
Nb_per	Number of periods	3	5
t	Number of years / number of periods	1	1
Rh	adjusted risk-free rate: (1+r)t	1,05	1,05
up	Exp $(\sigma \times t^{0,5})$	1,4918	1,4918
down	1 / up	0,6703	0,6703
Pu	(Rh-down) / (up-down)	0,4622	0,4622
Pd	1-Pu	0,5378	0,5378

Phase 2: Evolution of cash flows

	0	1	2	3
0	70,00	104,43	155,79	232,41
1		46,92	70,00	104,43
2			31,45	46,92
3				21,08

Phase 3: Evolution of cash flows

	0	1	2	3	4	5
0	115,00	171,56	255,94	381,81	569,60	849,74
1		77,09	115,00	171,56	255,94	381,81
2			51,67	77,09	115,00	171,56
3				34,64	51,67	77,09
4					23,22	34,64
5						15,56

To better understand the process, we first evaluate the two options as though they were disjoint. To obtain the value of the call of the third phase, we begin with the terminal value in period 5. In a risk neutral framework, the value at each node is calculated as the discounted expectation of the two possible values of the option.

Option the third phase (only)

I5 140 (exercice Price)

Call	0	1	2	3	4	5
0	42,04	78,52	143,45	254,83	436,27	709,74
1		14,59	30,02	61,08	122,60	241,81
2			2,69	6,11	13,89	31,56
3				0,00	0,00	0,00
4					0,00	0,00
5						0,00

Option the second phase (only)

I3 80

Call	0	1	2	3
0	20,27	40,54	79,60	152,41
1		4,73	10,75	24,43
2			0,00	0,00
3				0,00

For the valuation of the compounded option, we take the binomial tree option of the third phase. Periods 4 and 5 remain unchanged. However, in period 3, the payment includes that of the second phase and the discounted cash flows of the third phase when the second phase was launched. Indeed, if the project is stopped at the second phase (date 3), then it generates no cash flow.

Option made (second and third phases)

I5 140

I3 80

Call	0	1	2	3	4	5
0	60,19	117,46	223,05	407,24	436,27	709,74

1	16,57	37,64	85,51	122,60	241,81
2		0,00	0,00	13,89	31,56
3			0,00	0,00	0,00
4				0,00	0,00
5					0,00

The option value obtained is 60.19 million Euros and leads to launch the first phase of the project since the project's overall ANPV is positive. The second and third phases will be undertaken according to the state of the environment respectively in 3 and 5 years.

Total project value	
NPV 1	-7,083
Compounded Option composée	60,19
ANPV	53,10

2. “Medicat” case

This case concerns the development of a new drug. There are four main phases: the search for molecules (phase 1), clinical trials (phase 2), the application for approval with regulatory authorities (phase 3), and the launch of the drug on the market (phase 4). For each of the first three phases, the probability of success is due to an uncertainty of private order, while in the fourth phase, it is determined by the market. Project managers then define a subjective probability associated with the first three phases. For the fourth phase, they use a risk-neutral probability. In addition, we estimate that the weighted average cost of capital is 12%.

The following table summarizes the project:

	Phase 1	Phase 2	Phase 3	Phase 4
Probability of success	0,65	0,77	0,92	Risk- neutral
Probability of failure	0,35	0,23	0,08	Risk- neutral
Investment	3	10	2	49
duration (Year)	2	6	1	0
Cumulative duration (years)	2	8	9	9
Discounted cash flow			90	90
Free cash flow discounted	0	0	0	41

In fact, with results from the agreement of the authorities (phase 3), the drug is marketed immediately and generates a free cash flow discounted of 41 (90-49).

The introduction of a private order of uncertainty leads us to combine two approaches to evaluate this project. That of decision trees with that of real options.
We consider first the evaluation of Phase 4 for which the parameters of the binomial model are:

Variable	Description	
S	Present value of cash flows	90
T	life of option (years)	9
σ	Standard deviation of cash flows (volatility)	45%
r	Risk free rate	5%
Nb_per	Number of periods	9
t	Number of years / number of periods	1
Rh	adjusted risk-free rate: (1+r)t	1,05
up	Exp $(\sigma \times t^{0,5})$	1,5683
down	1 / up	0,6376
Pu	(Rh-down) / (up-down)	0,4431
Pd	1-Pu	0,5569

We deduce the evolution of the cash flows of 9 periods:

Evolution of cash flows										
	0	1	2	3	4	5	6	7	8	9
0	90,00	141,15	221,36	347,17	544,47	853,90	1339,18	2100,25	3293,84	5165,77
1		57,39	90,00	141,15	221,36	347,17	544,47	853,90	1339,18	2100,25
2			36,59	57,39	90,00	141,15	221,36	347,17	544,47	853,90
3				23,33	36,59	57,39	90,00	141,15	221,36	347,17
4					14,88	23,33	36,59	57,39	90,00	141,15
5						9,49	14,88	23,33	36,59	57,39
6							6,05	9,49	14,88	23,33
7								3,86	6,05	9,49
8									2,46	3,86
9										1,57

To obtain the value of the call, we start with the terminal value at date 9 and go back to the tree branches. Value is obtained at each node from discounted expectation of the two possible future values of the option.

Value of the'option

K 49 (exercice price)

Call	0	1	2	3	4	5	6	7	8	9
0	66,24	112,69	188,70	311,18	506,08	813,58	1296,85	2055,80	3247,17	5116,77
1		35,24	62,34	108,19	184,05	306,86	502,14	809,45	1292,51	2051,25
2			16,84	31,45	57,55	102,87	179,04	302,72	497,80	804,90
3				6,73	13,51	26,67	51,50	96,70	174,70	298,17
4					1,94	4,26	9,30	20,16	43,33	92,15
5						0,27	0,63	1,49	3,54	8,39
6							0,00	0,00	0,00	0,00
7								0,00	0,00	0,00
8									0,00	0,00
9										0,00

Once the value of the option set, we use a decision tree to evaluate the project:

	Node 1	Node 2	Node 3
Probability of success	0,65	0,77	0,92
Probability of failure	0,2	0,23	0,08
Investment	3	10	2
Duration (Years)	2	6	1
Value of the option			66,24

Node Phase 3		
Discounted value date 3	54,41	=0,92*66,24/1,12
NPV date 3	52,41	= 54,41-2

Node Phase 2		
Discounted value date 2	20,45	$=0,77*52,41/1,12^6$
NPV date 2	10,45	= 20,45-10

Node Phase 1		
Discounted value date 1	5,41	$=0,65*10,45/1,12^2$
NPV date 1	**2,41**	= 5,41-3

The evaluation of the project only with a decision tree gives:

Nœud Phase 3		
Discounted value date 3	33,68	=0,92*41/1,12
NPV date 3	31,68	= 33,68-2

Nœud Phase 2		
Discounted value date 2	12,36	=0,77*33,68/1,126
NPV date 2	2,36	= 12,36-10

Nœud Phase 1		
Discounted value date 1	1,22	=0,65*2,36/1,122
NPV date 1	**-1,78**	= 1,22-3

Note that the evaluation of the project only with a decision tree leads to a negative NPV, whereas the combined approach of decision tree and real option results in a positive NPV. This second approach allows us to integrate both events with a probability of subjective realization and an evaluation of the potential market in a risk neutral framework (where the probability of success is determined from the up and down that is to say the volatility of cash flows of the project).

The consideration of this option should bring Médicat managers to decide to develop this drug. The product launch depends on the success of the first three phases and the evaluation of the potential market in 9 years.

Conclusion

In terms of investment decisions, the real options theory applied to sequential investment presents two advantages. First, this approach incites operators to modify their behavior in relation to the uncertainty by taking into account potential benefits, namely the ability to strongly positive results associated with risky projects. Second, real options lead to enhanced flexibility and help to identify opportunities that were not previously validated.

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