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Valuing Innovative 4G (LTE) Technology with Real Options Approach

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Abstract: This paper contains the analysis of pitfalls related with innovation-based investments valuation. Being long-term projects with high uncertainty, innovation-based investments suffer from different types of errors if traditional discounted cash flow methodology is used for their valuation. The real options methodologyis being used for a long time as an alternative view at the evaluation of such projects, but the novelty of this paper is in the original approach based upon the consideration of the wide variety of project implementation scenarios. The presented weighted average polynomial option pricing model (WAPOPM) may help investors to increase the quality of decisions concerning their participation in innovation-based opportunities. The case of 4G (LTE) implementation in MTS Company (Russia) is considered.

Keywords: valuation of innovation-based projects; innovation technology; real options; 4G; Long Term Evolution (LTE).

1 Introduction

The strongest companies in different sectors of economy demonstrate leading market position, high return on assets and equity, rapid capitalization growth. Their success could be explained mostly by creation, transfer, and commercialization of unique technologies. Undoubtedly, it is a very attractive course of development for any company and for any economy (see Drucker (1985) and Ettlie (1998) papers for more details). However, high-technology projects differ from traditional investments by the next features:

- Extended uncertainty – very often cash flow has irregular nature, i.e. no reliable hypothesis about the probability distribution of key parameters could be formulated;
- Problems in strategic effect valuation – this effect may have more qualitative than quantitative character and hardly can be evaluated with reliable numbers.

Talking about future forecasting hardships it is interesting to note that financial managers recognize and understand the problem better if an annual budgeting topic is considered. KPI and correspondingly personnel bonuses mostly depend on the forecast (Banham, 2012). It is enough to remember 2008-2009 crisis years, when leading CFOs named future uncertainty as a main problem for business. There are many articles on this topic in professional literature, for example, in well-known “CFO Magazine” (Stuart, 2009).In case of innovation investments such and even worse future uncertainty is an everyday normal situation. Thus, efficient instruments that would allow managing high risks are urgently needed.

Concerning practical point of valuation it should be noted, that Discounting Cash Flow Method (DCF) with Net Present Value (NPV) as a main criterion is the most widespread analytical tool for the Investments Valuation. However, this approach, besides some unrealistic assumptions (i.e. ideal market conditions), has two fundamental inaccuracies concerning especially high-technology investments:

1. An investor’s flexibility ignoring;
2. Incorrectness of the risk calculation in the denominatorvia the cumulative discounting rate.

The first inaccuracy means that an investor is considered as a passive subject who does not change his decision, even if the decision had been made in the far past and market conditions have changed significantly since. In other words, DCF Method does not take into account any new unexpected market information that arises during the project lifetime. Changes in legislation, sudden competitor’s actions, a new technology development, exact experimental results, and others are examples of opportunities and threats that may change investor’s behaviour and strategy. Investors can force projects or stop them relying on the new market information (Antikarov V., Copeland T., 2001).

The second inaccuracy means that risk calculation in the denominator by the cumulative discounting rate does not solve the problem of considering high risk in innovation-driven projects. Incorrectness arises by the reason of decreasing value to the present moment not only for cash in-flows, but also for out-flows. This situation is associated with the fact that discounting to the present value gives correct values only if the cash flows sequence is standard. A simple example is shown in the Appendix 1.

We propose the following ways to overcome the two mentioned problems:

1. investors’ flexibility valuation;
2. risk calculation in the numerator by the scenarios (or decision) tree.

A leading analytical tool to implement these ways to decrease uncertainty of the high-technology projects is the Real Option Valuation (ROV). This idea as many others is borrowed from the stock market where investor’s opportunity, but not the obligation to sell or to buy an asset, is valued.(Myers S., 1977) was the first who implemented option finance technique to the real investment. Nowadays the leading specialists in the real option valuation are (Trigeorgis L., 1996, 2004), (Antikarov V., Copeland T., 2001), (Damodaran A, 1999), (Hull 2002)who have significantly contributed to this area. Annual International Conference "Real Options: Theory Meets Practice" is the biggest knowledge source where many theoretical ideas (assumptions, methodology and so on) meet with the real business cases (especially in the oil and high-tech investments).There are several important papers where Real Options method was applied in telecom business

(Harmantzis F. & Trigeorgis L., 2006), (d'Halluin Y., 2004), (Lassila J., 2001) and (Tanguturi V.P. & Harmantzis F., 2005). At the same time, the case of 4G (LTE) technology has not been analysedat academic or practical papers. Taking into account the promising future of this technology, it seems interesting to examine it as the innovative-based investment.

We would like to give a clear example of the real option application in recent business practice. Innovative company Kiva Systems disrupted usual pick-and-pack process in an online retailer's warehouse. This company offered an army of mobile robots that saves time and money. However, it turned out that it was not enough "to envision the novel approach, invent the required technology, and make it commercially viable" (Mountz, 2012). Online retailers did not want to take a risk of buying an untested solution. Then Kiva decided to guarantee that customer could demand all money back until final acceptance of the solution. In other words, Kiva took financial risks on itself. Actually, Kiva Systems suggested real put option to abandon the project. As a result, first customers appeared and after several successful years Amazon acquired the company.

We suppose that the plenty of researches devoted to the ROV method may be divided into two parts:

1. strong mathematic papers thatsometimes do not give the clear way of using results in practice (Turnbull 1987, Wilmott 1995);
2. papers devoted to method popularization (Leslie 1997).

Our paper attempts to stand on the intersection of mentioned groups. On the one hand, it pretends to develop the ROV methodology for more precise estimations for the sake of investor's interest. On the other hand, it allows financial managers to use quite easy analytical algorithm of calculations in contrast to, for example, difficult stochastic processes (Bastian-Pinto 2010) or continuous-state Markov (jump) process (Grillo 2010).

Almost all Option Valuation models can be divided into two main groups: models based on the Black-Scholes Option Pricing Model (BSOPM) (Black 1973) and the ones based on the Cox-Ross-Rubinstein Binomial Option Pricing Model (BOPM) (Cox 1979). However, an application of these methods to the innovation-based investments evaluation reveals their weaknesses:

- BSOPM is based on the continuous time assumption. This implies a possibility to sell or buy a share in the innovation project at any momentlike at the Stock Exchange. Such assumption seems unrealistic in case of R&D investment projects;
- BSOPM is based on the replicated portfolio assumption. It is also unrealistic concerning R&D investment projects;
- BOPM is based strictly on the binomial changes assumption. It is too strong restriction concerning R&D investment projects. However, researchers still have to concede to it (Pennings 2010).

Therefore, the pitfalls of these models promote the objective of the research: developing Real Option Valuation Method for more precise estimations on which investors can rely on. The Summary of the weaknesses in the traditional valuation methods concerning innovation-based investments is in the Appendix 2.

2The Methodology

In this work we propose Weighted Average Polynomial Option Pricing Model (WAPOPM).

BOPM has more realistic assumptions than BSOPM for the case of real investments, such as R&D projects: it does not need to estimate volatility parameter (σ), and it is based on the discrete time assumption. Therefore, Binomial Option Pricing Model is considered as a basic method in our work. Moreover, decision trees enable taking risk into account in the DCF numerator by different scenarios. We are aimed to construct a decision tree with any possible complex structure (any time-intervals between the project's stages, and any amount of the scenarios at each stage), for example as you can see on figure 1.

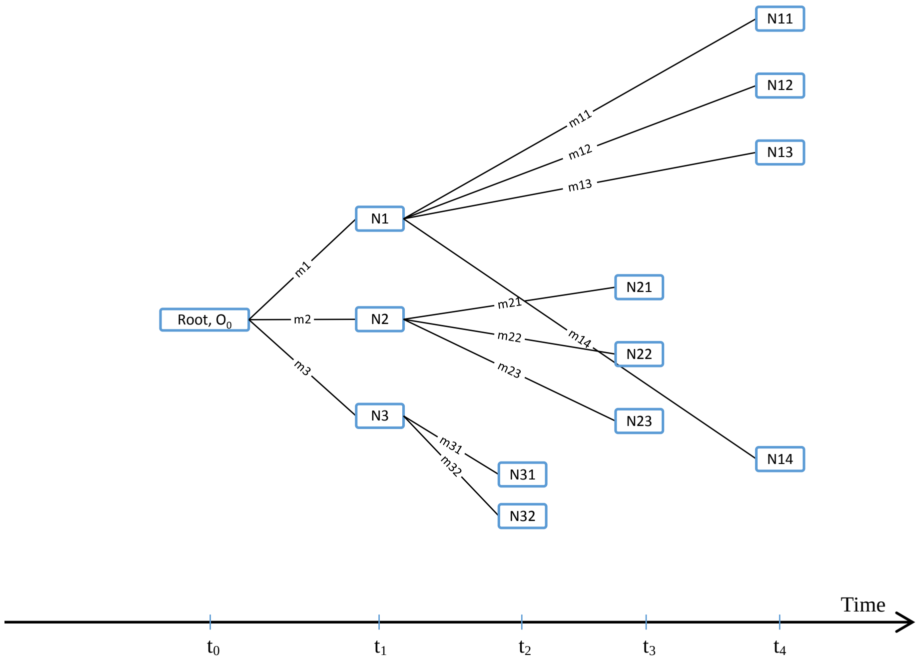

Figure 1 An Example of the R&D Project's Structure.

Introduce denotes as:

- O_0 – Option's Value at the initial moment of time;
- N – shortening from "node";
- i – order of the possible path from the parent node;
- $i \in [1\,;\,y]$;
- y – a number of possible paths from the parent node;
- m_i – a parameter which reflects change in basic asset price;
- mapping with tradition denotes is: $m_1 \equiv u$, $m_y \equiv d$.

Option value tree is fully identical to project tree.

Each specific R&D project leads to corresponding decision tree. This results in an impracticability of deriving a unique analytical formula for real option value at the initial moment of time in all possible cases. Instead of searching this formula, we propose a unique analytical algorithm of calculation in any subtree (part of the tree constructed from parent node and its children nodes). For example, there are 4 subtrees on figure 1 ($Root$ and$N1, N2, N3$; $N1$ and $N11, N12, N13, N14$; $N2$ and $N21, N22, N23$; $N3$ and $N31, N32$).

Real option value in the leafs (terminal nodes) is defined by famous logical limitations using input data:

$$Call\ Option\ value\ \equiv O_{call} = \max\{A_T - Ex\ ; 0\} \tag{1}$$

$$Put\ Option\ value\ \equiv O_{put} = \max\{Ex - A_T\ ; 0\} \tag{2}$$

where:

- A_T – basic asset price at the moment T. A_T depends on A_0 (basic asset price at the initial moment of time) and parameters m_i from the root to the leafs. For example, A_T at the leaf $N14$ (terminal node) equals to $A_0 * m1 * m4$. In case of real investments A_T is an amount of money an investor[1] acquires;
- Ex – option exercise price. It is defined by the contract with an investor.

After real option value calculation at the leafs we calculate ROV at the parent node of these leafs. By iterative process we evaluate ROV at the root which is our goal.

Let us consider an innovation project that has three possible scenarios (Figure 2):

1. Successful;
2. Non-profitable and breakeven;
3. Detrimental.

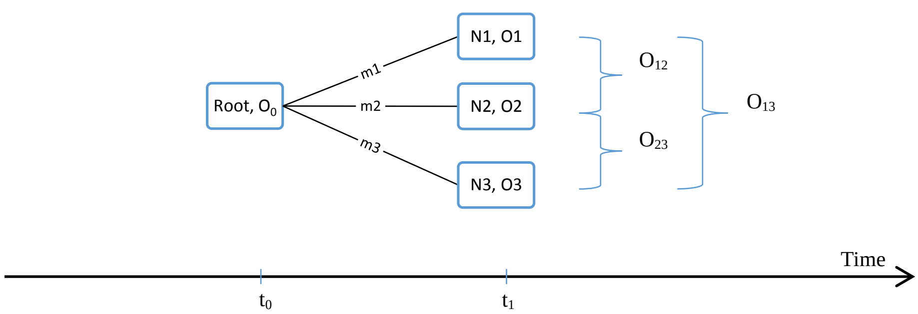

Figure 2 An example with the y = 3.

[1]or, for example, parent company which is financing R&D project

In this case nodes $N1, N2$ and $N3$ are leafs, consequently it is possible to evaluate option value in these nodes $O1, O2$ and $O3$ using equations 1 and 2. After that we can get 3 estimations for the ROV at the parent node O_0(O_{12}, O_{13} and O_{23}):

$$O_{ij} = \frac{pO_i+(1-p)O_j}{\left(1+r_{free}\right)^t} \quad (3)$$

where:

$$p = \max\left\{0\,;\, \frac{\left(1+r_{free}\right)^t - m_j}{m_i - m_j}\right\} \quad (4)$$

where:

- r_{free} – risk free rate;
- i belongs to $[1\,;\, y-1]$;
- j belongs to $[2\,;\, y]$;
- $j > i$.

Total amount of such estimations is a simple combination from y by 2:

$$C_y^2 = \frac{y!}{2!(y-2)!} \quad (5)$$

A key question is how to obtain ROV of the parent node O_0 from the estimations O_{12}, O_{13}, O_{23}. If we have only two possible ways ($y = 2$), then we would use famous and simple BOPM algorithm. The last one is based on the equal portfolio value assumption regardless of the way (basic asset price change). The portfolio consists from basic asset, risk-free obligations, and an option on them. We cannot ignore Cox-Ross-Rubinstein's remark (Cox 1979):

> "… from either the hedging or complete markets approaches, it should be clear that three-state or trinomial stock price movement will not lead to an option pricing formula based solely on arbitrage considerations."

In other words, in the next combined equations (6):

$$\begin{cases} \Delta Su + rB = C_u \\ \Delta Sd + rB = C_d \\ C = \Delta S + B \end{cases} \quad (6)$$

there are 3 equations and there are 3 unknown variables (Δ, B, C). If we introduce a new unknown variable, we should introduce additional equation.

Before we suggest one, the remark concerning denotes is needed. In Cox-Ross-Rubinstein paper a variable$C$means option value. This letter was chosen because a formula was derived for call-option. In this work we propose a valuation as for call-option and for put-option. Accordingly a letter O was chosen for target value.

Weighted Average Polynomial Option Pricing Model (WAPOPM) suggests next equation for discussed purpose:

$$O_0 = \frac{\sum_{i=1}^{y-1}\sum_{j=i+1}^{y}(O_{ij}(w_i+w_j))}{(y-1)(\sum_{i=1}^{y-1} w_i + w_y)} \quad (7)$$

Thereby all estimations O_{ij} are multiplied on the sum of weights w_i and w_j which lead to this estimation.

Weights w_i are defined as:

$$w_i = |1 - m_i| \quad (8)^2$$

The economic sense of equation 7 may be interpreted in the following way: we assume that portfolio values are equal each other regardless of the couple of ways we take (whether 1 and 2 or 1 and 3 or 2 and 3 … or any i and j). This is basic non-arbitrage WAPOPM assumption.

WAPOPM evaluates ROV at the parent node $O_0$from all the estimations O_{12}, O_{13}, O_{23}, … O_{ij} that could be obtained with BOPM in particular subtree. It should be noticed that Binomial Option Pricing Model is the particular case of the WAPOPM where $y$equals 2 (See Appendix 3).

As a result, strategic NPV of the project equals to the sum of (Smit H., Trigeorgis L., 2003):

$$Expanded\ (strategic) NPV = \\ = direct\ (passive\ NPV) + Real\ Options\ Value\ (flexibility\ value) \quad (9)$$

Let us remind important issues that:

- ROV does not depend on probabilities of ascending to any specific leaf;
- Estimations which we can obtain by using risk-neutral method are equal to estimations which we can obtain by using Arbitrage Pricing Theory (APT) and they do not depend on investor’s attitude to risk.

Finally, let us summarize a unique analytical algorithm of calculations in any subtree, which is intended especially for financial managers, for using in the practice:

1. To define technological input data (a decision tree which reflects particularities of the Innovation project, time-intervals between the project’s stages). Engineering and Marketing departments should play a main role at this step.
2. To define financial input data (risk-free rate r_{free}, basic asset price at the initial moment of time A_0, option exercise price Ex).
3. To define parameters m_i (we suggest using fuzzy sets theory in case of poor statistic data).
4. To calculate ROV at the leafs.
5. To evaluate ROV at the root by iteratively using WAPOPM in all subtrees.

3 4G (LTE) TechnologyCase

Consider WAPOPM in the case of 4G (LTE) technology application for the Company “Mobile TeleSystems” OJSC (“MTS”), Russia.

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[2]We suppose that such weights are better than $w_i = (\bar{m} - m_i)^2$ or $w_i = (1 - m_i)^2$

3.1 Long Term Evolution (LTE) Technology concise description

4G (fourth generation) is the standard of mobile phone communication technology. The distinguishing feature of this generation is a high-speed Internet access, both for the download (from the Internet to the user's device) and upload (from user to the Internet), see table 1 (exact speeds can vary – it depends on technology release and radio frequency. The last one depends on concrete country).

Table 1 Mobile generation's data speed.

Generation (technology)	*Year*	*Download*	*Upload*
1G (NMT, AMPS)	1984	1.9 kB/sec.	
2G (GSM)	1991	14.4 kB/sec.	
2.5 (EDGE)	2006	474 kB/sec.	474 kB/sec.
2.5 (E-EDGE)	2009	1.2 MB/sec.	474 kB/sec.
3G (UMTS, WCDMA)	2003	384 kB/sec.	128 kB/sec.
3.5G (HSPA)	2006	14.4 MB/sec.	5.7 MB/sec.
3.75G (HSPA+)	2008	168 MB/sec.	22 MB/sec.
3.9G (LTE)	2010	100 MB/sec.	50 MB/sec.
4G (LTE Advanced)	2013 (exp.)	1 GB/sec.	500 MB/sec.

Source: MTS internal educational database.

It should be mentioned that true technology, that can be named the 4^{th} generation according to international conditions[3], is LTE Advanced, not LTE (see table 1). However for the purpose of marketing telecommunication companies names LTE as 4G.

One may say without oversimplification that the first generation, 1G – means only voice calls. 2G – allows value added services, such as SMS. 3G – first web browsering on low speed.4G allows such services as high-definition mobile TV, rapid web surfing, cloud computing and others. For more detail, see for example (Bhalla 2010).

The Global mobile Suppliers Association (GSA) confirms that LTE technology has the fastest pace of development in all telecommunication history. Table 2 contents the information about biggest LTE networks worldwide.

Table 2 Biggest LTE networks.

Company	*Country*	*Launch Year*
Verizon	USA	12 / 2010
SK Telecom	South Korea	07 / 2011
NTT DoCoMo	Japan	12 / 2010
AT&T	USA	09 / 2011
LG Uplus	South Korea	07 / 2011

[3]International Telecommunication Union, ITU

TeliaSonera	Sweden	12 / 2009
China Mobile	China	04 / 2012
Metro PCS	USA	12 / 2010

Source: MTS internal educational database.

There is no doubt that LTE and LTE-A are the future of the telecommunication. According to Cisco authoritative forecast (Cisco, 2013) mobile traffic data will increase by 12.4 times between 2012 and 2017. Moreover, 67% of all mobile traffic will be video. This means that technology of data packaging that is widespread in the 3G network would not help in more than half mobile traffic.

Nevertheless, LTE technologies also have some substantial disadvantages. It is important to consider them:

- **Expensiveness.** This means that there is no evolution transfer from 3G network to 4G. Almost only revolution transfer (when company has to purchase a lot of new high-cost hard-ware equipment from vendors and has to build new part of network) is possible. Furthermore, telecommunication operators have been building 3G network for the last years actively (especially HSPA+). Investments in the 3G network are not returned fully to the companies.
- **Mobile devices.** This means that there is no big selection of devices that support 4G standard. Now only few flagman smartphones and tablets support 4G. Moreover, they are rather expensive for vast majority of Russian citizens. The situation is complicated by the fact, that in different countries there are different radio frequencies used for LTE. For example, iPhone 5 does not have radio module for partly-Europe, Russia and partly-Asia LTE frequencies. In turn not wide LTE expansion stops devices development. This is a vicious circle and some time is needed to break it.
- **Absence of Voice**. The bottleneck of the LTE technology is that it could not transmit voice data (phone call), only packet data (internet) right now. Correspondingly 3G and 2G networks are necessary as underlying networks. To clearly understand this point, imagine that a subscriber is browsering internet and at this time he receives a phone call. A subscriber will be automatically translated from 4G to 3G or 2G network. This is why LTE network sometimes is compared with “fast horse with three legs”. Telecommunication operator should maintain several networks and it leads to additional costs. VoiceLTE is coming, however right now it is not even fully tested to the best of our knowledge.
- **Radio frequencies limitation.** Accessible width of frequencies that could be used for commercial purposes is restricted. Distinguishing bands for LTE is not banal problem. Conflicts of interest and intersections are usual. Russian specific feature, for example, is the hardness of negotiations with military organizations and security services.

3.2 Russian telecommunication market concise description

MTS is the leading telecommunications group in Russia and the CIS. The Group serviced over 100 million mobile subscribers. MTS has been listed on the New York Stock Exchange since July 2000 and trades under the ticker MBT. The strength of the brand was recognized internationally by a ranking published by the Financial Times and Millward Brown – BRANDZ™ Top 100 Most Powerful Brands (during 2008 – 2012 years).

MTS has 2 main rivals in Russia: MegaFon and VimpelCom (brand "BeeLine"). In aggregate this group is called "Big 3".Simplistically[4] shares of the market can be presented as 31% (MTS), 27% (MegaFon), 24% (BeeLine), 18% (Others, especially Tele2). It is worth to note that for the last 3 years MegaFon took away from MTS 4% of subscribers in Russia (see Figure 3).

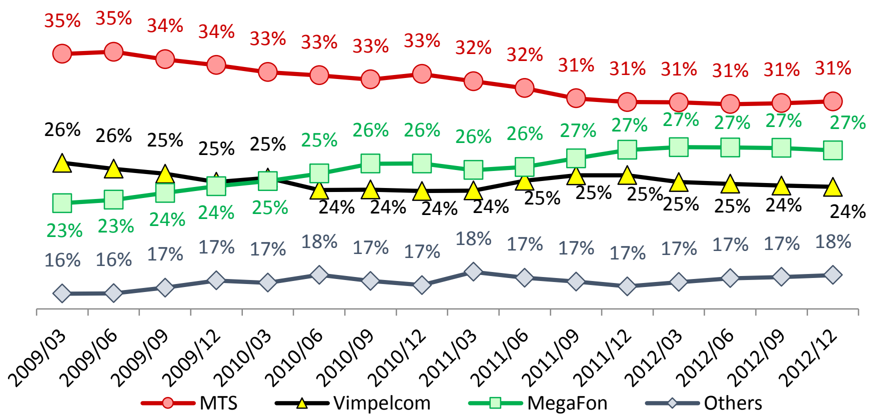

Figure 3 Market Shares on Mobile Subscribers (Source: AC&M Consulting).

Scartel Company (brand "Yota") deserves special mention. This relatively small company plays important role in the Russian LTE market. Previously Yota provided WiMAX services mainly in Moscow and Saint-Petersburg. WiMAX is an alternative standard of 4G which lost "battle between standards" to the younger LTE standard. Yota submitted its losses from investments in WiMAX network and was able to rebuild its business to LTE standard. Big 3 recognized a potential threat in young ambitious company which was able to take a substantial part from market revenues from data transfer. Big 3 almost forced out Yota with some combined efforts. Nevertheless, Russia has its distinguishing feature in business – big role from ties with government. Scartel's top-management had such ties with Government Company "Rostec". As a result, Big 3 had to sign[5] the agreement that Yota would get rights on substantial quantity of bands that match LTE standard. In turn Big 3 could use Yota network to provide services to it's subscribers. This scheme of collaboration was named mobile virtual network operator (MVNO). After the agreement had been reached, Federal Service for Supervision in the Sphere of Telecom, Information Technologies and Mass Communications

[4]Exact figures vary subject to index (revenue, active subscribers, profit and others) and to period.

[5]May 2011. Conference with the presence of Prime Minister Vladimir Putin.

(ROSKOMNADZOR) organized the tender[6] on remain LTE radio frequencies bands. Big 3 and the forth company Rostelecom divided equally all bands between themself.

Further development that is important for our case came rather unexpectedly. Somehow, MegaFon purchased Scartel[7]. Hence, MegaFon got four times more LTE bands than MTS or BeeLine. It is a strong strategic advantage for MegaFone and a serious threat for MTS that could lost its leading position. Moreover, Yota was the first company in the world that tested true 4G Technology – LTE-Advanced[8].

3.3 Real Option application

MTS company clearly understands availability of the LTE technology. Moreover, MTS was the second telecommunication operator in the world (after TeliaSonera) that launched LTE network in commercial purpose – Uzbekistan, Jule 2010. It was a test for more important and responsible launch in Russia – main CIS market.

MTS, together with its strategic partner Vodafone, has analyzed foreign experience of the LTE expansion. It could be:

- **Like Verizon –**to be the firstcomer, to build network almost everywhere, to spend a lot of investments;
- **Like AT&T –** to be the second, to build network only where it is highly demanded, not to waste money.

Current situation is the following:

- MTS launched its own LTE network in Moscow city on the 1st of September 2012;
- MTS uses MVNO scheme with Yota in Kazan city (from the 1st of September 2012);
- MegaFon operates LTE network in more than 27 regions (76 cities).

To minimize risks, Real Option Approach could be used in case of 4G (LTE) implementation. Several financial and technical specialists from the departments of cellular communications, of radio subsystems, and budgeting were interviewed. Internal financial, technical, and strategic forecasting data were examined. Results of the Russian radio frequency auction were analyzed.

For the purpose of flexibility several pivots (real options accordingly) were constructed in the LTE introduction project:

- The collaboration with Yota on the MVNO – taking into account that the main rival MegaFon had acquired Yota, there are serious doubts that joint business could prosper. Real **put** option to abandon the project (to leave MVNO scheme) was constructed;

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[6] Middle of July 2012

[7] End of July 2012.

[8]October of 2012. Moscow, 11 basic stations.

- VoiceLTE technology development – if this technology would be invented 4G network could replace older networks that would lost their underlying status. Real **call** option to accelerate the project was constructed;
- The degree of the growth of the devices quantity - explosive growth of the LTE compatible devices leads to the real **call** option (to accelerate the project) execution. Only MTS subscribers devices are considered;
- The degree of the traffic growth – it assumes that an average subscriber that uses LTE consumes 9 times more traffic than average 3G subscriber. This estimation is based on the first statistic data in Russia. However, such state of affairs could change in the end of 2013 when new 3G technologies - MIMO (multiple-input and multiple-output) and Dual Carrier technologies - are expected to be launched. MIMO and DC could lead to the situation when subscribers would not observe any sufficient differences in the 3,75G and LTE speeds. It does not matter if your smartphone loads the internet page with video in 8 or 6 seconds. In turn, LTE tariff plans are usually notably more expensive. Real **put** option to extend the project was constructed;
- Others (for example, a dispute about the principle of technological neutrality for radio frequency with possible real call option to accelerate the project).

For purpose of this ARDS (Academic Research Development Submissions) paper we would like to consider the example of the WAPOPM application in case of real **put** option to extend the project (depends on the degree of the traffic growth). It should be mentioned that concrete financial data was changed for the purpose of commercial information safety. This change does not influence the innovation management methodology applying.

According to analytical algorithm of calculations for financial managers (see methodology section):

1. The decision tree was defined. There is a simplified subtree on figure 4. The initial moment of time is 01.02.2013. The first pivot is 01.09.2013 when it is expected to measure the degree of the growth of the devices quantity. This degree could belong to one from four possible interval:

   N4 = [1 ; 1.05),

   N3 = [1.05 ; 1.1),

   N2 = [1.1 ; 1.15)

   and N1 = [1.15 ; +∞)

   The second pivot is 01.02.2013 when it is expected to measure the degree of the traffic growth. This degree could belong to one from three possible interval:

   Ni3 = [1 ; 8),

   Ni2 = [8 ; 10),

   Ni1 = [10 ; +∞)

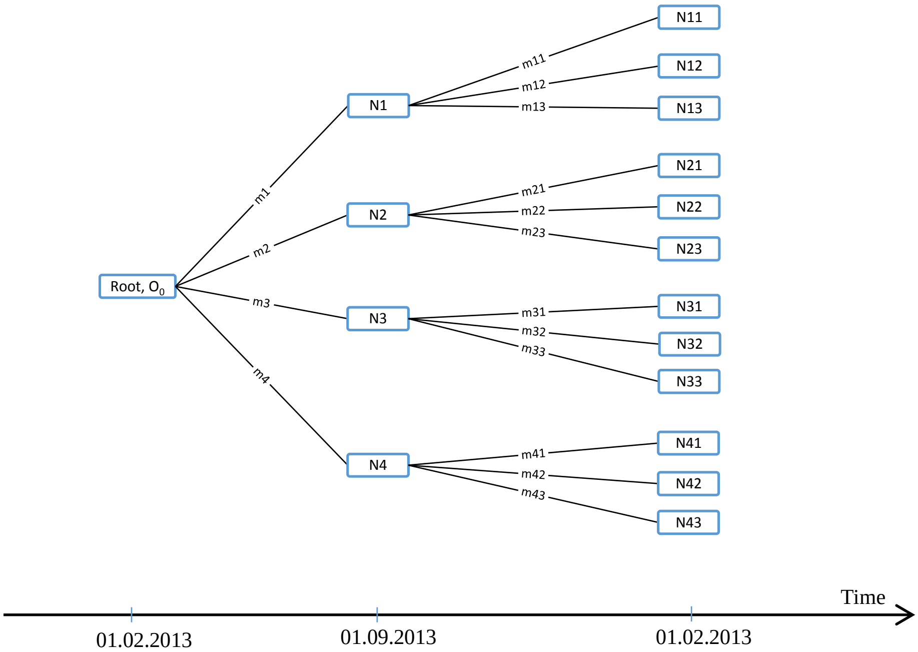

Figure 4 The subtree from the LTE application decision tree – step 1.

2. Financial input data was defined:
   - risk-free rate $r_{free} = 9.5\%$;
   - basic asset price at the initial moment of time $A_0 = 7.45$billion of USD – it is the usual passive NPV of the project (see equation 9);
   - option exercise price $Ex = 3.4$ billion of USD – it is a gain, that MTS will get if LTE implementation project stops (mainly it is the economy on the credit interest).

3. Parameters m_i were defined:

   m1 = 1.87;

   m2 = 1.30;

   m3 = 0.75;

   m4 = 0.45;

   m11 = m21 = m31 = m41 = 1.51;

   m12 = m22 = m32 = m42 = 1.00;

   m13 = m23 = m33 = m43 = 0.59.

4. According equation (2), if the future agree with optimistic part of decision tree then put option to extend the project equals to zero. On the contrary, if the future agrees with pessimistic part of decision tree, then put option would be valued

highly. On the figure 5 a number below means an option value, a number above is basic asset price:

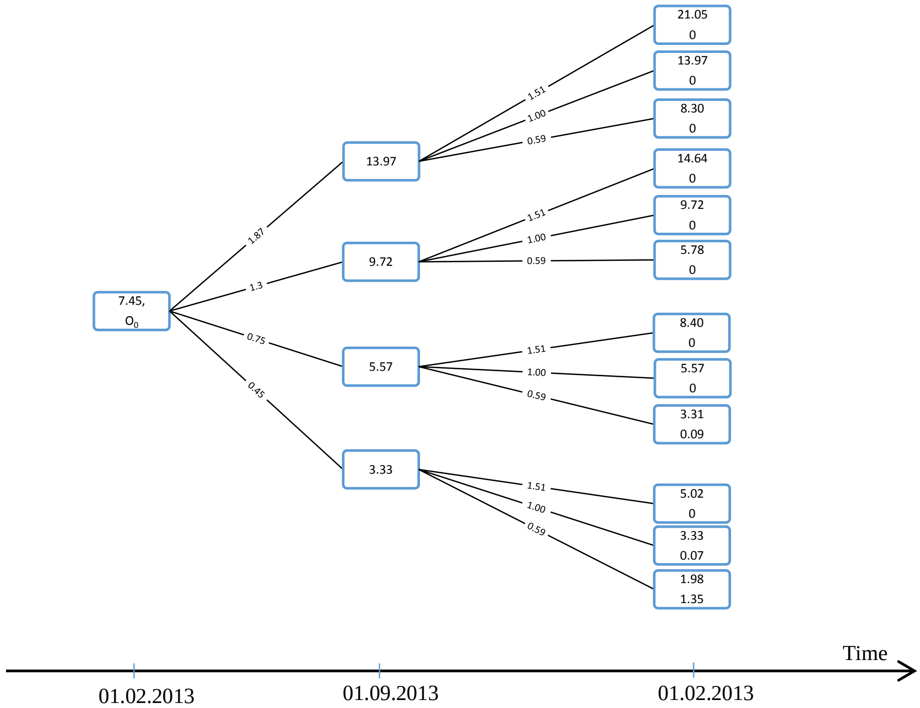

Figure 5 The subtree from the LTE application decision tree – step 4.

5. Using WAPOPM equations (7) and (8) 5 times in all subtrees we can get ROV at the root (see figure 6):

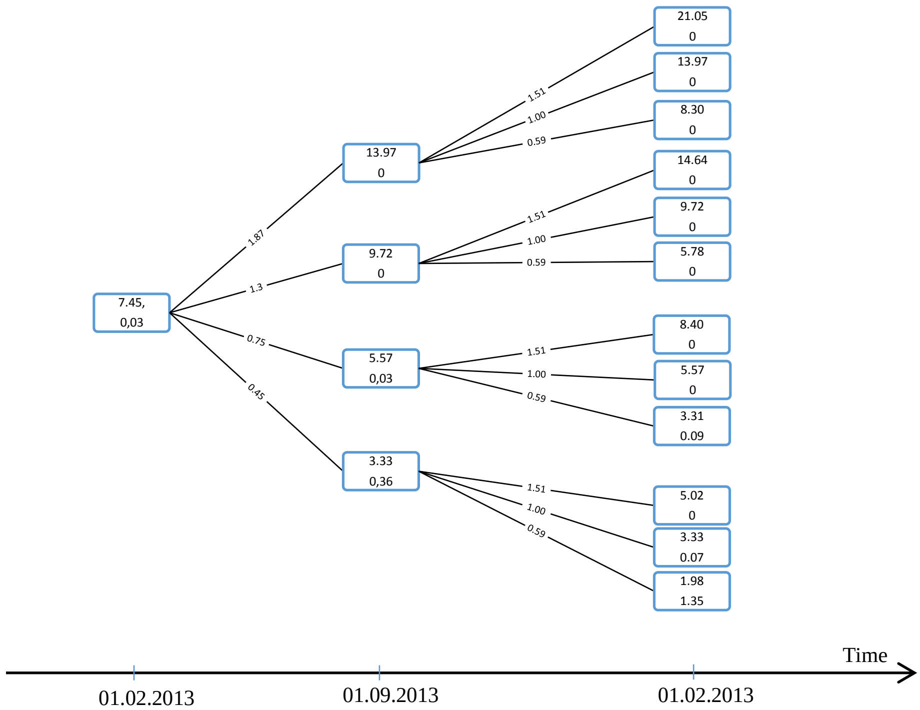

Figure 6 The subtree from the LTE application decision tree – step 5.

We found that real put option to extend the project (depends on the degree of the traffic growth) adds to the passive NPV of the project 0.03 billion of USD in this particular subtree.

We should note that if more real options are constructed than more managerial flexibility, less risks in the innovation-based investments, and more strategic NPV could be achieved.

4 Conclusions and Extensions

The valuation of the real options in the high-cost innovation-based investment projects with extended uncertainty is an important practical problem. In this paper we study traditional methodology for R&D projects valuation, analyse assumptions, mark out weaknesses and develop a novel approach to valuate real options. Weighted Average Polynomial Option Pricing Model (WAPOPM) seemed to be more precise model, because in compassion with:

- DCF method it takes into account investors' flexibility and it calculates investment risk by the scenarios tree (decision tree);
- Black-Scholes Option Pricing Model (BSOPM) it does not need an estimation of the volatility parameter, σ, and it is based upon the discrete time assumption;

- Cox-Ross-Rubinstein Binomial Option Pricing Model (BOPM), it is based on the polynomial changes;
- difficult and strong mathematic models it can be easily used by financial managers in practice.

The case of 4G implementation in MTS Company, Russia was is considered in this paper . Long Term Evolution (LTE) Technology and Russian telecommunication market concise description is given. For purpose of this ARDS (Academic Research Development Submissions) paper the example of the WAPOPM application in case of real **put** option to extend the project (depends on the degree of the traffic growth) is analyzed.

It is very important and interesting to scrutinize in the further research such questions as:

- a comparison of results from BSOPM, BOPM, Monte-Carlo method, Fuzzy ROV, WAPOPM;
- a property of the additiveness of several Real Options in one investment project.

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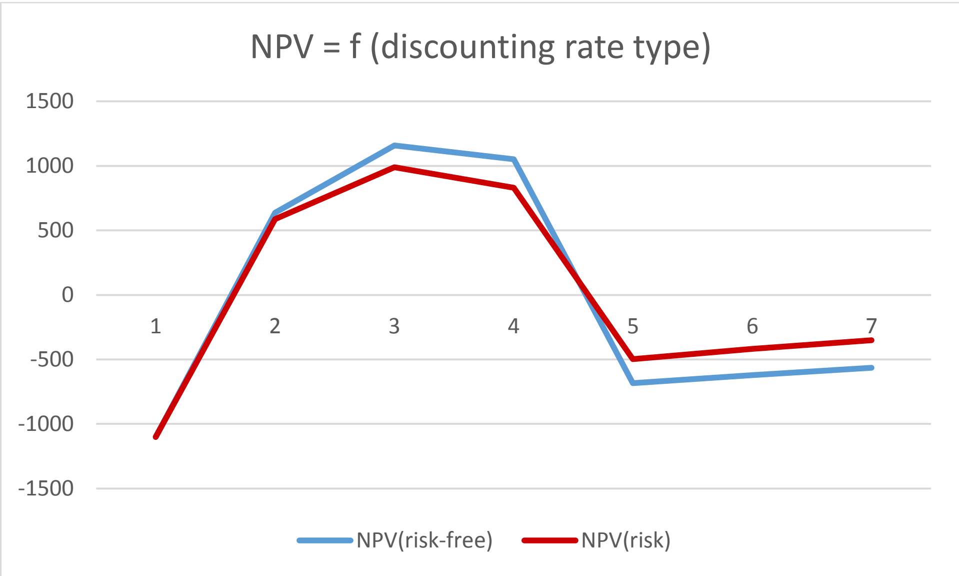
6Appendix

Appendix 1. An Example of the incorrectness of the risk calculation in the denominator.

	Years, t						
	0	**1**	**2**	**3**	**4**	**5**	**6**
Cash In-Flow		2 500	3 200	3 200	3 200	3 200	3 200
Cash Out-Flow	-1 100	-1 800	-1 800	-1 800	-4 200	-4 200	-4 200
NCF	-1 100	700	1 400	1 400	-1 000	-1 000	-1 000
(1+r(risk-free)) ^ t	1	1,10	1,21	1,33	1,46	1,61	1,77
NPV (risk-free)	**-123,18**						
(1+r(risk)) ^ t	1	1,19	1,42	1,69	2,01	2,39	2,84
NPV (risk)	**37,79**						

r(risk-free) = 10%
r(risk) = 19%
NPV (risk) > NPV (risk-free)



Appendix 2. Weaknesses in the traditional valuation methods concerning R&D projects.

Method	**DCF Method**			
DCF Weaknesses	Failure to take Investors' flexibility into account	Incorrectness of the risk calculation in the denominator by the cumulative discounting rate		
	↓	↓		
Method	**BSOPM**			
DCF Weaknesses Solution	Real Option Valuation	Risk calculation by the volatility parameter, σ		
BSOPM Weaknesses		Hard to estimate volatility parameter, σ in the practice	Continuous time assumption	
	↓	↓	↓	
Method	**BOPM**			
DCF Weaknesses Solution	Real Option Valuation	Risk calculation by the scenarios tree (decision tree)		
BSOPM Weaknesses Solution		We don't need to estimate volatility parameter, σ	Discrete time assumption	
BOPM Weaknesses				Based just only on the binomial changes
	↓	↓	↓	↓
	New Method			
New Method Should	Real Option Valuation	Risk calculation by the scenarios tree (decision tree). We don't need to estimate volatility parameter, σ	Discrete time assumption	**Based on the polynomial changes**

Appendix 3. Cox-Ross-Rubinstein Binomial Option Pricing Model (BOPM) is the case of the WAPOPM where "y" equals 2.

$$O_{o|y=2} = \left. \frac{\sum_{i=1}^{y-1} \sum_{j=i+1}^{y} (O_{ij}(w_i + w_j))}{(y-1)\sum_{i=1}^{y} w_i} \right|_{y=2} =$$

$$= \frac{O_{12}(w_1 + w_2)}{(w_1 + w_2)} =$$

$$= O_{12} \equiv O_{ud} =$$

$$= \frac{pO_u + (1\text{-}p)O_d}{(1+r_{free})^t}$$

7 Areas for feedback & development

We would like to discuss any apprehensions concerning methodology (WAPOPM).

We would be grateful for any ideas for future development – maybe new innovation-based project that looks strategically attractive but has poor direct NPV estimation.