Implementing a Game Theory model for 3G Operators

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***Abstract*- This paper presents the techno-economic evaluation of a 3G rollout scenario followed by the identification of the market conditions for two operators in a simple game theory model. The considered scenarios reflect the point of view of both dominant operators and new entrants. Techno-economic results are presented in terms of net present value (NPV), acting like the pay-off function in the proposed theoretical Game Theory model. The business case presented here was studied by using a tool, developed by European Projects IST – 25172 TONIC/ECOSYS and the Game Theory Tool named Gambit.**

***Index Terms*: Techno – economics, Game theory, NPV, investment UMTS, 3G, Market conditions, telecommunications**

I. Introduction

The investigation of a 3G rollout investment case (UMTS), is one of the hot topics in the last decade. This is true in both technical and economical points of view. In fact, these all pertain to global liberalization of Telecommunication and to the competition raise when the operators purchase the licenses. So, one of the main viewpoints here should be necessarily the competition and its impacts on business. In this paper we tried to model a simple UMTS investment case model following a game theory approach, which was based upon near real conditions and figures. This model could be easily expanded and used with modified market conditions and tariffs schemes.

II. Description of the case

This investment analysis was carried using the tool, which was developed by IST TONIC [1], [2] and ECOSYS project [3]. A 10-year time frame, spanning the period 2004 to 2014 has been chosen. In order to calculate discounted cash flows, a discount rate of 10% has been selected. Tariffs, market penetration of both fixed broadband and mobile services in various European countries and existing forecasts for UMTS services were gathered, and an analytical market model was developed [4]. The main assumptions regarding tariff policy as well as market conditions are analytically described in [4]. The area study represents a central or southern European country with higher population density (60 million) and lower mobile penetration (40%). The areas are composed of dense down. The UMTS network is assumed to cover 80% of the total population and total mobile penetration is assumed to saturate at 80% (phone owners, not number of terminals) in 2009. Service classes are described in [4] and [6] as well as analytical techno-economic results for the regular financial analysis

A. Structure of the Tool for Techno-Economic Evaluations.

Fig. 1 analyses the main principles of the methodology used in this paper. The cost figures for the network components have been collected in an integrated cost database, which is the "heart" of the model. This database is frequently updated with data obtained from the major telecommunication operators, suppliers, standardization bodies and other available sources. These data correspond to the initial prices for the future commercial networks components as well as to the projection for the future production volume of them. The cost evolution of the different components derives from the cost at a given reference year and a set of parameters, which characterizes the basic principles of the component. For each component in the database, the cost evolution is estimated according to a cost evolution model [7], [8]. In addition, estimations for the OA&M cost as well as the production volume of the component are incorporated in the database. As a next step in the network evaluation and services, specification is needed, which will be provided to the consumers. The network architectures for the selected set of services will be defined, and a radio model, has been used in order to calculate Base Transceiver Station (BTS) positions as well as the civil works for their installation (database data). The future market penetration of these services and the tariffs associated, according to each operator's policy, will be used for the construction of the market evolution model. The operator tariff policy could be taken into account by modifying the tariff level in conjunction with the expected penetration of the offered services. Results from statistics or surveys can be easily integrated into the tool when formulas measuring the impact of tariff level to the saturation of the services are available.

By entering the data into a financial model we calculate the revenues, investments (and IFC) cash flows and profits (or other financial results) of the studied network architectures for each year throughout a project's study period. In the final evaluation of the techno-economic (TE) model, critical indexes are calculated in order to decide about the profitability of the investment. The methodology is illustrated in Fig. 1. The adoption of alternative financial and strategic methods, e.g. real options approach and game theory, can be included in the tool.

TABLE I: OPERATOR1/PLAYER 1 (INCUMBENT) NPVS IN BEURO

Beuros	0,5	0,6	0,7	0,8	0,9	1	1,1	1,2	1,3	1,4	1,5
5%	1,69	2,39	3,12	3,81	4,51	5,20	5,89	6,58	7,28	7,97	8,66
10%	2,38	3,18	3,99	4,77	5,55	6,33	7,12	7,90	8,68	9,46	10,24
15%	3,08	3,96	4,86	5,73	6,60	7,47	8,34	9,21	10,08	10,95	11,81
20%	3,77	4,74	5,73	6,69	7,65	8,61	9,56	10,52	11,48	12,44	13,39
25%	4,46	5,52	6,60	7,64	8,69	9,74	10,79	11,84	12,89	13,93	14,97
30%	5,16	6,31	7,47	8,60	9,74	10,88	12,01	13,15	14,29	15,42	16,55
35%	5,85	7,11	8,34	9,56	10,79	12,01	13,24	14,47	15,69	16,91	18,13
40%	6,54	7,89	9,21	10,52	11,84	13,15	14,47	15,78	17,10	18,40	19,71
45%	7,24	8,67	10,08	11,48	12,89	14,29	15,70	17,10	18,50	19,90	21,30
50%	7,93	9,45	10,95	12,44	13,94	15,43	16,92	18,42	19,91	21,39	22,88
55%	8,63	10,24	11,82	13,40	14,99	16,57	18,15	19,74	21,31	22,89	24,46
60%	9,32	11,02	12,69	14,36	16,04	17,71	19,38	21,05	22,72	24,38	26,05
65%	10,01	11,80	13,56	15,32	17,08	18,85	20,61	22,37	24,12	25,88	27,63
70%	10,71	12,58	14,43	16,28	18,13	19,98	21,84	23,68	25,53	27,37	29,21
75%	11,42	13,36	15,30	17,24	19,18	21,12	23,06	25,00	26,93	28,86	30,80

The maim body of the calculations is made in MS Excel worksheets. This is also true for market functions, tables as well as for pay-off tables. Pay-off tables stood as input of a simple translator program written on C language. The output of this little program served GAMBIT solver with input. GAMBIT software is quite deeply explained in [5]. The results of GAMBIT were the places of Nash-equilibrium points (in this game). These points were then drawn back to pay-off matrixes in MS Excel.

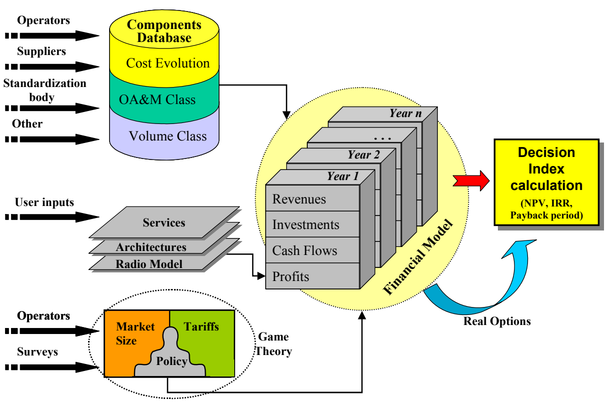

Fig. 1 Techno-economics Methodology [4] and the connection with the Game Theory model

B. *Game Theory Modeling (general assumptions)*

To keep simplicity, the initial techno-economic model described in [4] has been used. The new model has been build, based on the following main assumptions /criteria:

1) Investigating *Oligopoly*, or more precise *Duopoly* case. As it was considered to be realistic (in terms of modelling) the number of players would be only two, and the first of them would be the incumbent operator with high market share, whereas the other would be a new company with relatively small market share and with Greenfield investment needs.

2) We decided to see the market for UMTS services as *homogenous* market with only *one product*. It means we "merged" all of the services and market segments to one, independently of different wavelength and tariffs.

3) During calculation we have not taken into account general price levels feedback to the *total market*, so the total market was *stable or insensible*. We supposed transmigration only between competitors, which means *dynamic market inside*.

4) The game was built as being a *non-cooperative game*, which means both players know everything of importance about the other, but they have to decide approximately at the same time and independently. Players were not allowed to form any kind of coalition.

5) At this stage of the work we "voted" to keep the game *static* with only *one decision point* at the beginning of the estimated time period. (In case of longer time horizon it could fail to be "realistic".) This one decision point might be e.g. just before national auctions for frequency allocation.

6) In UMTS game companies *play price-adjusting* mean and regarding quantities (quantity here refers to the size of and investment in the network and infrastructure) could not bear on results heavily. (This seems to be realistic, as simple investing in the global coverage might be sufficient along the investigated period.)

7) The *pay-off function* of the game was decided to be the

NPV of a ten-years long investment case, and in the first step leaving out option values, so skipping the "adjusted" NPV that could be produced.

III. TECHNO ECONOMIC RESULTS

The calculations were based on two main inputs from the TE model results and the hypothetical market parameters. TE model served as the main root for calculating inputs of our calculations. So we accepted all the supposition built into the TE model, and different models for "incumbent" and "newcomer" were prepared. We obeyed the 10-years time horizon, and naturally all the investments, costs and revenue figures. All the other basic parameters were set to illustrate an "average western European case". To be able to calculate pay-off, two important parameters were picked up, namely:

- The market share and
- The tariff multiplier or in other words the "price"

The tariff multiplier parameter was used in order to increase or decrease the tariff of the offered product by a % percentage.

With immense running of TE model the project changed market share in 5%-75% range, while tariff multiplier changed in 0.5-1.5 ranges in case of both players (incumbent or not). This kind of running meant that operators (players) made a decision at the beginning of the investigated time period. Results of TE model running can be seen on Table I for incumbent (Player 1) and on

Table II for the newcomer (Player 2). In the table, the top heading row contains tariff multiplier, while the left heading column contains market share values (percentage).

one part means that all services merged to one, and on the other part there is no real market segmentation.

In the Price-adjusting model, "price-war" was assumed, and we tried to depict this "war" by an hypothetical transmigration market function. The simple reason behind, is that when one player's cheaper products are related to the other's, and the cheaper reach the higher portion of market (share). i.e when lowering the price compared to the competitors, a gain market share is obtained.

A general "S-like" curve was supposed, with three- (3) sort of market behavior regarding price-reaction of customers. This kind of function stands for both companies, but with different parameters. In our calculation market function is built from the newcomer (player 2) point of view. All the parameters refer to the newcomer. The Market Share of the new comer is given by:

$$MS = MS_{\text{Start}} + \Delta MS_{\text{Min}} + \Delta MS_{Max} \cdot e^{\left(a + b\frac{TM_1 - TM_2}{\sqrt{1 + TM_2 - TM_1}}\right)} \qquad (1)$$

Where,

MS : Market share

MS_{Start} : Market share at the beginning, where decision is made

$\Delta MSD_{Min}, \Delta MSD_{Max}$: Minimum and maximum of market share changes (delta)

TM_1, TM_2 : Tariff multiplier of player 1 and player 2 respectively.

The three sort of market share ranged from insensible to sensible with different parameters of the function.

TABLE II: OPERATOR2/PLAYER 2 (NEWCOMER) NPVS IN BEURO

Beuros	0,5	0,6	0,7	0,8	0,9	1	1,1	1,2	1,3	1,4	1,5
5%	-2,32	-2,07	-2,00	-1,83	-1,18	-0,93	-0,69	-0,45	-0,20	0,04	0,28
10%	-1,58	-1,24	-1,03	-0,75	-0,09	0,25	0,58	0,91	1,25	1,58	1,91
15%	-0,84	-0,41	-0,07	0,33	1,00	1,43	1,85	2,27	2,69	3,12	3,54
20%	-0,10	0,41	0,89	1,42	2,09	2,61	3,12	3,63	4,14	4,66	5,17
25%	0,63	1,24	1,85	2,50	3,19	3,79	4,39	4,99	5,59	6,19	6,80
30%	1,37	2,07	2,81	3,59	4,28	4,97	5,66	6,35	7,04	7,73	8,42
35%	2,11	2,92	3,80	4,59	5,37	6,15	6,93	7,71	8,49	9,27	10,05
40%	2,84	3,82	4,72	5,59	6,46	7,33	8,20	9,07	9,94	10,81	11,67
45%	3,64	4,67	5,63	6,59	7,55	8,51	9,47	10,43	11,39	12,34	13,29
50%	4,43	5,49	6,54	7,59	8,64	9,69	10,74	11,78	12,83	13,87	14,92
55%	5,17	6,31	7,45	8,59	9,73	10,87	12,00	13,14	14,27	15,40	16,54
60%	5,90	7,13	8,36	9,59	10,82	12,04	13,27	14,49	15,71	16,94	18,16
65%	6,63	7,95	9,27	10,59	11,90	13,22	14,53	15,85	17,16	18,47	19,78
70%	7,36	8,77	10,18	11,59	12,99	14,40	15,80	17,20	18,60	20,00	21,40
75%	8,09	9,59	11,09	12,59	14,08	15,57	17,06	18,55	20,04	21,53	23,02

IV. HYPOTHETICAL MARKET PARAMETERS

Only for emphasizing assumptions made regarding the market, we supposed that the total market is stable, and only transmigration between competitors was taken into account. This is combined with having only one "product", which on

Additionally, three different measures of the newcomer (player 2) initial or start market share were assumed, namely 15%, 20% and 25%. Table III shows the different versions of calculation, and Figure 2 illustrates the shape of the used function.

It is important to note, that "hypothetical" corresponds to experts' opinions and feelings. So, in reality, market punishes definitely more heavily high-priced operators. Reader should tailor this kind of functionality to its own market, both in shape and measure. To fit this kind of model into the reality, taking interdependencies of price and total market size into consideration would be necessary. The parameters for the Greenfield operator/newcomer are illustrated below:

TABLE III: DIFFERENT VERSIONS OF MARKET PARAMETERS USED IN THE CALCULATION (GREENFIELD)

Versions: Operator2 (newcommer) parameters			
MS Start	15% (S:Small)	20% (M:Medium)	25% (H:High)
MS Delta	-3%-37% (I)	-5%-45% (A)	-7%-53% (E)
a=	0	0,1	0,3
b=	-3	-4	-5

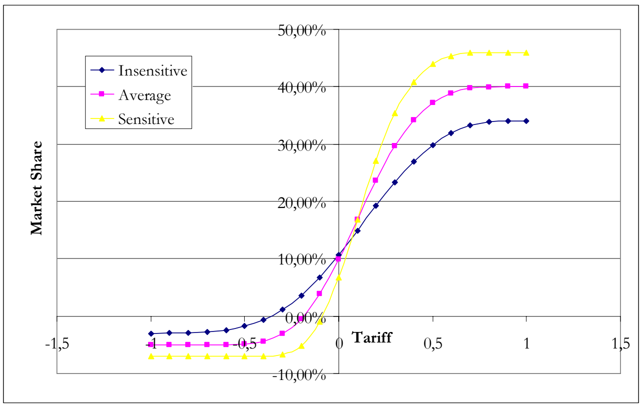

Fig. 2: Illustration of shape of the hypothetical market function

Our hypothetical market function could be termed unfettered. It has been fabricated in order to be realistic following the market condition already proven in GSM market. The way of achieving this kind of function may rely on time series of similar products/services history. In case of services of UMTS we might consider GSM services. If there were analytical GSM prices - Market shares (for at least two providers) time series, we could be able to construct a simplest function for the description of the market conditions. Probably, the derived function would be simpler. In our UMTS example we assumed only one decision point in the beginning and a 10-years long study. Someone could disagree with this approach. If we would like the approach to be closer to reality, the decision point should follow one after the other on a year or month basis. In that case, we might use a simple function, reached from time series year by year. Furthermore, in gaming, the higher the number of decision point, the more complex the model grows are.

The sensitivity analysis that we used and applied in UMTS BC has not been used in constructing the hypothetical market function, but has been greatly used in estimating the pay-offs (i.e. NPVs). Following a different approach, another kind of sensitivity analysis would be (price level)/(market share), which might fruit into a simple linear function and can be used in limited circumstances (time frame, price-cap, Market-size). In our paper we have not investigated sensitivity in that way, but it might have fitted in market issues when assuming e.g. yearly decision points in the TE and GT model, and by using results from market sensitivity functions. The next paragraph explains thoroughly the outputs.

V. RESULTS AND DISCUSSION

The following tables (Table IV-Table XII in B€) show the results reached by calculating pay-off functions and also the found Nash-equilibrium points are illustrated. Each cell contains two numbers. The first number is the NPV of Operator 1 and the second is the NPV of Operator 2 for a specific tariff policy. (i.e. First cell [0.5, 0.5] means 50% reduction in tariff for both players). The Nash-equilibrium points are colored differently and so do strategies of competitors bound to the equilibrium. In case of having solutions with mixed strategies probabilities of specific strategies, these are put at the end of rows or columns (i.e. Table VII 82% and 12% probability). Important to notice is that these strategy combinations and equilibrium points should be seen as being Nash-sense, and even if we might speak about strategy likely to be followed, the general meaning of this, is different from i.e. "dominant strategy".

Having Nash-sense equilibrium practically means both competitors play their best strategy, related to the other strategies selected. This can be done only in such a way, that players know each other's strategy in advance. Within limits, this could be a real situation. Formation of mixed strategies as solutions, means that unambiguous or simple strategies do not exist in order to reach equilibrium. Of course, the reader might define other kind of equilibrium condition than Nash-sense, e.g. managers may be interested in strategy being "the best" independently of other players' strategy-selection, or what happens if all the other players work the ruin of the others. In the first case we can reach "dominant strategy" and in the second we would have in our hands "the safe strategy", both being a kind of equilibrium.

Falling back on our Nash-equilibrium points, and having mixed strategy solutions, the operators should play on a "statistical base", and choose strategies relying on numerical possibilities. As this seems to be rather "unrealistic", operators would likely follow a strategy of higher probability value.

Quite independently of initial market share of the newcomer and type of market, newcomer has to have always smaller prices, as the market analyzer might feel that this is "natural". In most of our results this offers quite small tariffs compared to the incumbent operator's ones.

As initial market share of newcomer increases, both competitors should decrease their prices, but regarding our inelastic total market models, incumbent always has a chance of having "the highest" price, being viable at the same time (quite positive NPV).

It is interesting that with increasing sensibility of the market the solutions exist only with mixed strategies. This means that the mutual impact of competitors on each other, assumes that players have investigated what the other player does, deeply into statistical decision making "process".

These ideas above were only initial ones, and the reader should feel free to draw deeper experiences.

TABLE IV: PAY-OFF MATRIX OF HI VERSION (HIGH MARKET SHARE, INSENSIBLE MARKET) (OP1/OP2)

	0.5		0.6		0.7		0.8		0.9		1		1.1		1.2		1.3		1.4		1.5	
0.5	9.9	2.2	10.5	2.4	10.9	2.5	11.2	2.7	11.5	3.0	11.7	3.4	11.8	3.8	11.8	4.2	11.8	4.8	11.8	5.3	11.8	5.8
0.6	11.0	2.8	11.7	3.0	12.3	3.2	12.8	3.3	13.2	3.4	13.5	3.6	13.6	3.9	13.7	4.3	13.8	4.8	13.8	5.3	13.8	5.8
0.7	12.0	3.5	12.7	3.8	13.5	3.9	14.1	4.0	14.7	4.0	15.1	4.0	15.4	4.2	15.6	4.5	15.7	4.9	15.8	5.3	15.8	5.8
0.8	12.8	4.2	13.6	4.6	14.4	4.8	15.2	4.7	15.9	4.7	16.6	4.6	17.0	4.7	17.4	4.8	17.6	5.1	17.7	5.5	17.8	5.9
0.9	13.5	4.7	14.3	5.2	15.2	5.5	16.1	5.6	17.0	5.5	17.8	5.4	18.4	5.3	19.0	5.3	19.3	5.4	19.6	5.6	19.7	6.0
1	14.3	5.2	15.0	5.8	15.8	6.2	16.8	6.4	17.7	6.4	18.7	6.3	19.6	6.1	20.3	6.0	20.9	5.9	21.3	6.0	21.5	6.2
1.1	15.2	5.5	15.7	6.3	16.5	6.9	17.3	7.2	18.4	7.4	19.4	7.3	20.5	7.1	21.4	6.8	22.2	6.6	22.8	6.5	23.2	6.6
1.2	16.3	5.6	16.6	6.6	17.1	7.4	17.9	8.0	18.9	8.3	19.9	8.3	21.1	8.2	22.2	7.9	23.2	7.6	24.1	7.3	24.7	7.2
1.3	17.4	5.7	17.6	6.8	18.0	7.8	18.6	8.5	19.4	9.1	20.4	9.3	21.5	9.3	22.8	9.0	24.0	8.7	25.0	8.3	25.9	8.0
1.4	18.7	5.8	18.8	6.9	18.9	8.0	19.3	9.0	20.0	9.7	20.8	10.1	21.9	10.3	23.1	10.2	24.4	9.9	25.7	9.5	26.8	9.0
1.5	20.0	5.8	20.0	7.0	20.1	8.1	20.3	9.2	20.7	10.1	21.4	10.8	22.3	11.2	23.4	11.3	24.7	11.2	26.1	10.8	27.4	10.3

TABLE V: PAY-OFF MATRIX OF MI VERSION (MEDIUM M. SHARE, INSENSIBLE MARKET)

	0.5		0.6		0.7		0.8		0.9		1		1.1		1.2		1.3		1.4		1.5	
0.5	10.6	1.5	11.2	1.5	11.6	1.6	12.0	1.7	11.5	2.0	11.7	2.2	11.8	2.5	11.8	2.9	11.8	3.3	11.8	3.7	11.8	4.2
0.6	11.8	2.1	12.5	2.2	13.1	2.2	13.6	2.2	14.0	2.3	13.5	2.5	13.6	2.7	13.7	3.0	13.8	3.3	13.8	3.8	13.8	4.2
0.7	12.8	2.7	13.6	2.9	14.3	2.9	15.0	2.9	15.6	2.9	16.0	2.9	15.4	3.0	15.6	3.2	15.7	3.4	15.8	3.8	15.8	4.2
0.8	13.7	3.3	14.5	3.6	15.4	3.7	16.2	3.7	16.9	3.6	17.5	3.5	18.0	3.4	17.4	3.5	17.6	3.6	17.7	3.9	17.8	4.3
0.9	14.6	3.9	15.3	4.4	16.2	4.6	17.1	4.6	18.0	4.4	18.8	4.2	19.5	4.0	20.0	3.9	19.3	4.0	19.6	4.1	19.7	4.4
1	15.5	4.4	16.1	5.0	17.0	5.3	17.9	5.4	18.9	5.3	19.8	5.1	20.7	4.8	21.4	4.6	22.0	4.5	21.3	4.5	21.5	4.6
1.1	16.5	4.7	17.0	5.5	17.7	6.0	18.6	6.2	19.6	6.3	20.6	6.1	21.7	5.8	22.6	5.5	23.4	5.2	24.0	5.0	23.2	5.0
1.2	17.6	4.9	17.9	5.8	18.5	6.5	19.2	7.0	20.2	7.2	21.3	7.1	22.4	6.9	23.5	6.5	24.5	6.1	25.4	5.8	26.0	5.5
1.3	18.8	5.0	19.0	6.0	19.4	6.9	20.0	7.6	20.8	8.0	21.8	8.1	22.9	8.0	24.2	7.7	25.4	7.2	26.4	6.7	27.3	6.3
1.4	20.2	5.1	20.2	6.1	20.4	7.1	20.8	8.0	21.4	8.6	22.3	9.0	23.4	9.0	24.6	8.8	25.9	8.4	27.2	7.9	28.3	7.4
1.5	21.6	5.1	21.6	6.1	21.7	7.2	21.9	8.2	22.3	9.1	22.9	9.6	23.9	10.0	25.0	10.0	26.3	9.7	27.7	9.2	29.0	8.6

TABLE VI: PAY-OFF MATRIX OF SI VERSION (SMALL MARKET SHARE, INSENSIBLE MARKET)

	0.5		0.6		0.7		0.8		0.9		1		1.1		1.2		1.3		1.4		1.5	
0.5	11.3	0.7	11.9	0.7	11.6	0.6	12.0	0.6	11.5	0.9	11.7	1.0	11.8	1.2	11.8	1.5	11.8	1.9	11.8	2.2	11.8	2.6
0.6	12.6	1.3	13.3	1.3	13.9	1.2	13.6	1.1	14.0	1.2	13.5	1.3	13.6	1.4	13.7	1.6	13.8	1.9	13.8	2.2	13.8	2.6
0.7	13.7	2.0	14.5	2.0	15.2	2.0	15.9	1.8	15.6	1.8	16.0	1.7	15.4	1.7	15.6	1.8	15.7	2.0	15.8	2.3	15.8	2.6
0.8	14.7	2.6	15.5	2.8	16.3	2.8	17.1	2.6	17.9	2.5	17.5	2.3	18.0	2.1	17.4	2.1	17.6	2.2	17.7	2.4	17.8	2.6
0.9	15.6	3.1	16.4	3.5	17.3	3.6	18.2	3.6	19.1	3.3	19.9	3.0	19.5	2.8	20.0	2.6	19.3	2.5	19.6	2.6	19.7	2.8
1	16.6	3.6	17.3	4.2	18.1	4.5	19.0	4.5	20.0	4.2	21.0	3.9	21.9	3.6	21.4	3.2	22.0	3.0	21.3	2.9	21.5	3.0
1.1	17.7	3.9	18.2	4.7	18.9	5.1	19.8	5.2	20.8	5.2	21.9	4.9	22.9	4.5	23.9	4.1	23.4	3.7	24.0	3.5	23.2	3.3
1.2	18.9	4.1	19.2	5.0	19.8	5.6	20.5	6.0	21.5	6.1	22.6	6.0	23.7	5.6	24.8	5.2	25.8	4.7	25.4	4.2	26.0	3.9
1.3	20.2	4.2	20.4	5.2	20.8	6.0	21.4	6.6	22.2	6.9	23.2	6.9	24.4	6.7	25.6	6.3	26.8	5.8	27.8	5.2	27.3	4.7
1.4	21.7	4.3	21.7	5.3	21.9	6.2	22.3	7.0	22.9	7.5	23.8	7.8	24.9	7.8	26.1	7.5	27.4	7.0	28.7	6.4	29.8	5.7
1.5	23.2	4.3	23.2	5.3	23.3	6.3	23.4	7.2	23.9	8.0	24.5	8.5	25.4	8.7	26.6	8.6	27.9	8.3	29.3	7.7	30.6	7.0

TABLE VII: PAY-OFF MATRIX OF HA VERSION (HIGH MARKET SHARE, AVERAGE MARKET)

	0.5		0.6		0.7		0.8		0.9		1		1.1		1.2		1.3		1.4		1.5		
0.5	10.0	2.1	10.9	1.9	11.5	1.8	11.9	1.8	12.0	2.2	12.1	2.6	12.1	3.1	12.1	3.6	12.1	4.1	12.1	4.7	12.1	5.2	
0.6	10.7	3.1	11.8	2.9	12.7	2.6	13.4	2.4	13.8	2.5	14.0	2.8	14.1	3.2	14.1	3.6	14.1	4.1	14.1	4.7	14.1	5.2	
0.7	11.2	4.2	12.4	4.1	13.6	3.8	14.6	3.4	15.4	3.1	15.8	3.1	16.1	3.3	16.1	3.7	16.2	4.2	16.2	4.7	16.2	5.2	
0.8	11.6	5.2	12.7	5.3	14.0	5.0	15.3	4.7	16.5	4.0	17.3	3.7	17.8	3.6	18.1	3.8	18.2	4.2	18.2	4.7	18.2	5.2	
0.9	12.0	5.8	13.0	6.2	14.2	6.3	15.7	5.9	17.1	5.3	18.4	4.7	19.3	4.3	19.8	4.1	20.1	4.3	20.2	4.7	20.2	5.2	
1	12.7	6.2	13.4	7.0	14.4	7.4	15.7	7.3	17.3	6.8	18.9	6.1	20.2	5.4	21.2	4.9	21.8	4.7	22.1	4.8	22.2	5.2	
1.1	13.5	6.5	13.9	7.5	14.7	8.2	15.8	8.5	17.3	8.3	18.9	7.8	20.6	6.9	22.1	6.1	23.2	5.5	23.8	5.2	24.1	5.4	37%
1.2	14.5	6.6	14.8	7.8	15.2	8.7	16.0	9.4	17.2	9.6	18.8	9.4	20.6	8.7	22.4	7.7	24.0	6.7	25.1	6.1	25.8	5.8	
1.3	15.7	6.6	15.8	7.9	16.0	9.1	16.5	10.0	17.3	10.6	18.6	10.8	20.3	10.4	22.2	9.6	24.2	8.5	25.8	7.4	27.1	6.6	
1.4	16.9	6.6	16.9	7.9	17.0	9.2	17.2	10.4	17.8	11.3	18.7	11.8	20.0	11.9	21.8	11.4	23.8	10.5	25.9	9.2	27.7	8.1	
1.5	18.1	6.6	18.1	7.9	18.1	9.3	18.2	10.5	18.5	11.7	19.0	12.6	20.0	13.1	21.4	13.0	23.3	12.4	25.5	11.4	27.7	10.0	63%
											88%		12%										

TABLE VIII: PAY-OFF MATRIX OF MA VERSION (MEDIUM MARKET SHARE, AVERAGE MARKET)

	0.5		0.6		0.7		0.8		0.9		1		1.1		1.2		1.3		1.4		1.5		
0.5	10.7	1.4	11.6	1.1	11.5	0.8	11.9	0.7	12.0	1.1	12.1	1.5	12.1	1.9	12.1	2.3	12.1	2.7	12.1	3.1	12.1	3.5	
0.6	11.5	2.4	12.6	2.1	13.5	1.6	13.4	1.3	13.8	1.4	14.0	1.6	14.1	1.9	14.1	2.3	14.1	2.7	14.1	3.1	14.1	3.5	
0.7	12.1	3.4	13.2	3.2	14.4	2.8	15.5	2.3	15.4	2.0	15.8	1.9	16.1	2.0	16.1	2.3	16.2	2.7	16.2	3.1	16.2	3.5	
0.8	12.5	4.4	13.7	4.5	15.0	4.2	16.3	3.6	17.4	3.0	17.3	2.5	17.8	2.3	18.1	2.4	18.2	2.7	18.2	3.1	18.2	3.5	
0.9	13.1	5.1	14.0	5.4	15.3	5.4	16.7	4.9	18.2	4.3	19.4	3.5	19.3	3.0	19.8	2.8	20.1	2.9	20.2	3.2	20.2	3.5	
1	13.8	5.5	14.5	6.2	15.5	6.5	16.9	6.3	18.4	5.8	20.0	4.9	21.4	4.1	21.2	3.5	21.8	3.2	22.1	3.3	22.2	3.6	
1.1	14.7	5.7	15.2	6.7	15.9	7.3	17.0	7.5	18.5	7.3	20.2	6.6	21.9	5.6	23.3	4.7	23.2	4.0	23.8	3.7	24.1	3.7	30%
1.2	15.9	5.9	16.1	6.9	16.5	7.8	17.3	8.4	18.5	8.5	20.1	8.2	21.9	7.4	23.7	6.3	25.3	5.3	25.1	4.5	25.8	4.2	
1.3	17.1	5.9	17.2	7.1	17.4	8.2	17.9	9.0	18.7	9.5	20.0	9.6	21.7	9.1	23.6	8.2	25.6	7.0	27.2	5.9	27.1	5.0	
1.4	18.4	5.9	18.4	7.1	18.5	8.3	18.7	9.4	19.3	10.2	20.2	10.7	21.5	10.6	23.3	10.1	25.3	9.0	27.4	7.7	29.2	6.4	
1.5	18.1	5.9	19.7	7.1	19.7	8.4	19.8	9.5	20.1	10.6	20.6	11.4	21.6	11.8	23.0	11.7	24.9	11.0	27.1	9.8	29.2	8.4	70%
											39%		61%										

TABLE IX: PAY-OFF MATRIX OF SA VERSION (SMALL MARKET SHARE, AVERAGE MARKET)

	0.5		0.6		0.7		0.8		0.9		1		1.1		1.2		1.3		1.4		1.5		
0.5	11.4	0.6	11.6	0.2	11.5	-0.2	11.9	-0.3	12.0	0.0	12.1	0.3	12.1	0.6	12.1	0.9	12.1	1.2	12.1	1.6	12.1	1.9	
0.6	12.3	1.6	13.4	1.2	13.5	0.7	13.4	0.2	13.8	0.3	14.0	0.4	14.1	0.6	14.1	0.9	14.1	1.2	14.1	1.6	14.1	1.9	
0.7	12.9	2.6	14.1	2.4	15.3	1.8	15.5	1.2	15.4	0.9	15.8	0.7	16.1	0.7	16.1	1.0	16.2	1.3	16.2	1.6	16.2	1.9	
0.8	13.5	3.5	14.6	3.5	15.9	3.2	17.3	2.5	17.4	1.9	17.3	1.3	17.8	1.1	18.1	1.1	18.2	1.3	18.2	1.6	18.2	1.9	
0.9	14.1	4.3	15.1	4.6	16.3	4.5	17.8	4.0	19.2	3.2	19.4	2.4	19.3	1.7	19.8	1.4	20.1	1.4	20.2	1.6	20.2	1.9	
1	14.9	4.8	15.6	5.4	16.7	5.6	18.0	5.3	19.6	4.7	21.1	3.8	21.4	2.8	21.2	2.1	21.8	1.8	22.1	1.8	22.2	2.0	
1.1	16.0	5.0	16.4	5.8	17.1	6.4	18.3	6.5	19.7	6.2	21.4	5.4	23.1	4.4	23.3	3.3	23.2	2.6	23.8	2.2	24.1	2.1	
1.2	17.2	5.2	17.4	6.1	17.8	6.9	18.6	7.4	19.8	7.5	21.4	7.0	23.2	6.1	25.0	5.0	25.3	3.8	25.1	3.0	25.8	2.5	26%
1.3	18.5	5.2	18.6	6.3	18.8	7.2	19.3	8.0	20.2	8.4	21.4	8.4	23.1	7.9	25.0	6.8	27.0	5.6	27.2	4.3	27.1	3.4	
1.4	19.9	5.2	19.9	6.3	20.0	7.4	20.2	8.4	20.7	9.1	21.7	9.5	23.0	9.4	24.8	8.7	26.8	7.6	28.9	6.2	29.2	4.8	
1.5	19.7	5.2	21.3	6.3	21.3	7.4	21.4	8.5	21.6	9.5	22.2	10.2	23.2	10.5	24.6	10.3	26.5	9.5	28.6	8.3	30.8	6.8	74%
											7%		93%										

TABLE X: PAY-OFF MATRIX OF HS VERSION (HIGH MARKET SHARE, SENSIBLE MARKET)

	0.5		0.6		0.7		0.8		0.9		1		1.1		1.2		1.3		1.4		1.5		
0.5	10.5	1.6	11.6	1.1	11.4	0.9	11.6	1.1	11.7	1.7	11.7	2.1	11.7	2.6	11.7	3.1	11.7	3.6	11.7	4.0	11.7	4.5	
0.6	10.7	3.1	12.3	2.4	13.5	1.7	13.4	1.4	13.6	1.7	13.7	2.1	13.7	2.6	13.7	3.1	13.7	3.6	13.7	4.0	13.7	4.5	
0.7	10.6	4.8	12.4	4.2	14.1	3.1	15.5	2.3	15.3	2.1	15.6	2.2	15.6	2.6	15.6	3.1	15.6	3.6	15.6	4.0	15.6	4.5	
0.8	10.5	5.9	12.0	5.8	14.0	5.1	15.9	4.0	17.4	3.0	17.3	2.6	17.6	2.7	17.6	3.1	17.6	3.6	17.6	4.0	17.6	4.5	
0.9	10.6	6.8	11.8	7.2	13.5	6.9	15.6	6.0	17.8	4.7	19.4	3.6	19.2	3.1	19.5	3.2	19.6	3.6	19.6	4.0	19.6	4.5	47%
1	11.1	7.2	11.8	8.1	13.1	8.4	15.0	8.0	17.3	6.9	19.6	5.4	21.3	4.1	21.2	3.6	21.5	3.7	21.6	4.1	21.6	4.5	3%
1.1	11.9	7.4	12.3	8.6	13.0	9.4	14.4	9.7	16.4	9.1	18.9	7.8	21.4	6.1	23.3	4.7	23.1	4.1	23.5	4.1	23.5	4.5	
1.2	12.9	7.5	13.1	8.8	13.4	10.0	14.2	10.8	15.7	10.9	17.9	10.2	20.6	8.7	23.2	6.8	25.3	5.3	25.0	4.4	25.4	4.6	
1.3	14.0	7.5	14.0	8.9	14.2	10.2	14.6	11.4	15.4	12.1	17.0	12.1	19.3	11.3	22.2	9.6	25.0	7.5	27.2	5.9	27.0	5.1	
1.4	15.1	7.5	15.1	8.9	15.2	10.3	15.3	11.7	15.7	12.8	16.7	13.4	18.3	13.4	20.8	12.4	23.8	10.5	26.9	8.3	29.2	6.5	
1.5	16.2	7.5	16.2	8.9	16.2	10.4	16.3	11.8	16.4	13.1	16.9	14.2	17.9	14.8	19.6	14.6	22.2	13.4	25.4	11.4	28.7	9.0	50%
							68%		8%				24%										

TABLE XI: PAY-OFF MATRIX OF MS VERSION (MEDIUM MARKET. SHARE, SENSIBLE MARKET)

	0.5		0.6		0.7		0.8		0.9		1		1.1		1.2		1.3		1.4		1.5		
0.5	11.2	0.9	11.6	0.3	11.4	-0.1	11.6	0.0	11.7	0.6	11.7	1.0	11.7	1.3	11.7	1.7	11.7	2.1	11.7	2.5	11.7	2.9	
0.6	11.5	2.4	13.1	1.5	13.5	0.7	13.4	0.3	13.6	0.6	13.7	1.0	13.7	1.3	13.7	1.7	13.7	2.1	13.7	2.5	13.7	2.9	
0.7	11.5	4.0	13.2	3.2	15.0	2.2	15.5	1.2	15.3	1.0	15.6	1.0	15.6	1.4	15.6	1.7	15.6	2.1	15.6	2.5	15.6	2.9	
0.8	11.4	5.2	13.0	5.0	15.0	4.2	16.9	2.9	17.4	1.9	17.3	1.4	17.6	1.4	17.6	1.7	17.6	2.1	17.6	2.5	17.6	2.9	
0.9	11.9	6.0	12.8	6.4	14.5	6.0	16.7	5.0	18.8	3.6	19.4	2.4	19.2	1.8	19.5	1.8	19.6	2.1	19.6	2.5	19.6	2.9	47%
1	12.3	6.5	13.0	7.3	14.2	7.5	16.1	7.0	18.4	5.8	20.7	4.2	21.3	2.9	21.2	2.2	21.5	2.2	21.6	2.5	21.6	2.9	
1.1	13.1	6.7	13.5	7.8	14.3	8.5	15.6	8.7	17.6	8.0	20.1	6.6	22.6	4.8	23.3	3.4	23.1	2.6	23.5	2.6	23.5	2.9	
1.2	14.2	6.8	14.4	8.0	14.7	9.1	15.6	9.8	17.0	9.8	19.2	9.0	21.9	7.4	24.5	5.5	25.3	3.9	25.0	3.1	25.4	3.0	
1.3	15.4	6.8	15.4	8.1	15.6	9.3	16.0	10.4	16.9	11.0	18.4	10.9	20.7	10.0	23.6	8.2	26.4	6.1	27.2	4.4	27.0	3.5	
1.4	16.6	6.8	16.6	8.1	16.6	9.4	16.8	10.7	17.2	11.7	18.1	12.2	19.8	12.1	22.3	11.0	25.3	9.0	28.3	6.7	29.2	4.8	
1.5	17.8	6.8	17.8	8.1	17.8	9.4	17.8	10.8	18.0	12.0	18.5	13.0	19.4	13.5	21.2	13.2	23.8	12.0	27.0	9.9	30.2	7.4	53%
							41%		59%														

TABLE XII: PAY-OFF MATRIX OF SS VERSION (SMALL MARKET SHARE, SENSIBLE MARKET)

	0.5		0.6		0.7		0.8		0.9		1		1.1		1.2		1.3		1.4		1.5		
0.5	11.9	0.2	11.6	-0.6	11.4	-1.1	11.6	-1.1	11.7	-0.5	11.7	-0.2	11.7	0.1	11.7	0.4	11.7	0.7	11.7	1.0	11.7	1.3	
0.6	12.3	1.6	13.9	0.7	13.5	-0.3	13.4	-0.8	13.6	-0.5	13.7	-0.2	13.7	0.1	13.7	0.4	13.7	0.7	13.7	1.0	13.7	1.3	
0.7	12.3	3.2	14.1	2.4	15.9	1.5	15.5	0.1	15.3	-0.1	15.6	-0.1	15.6	0.1	15.6	0.4	15.6	0.7	15.6	1.0	15.6	1.3	
0.8	12.4	4.5	14.0	4.2	15.9	3.2	17.9	1.8	17.4	0.8	17.3	0.2	17.6	0.2	17.6	0.4	17.6	0.7	17.6	1.0	17.6	1.3	
0.9	12.7	5.3	13.9	5.5	15.6	5.1	17.7	4.0	19.9	2.5	19.4	1.2	19.2	0.5	19.5	0.5	19.6	0.7	19.6	1.0	19.6	1.3	43%
1	13.4	5.8	14.1	6.4	15.4	6.6	17.2	6.0	19.6	4.7	21.9	3.0	21.3	1.6	21.2	0.9	21.5	0.8	21.6	1.0	21.6	1.3	
1.1	14.4	6.0	14.7	7.0	15.5	7.6	16.8	7.7	18.7	6.9	21.4	5.4	23.9	3.6	23.3	2.0	23.1	1.2	23.5	1.1	23.5	1.3	
1.2	15.5	6.0	15.7	7.2	16.1	8.2	16.9	8.8	18.3	8.7	20.5	7.8	23.2	6.1	25.9	4.1	25.3	2.4	25.0	1.5	25.4	1.4	
1.3	16.8	6.0	16.8	7.3	17.0	8.4	17.4	9.4	18.3	9.9	19.8	9.8	22.1	8.7	25.0	6.9	27.8	4.6	27.2	2.8	27.0	1.9	
1.4	18.1	6.0	18.1	7.3	18.1	8.5	18.3	9.7	18.7	10.6	19.6	11.1	21.3	10.8	23.8	9.6	26.8	7.6	29.8	5.2	29.2	3.2	
1.5	19.4	6.0	19.4	7.3	19.4	8.5	19.4	9.8	19.6	10.9	20.0	11.8	21.0	12.2	22.8	11.9	25.4	10.5	28.6	8.3	31.8	5.7	57%
							14%		86%														

VI. CONCLUSION AND DISCUSSION

As far as Game Theory is concerned the investigated model served mainly as a good illustrative example to show a UMTS business situation. It contains quite some limitations, but it succeeded in illustrating how competitors might effect on each other. Incorporation of real options into the calculation would be possible in the TE tool in the latest version [3]. In this case NPV should be changed to the adjusted NPV. The hypothetical market function remains to be proved by the new statistics including data from the western European Countries, or relying on real market movement that any other type of function might be built on. The independence of the total market from price level can be true only in a certain degree. Therefore, building a model with a price feedback to total market would be important. In addition, a case study of another scenario with a third player buying an unused license and competing with two dominant actors or 3G auctions in emerging markets could be an extension to this model.

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