Abstract

This article presents a techno-economic evaluation of 3G rollout scenarios in two "typical" European countries with contrasting profiles, analyzing both the incumbent and newcomer business cases. The analysis is based on a techno-economic methodology developed within the ACTS-TERA project. Market and tariff forecasts as well as the technological evolutionary paths are discussed and financial figures are analyzed. Sensitivity analysis follows these basic results in order to identify the impact of uncertainties and risks. The success of such an investment project mainly depends on the regulatory framework, demand and tariff structure, and the market share.

The Financial Perspective of the Mobile Networks in Europe

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Within the next years, about 70 licenses for 3G mobile or Universal Mobile Telecommunication System (UMTS) spectrum will have been distributed in Europe, either through auctions or comparative hearings. Mobile operators are making critical decisions, which will shape their business over the next ten years. The main challenge is to maximize investment efficiency to provide next-generation, mobile data services, at announced speeds of up to 2 Mb/s. Such systems are expected to emerge in late 2001 in Japan and in 2002-3 in Europe, hence the intense preparations in progress at the manufacturing, regulatory, and operator levels.

The European ACTS project Techno-Economic Results from ACTS AC364 (TERA) [1] is among the first groups in the world to publish figures [2–5] on the economic feasibility of next-generation mobile systems for mobile operators in Europe. This article presents the techno-economic perspective of these technologies, aiming to provide guidelines for strategies in the move toward broadband mobile services. The analysis has been carried out during 2000 and is based on 3G rollout scenarios in two "typical" European countries with contrasting profiles: a large country with moderate mobile penetration and a "fast-track" smaller country with higher mobile penetration around 60 percent today and slated to grow to 80 percent in upcoming years. Comparison of both incumbents' and newcomers' (greenfield) business cases in these two country types is presented.

The techno-economic evaluation is followed by a sensitivity analysis in order to identify the impact of important parameters such as the operator's market share and overall level of demand for next-generation mobile systems.

Following an overview of the different paths that may be taken toward 3G mobile systems, the general approach and main assumptions adopted for the business case are described. Final results are presented and discussed.

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Context and Evolution Paths

Europe's digital cellular Global System for Mobile Communications (GSM) standard is being enhanced with data capabilities based on HSCSD [6] and GPRS [7, 8], which require a hardware upgrade to the GSM core network. Enhanced Data for GSM Evolution (EDGE) [9], which includes advanced (enhanced) versions of High-Speed Circuit-Switched Data (EHSCSD) and Generic Packet Radio System (EGPRS), is another upgrade solution. Since EDGE uses a different coding scheme, extra hardware and software must be added to the HSCSD or GPRS systems. UMTS [10] will provide mobile telephony and high-throughput data services. In all cases, the user will be required to change terminals, a fact that must not be neglected by the operator. Figure 1 illustrates these different evolution paths. While the intermediate steps are overlaid onto a GSM network, UMTS requires full buildout of the radio access subsystem. Incumbent operators may, however, reuse existing GSM sites. This is a major advantage for an incumbent operator in order to provide advanced multimedia mobile services.

The Business Case

This investment analysis was carried using the tool developed by ACTS 364/TERA [1, 4]. Figure 2 analyzes the main principles of the methodology used. The cost figures for the network components are collected in an integrated cost database, which is the heart of the model. This database is frequently updated with data collected from the major telecommunications operators, suppliers, standardization bodies, and other available sources. The model calculates the cost evolution of the different components over time [4]. In the network evaluation, the services to be provided to consumers must be specified. The network architectures for the selected set of services are defined, and a radio-dimensioning model is used to calculate the number of base transceiver stations (BTSs) as well as their installation cost. The future market penetration of these services and the tariffs associated with them are inserted in the

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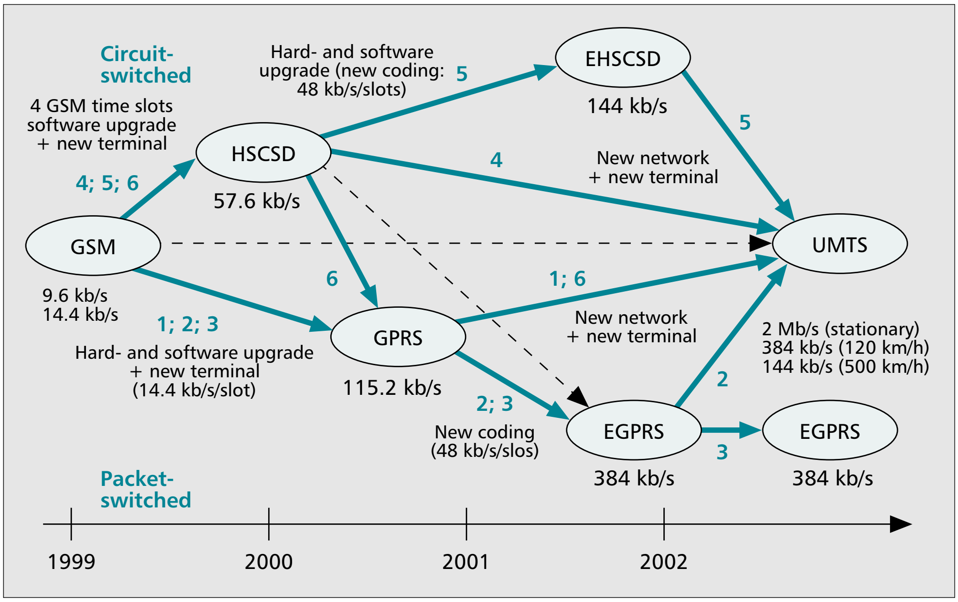

Figure 1. *Mobile evolution steps.*

model through market forecasts and benchmarking. By feeding these predefined data into a financial model, revenues, investments, cash flows, and other financial results are calculated for the network architectures for each year over the study period.

General Assumptions

Since initial estimations [5, 11] ruled out short-term profitability for UMTS, a 10-yeartime frame, spanning the period 2000–2009 was chosen. In order to calculate discounted cash flows a discount rate of 10 percent has been selected. This value is a mean value among the major European telecommunications operators participating in this project. 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 [12]. The GPRS and UMTS radio and core network architectures were derived from public sources like ETSI UTRA end relevant ACTS projects such as FRAMES [13] and RAINBOW [14].

For the UMTS case study, two kinds of operators have been studied. In the first case, it is assumed that an existing GSM operator implements GPRS as an evolutionary path toward UMTS. In 2002, it rolls out UMTS. In the second case, a new operator (possibly a fixed network operator) invests directly in UMTS in a competitive environment.

Area Studied

Two different kinds of European countries have been evaluated. One is a typical Nordic country (later referred to as the small country) with relatively low population density (4 million) and high mobile penetration (60 percent). The other area represents a central or southern European country (later called the large country) with higher population density (60 million) and lower mobile penetration (40 percent). In both cases, the areas are composed of dense downtown zones surrounded by less dense peripheral zones, and larger suburban areas. It is assumed that rural areas will be covered using techniques such as GPRS and EDGE, which can reuse existing GSM radio infrastructure. The UMTS network is assumed to cover 80 percent of the total population, and total mobile penetration is assumed to saturate at 80 percent (phone owners, not number of terminals) in 2009.

The Regulatory Environment

The role of the National Regulatory Authority is of key importance for several cost parameters in UMTS deployment. First, the choice of assignment mechanism impacts heavily on the cost of entry, as observed by two extreme examples, those of Finland and the United Kingdom. In Finland licenses were awarded through a comparative hearing process to four operators for a minimal annual fee covering administrative costs. In the United Kingdom auctions were held in order to assign five licenses, with one license open for bidding by new entrants only. The resulting fees, on the order of €8 billion/operator, are to be paid up front. The license fee of comparative hearings has been chosen as the lower limit; thus, in the large country the fee is €10/inhabitant, and in the small country €2/inhabitant. Fees are payable over a 10-year period in equal installments (independent of the duration of the license). The impact of license costs is also examined through sensitivity analysis.

Service obligations following license assignation have also been taken into account. In particular, the coverage of 60 percent of the population within three years as the most expected

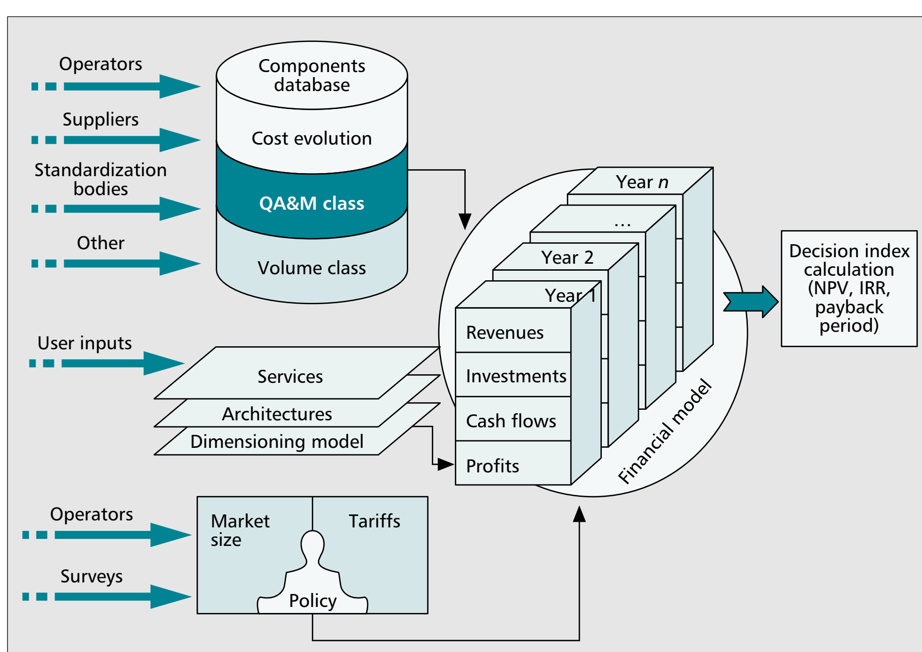

Figure 2. *Techno-economic methodology.*

Type of service	Professional customers	Residential/SOHO customers
Audio and video broadcasting	Specialized programs (medical, sales promotions...)	Digital TV
Asymmetrical exchanges, consultation	Internet, intranet, tele-activities	Games, VOD, NOD, Internet, e-commerce, tele-learning, driving assistance
Voice	Telephone, voice mail	Telephone, voice mail
Data	E-mail, file transfers	E-mail
Symmetric image communications	Video telephony, conferencing	Video telephony

Table 1. *UMTS applications [11].*

	Picocell	Microcell	Macrocell	Satellite
Zone	In-building, downtown	Urban	Semi-urban, rural	Rural
Max. bit rate	1–2 Mb/s	384 kb/s; 1 Mb/s, low mobility	384 kb/s	9.6 kb/s 384 kb/s (S-UMTS)
User speed	Stationary-pedestrian	120 km/h	500 km/h	120 km/h

Table 2. *Available bit rates in different areas [11].*

European practice is ensured by scheduling deployment in suburban areas in 2005. Regarding roaming agreements, it has been assumed that the new entrant is allowed to seek such agreements for calls in areas in which it has no infrastructure and pays an interconnection fee of €2/call to the incumbent.

Telecommunications Mobile Services

The UMTS Forum [11] has listed a broad range of services that should be made available with the advent of UMTS systems (Table 1).

It is also recalled that the data rates available for the different services depend on the zone and speed of the user (Table 2).

According to their requirements in terms of delay, bit error rate, or other criteria, these services will utilize bearer services for UMTS. For the model, we deal with a limited number of bearer services (Table 4). Although UMTS bearer services have been defined as real-time (low constrained delay, LCD) or non-real-time (unconstrained delay, UDD), only the more restrictive LCD bearer service has been considered. Finally, for GPRS a best effort average bit rate of 40 kb/s is assumed.

Market Forecast

We first considered uptake of GPRS services starting in 2000 and then uptake of UMTS services starting in 2002 in dense urban and urban areas. Regarding market share evolution, the incumbent starts with 31 percent market share in 2000, while the new entrant starts with 5 percent market share in 2002. Both saturate at 25 percent in 2009, which is a relatively optimistic scenario. To evaluate the data rates to be handled by 3G mobile systems, it is necessary to identify the different types of customers [12], since their calling patterns and usage differ. The following segmentation was used:

- **Corporate users**, with intensive and almost entirely professional use, primarily during office hours
- **Small office/home office (SOHO)/telecommuters and high-end residential customers**, with both professional and private use, during the day and in the evening
- **Mass market**, with low use (i.e., stay within flat rate limits or use prepaid options)

Demand curves for GPRS [12] reflect a synthesis of European market forecasts and are applied to the defined areas, yielding year-end customer numbers (Fig. 3).

The UMTS central scenario's uptake is mainly related to the corporate/professional market segment during 2000–2005 [15]. UMTS services become attractive to the residential/SOHO market with a slight delay, and then to the mass market. Demand for GPRS flattens as customers migrate from GPRS to UMTS (Fig. 3).

Tariffs — Tariff schemes and usage volume were based on benchmarking from Europe for fixed telephony, broadband access, and mobile telephony and data [12], taking into account competition and rapidly falling prices for wireline broadband services (Table 3).

For GPRS, IP service is comparable to Internet access via cable or asynchronous digital subscriber line (ADSL), in the sense that the attached mode means the terminal is always on. However, the data rates offered are similar to or lower than modem rates using the public switched telephone network (PSTN). Considering added value for mobility, an initial monthly flat fee of €20 was selected.

Table 4 lists the services considered and pricing proposals, based on the tariffs of existing services [15] plus a 50 percent premium for mobility.

For both GPRS and UMTS tariffs a 10 percent reduction per year is implemented for the first two years, then 5 percent for two years, and then tariffs remain stable. The connection fee reduction is 5 percent/year.

Because subscribers must change terminals when adopting GPRS and then UMTS services, the operator may find it necessary to subsidize the purchase of terminals. Marketing and advertising budget (€1/inhabitant for both GPRS and UMTS), as well as a subsidy for the purchase of GPRS and UMTS terminals have been included. A 15 percent churn figure was taken into account to compute the additional number of terminals to be subsidized.

Network Architectures and Upgrades

Upgrade for GPRS — The basis for GPRS is the current GSM network [7, 8]. GPRS requires the addition of transmitter-receivers (TRXs) to handle the increased traffic load. The TRXs also require a software upgrade, which is actually performed at the base station controller (BSC) level. The cost of a GSM TRX (including installation) is €10,000. The number of additional TRXs is computed according to the existing capacity and additional packet data user load.

Upgrade for UMTS — Since UMTS can utilize many of the GSM network's elements, an incumbent operator's UMTS network includes both kinds of elements. Radio equipment will initially accommodate UMTS, EDGE, GPRS, and GSM, to ease the migration from GSM to UMTS. Such an upgraded network is illustrated in Fig. 4. A pure UMTS network would not have GSM BTSs and BSCs.

The following elements are necessary to offer UMTS services: The base station subsystem (BSS) comprises specific BSs and radio network controllers (RNCs) (1/256 BSs). The RNCs are connected to the UMTS serving GPRS support node (SGSN), which may be common to GPRS and UMTS. The network subsystem (NSS) requires one UMTS SGSN/100,000 customers. For operations and maintenance one operations and maintenance center (OMC)/1 million subscribers is required. In the case of an incumbent operator, other components, such as the Domain Name Service (DNS), gateway GPRS support node (GGSN), mobile switching center (MSC), home location register (HLR), and billing system can be shared with GPRS. The greenfield operator has to acquire all these network elements.

Radio Dimensioning for UMTS

The radio dimensioning procedure takes into account first *coverage*, then *capacity*. This process is entirely independent of the existing GSM infrastructure. To ensure physical coverage, we start with the cell radius determined from representative link budgets calculated on the uplink, which is more restrictive since the transmitter power from the mobile is lower than that of the base station. The cell radius in different area types are listed in Table 5.

Dimensioning is based on the most constraining service offered in this case 1 Mb/s. According to the data rate required, the existing number of BTS sites and sectors and the maximum number of users, we compute the available capacity per square kilometer. This capacity is matched against that computed from the demand curves and the usage patterns, and when the user load exceeds the offered capacity, it is necessary to add UMTS base stations.

	Usage Mbyte/day	Connection fee	Monthly flat rate
Business	0.5	10	20
Residential	0.25	10	20
Mass market	0.1	10	20

Table 3. *GPRS volumes and tariffs (in €).*

	Usage MB/ day	Connection fee	Price per month	Reference
64 kb/s symmetric	1	25	30	GPRS + symmetry
128/144 kb/s symmetric	2	45	45	ISDN + mobility
384 kb/s asymmetric	4	50	35	GPRS + data speed
1 Mb/s asymmetric	5	70	75	ADSL+ mobility

Table 4. *UMTS volumes and tariffs (in €).*

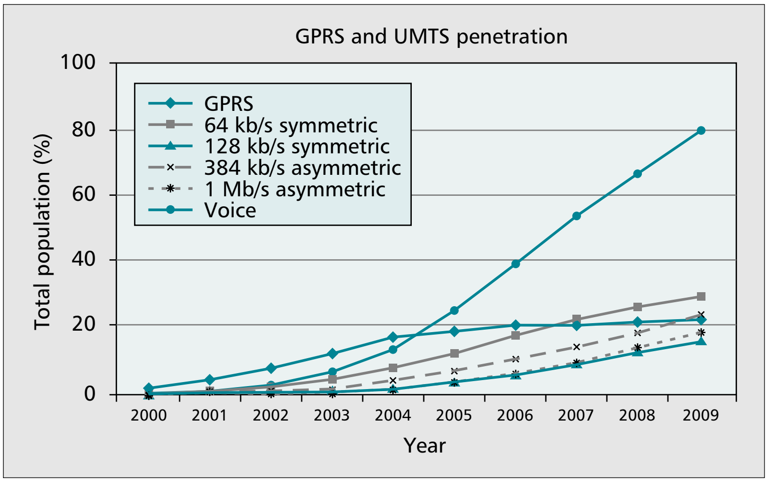

Figure 3. *Demand for UMTS and GPRS services as percentages of total population.*

Main Economics Results

The main techno-economic criteria are net present value (NPV), internal rate of return (IRR), and payback period. We also studied the sensitivity of the NPV to market share, and overall service penetration. Since IRR isn't comparable for projects of different scale, it is presented only for additional information. With four operators sharing the market, the customer base appears sufficient to achieve a positive NPV over the study period in all four cases as summarized in Table 6.

Figures 5 and 6 illustrate the revenues, investments, and cash balance of all scenarios. Significant investments are required during the second year of the project in order to install the UMTS BTSs in urban and suburban areas. The lowest point of the cash balance indicates the amount of investment funding required from the operator. The maximum need for funding is quite significant, especially for a large country: €4.6 billion for an incumbent, and €5.4 billion for a new operator. For a small country, the maximum finance needed is €0.44 and €0.55 billion, respectively. The average revenue per user (ARPU) during the study period is higher in the case of the greenfield operator because the income from voice traffic is not shared with the GSM network as it is in the case of the incumbent. The incumbent also has GPRS subscribers with lower monthly spending.

In all cases, the slopes of the cash balance curves at the end of the period indicate good future earning potential. The large country has much larger potential revenues than the same investment in a small country due to the greater potential market size. Of most significant importance is to compare the investment project in the same area for an incumbent and a greenfield operator. The percentage difference in cash balance between the operators in a small country in 2009 exceeds 80 percent. For a large country the difference is around 70 percent.

Figure 7 illustrates NPV and IRR for all cases. With the same tariffs, the incumbent's payback period is almost seven years and for the greenfield more than eight years regardless the country size. However, this seven- or eight-year payback period may appear long to decision-makers, since it could be the turning point for the failure of a greenfield project. Hence, the investing operator should be solid enough to survive for several years without

Cell radius (km) for 80% indoor coverage probability				
Data rate	64 kb/s	128 /144 kb/s	384 kb/s	1 Mb/s
Dense urban	0.39	0.38	0.30	0.28
Urban	0.97	0.97	0.73	0.70
Suburban	1.56	1.55	1.17	0.94

Table 5. *Cell radius for services and areas.*

any real profits. Under these conditions, the operator must either accept a delayed return on investment while maintaining attractive tariffs, or raise tariffs at the risk of losing customers.

Figure 7 and Table 6 show the overall difference between the two different operators. The NPV for an incumbent operator is almost 300 percent (small country) and 150 percent (large country) greater than the NPV for the greenfield operator. The IRR in the two cases for the incumbent is 26 percent and 29 percent, and for the greenfield 14 percent and 17 percent, respectively. This is crucial for strategic decisions. The lowest accepted IRR value for a telecommunication operator varies according to its investment strategy and potential economic situation. Concerning the IRR, we conclude that the investment of an incumbent operator is not as risky as that of the greenfield operator in absolute values. In the small country the discounted investment per connected customer for the incumbent is €344 and €498 for the greenfield, and in the large country it is €259 for the incumbent and €364 for the greenfield (Table 6).

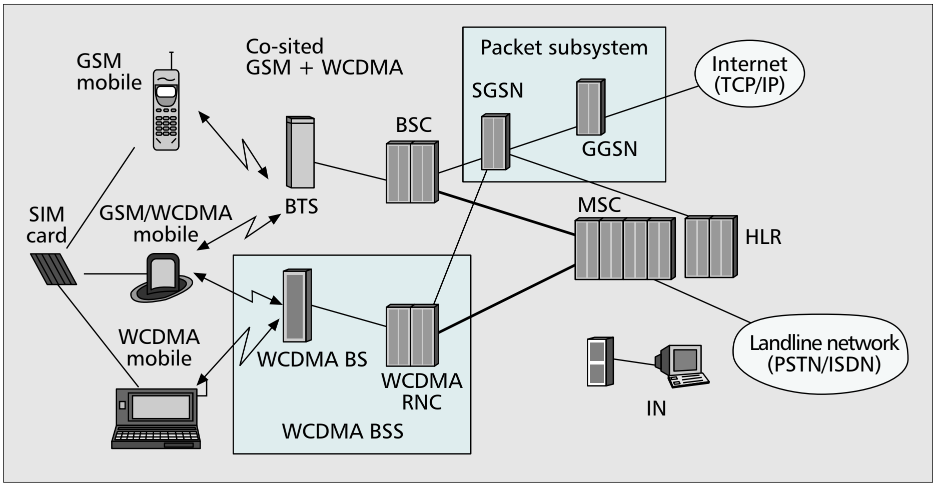

Figure 4. *UMTS architecture.*

Sensitivity Analysis

Telecommunications network operators very often resort to plain discounted cash flow when assessing their business cases [16]. These traditional approaches are often unable to capture the flexibility of the decision makers to adapt and revise later decisions in response to unexpected market developments.

Sensitivity analysis consists of studying the impact of a single parameter with no correlation to other parameters. NPV, as a financial criterion, has been used for the sensitivity analysis. The sensitivity results are presented after the identification and ranking of the four parameters with greatest impact (with 95 percent confidence): *tariffs*, *market share*, *license fee*, and *BTS cost* (Table 7).

Figure 8 illustrates indicatively two of the four combinations. For instance, in Fig. 8 the NPV base value is €4961 million (with 25 percent market share in 2009). For 2009 market share equal to 30 percent (high value) the NPV attains 4916 + 4121= €9082 million. For the variation of values of UMTS tariff and BTS cost, multipliers are used (i.e., 0.4 means 40 percent of the base value).

Conclusions and Discussion

The techno-economic prospects for a new entrant and especially for an incumbent operator planning to deploy the UMTS technology are found to be positive according to the base scenarios of this study. However, after investigating the sensitivity of NPV to factors such as market share, tariffs, license costs, and base station costs, we draw the reader's attention to potential pitfalls. Specifically, the following elements were identified to have major consequences on the profitability of this new business:

- **Regulatory decision to promote competition**: By deciding to open the UMTS market to at least four competing operators, regulators are hoping that the competitive dynamics will work to offer the widest range of services to the most customers possible at the least cost. However, overcrowding leading to an end market share of 10 percent results in negative NPV for both the incumbent and greenfield operators.

	Incumbent small	Incumbent large	Greenfield small	Greenfield large
NPV (M€)	357	4961	90	1992
IRR	26%	29%	14%	17%
Payback period	6.8	6.7	8.3	8.0
Number of customers 2009	1,100,000	14,600,000	800,000	11,500,000
Investments (M€)	364	3773	417	4194
Running costs (M€)	564	10,127	421	7113
Investment per connected customer (€)	340	260	500	360
Monthly ARPU (€)	42	42	60	60

Table 6. *Summary of economic results for operators with 25 percent end market share.*

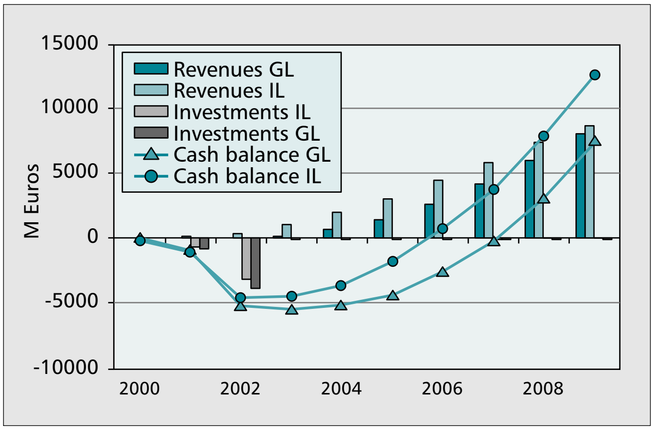

Figure 5. *Economics of the large country case (I: incumbent, G: greenfield, L: large).*

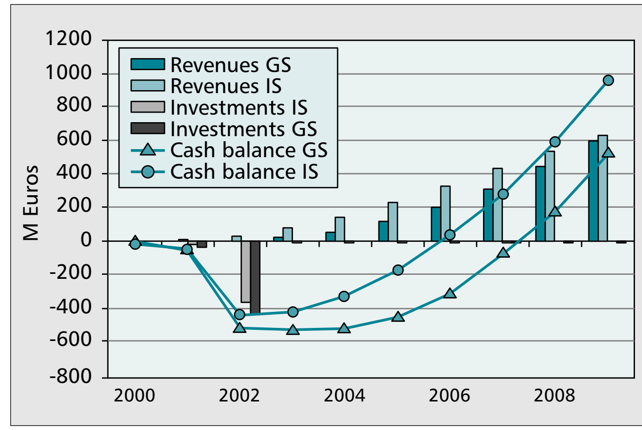

Figure 6. *Economics of the small country case (I: incumbent, G: greenfield, S: small).*

Conversely, NPV is improved by €1200 million for a 5 percent increase in market share in 2009.

- **Cost of licenses**: License fees and therefore the license assignation mechanism (auction or comparative hearings) can seriously deteriorate the business case since the payback period can be delayed by more than a year, together with significantly decreasing NPV. License fees increasing from €10 to 150/inhabitant decreases the NPV by 66 percent for the incumbent.
- **Tariffing of voice and data services**: The tariff level ranks first over service penetration and market share as the most significant factor in UMTS profitability. This result seems logical since, in NPV calculation, the tariff level directly impacts total revenues, whereas the other parameters affect the number of customers, and hence the costs. Nonetheless, it must not be construed that operators are free to hike tariffs as they wish to achieve a positive result. Indeed, the competitive context and dropping prices for fixed network services will severely limit their room to maneuver in this area.
- **Investment schedule**: Since operators deploy the radio network, using a coverage rather than capacity approach (mainly due to license obligation), the cost of BTS equipment incurs a heavy financial burden. Although increased BTS cost has limited impact, it leads to larger investments in the pre-service year.

In conclusion, UMTS operators will have not very much latitude to roll out their networks. Heavy investments are required early on in order to cover the most dense areas, and then once again for the suburban areas. Competitive pressure will keep tariff levels low, and operators will need to consolidate their market assumptions with extreme care in order to evaluate the payback period. Lastly, they must have enough financial resources to stay in debt for a long period of time.

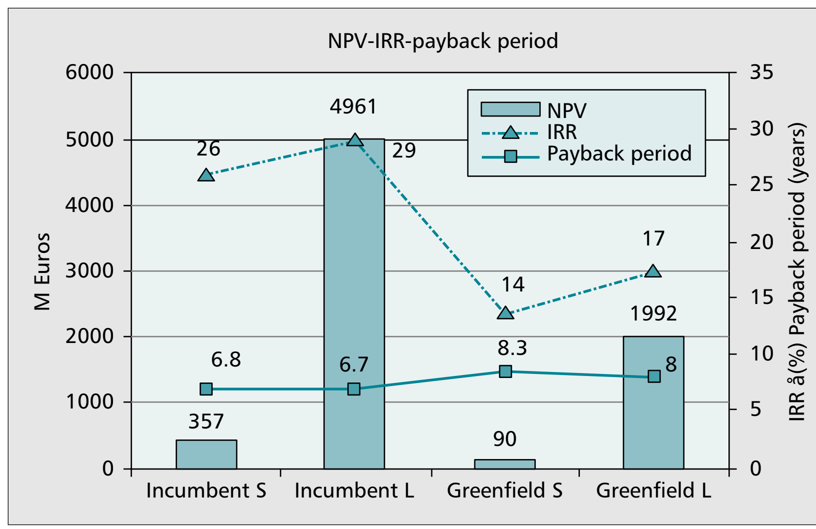

Figure 7. *NPV–IRR–payback period (all cases).*

Uncertain parameter	Low	Base	High
Market share in 2009	10%	25%	30%
UMTS tariff multiplier	0.4	1	1.6
UMTS license fee [€] (large)	0	10	150
UMTS license fee [€] (small)	0	2	150
UMTS BTS cost multiplier (84–156 k€)	0.7	1	1.3

Table 7. *Sensitivity ranges.*

Acknowledgments

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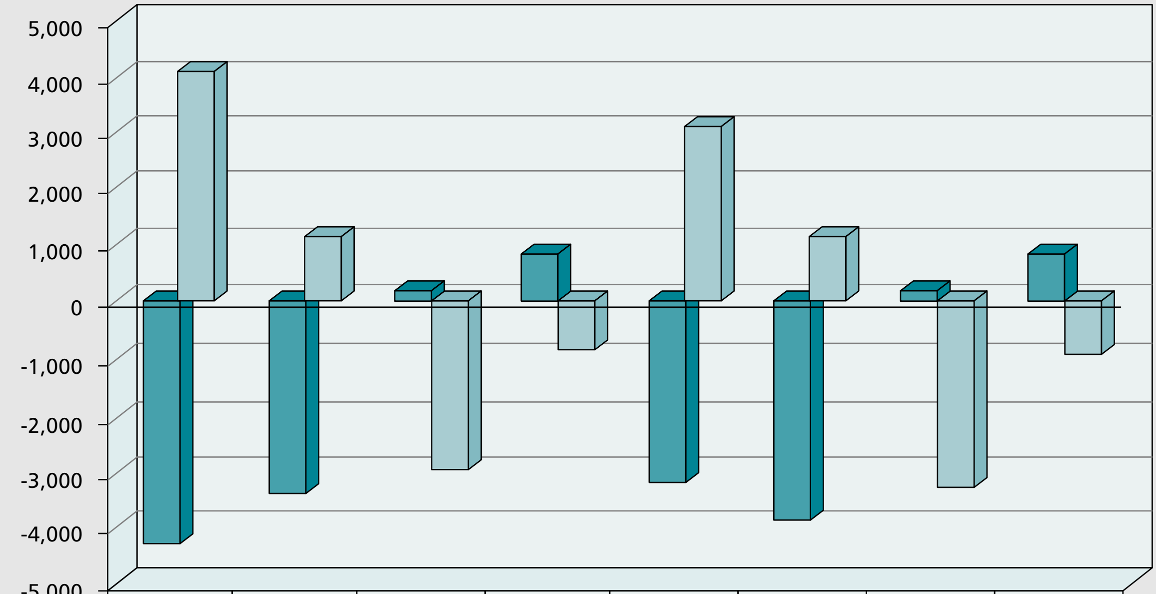

	UMTS tariff multiplier I	Market share in 2009 I	UMTS licence fee I	UMTS BTS cost multiplier I	UMTS tariff multiplier G	Market share in 2009 G	UMTS licence fee G	UMTS BTS cost multiplier G
Low value	-4,277	-3,425	200	857	-3,188	-3,866	204	911
High value	4,121	1,142	-2,961	-857	3,035	1,188	-3,301	-911

Figure 8. *Sensitivity analysis results. Change in NPV compared to base value (€4961 M) in a large country for both incumbant (I) and greenfield (G) cases.*

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