A business case for the deployment of a 4G wireless heterogeneous network in Spain

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Abstract
The emergence of wireless packet-switched networks such as UMTS, WLAN and WiMAX allows the introduction of innovative services and opens up a new range of revenues. It is considered that 4G wireless networks could be heterogeneous networks with different access technologies. Moreover, the introduction of the IMS (IP Multimedia Subsystem) in the core network of packet-switched networks permits a rapid provisioning of new services. The main objective of this paper is to determine the feasibility of a 4G wireless heterogeneous network in Spain. An urban zone and a rural zone were considered in the study.

Keywords: business case, 4G, heterogeneous network, Spain

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1 Introduction

The success of the wireless communications, the creation of more complete and smaller devices, and the emergence of the Internet have transformed the way of communicating in the residential and business environments. The emergence of wireless packet-switched networks such as UMTS, WLAN and WiMAX allows the introduction of innovative services and opens up a new range of revenues. It is considered that 4G wireless networks could be heterogeneous with different access technologies. The convergence of different services such as voice, video and data has important consequences. The provisioning of voice, data and video services over one network or the integration of different networks into only one network is becoming a reality. Moreover, the introduction of the IMS (IP Multimedia Subsystem) in the core network of packet-switched networks permits a rapid deployment of new services.

Building a business case for the introduction of a new technology implies a great number of hypothesis and assumptions, such as the penetration rate, capital expenditures (CAPEX) and operational expenditures (OPEX), and the market share rate. It is impossible to get an exact forecast of its performance. Nevertheless, the utility of a business case is to offer a reasonable estimation that allows the construction of scenarios for the future. On the other hand, a business case should be as realistic as possible in order to be useful and reflect all the variables of interest of the market as well as their evolution and expected behavior.

One of the milestones in this area is the work done by Forge, Blackman and Bohlin in which they make a business model and a business case for a 4G “linear network”: a fictitious country named “Eurolandia”, which represents an average country in Western Europe, is created according to density population and demand of services [1]. Another report describes the requirements and new technical and economical challenges that a 4G network will face in its deployment, such as bandwidth capacity, interoperability, seamless connectivity between wireless and wired technologies, quality of service (QoS), security and network management, etc. [2]. There is another business case for a citywide WiFi/WiMAX deployment that offers the same broadband services as DSL. The architecture that this model proposes is a WiFi network built around a complete city with a WiMAX network as backhaul. With this solution a profitable business case and at the same time a cost-effective service model affordable to all types of users was determined [3]. A recent work done by the European ITS ECOSYS project proposes few business models for telecom operators in different situations. All inputs to the model are based on real issues from Nordic countries such as Sweden and Norway and large countries like France and Germany. These inputs are coverage area, type of users, expected traffic, population density, etc. The results delivered are different CAPEX, OPEX and revenues for each operator in each scenario [4].

In this paper, a business case for a 4G “concurrent network”, similar to a heterogeneous network, is presented. To the authors’ knowledge, in the literature there are no business cases done for this kind of networks in Spain. The architecture consists of a combination of different air interfaces (GPRS/UMTS, WLAN and WiMAX) and an IMS as core network. The main reason for this architecture is the reusability of components that the IMS architecture provides in the core network and the velocity at which new services can be offered. The inputs to the simulation are based on statistics from Spain. The insight acquired from this model could be extrapolated to other countries with similar characteristics within Western Europe.

The paper is organized as follows: section 2 describes the general assumptions used at the moment of building the business case, whereas section 3 presents the business case. In section 4 the results are described. Finally, the conclusions are addressed in section 5.

2 General Assumptions

In order to obtain the results we considered a number of assumptions that are described below. It has to be mentioned that the network operator described is supposed to be a GSM and a UMTS licensee.

2.1 Geographical coverage

One of the most important factors for a business case is the coverage area of the network due to its influence on the deployment cost. The areas that have been considered are a city with high population density and a tiny town/village with low population density. The considered geographical areas in this report are the following ones:

a) **Urban area. -** The city of Barcelona was chosen due to the high population density and to the high demand of services. Demographic indicators are presented in Table 1 [5].

City	Surface [km^2]	Population	Density [pop/km^2]
Barcelona	100.69	1,605,602	15,596

Table 1. Total population and territorial characteristics of Barcelona.

b) **Rural area**. **-** The little town/village of Caserras was chosen due to its low population density and its relatively low service demand compared with the average. Demographic indicators are presented in Table 2 [5].

Municipality	Surface [km^2]	Population	Density [pop/km^2]
Caserras	29.5	1,586	54

Table 2. Total population and territorial characteristics of Caserras.

2.2 Architecture of the network

The network architecture selected for this study consists of a heterogeneous network, in which access is provided by WiFi, UMTS and WiMAX subnetworks. These interfaces will cover the territory according to the benefits that each technology provides and the current deployment done by the operator. In the core network there will be an IMS for the easy integration of services that work in the different subnetworks. The core network will have interconnection to the Internet and to PLMN and PSTN networks. Figure 1 illustrates the architecture used in this study.

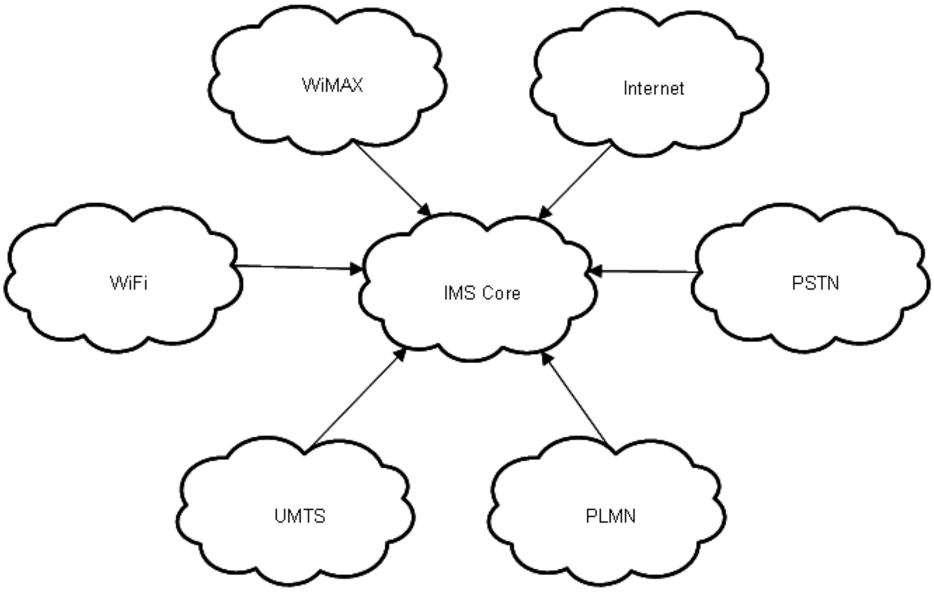

Figure 1. General architecture assumed for the business case.

2.3 Handset types

In order to offer a broader network coverage, it is assumed that end-users' devices will be able to connect to different wireless interfaces which means that a subscriber will not lose his profile when he changes from one type of network to another. The different handsets that may be available in this network are:

1) **Only cellular capabilities**. – This type of mobile will be able to connect to a GSM/GPRS network if there is poor UMTS coverage or none.
2) **PDA and Laptops**. **-** These devices and computers will operate with UMTS/WiFi connections or with UMTS/WiMAX networks.

2.4 Business Model

The ECOSYS project states that a "business model consist of service and information flows, including a description of various business players, their roles and relationships, their relative position within a value network and descriptions of their costs structure and source of revenue" [6]. In our study two main actors were taken into account: the Network Operator (NO), which acts as Service Operator (SO), and the Content Producer/Provider. Figure 2 shows the main cash flows between actors and the roles that each actor plays. Each ellipse or circle means a different actor and each rectangle represents a different role for the actor [6]. The NO is responsible for the correct provisioning of contents such as downloads of music, games and videos, and voice and data transfers to the subscriber. The Content Producer is the entity that creates or promotes the videos, games and music that the NO sells the subscriber. The NO is responsible for the provisioning of the bandwidth that the SO offers to the subscriber.

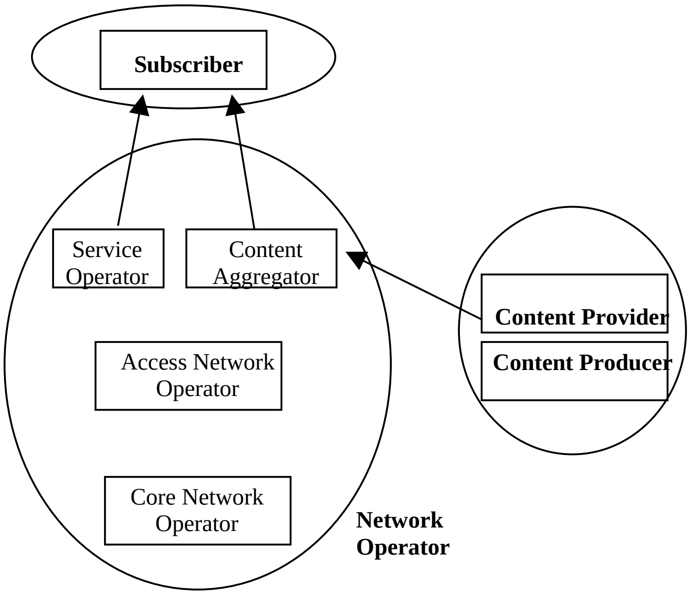

Figure 2. Main cash flows and roles for the model

2.5 Definition of the business case

Figure 3 describes the main logical flows that are assumed in order to obtain economic results for the business case. The chart flow is based on the research carried out for the ECOSYS project [4].

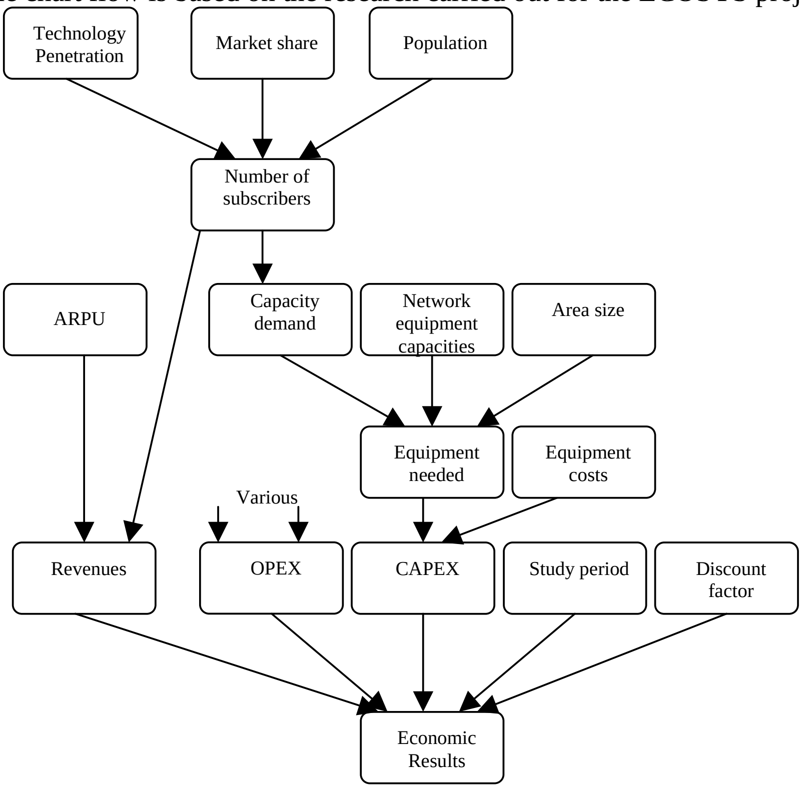

Figure 3. Model revenues and costs flows based on the ECOSYS project [4].

Inputs for the business case are the size of the territory, population, market share, penetration rate, the ARPU, the timeframe for the study period and equipment costs; on the other hand, outputs for the business case are the NPV (Net Present Value), the IRR (Internal Rate of Return), the cumulative and annual cash flows, Payback Period and the Profitability Index. The variables that were used to obtain the results are the number of subscribers, ARPU and CAPEX and OPEX values.

The timeframe considered in the study is 8 years, which is a reasonable life cycle for wireless technologies and should be enough time for the payback period. This timeframe starts in 2008 and ends in 2015. On the other hand, the discount factor will be 15%, which is based on approximated discounted factors taken from other studies [4], [1].

For this business case, the NPV was chosen as the key economic indicator. According to [7], the NPV represents the present value of net cash flows. The following formula defines the NPV [5]:

$$NPV = -CF_0 + \sum_{i=1}^{n} \frac{CF_i}{(1+rate)^i}$$

where
i: the time of the cash flow
n: the total time of the project
rate: the discount rate
CF_i: the net cash flow (the amount of cash) at time i.
CF_o: the capital outlay at the beginning of the investment time (t = 0)

In addition to the NPV, other economic indicators were used to provide more detailed information about the project. For example, the Payback Period, defined as the number of periods required for the sum of the project's expected cash flows to equal its initial cash outlay, is obtained when the cumulative cash flows crosses the zero, i.e., when the cumulative cash flows becomes positive [7].

The Profitability Index (PI) rule determines if a project is accepted or not: if PI is greater than 1, the project should be accepted, otherwise, it should be rejected. The Profitability Index is defined as the NPV divided by the initial investment. In the following formula the $presentevalue(CF_1,CF_2,\ldots CF_n)$ represents the NPV of the project and *InitialCashOutlay* represents the CF_0 or the initial investment [7].

$$PI = \frac{presentValue(CF_1, CF_2, ...CF_n)}{InitialCashOutlay}$$

3 Business Case

3.1 Deployment strategy

The 4G wireless network was deployed depending on the characteristics of an area. The UMTS network will be deployed in two phases completely in the area. In the first phase, due to the low demand of services on the UMTS network, the purpose is to cover the territory as fast as possible, regardless the network capacity constraint. In the second phase, the objective is to provide an upgrade of the network capacity and core network. This is achieved by adding more transceivers and core network elements. The first phase will be accomplished during the first year, whereas the second phase will be finished during the second and third year.

The WiFi network will be deployed only in places with high population densities. The WiFi network will be deployed during the first year. Finally, the WiMAX network will be deployed in places where the UMTS network has poor coverage or none, so that devices could improve the transmission speed; this network is assumed to cover 40% of the total area. The WiMAX network will be deployed during the first two years. Figure 4 illustrates how the different wireless technologies will provide coverage to the area.

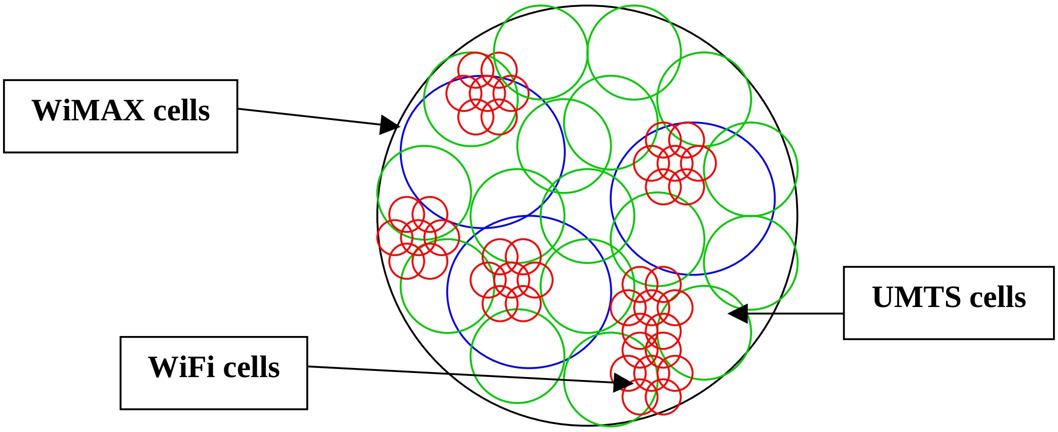

Figure 4. Network coverage in the area.

3.2 Market Forecast

Based on statistics from the NRA of Spain, CMT (Comisión del Mercado de las Telecomunicaciones) [8], the penetration of mobile telephony was 103.4% in the fourth quarter of 2006, and the market shares for the different operators was the following: Telefónica Móviles had 46.2% of the total market, Vodafone had 29.8% of the market and Orange had 24% of the total market. In this study, the market share of Vodafone is used as starting point for the operator considered in the business case. According to the data published by Vodafone Spain [9], the coverage offered in 2007 with its GSM/GPRS network is of 99.08% in Spain, whereas UMTS network has a smaller coverage.

According to statistics published by the CMT Spain [10], in 2006 there were 46.2 million of mobiles lines in Spain. Figure 5 shows the evolution of the mobile lines during the last 7 years.

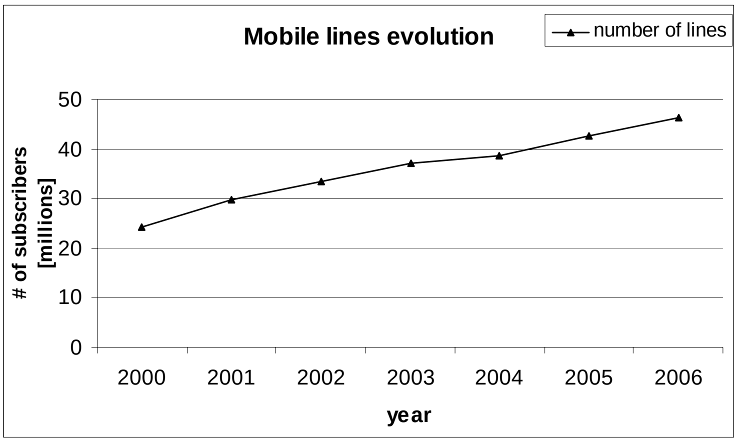

Figure 5. Mobile lines evolution

Based on these statistics, in this study a projection for the possible future number of subscribers was done, using three scenarios: the normal scenario, the optimistic scenario and the pessimistic scenario. The normal scenario considers that the network operator continues with the same growth rate of the last 7 years, as shown in Figure 5. The number of subscribers starts from the number of subscribers that Vodafone had in 2006. The optimistic scenario considers that the operator will have 5% more subscribers than in the normal scenario. In the pessimistic scenario the operator will have 5% less subscribers than in the normal scenario. Figure 6 illustrates the number of subscribers that the operator will have for each scenario.

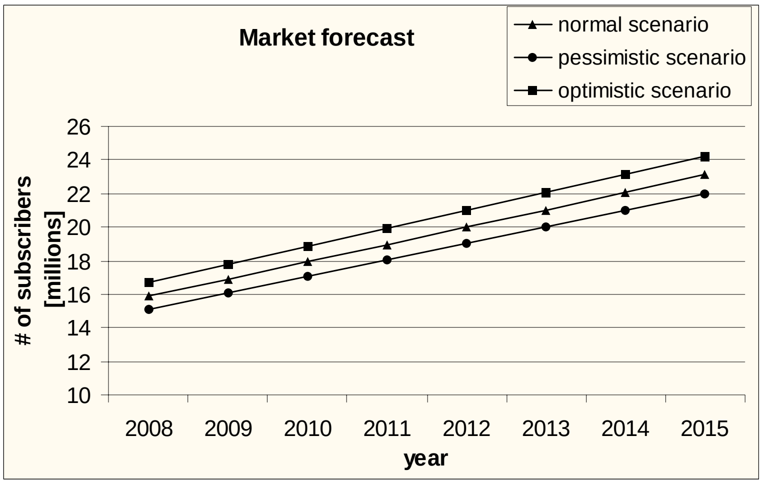

Figure 6. Market forecast scenarios for the operator.

3.3 Traffic generated by users

Based on data published by CMT Spain [8], users can be classified according to two contract types: prepaid users and postpaid users. Each type of subscriber has a different demand of services, depending on the preferences and the needs. Table 3 shows an average expense in services for both types of users. Based on these results, in our business model we assume that a user can dedicate **€** 25 per month to mobile telephony services.

Service	Prepaid[€]	Postpaid[€]	Total/ trimester[€]
Voice	22.67	89.38	59.31
Subscription fee	0.02	3.27	1.8
Traffic	22.65	86.12	57.5
Data	7.72	15.86	12.19
SMS	6.24	11.96	9.39
GPRS services	1.25	3.26	2.35
WAP	0.23	0.64	0.45
Interconnection to other Networks	0.78	6.87	4.12
Total	31.18	112.11	75.62

Table 3. Revenues generated by users.

3.4 Scenarios considered

This section describes the different scenarios considered for the business case. In table 4 the scenarios for both areas are presented.

Scenario	
1	Normal Barcelona
	Pessimistic Barcelona
	Optimistic Barcelona
2	Normal Caserras
	Pessimistic Caserras
	Optimistic Caserras

Table 4. Scenarios considered for the business case

3.5 Network dimensioning

This subsection describes the radius and the area that each base station covers depending on the technology used (UMTS, WiMAX, WiFi). Table 5 shows the radius and the base station coverage for each area.

Area Type	**Population density [pop/km^2]**	**Radius [km]**	**Coverage [km^2]**
Dense Urban Area	>2000	0.46	1.66
Urban Area	500-2000	0.8	5.11
Suburban Area	250-500	1.25	12.58
Rural Area	<250	1.82	26.62

Table 5. Radius and coverage per UMTS base station

Secondly, the dimensioning for WLAN was done. The access point in WLAN only transmits omni-directionally; the coverage area was assumed a circle. Table 6 shows the radius and the coverage in dense urban areas.

Area type	**Population density (pop/km^2)**	**Radius[m]**	**Area [km2]**
Dense urban area	6000	200	0.13

Table 6. WLAN Radius and coverage in dense urban areas.

Finally, the WiMAX dimensioning is presented. The calculus is similar to that of the UMTS case. However, the results are different due to technology capabilities [11]. Table 7 shows the radius and coverage in the different area types considered.

Area type	**Population density [pop/km^2]**	**Radius[m]**	**Area[km^2]**
Urban zone	9000	1000	0.57
Suburban/Rural zone	500	2360	6.91

Table 7. WiMAX radius and coverage per area types.

3.6 Capital Expenditure (CAPEX)

The CAPEX considers the cost of the initial equipment and the cost of the license for the use of the spectrum necessary to deploy a new wireless technology. These costs are normally classified as assets of the company. For the purpose of this study, the CAPEX is divided into the following four parts: UMTS CAPEX, WiFi CAPEX, WiMAX CAPEX and IMS CAPEX.

3.6.1 UMTS CAPEX

This part consists of the costs for the deployment of a 3G base station (BS), called Node B in the UMTS network. A base station (BS) requires a platform where the antenna is mounted; the platform gives security and support to the antenna; this construction has an approximated cost of € 60,000 when there is no building. However, when there is present a previous construction for an older wireless network, the cost is € 30,000 due to the reuse of materials. The Node B has an approximated cost of € 105,000 and € 60,000 for urban and suburban/rural areas, respectively. The Node B contains transceivers of high or medium capacity depending on the zone: rural o urban. The transceivers are expected to have a basic capacity at the moment of deploying the network. Later, when the network is completely deployed, the capacity is upgraded to support all the traffic demanded by users. This upgrade can cost € 105,000 for urban zones and € 60,000 for suburban and rural zones.

The RNC (radio network controller) has an approximated cost of € 2,000,000; this device can support up to 400 Nodes B, 1200 transceivers or 200 Mbps of capacity. In the initial phase of the deployment of the network it will only have a cost per BS of € 5,000. In the second phase, which consists of the capacity upgrade, there is an extra cost for the RNC of € 75,000 and € 35,000 for urban and suburban/rural zones, respectively. On the other hand, in the core network there are nodes like the MSC (mobile switching center), the SGSN (Serving GPRS Support Node), etc., that have a cost of around 30% of the total expenditure of the network. Finally, the replacement costs were considered. The replacement costs are the costs of replacing the components when after several years of usage the equipment stops working. This value is 8.7% of the total cost of the network [12].

Finally, according to the report published by the European Commission [12], the license fee for Spain operators was agreed to be 3.1 €/pop/5 MHz per year. The license is valid for 28 years and it is valid since 2002. In this model, the cost of the license fee per area was calculated as the total number of people in the area multiplied by the cost of the license per person. In Table 8 the UMTS CAPEX values are summarized.

CAPEX item	Cost	
Site buildout	€	60,000.00
Upgrading the site	€	30,000.00
BS(urban)	€	105.000,00
BS(rural)	€	60,000.00
RNC	€	5.000,00
RNC upgrade (urban)	€	75,000.00
RNC upgrade (rural)	€	35,000.00
Core network		30%
Replacement		8,70%
License(urban)	€	4,977,366.20/year
License(rural)	€	4916.6/year

Table 8. UMTS CAPEX

3.6.2 WiFi CAPEX

The main CAPEX for a WLAN technology is the cost of the AP (Access Point). An AP with the possibility of operating in the three different standards (802.11a, 802.11b and 802.11g) has a cost of approximately € 1000. The AP installation requires approximately 10 working hours and the monthly payment of a worker is approximately € 5.000. Therefore, there is an installation cost of € 300 per AP. Table 9 summarizes the CAPEX values for WLAN [13].

CAPEX item	Cost
AP	€ 1.000,00
Installation	€ 300,00

Table 9. WLAN CAPEX.

3.6.3 WiMAX CAPEX

The site has an approximated cost of € 37,594.1 (50,000 USD). The WiMAX BS has a price of € 37,594 (50,000 USD). The antenna has a four-sector configuration. The installation cost of the antenna is € 2,256 (3,000 USD). The costs for the core network, which contains routers, switches, NMS (Network Management System), etc., are € 375,940 (500.000 USD). Table 10 shows the WiMAX CAPEX values [14].

CAPEX item	Cost
WiMAX BS	€ 37.594,00
Site build out	€ 37.594,00
Installation	€ 2.256,00
core network and access equipment	€ 375940,00

Table 10. WiMAX CAPEX

3.6.4 IMS CAPEX

The last part for the CAPEX is the cost of the acquisition of the IMS equipment, which has an average price of € 500,000. This equipment can support up to 200,000 subscribers.

3.7 Operational Expenditures (OPEX)

In the present study the operational expenditures (OPEX) are divided into the following three groups: UMTS OPEX, WiFi OPEX and WiMAX OPEX.

3.7.1 UMTS OPEX

This part considers the OPEX of a 3G network. The site lease on which the BS is mounted has an approximated price of € 10,000 per year in the urban areas and € 3.000 per year in the suburban/rural areas. The cost for data transmission, or also known as backhaul, is € 5.000 per year. The cost of energy consumption, which is considered as the electrical energy needed for the Base Stations, routers, switches and other equipment, is approximately 3% of the total cost of the equipment. Therefore, it has a cost of € 5.100 per year. Operation and maintenance costs, which are considered as the cost generated by the personnel that is dedicated to maintenance and to operate the equipment used in the network, are approximately 5% of the total cost of the equipment. Therefore, there is an expenditure of € 8,500 per year. Table 11 summarizes the 3G UMTS OPEX values [13].

OPEX item	Cost
Site lease (urban)	€ 10.000,00
Site lease (rural)	€ 3.000,00
Transmission	€ 5.000,00
Energy consumption	€ 5.100,00
Operation and maintenance	€ 8.500,00

Table 11. 3G OPEX.

3.7.2 WiFi OPEX

The site lease price of the APs is € 90 per year. The maintenance costs of the APs was calculated taking into account that a employee can manage around 500 APs per month and the salary of the employee is € 5.000 monthly. Therefore the annual cost for maintenance is € 120 per annum [11]. Finally, the cost to connect the APs to the core network is free due to the fact that the operator owns the 3G-backhaul infrastructure and the APs are connected to the same backhaul connection. Table 12 summarizes the WLAN OPEX values.

OPEX item	Cost
Site lease	€ 90,00
Maintenance	€ 120,00

Table 12. WLAN OPEX.

3.7.3 WiMAX OPEX

This part considers the WiMAX OPEX values. The data transmission cost for the backhaul is € 18797 per year (25.000 USD). Point-to-point microwave connections were considered. The maintenance cost is 5% of the total cost of the BS; therefore, it has a cost of € 3,872 per year. The site lease on which the BS was mounted has a cost of € 13,534 per year. The cost to operate the network is 10% of the revenue in year 1, dropping to 7% in year 5. Finally, the cost of the general management of the network is 6% of the revenue in year 1, dropping to 3% in year 5 [14]. Table 13 shows the WiMAX OPEX values.

OPEX item	Cost
Backhaul	€ 5,000
Maintenance	€ 3,872
Site lease	€ 13,534
Operation	10%
G&A	6%

Table 13. WiMAX OPEX

3.7.4 IMS OPEX

A value of € 50,000 per year is considered to maintain the IMS.

4 Results

This section shows the results for the two scenarios considered: Barcelona and Caserras.

4.1 Scenario 1

In this scenario Barcelona was the territory to be covered. Table 14 shows the number of base stations that were required to cover the total surface. Due to the large concentration of people in dense urban areas, it was considered that the territory was covered with small radio equipments in order to satisfy the capacity requirements and to offer a good transmission speed.

Technology	Area type	Surface [km^2]	Coverage/BS [km^2]	# BS needed
UMTS	Dense Urban	100.69	1.66	61
WLAN	Dense Urban	30.207	0.13	241
WiMAX	Dense Urban	40.276	0.57	71

Table 14. BS required in Barcelona.

The number of BS required, the core equipment, the cost of the license for UMTS and the OPEX are the variables that mainly determine the NPV for each scenario. In Table 15 the outputs for each scenario are presented.

Scenario	NPV [€ millions]	IRR [%]	PI	Payback Period [years]
Normal Barcelona	519.963	Not defined	6.46	Less than a year
Pessimistic Barcelona	498.823	Not defined	6.12	Less than a year
Optimistic Barcelona	549.353	Not defined	7.68	Less than a year

Table 15. Main economic indicators for Barcelona

Figure 7 shows the CAPEX values for the operator in each scenario. It can be seen that at the beginning of the deployment are the higher costs, which implies that the network is deployed in the first three years.

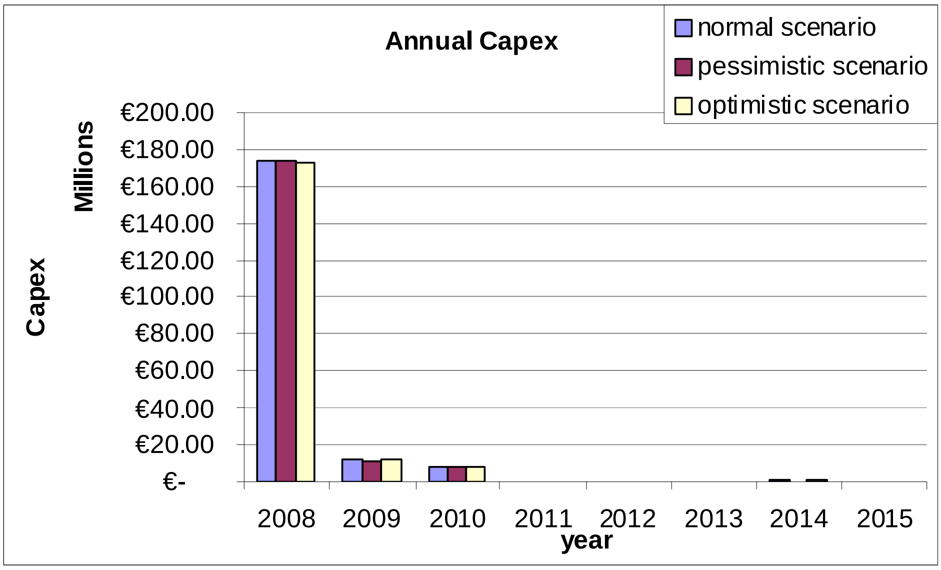

Figure 7. CAPEX values in Barcelona

Figure 8 presents the OPEX values.

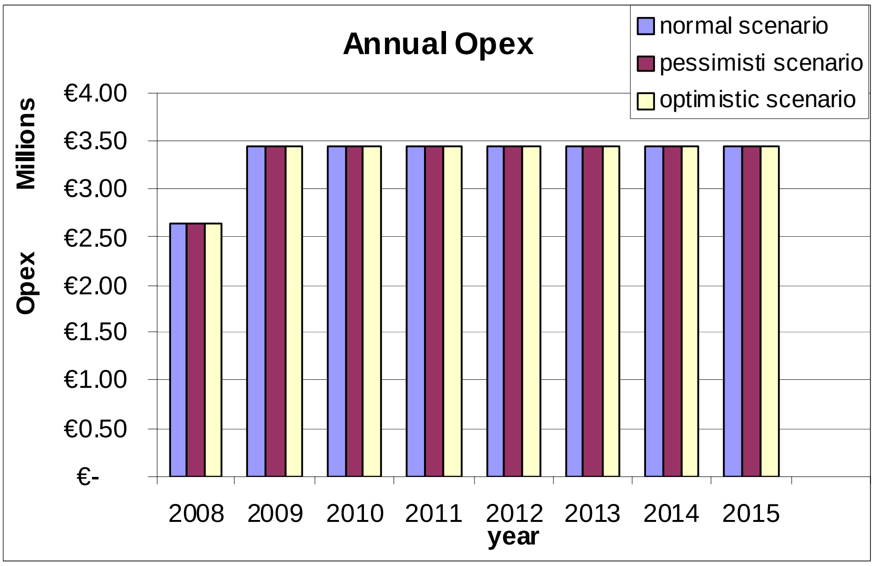

Figure 8. OPEX values

Figures 9 and 10 show the cumulative CAPEX and OPEX, respectively.

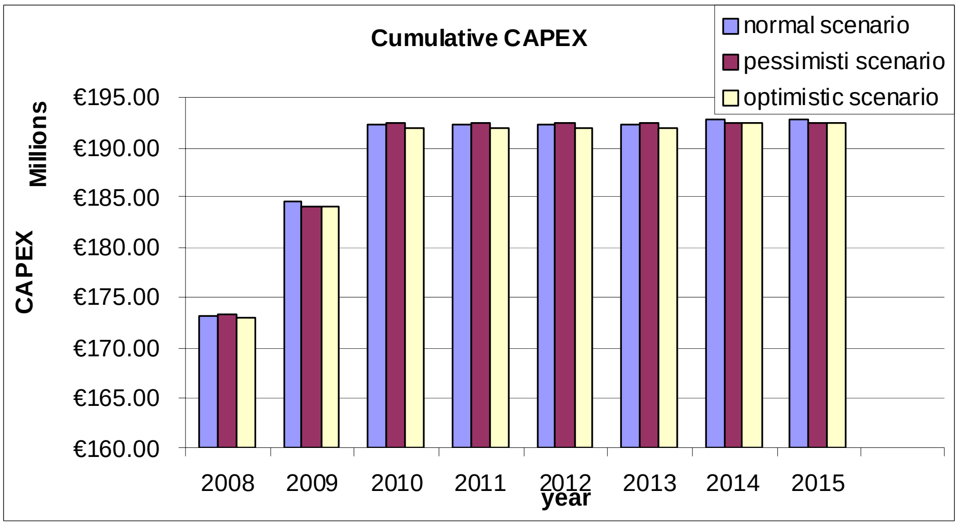

Figure 9. Cumulative CAPEX values

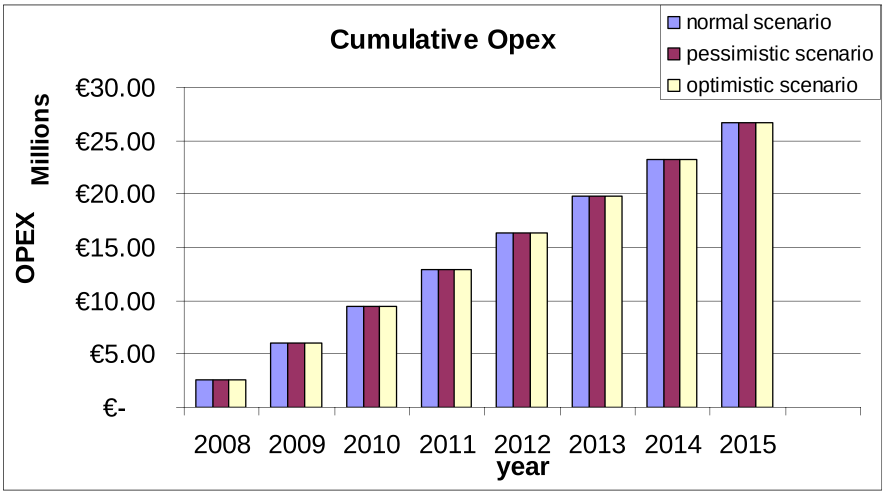

Figure 10. Cumulative OPEX values

Figure 11 shows the annual cash flows, which gives a detailed description of the revenues and costs presented during the deployment. These cash flows are helpful to understand better the NPV value. The Figure shows that the pessimistic scenario has a deeper funding due to lower number of subscribers.

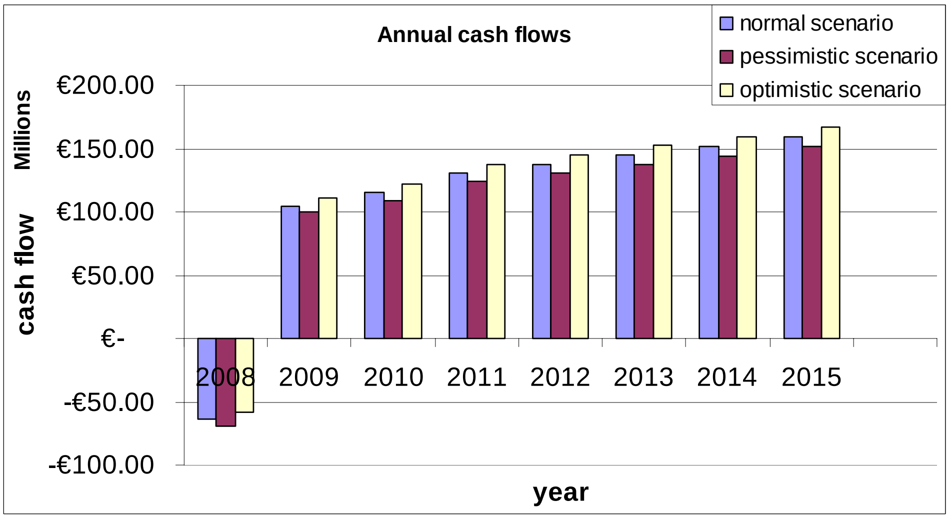

Figure 11. Annual cash flow during the period

Figure 12 show the cumulative cash flow for whole period. As is shown in the Figure, the optimistic scenario is the one with higher revenues and the pessimistic is the one with the lower revenues. The main reason of this difference is the number of subscribers.

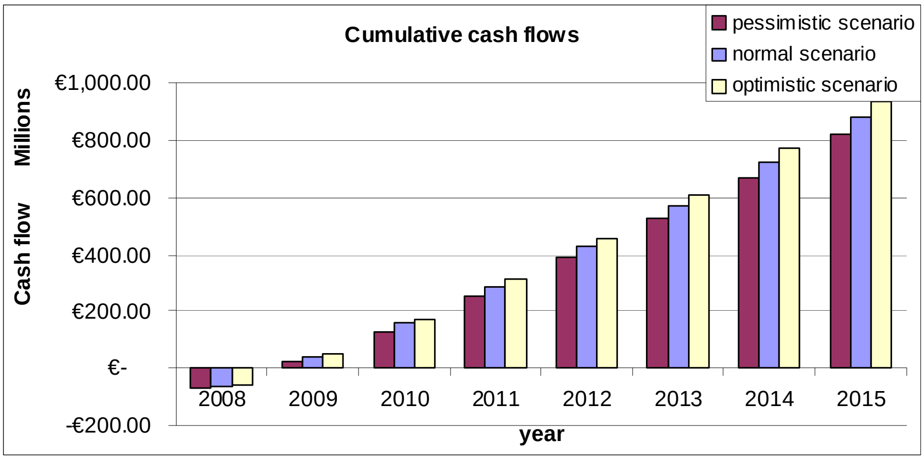

Figure 12. Cumulative cash flows during the period

4.2 Scenario 2

In this scenario the network will be deployed in Caserras. Table 16 shows the number of base stations that are required to cover the total surface. This area was covered with larger radio equipments.

Technology	Area type	Surface [km2]	Coverage/BS [km2]	# BS needed
UMTS	Suburban/rural	29.5	26.62	2
WLAN	Suburban/rural	8.85	0.13	71
WiMAX	Suburban/rural	15	6.91	3

Table 16. Base stations needed to cover Caserras.

Table 17 presents the main economic indicators for each scenario.

Scenario	NPV [€ millions]	IRR [%]	PI	Payback Period [years]
Normal Caserras	-1.318	Not defined	-1.002	More than 8 year
Pessimistic Caserras	-1.352	Not defined	-1.023	More than 8 years
Optimistic Caserras	-1.283	Not defined	-0.980	More than 8 years

Table 17. Main economic indicators for Caserras.

In order to determine the IRR, the cash flows must turn positive. In the following figures it can be seen that in the timeframe considered for the study the cash flows do not cross the zero value. On the other hand, the payback period could not be determined exactly for the same reason, although it can be mentioned that it takes more than 8 years to recover the investment.

Figures 13 and 14 illustrate the annual CAPEX and OPEX during the period, respectively.

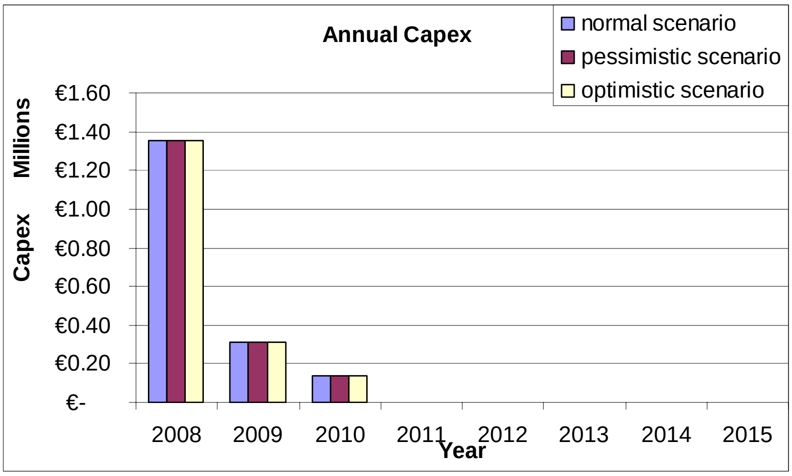

Figure 13. Annual CAPEX for Caserras.

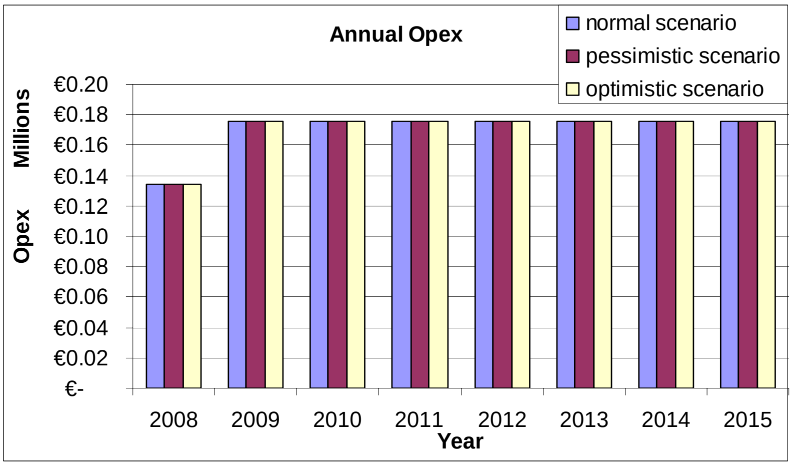

Figure 14. Annual OPEX for Caserras.

On the other hand, the cumulative CAPEX and OPEX values are presented in Figures 15 and 16.

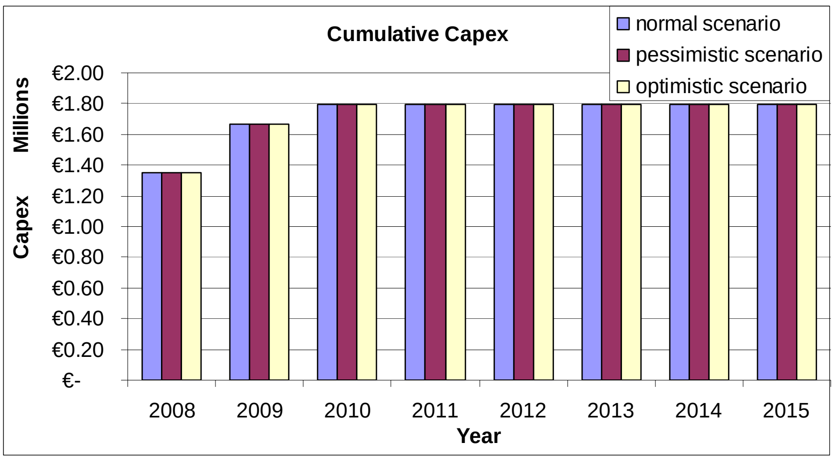

Figure 15. Cumulative CAPEX in Caserras.

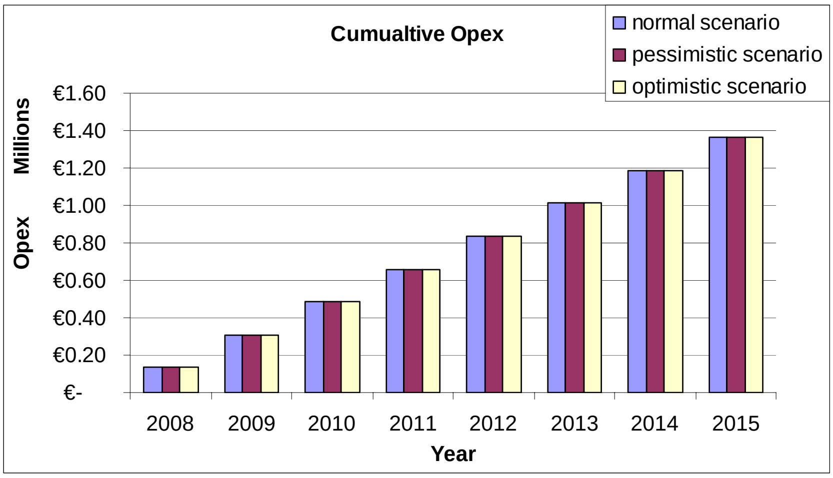

Figure 16. Cumulative OPEX in Caserras.

Finally, Figures 17 and 18 show the annual cash flow and the cumulative cash flow during the period studied. It can be seen that in the middle of the period the annual cash flows become positive, even though there are not enough revenues to recover the investment.

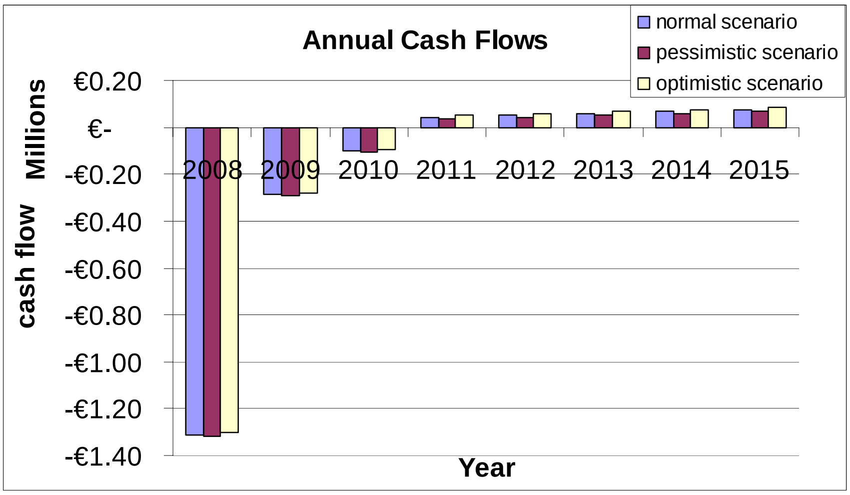

Figure 17. Annual cash flows during the period.

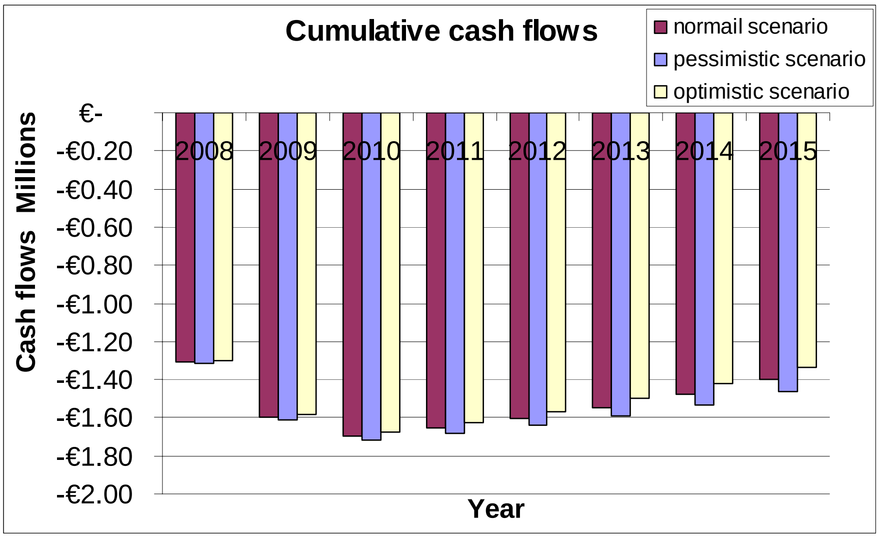

Figure 18. Cumulative cash flows during the period

5 Conclusions

A business case for the deployment of a 4G wireless heterogeneous network in Spain was presented. Two regions were considered in the study: Barcelona, which represents a dense urban area, and Caserras, which is an example of a rural area. The results indicate that it is feasible to deploy a heterogeneous network in Barcelona due to the possible large number of subscribers. On the other hand, if the 4G heterogeneous network had to be deployed exclusively in a rural area, the project wouldn't be financially feasible.

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