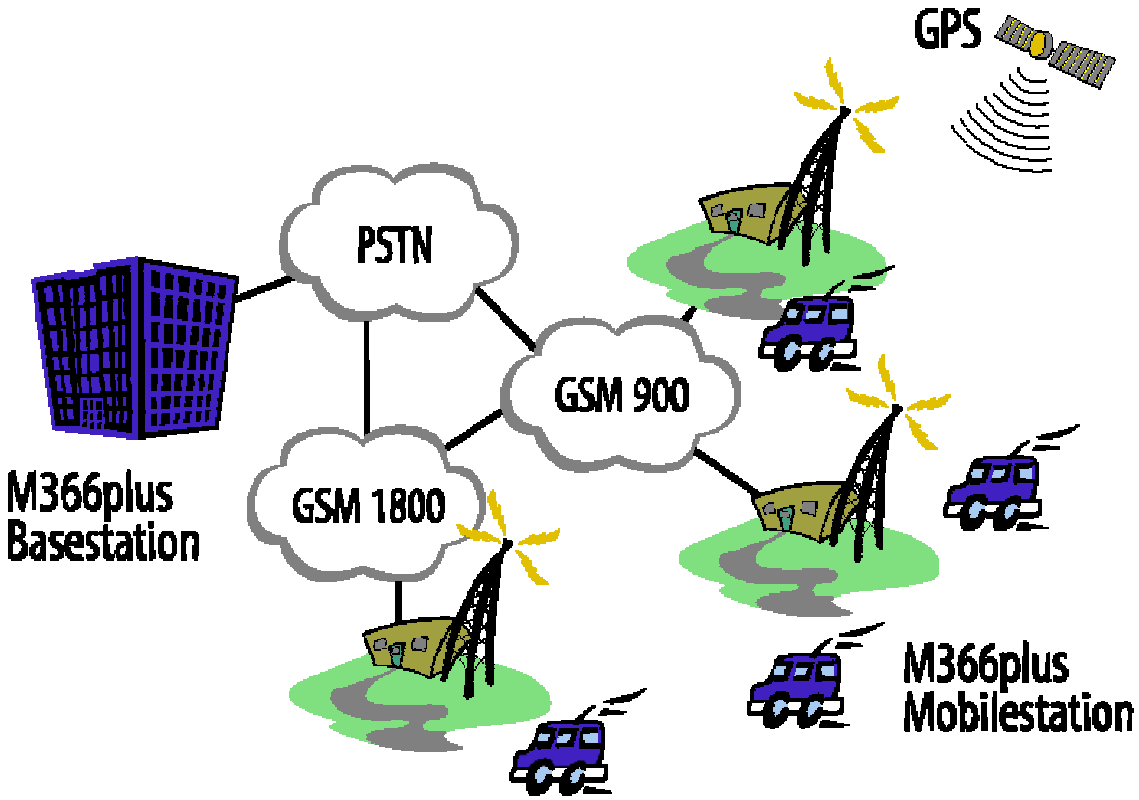
ANACOM
AUTORIDADE NACIONAL DE COMUNICAÇÕES

GSM Mobile Networks

Quality of Service Survey

February 2005



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Contents

I EXECUTIVE SUMMARY

I.I BACKGROUND

For the fifth consecutive year, the Autoridade Nacional de Comunicações (ANACOM) has carried out a Survey of the GSM Mobile Networks' Quality of Service, which is once again from the standpoint of consumers, so that the results obtained reflect their perception of the performance of the mobile networks.

An innovation compared to previous studies was the extension to railways, as this study for the first time covers two of the main national rail axes: Braga-Oporto-Lisbon and Lisbon-Faro.

The cities of Lisbon and Oporto were also subject to detailed analysis. This kind of approach enabled a more refined survey, enriching the results and enabling a closer approximation to the situation faced by consumers in those places.

Data from previous years was used to obtain a representative sample so that the results would reflect, with calculated precision, the mobile networks' overall performance. Thus, based on results of the study completed in December 2003, a sampling was planned to ensure, for a confidence interval of 95%, that the aggregate results (overall, urban areas and road arteries) contained maximum errors of less than 3% for the Accessibility and Audio Quality indicators.

The sample size for the rail axes was not calculated using this method, given the absence of back data that would allow estimation of the indicators' distribution parameters, specifically variance.

Analysis of this study's overall results indicated that the latter contained maximum errors of less than 1%, with a confidence interval of 95%.

The extent of the QoS-GSM survey sample was once again optimised, along with the consequent data collection time, without compromising the precision of the results.

The selection of test areas obeyed criteria that were related specifically to the highest service usage indices, i.e., the main road arteries and rail axes and the largest urban areas. Another similarly important criterion was consideration of the sites' geographic distribution, to take interior

regions into account. This approach led to a richer sample, avoiding the effect of results based solely on measurements concentrated in the densely populated Lisbon and northern coastal areas.

Tests were thus carried out in all mainland district capitals, with the collection area extended to the Lisbon and Oporto metropolitan regions, as well as along the major mainland road arteries and rail axes.

The population of the urban areas that constitute the chosen sample represents 40% of total Portuguese population, according to results of the last census (2001 Census).

Measurement collection in urban areas and along road arteries took place on working days, and during normal working hours, between 11 October and 21 December 2004. Measurements were collected along rail axes on 9 and 10 February 2005. Some 18,147 test calls were made in 30 cities and along 10 major road arteries and two rail axes on the Portuguese mainland; this corresponds to about 274 measurement hours over 10,331 kilometres.

Three vitally important mobile network indicators were studied, considering quality from the users' standpoint:

a. Coverage;
b. Accessibility;
c. Audio Quality.

The methodology followed is based on automatic end-to-end testing. Although time-consuming, this enables field verification of a given telecommunications operator's quality of service (QoS) by providing a picture as realistic as possible of network performance from the user standpoint.

According to the most recent statistical data available to ANACOM, there are more than 9.8 million subscribers to the services provided by the mobile networks. When we also consider the diversity of terminal equipment on the market and the very subjectivity inherent to each user, it is impossible to accurately reproduce the conditions of each user's interaction with the networks. This study's results should thus be viewed as an indicator of the networks' overall performance. A certain amount of caution is advised vis-à-vis their transposition/extrapolation to specific situations, as there is a risk of drawing skewed conclusions.

The technical and methodological options used in this study directly influenced the results obtained and should be taken into consideration when the results are analysed, namely the following:

- The terminal equipment used was Dual-Band with EFR. Users whose equipment does not have these features are likely to obtain results different from those obtained in this study;

- The testing was effected exclusively via a technical solution (equipment + software) and processed in an entirely automatic manner. This enabled the homogeneous establishment of assessment conditions for the three operators and elimination of the subjectivity inherent to human users;

- Tests were conducted in moving vehicles with outside antennas, except along rail axes, where inside antennas were used;

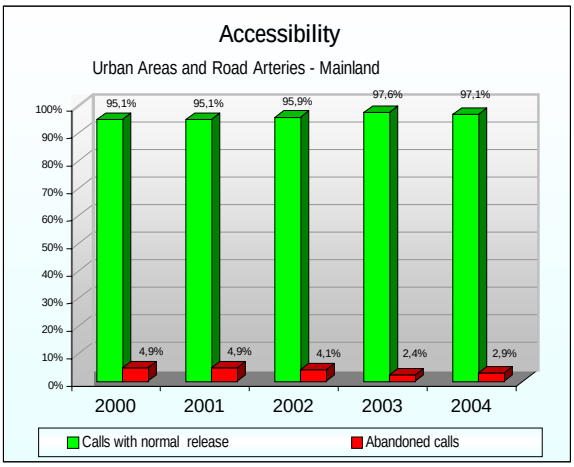
- To simultaneously study the accessibility and audio quality of conversations, a compromise conversation time of 110 seconds was used. This approximates the average conversation time for such communications in the networks under study in the second quarter of 2004 – the criterion considered when making the choice;

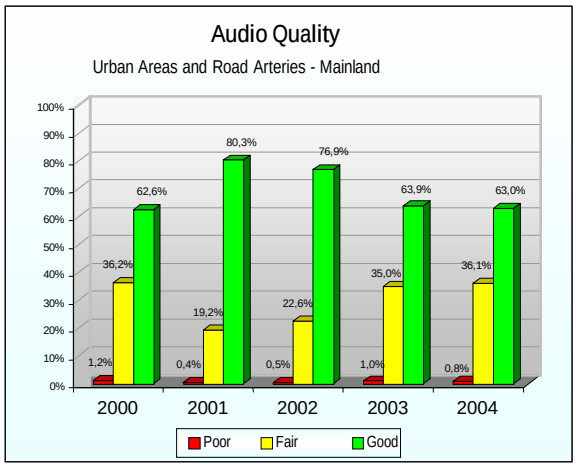
- Results of the study reflect network behaviour only in the places and times in which measurements were taken;

- On the other hand, operators are continually improving their networks. The technical intervention needed for such work can lead to momentary disruptions of service in the respective geographical intervention area.

I.II MAIN CONCLUSIONS

Analysis of the study results enables conclusion that the coverage and performance levels of GSM mobile networks are good.





Precision of the indicators, with a 95% confidence interval:

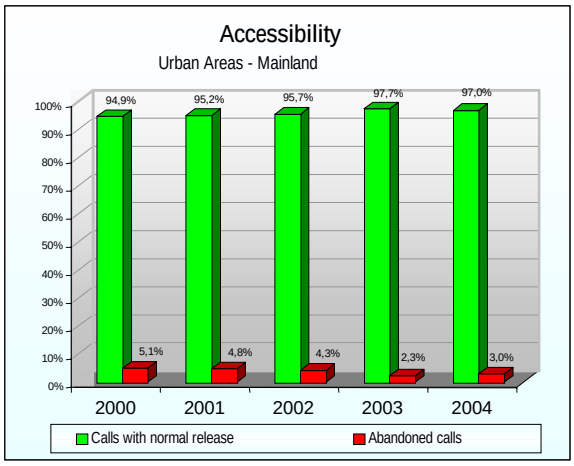
	2000	2001	2002	2003	2004
Accessibility	0,28%	0,22%	0,19%	0,24%	0,28%
Poor Audio Quality	0,10%	0,05%	0,05%	0,12%	0,11%
Fair Audio Quality	0,45%	0,29%	0,28%	0,55%	0,57%
Good Audio Quality	0,45%	0,29%	0,28%	0,55%	0,58%

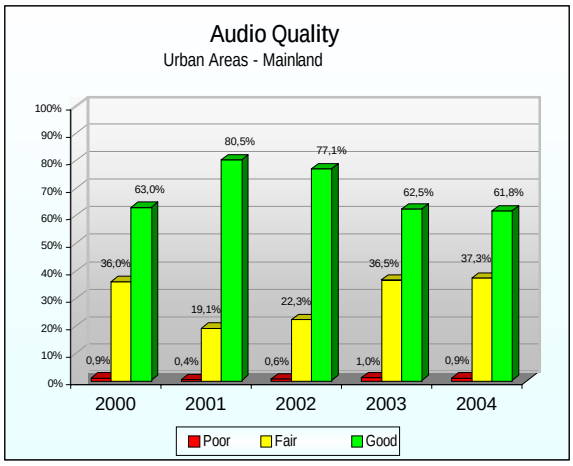
Figure 1 – Performance of the GSM Mobile Networks.

About 97% of test calls in urban areas and along road arteries were made successfully, with the conversation phase taking place properly and ending normally (by disconnection) at the end of a pre-set time. However, this year a reversal of this indicator's trend in recent years was verified.

Regarding the Audio Quality indicator, approximately 99% of test calls had good or fair average audio quality levels. Only about 1% had poor or bad levels.

However, there was again a reduction in the number of calls with good audio quality, following the trend already noted in the studies carried out in 2002 and 2003.

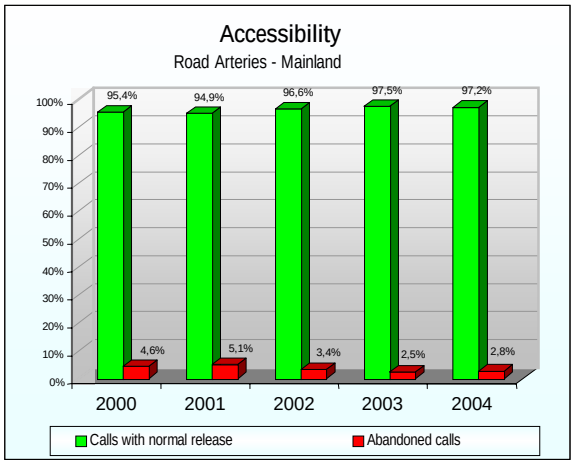


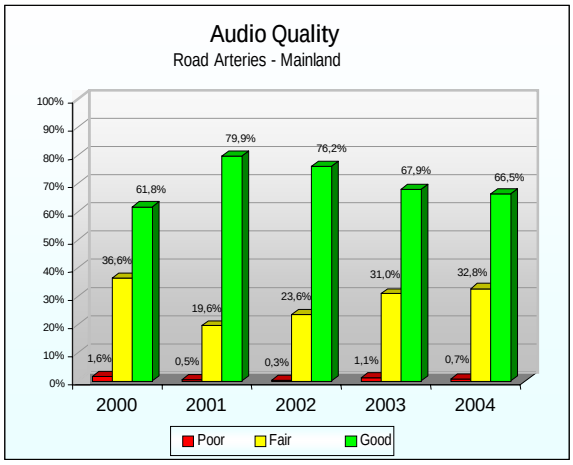


Precision of the indicators, with a 95% confidence interval:

	2000	2001	2002	2003	2004
Accessibility	0,35%	0,25%	0,21%	0,28%	0,33%
Poor Audio Quality	0,11%	0,06%	0,06%	0,13%	0,13%
Fair Audio Quality	0,55%	0,33%	0,31%	0,65%	0,68%
Good Audio Quality	0,56%	0,34%	0,32%	0,65%	0,68%

Figure 2 – Evolution of Results Obtained in Urban Areas.





Precision of the indicators, with a 95% confidence interval:

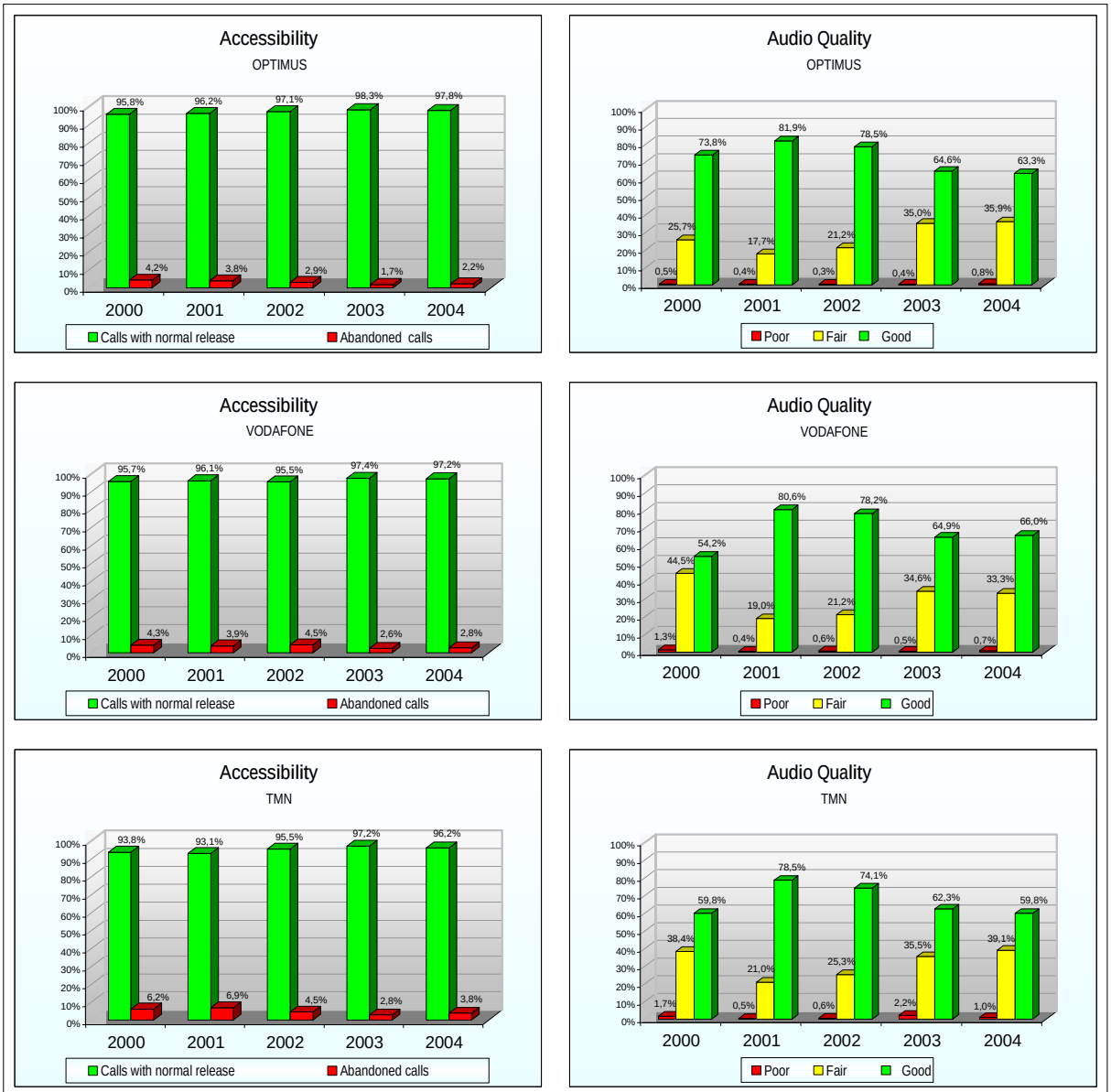
	2000	2001	2002	2003	2004
Accessibility	0,45%	0,46%	0,39%	0,48%	0,53%
Poor Audio Quality	0,19%	0,10%	0,08%	0,23%	0,19%
Fair Audio Quality	0,75%	0,60%	0,65%	1,02%	1,08%
Good Audio Quality	0,75%	0,61%	0,65%	1,03%	1,09%

Figure 3 – Evolution of Results Obtained along Road Arteries.

Regarding Accessibility, there are no major differences in results between road arteries and urban areas.

The Coverage indicator has good levels, both in urban areas and along the road arteries studied, as can be seen in the appended maps.

The graphs in Figure 4 show evolution of the Accessibility and Audio Quality indicators by operator over the last five years, to facilitate better perception of the networks under study.

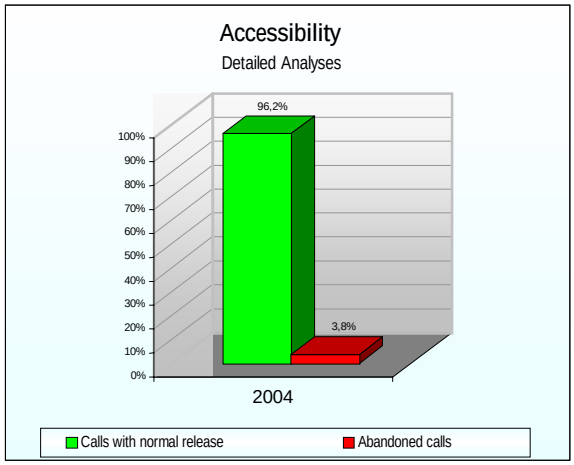


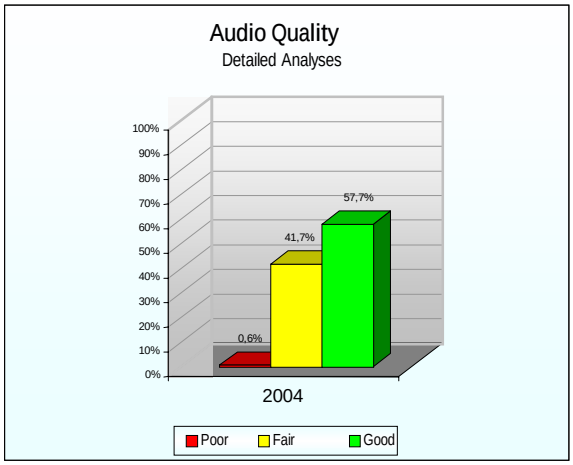
Precision of the indicators, with a 95% confidence interval:

	OPTIMUS					VODAFONE					TMN				
	2000	2001	2002	2003	2004	2000	2001	2002	2003	2004	2000	2001	2002	2003	2004
Accessibility	0,45%	0,34%	0,27%	0,36%	0,42%	0,45%	0,34%	0,34%	0,44%	0,48%	0,53%	0,45%	0,34%	0,46%	0,55%
Poor Audio Quality	0,11%	0,08%	0,07%	0,12%	0,18%	0,18%	0,08%	0,09%	0,14%	0,17%	0,21%	0,09%	0,09%	0,29%	0,21%
Fair Audio Quality	0,70%	0,49%	0,48%	0,95%	0,99%	0,80%	0,50%	0,48%	0,95%	0,98%	0,78%	0,53%	0,51%	0,95%	1,01%
Good Audio Quality	0,71%	0,49%	0,48%	0,95%	1,00%	0,80%	0,51%	0,48%	0,95%	0,98%	0,79%	0,53%	0,51%	0,97%	1,02%

Figure 4 – Evolution of Results by Operator in Urban Areas and along Road Arteries on the Mainland.

The results obtained in the Detailed Analyses carried out in the cities of Lisbon and Oporto are very similar to those obtained in the studies undertaken in Greater Lisbon and Greater Oporto.





Precision of the indicators, with a 95% confidence interval:

	2004
Accessibility	0,64%
Poor Audio Quality	0,19%
Fair Audio Quality	1,17%
Good Audio Quality	1,17%

Figure 5 – Results obtained in the Detailed Analyses.

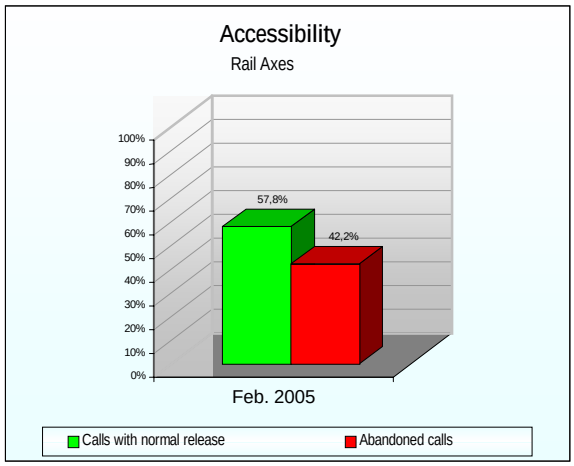
The Accessibility indicator has values of 96.2% for normal call release, about the same as the value registered in Greater Lisbon and Greater Oporto.

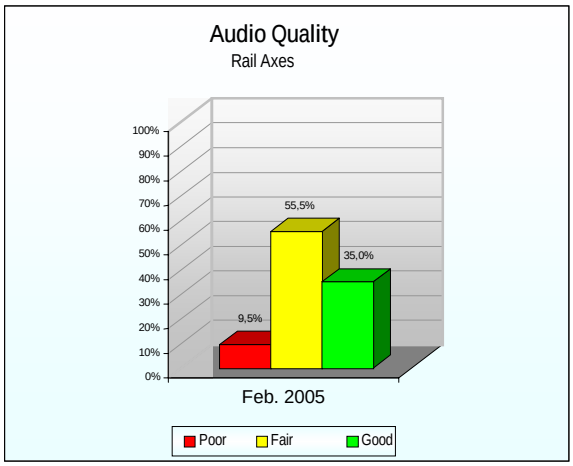
Regarding the Audio Quality indicator, the fair and good levels were once again above 99%. The level of good audio quality is slightly less than that verified in the analyses carried out in Greater Lisbon and Greater Oporto.

The Coverage indicator has good levels throughout the study area (see appended maps).

The GSM mobile networks performed worse along the rail axes, included for the first time in this study.

Serious coverage deficiencies, at times a complete absence of radio signal, were verified over the course of the studied axes, particularly the Lisbon-Faro route; this was reflected in the results obtained.





Precision of the indicators, with a 95% confidence interval:

	Feb. 2005
Accessibility	3,16%
Poor Audio Quality	1,54%
Fair Audio Quality	2,61%
Good Audio Quality	2,50%

Figure 6 – Results Obtained Along the Rail Axes.

Only 57.8% of the calls ended normally, i.e., by disconnection. The Audio Quality indicator values were also long from the average values observed in urban areas and along road arteries. Note that 9.5% of calls had poor or bad average Audio Quality values.

The situations observed along the rail axes indicate the need for additional investment in order to overcome the deficiencies.

1 TECHNICAL ASPECTS OF THE STUDY

1.1 METHODOLOGY

1.1.1 FUNDAMENTAL ASPECTS

The methodology used in this study is based on three fundamental aspects:

a) End-to-end measurement: Measurements are made between a mobile network terminal point and a fixed network terminal point.

The advantages of end-to-end testing are as follows:

- Same viewpoint as consumers;
- Reflect interconnection problems as felt by consumers;
- Enable sample selection so that results reflect the real situation felt by most consumers (route selection, call number and length, time of day when measurements are made, etc.);
- Reveal and locate problems affecting networks;
- Also enable analysis and comparison of the various networks' performance.

b) Impartiality: Measurements are carried out simultaneously, in both time and space, for the three operators (OPTIMUS, VODAFONE and TMN), thus ensuring equal test conditions.

c) Objectivity: Tests are carried out in an entirely automatic manner. This eliminates the subjectivity inherent to human intervention or decisions.

1.1.2 QUALITY OF SERVICE INDICATORS

The survey studied three mobile network indicators that are vitally important for the consideration of quality from the user standpoint:

a) Coverage: Verification of signal levels.

The test equipment allowed measurement of the signal strength received by the mobile terminal.

All measurements are geo-referenced in order to graphically represent them later on a chart. This facilitates visualisation of each operators' coverage levels on the routes studied.

Table 1 – Signal Strength

Signal Strength (dBm)	
> -100	Coverage
> -110 ∧ <= -100	Bad Coverage
<= -110	No Coverage

b) Accessibility: Consists of verifying a mobile network's capacity to make and maintain calls.

The capacity to successfully establish voice communications between two extremes – a mobile network terminal and a fixed network terminal – is verified, along with the networks' capacity to maintain that call for a preset time.

In cases where it is not possible to establish communication or where same is interrupted during conversation, the test system identifies the cause of that failure or interruption.

c) Audio Quality: Consists of assessing perception of conversations via the establishment of a successful connection for a preset time period.

To measure this indicator, the system simulates a telephone conversation between two users.

The method used to evaluate audio quality, as perceived by users, is based on the "E-Model" recommended by international bodies such as ETSI[1] (ETR 250) and the

1 *European Telecommunications Standards Institute*.

ITU[2] (ITU-T *Recommendation* G.107). The MOS (*Mean Opinion Score*) index is calculated based on this model.

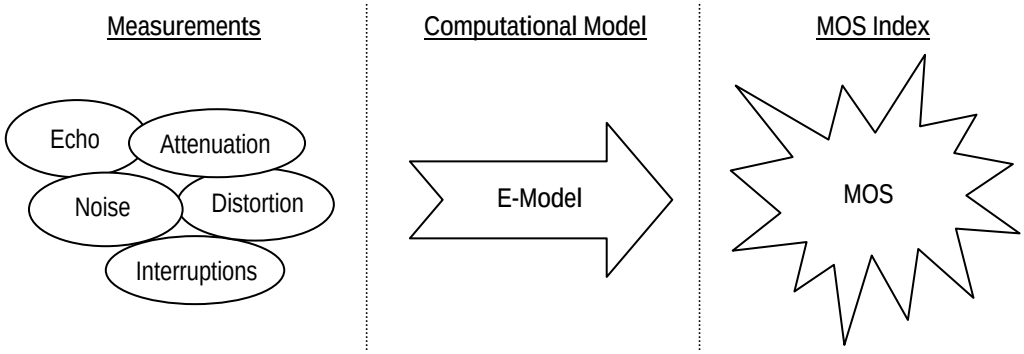


Figure 7 – Method used to gauge audio quality.

The MOS scale quantifies the effort needed to understand a conversation and has a value of 0 when there is no communication and 5 when communication is perfect. The values 0 and 5 are theoretical and thus never appear in the measurements.

Table 2 – MOS Scale

MOS	Quality
5	Excellent
4	Good
3	Fair
2	Poor
1	Bad

2 *International Telecommunications Union.*

1.1.3 MEASUREMENT PROCEDURES

The tests consisted of making and maintaining voice calls under the following conditions:

1. Between GSM Mobile Networks and terminals of a Fixed Telephone Network (Mobile-Fixed);

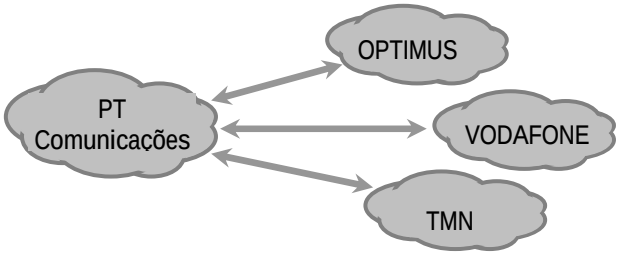


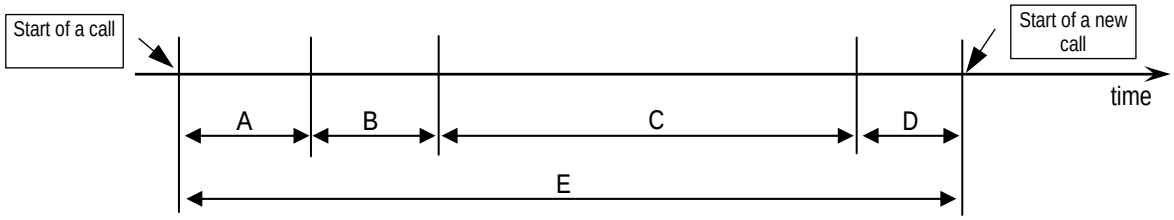
Figure 8 – Origin and Destination of Test Calls.

2. During measurement collection, the mobile terminal equipment (1 per operator) moved along the route being studied;

3. Calls were alternately made from the two terminals, mobile and fixed;

4. The time interval between consecutive calls was 160 seconds;

5. After the call was successfully established, a conversation phase (simulation of a real conversation) followed, lasting for a maximum 110 seconds[3] (less if the call was interrupted or the call set-up time was long);



A - Dialling and routing of call (depending on network, between 5 and 15 seconds)
B - Verification of routing (approximately 15 seconds)
C - Conversation (programmable, maximum 4 hours)
D - Disconnection of call and interval between consecutive calls (minimum 10 seconds)
E - Interval between calls

Figure 9 – Time frame for a voice call made by Datamat M366plus equipment.

6. During the conversation phase audio quality measurements (MOS) were carried out at each of the terminals involved in the call.

[3] The average length of voice calls in the second quarter of 2004 was 106.3 seconds.

1.1.4 DATA COLLECTED DURING FIELD WORK

a) MOS (*Mean Opinion Score*) – Audio quality index for an end-to-end call. Average values were obtained for each call and at each terminal involved in same.

b) Routed Calls – Telephone calls successfully established by the network and between the two terminals in question ("the call reached the called terminal").

c) Non-routed Calls - Telephone calls not established by the network between the two terminals in question ("the call did not reach the called terminal").

d) Calls Abandoned During Conversation – Telephone calls successfully set up by the network but abandoned during the conversation phase.

e) Calls with Normal Release – Telephone calls successfully set up by the network and which ended as expected.

f) Reasons Why Calls Were Abandoned – Situations leading to abandonment of communications: no service, congestion, radio link failure, other.

g) Level of RSSI (Received Signal Strength Indication, in dBm) Signal – Indication of the signal strength received by the mobile terminal.

h) Geographic Co-ordinates – Correspond to the places where measurements were made.

1.2 TESTED AREAS

As the aim of this study is to gauge the quality of GSM mobile service from the consumers' standpoint, it would be desirable for measurements to be made in all places where such telecommunications are or could be made available. At most, the whole geographic area of Portugal should be considered, including the interior of buildings. Yet the realisation of tests in all these places is obviously infeasible.

However, the idea was not to carry out exhaustive measurements, but rather to select an appropriate sample that would serve as an indicator of the mobile networks' overall performance.

To that end, major road arteries, rail axes and urban areas were thus chosen, as they reflect more intense service usage.

But exclusive adoption of such criterion would lead to an excessive concentration of measurements in the more densely populated coastal areas. For this reason, beyond this criterion, a decision was made to also consider a geographic distribution of sites, in order to cover interior regions.

Tests were thus conducted in all of the country's district capitals, expanding the collection area to the Lisbon and Oporto metropolitan regions and to the major road arteries and rail axes.

Detailed analyses were additionally undertaken in the cities of Lisbon and Oporto.

Table 3 – Places and respective population.

Territorial Unit		Resident Population	Present Population
Aveiro		73.136	76.415
Beja		35.659	37.001
Braga		163.981	165.048
Bragança		34.689	37.170
Castelo Branco		55.909	56.280
Coimbra		148.122	159.039
Évora		56.359	58.564
Faro		57.151	59.527
Guarda		43.759	44.593
Leiria		119.319	119.065
Portalegre		25.814	26.511
Santarém		63.418	63.106
Setúbal		113.480	112.227
Viana do Castelo		88.409	86.355
Vila Real		49.928	52.129
Viseu		93.259	93.041
	Total	1.222.392	1.246.071
Greater			
Oport		262.928	266.790
Gondomar		163.462	159.547
Maia		119.718	117.539
Matosinhos		166.275	162.671
Vila Nova de Gaia		287.597	280.466
	Total	999.980	987.013
Greater Lisbon			
Lisbon		556.797	559.248
Amadora		174.788	169.507
Cascais		168.827	166.539
Loures		198.685	193.320
Oeiras		160.147	157.152
Sintra		363.556	351.976
Almada		159.550	156.746
Seixal		150.095	146.843
Odivelas		132971	130569
	Total	1.932.445	1.901.331
	Overall Total	4.154.817	4.134.415

Source: INE – National Statistics Institute

The population present in the urban areas constituting the selected places represents 40% of the Portuguese population, according to results of the last census (2001).

Table 4 – Road Arteries and Rail Axes

Road Arteries	Approximate Distance (Km)
Lisbon-Sintra-Cascais-Lisbon (A5 + IC19)	60
Lisbon-Oporto (A1)	320
Lisbon-Torres Novas-Castelo Branco (A1 + A23)	220
Lisbon -Vila Real de S^{to}. António (A2 + A22)	337
Vila Real de S^{to}. António-Lagos (EN 125)	138
Lisbon-Évora-Elvas (A2 + A6)	223
Oporto-Braga-Valença-Viana do Castelo-Oporto (A3 + IC1)	240
Oporto-Bragança (A4 + IP4)	270
Aveiro-Vilar Formoso (IP5)	211
Vila Real-Figueira da Foz (IP3)	230

Rail Axes	Approximate Distance (Km)
Braga-Oporto-Lisbon	390
Lisbon-Faro	315

1.3 SAMPLE SIZE

By using results of the 2003 quality of service survey of GSM mobile networks, the variance of the *"Accessibility"* and *"Audio Quality"* indicators was estimated per mobile operator for the urban areas and road arteries

The field considered was the "Number of GSM Calls" per year in mainland Portugal, which, for the practical effects of this study, was considered *"infinite"*; an approximation to Normal distribution was used. The variances were then used to estimate the minimum sample size (number of test calls) needed to guarantee E precision with a confidence interval of 95% for urban areas and road arteries and per operator.

$$n = \left[\frac{Z(\alpha/2) * \sigma}{E} \right]^2$$

Various E precision values were tested for the *"Accessibility"* and *"Audio Quality"* indicators, until the best precision versus sample size compromise was obtained. The value found for E was +/- 3%. It is noteworthy that from a given point the marginal gains from increasing the sample size are almost nil.

After converting the number of sample calls needed in urban areas into time values, and considering the need to also analyse the *"Coverage"* indicator, a decision was made to carry out a full measurement day in each urban area. Taking the study areas and resident population of

Greater Lisbon and Greater Oporto into account, the measurement collection time was thus extended to 5 and 2.5 days, respectively. Along road arteries, it was decided to collected measurements during two trips.

The rail axes were not subject to this statistical treatment as it was their first time included in the study. As such, there were no previous results that enabled calculation of the indicators' variance.

The size of the survey sample was thus optimised, along with the consequent data collection period.

1.4 Data Collection Conditions

In the Greater Lisbon and Greater Oporto regions data collection occurred during normal working hours on weekdays. Two measurement sessions were held each day: from 8 a.m. to 11:30 a.m. and from 4:30 p.m. to 8 p.m.

In the other urban areas the measurement sessions lasted for three hours and were carried out during normal working periods on weekdays.

Regarding the road arteries and rail axes, data collection was carried out during two trips.

Table 5 – Measurement Collection Time

		Measurement Hours	
		Planned	Accomplished
Urban Areas and detailed Analyses	Aveiro	6 h 00	6 h 01
	Beja	6 h 00	6 h 03
	Braga	6 h 00	6 h 09
	Bragança	6 h 00	6 h 04
	Castelo Branco	6 h 00	6 h 11
	Coimbra	6 h 00	6 h 01
	Évora	6 h 00	6 h 05
	Faro	6 h 00	6 h 12
	Guarda	6 h 00	6 h 00
	Leiria	6 h 00	6 h 04
	Portalegre	6 h 00	6 h 01
	Santarém	6 h 00	6 h 01
	Setúbal	6 h 00	6 h 00
	Viana do Castelo	6 h 00	6 h 08
	Vila Real	6 h 00	6 h 10
	Viseu	6 h 00	6 h 07
	Greater Oporto	17 h 30	18 h 06
	Greater Lisbon	35 h 00	35 h 37
	Detailed analysis - City of Lisbon	30 h 00	0 h 00
	Detailed analysis - City of Oporto	18 h 00	0 h 00
Road Arteries and Rail Axes	Lisbon-Cascais-Sintra-Lisbon (A5 + IC19)	7 h 00	7 h 15
	Lisbon-Oporto (A1)	7 h 00	6 h 16
	Lisbon-Castelo Branco (A1+ A23)	5 h 00	4 h 30
	Lisbon-Vila Real de Sto. António (A2+A22)	6 h 00	6 h 01
	Vila Real de Sto. António-Faro-Lagos (EN125)	5 h 00	4 h 54
	Lisbon-Évora-Elvas (A2+A6)	4 h 00	3 h 58
	Oporto-Braga-Valença-Viana do Castelo-Oporto (A3+IC1)	5 h 30	5 h 45
	Oporto-Bragança (A4+IP4)	6 h 00	6 h 01
	Aveiro-Vilar Formoso (IP5)	5 h 00	5 h 47
	Vila Real-Figueira da Foz (IP3)	6 h 00	4 h 59
	Lisbon-Faro (Rail Axis)	6 h 00	0 h 00
	Braga-Oporto-Lisbon (Rail Axis)	8 h 00	0 h 00
	Total	267 h 00	206 h 26

In the detailed analyses of the cities of Lisbon and Oporto, the measurement sessions lasted for three hours and were carried out during normal working periods on weekdays.

1.5 TESTING AND MEASUREMENT EQUIPMENT

To conduct these tests, ANACOM used *DATAMAT M366plus* test and measurement equipment, which analyses quality of service for GSM networks

Main features:

- Allows measurements in GSM 900, DCS 1800 or Dual-Band;
- Allows simultaneous measurement of three operators/networks;
- Allows geo-referencing of all measurements;
- Measurement data is post-processed with specific manufacturer-developed tools, enabling detailed reports to be elaborated;
- The equipment can be configured, namely with respect to call length, the number to dial and the time interval between calls.

The equipment is composed of two module types:

a) Base Station: the fixed node of the M366plus system. It incorporates interfaces for three analog Fixed Telephone Network lines and also DSP boards[4]. It includes a PC that interacts with the module to enable its configuration and maintenance

   This module performs all the required operations: it makes and receives voice calls, carries out quality measurements and stores data.

b) Mobile Station: This module includes three mobile telephone interface boards with incorporated DSP, which are linked to three SAGEM OT160 Dual Band mobile telephones with EFR[5]. It also includes a component (board) for processing GPS signals. The antennas associated to GPS and to the three mobile telephones are placed on the outside of the vehicle (when the module is vehicle-mounted). It also includes a portable PC, for configuration and maintenance.

   The operations performed by this module are identical to those of the Base Station module, i.e., to make and receive voice calls, measure audio quality and store data.

1.6 Post-Processing Tools

A software tool known as "Report" is associated to the M366plus equipment. It stores, organises

[4] Digital Signal Processor.
[5] *Enhanced Full Rate* – Voice coder/decoder that enables audio quality comparable to fixed telephony.

and generates information statistics collected by the measurement units.

Files generated by the measurement units are organised in a database structure; “Report” may use “MS ACCESS” or “ORACLE” to this end.

Various reports may be obtained from single or multiple sessions with this tool, with different degrees of detail.

The M366plus equipment includes a GPS receiver that enables geo-referencing of all measurements. This information is handled by the “GeoReport” tool, which, parallel to a third tool – “MAPINFO” - enables the statistical information generated by “REPORT” to be viewed in digital geographical charts.

2 AGGREGATE RESULTS

2.1 DEFINITIONS

MOS	Mean Opinion Score - Level of audio quality for an end-to-end communication. Value is 0 when there is no communication and 5 when communication is perfect. The 0 and 5 values are theoretical and thus never appear in measurements. The presented data refers to average values per call.
Routed calls:	Telephone calls successfully established by the network and between the two terminals in question ("the call reached the called terminal").
Abandoned during conversation:	Calls successfully set up by the network but abandoned during the conversation phase.
Normal release:	Calls successfully set up by the network and which end normally.
Calls not routed:	Calls not established by the network between the two terminals in question ("the call did not reach the called terminal").
Abandoned calls:	Calls interrupted either in the phase of setting up the connection or during conversation.
Causes:	Reasons for the interruption of communications.
No service:	Service unavailable (no network).
Congestion:	Network congestion.
Radio link failure:	Failure of the radio link between the mobile terminal and the base station. This can occur when passing through a shadow area of the network in question.
Other:	Other reasons for call interruption.
RSSI signal strength (dBm):	Received Signal Strength Indication - Indication of signal strength received by the mobile terminal.
BCCH	Broadcast Control Channel - Conveys information to all mobile terminals (MSs) served by a given BTS (Base Transceiver Station). Transmitted in downlink mode and transports numerous parameters, such as CI (Cell Identity), LAC (Local Area Code), MCC (Mobile Country Code), MNC (Mobile Network Code) and FH (Frequency Hopping) algorithm.
FTS	Fixed Telephone Service.
PSTN	Public Switched Telephone Network

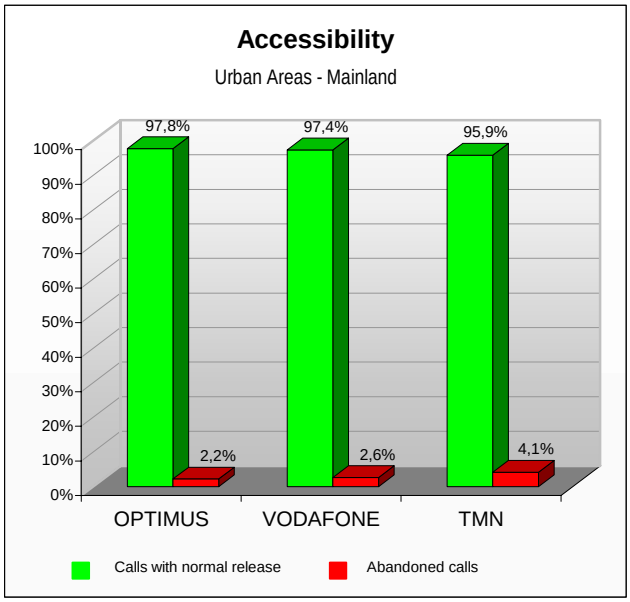
2.2 URBAN AREAS - MAINLAND

Precision of the indicators, with a 95% confidence interval:

	OPTIMUS	VODAFONE	TMN
Accessibility	0,50%	0,54%	0,68%
Poor Audio Quality	0,21%	0,21%	0,25%
Fair Audio Quality	1,16%	1,16%	1,19%
Good Audio Quality	1,17%	1,17%	1,19%

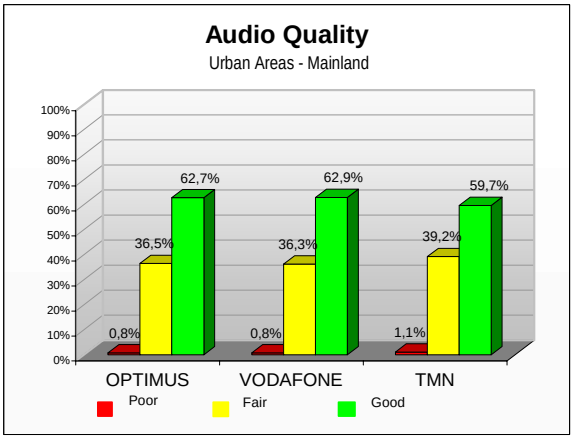
2.2.1 ACCESSIBILITY

		Operator	OPTIMUS	VODAFONE	TMN
Calls Made		Total	3346 100%	3344 100%	3339 100%
Routed calls		Total	3303 98,7%	3289 98,4%	3256 97,5%
		Abandoned conversation	31 0,9%	32 1,0%	55 1,6%
		Normal release	3272 97,8%	3257 97,4%	3201 95,9%
Calls not routed			43 1,3%	55 1,6%	83 2,5%
Abandoned calls		Total	74 2,2%	87 2,6%	138 4,1%
	Causes	No service	1 0,0%	0 0,0%	1 0,0%
		Congestion	35 1,0%	41 1,2%	50 1,5%
		Radio link failure	15 0,4%	17 0,5%	20 0,6%
		Others	23 0,7%	29 0,9%	67 2,0%



2.2.2 AUDIO QUALITY

	Operator	OPTIMUS	VODAFONE	TMN
Calls with	Total	6588 100%	6559 100%	6484 100%
Audio Quality (MOS)	Poor	52 0,8%	52 0,8%	71 1,1%
	Fair	2405 36,5%	2381 36,3%	2544 39,2%
	Good	4131 62,7%	4126 62,9%	3869 59,7%



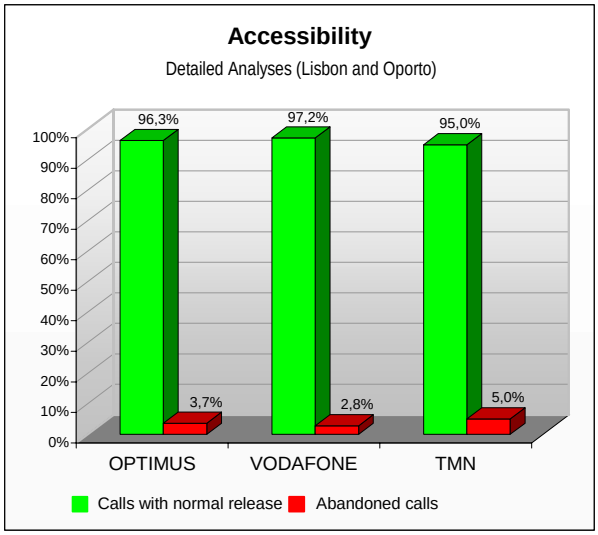
2.3 Detailed Analyses

Precision of the indicators, with a 95% confidence interval:

	OPTIMUS	VODAFONE	TMN
Accessibility	1,08%	0,95%	1,25%
Poor Audio Quality	0,31%	0,25%	0,39%
Fair Audio Quality	2,02%	1,84%	2,04%
Good Audio Quality	2,02%	1,85%	2,04%

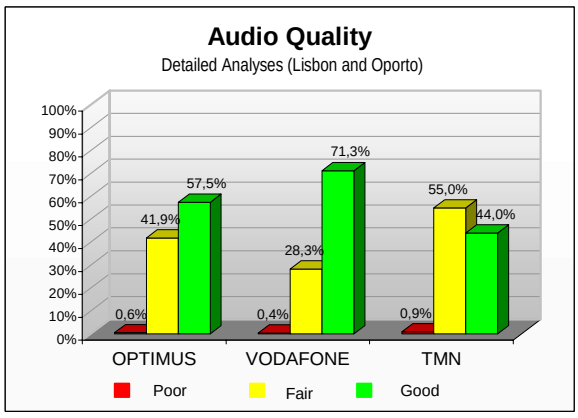
2.3.1 Accessibility

		Operator	OPTIMUS	VODAFONE	TMN
Calls Made		Total	1171 100%	1174 100%	1170 100%
Routed calls	Total		1155 98,6%	1155 98,4%	1147 98,0%
	Abandoned conversation		27 2,3%	14 1,2%	36 3,1%
	Normal release		1128 96,3%	1141 97,2%	1111 95,0%
Calls not routed			16 1,4%	19 1,6%	23 2,0%
Abandoned calls	Total		43 3,7%	33 2,8%	59 5,0%
	Causes	No service	0 0,0%	0 0,0%	0 0,0%
		Congestion	23 2,0%	15 1,3%	35 3,0%
		Radio link failure	12 1,0%	5 0,4%	8 0,7%
		Others	8 0,7%	13 1,1%	16 1,4%



2.3.2 Audio Quality

	Operator	OPTIMUS	VODAFONE	TMN
Calls with measurement	Total	2300 100%	2304 100%	2277 100%
Audio Quality (MOS)	Poor	13 0,6%	9 0,4%	21 0,9%
	Fair	964 41,9%	653 28,3%	1253 55,0%
	Good	1323 57,5%	1642 71,3%	1003 44,0%



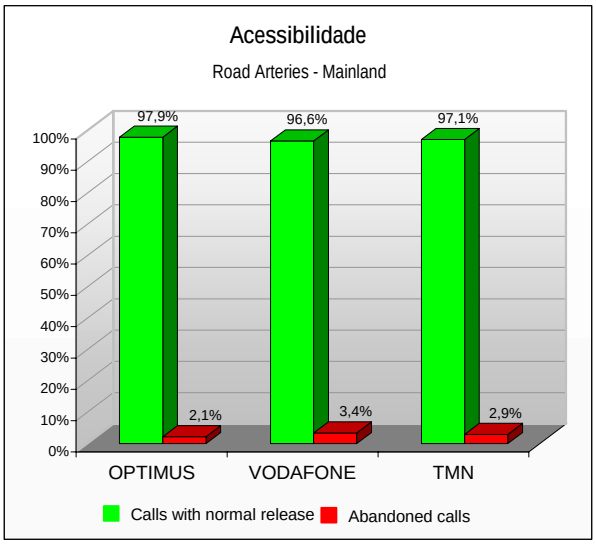
2.4 Road Arteries - Mainland

Precision of the indicators, with a 95% confidence interval:

	OPTIMUS	VODAFONE	TMN
Accessibility	0,81%	1,01%	0,93%
Poor Audio Quality	0,36%	0,27%	0,36%
Fair Audio Quality	1,89%	1,74%	1,95%
Good Audio Quality	1,90%	1,75%	1,95%

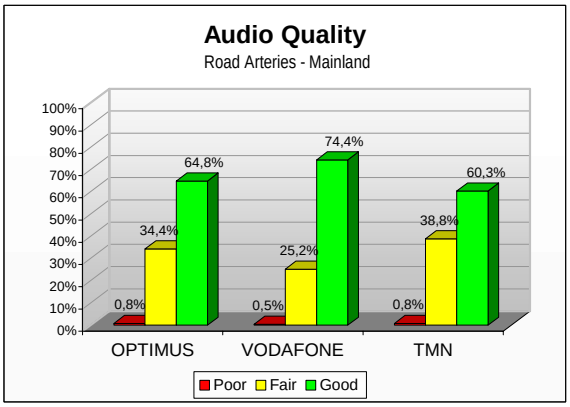
2.4.1 Accessibility

		Operator	OPTIMUS	VODAFONE	TMN
Calls Made		Total	1222 100%	1221 100%	1223 100%
Routed calls	Total		1213 99,3%	1196 98,0%	1207 98,7%
	Abandoned conversation		17 1,4%	16 1,3%	19 1,6%
	Normal release		1196 97,9%	1180 96,6%	1188 97,1%
Calls not routed			9 0,7%	25 2,0%	16 1,3%
Abandoned calls	Total		26 2,1%	41 3,4%	35 2,9%
	Causes	No service	0 0,0%	0 0,0%	0 0,0%
		Congestion	12 1,0%	19 1,6%	15 1,2%
		Radio link failure	8 0,7%	8 0,7%	10 0,8%
		Others	6 0,5%	14 1,1%	10 0,8%



2.4.2 Audio Quality

	Operator	OPTIMUS	VODAFONE	TMN
Calls with measurements	Total	2421 100%	2383 100%	2410 100%
Audio Quality (MOS	Poor	20 0,8%	11 0,5%	20 0,8%
	Fair	832 34,4%	600 25,2%	936 38,8%
	Good	1569 64,8%	1772 74,4%	1454 60,3%



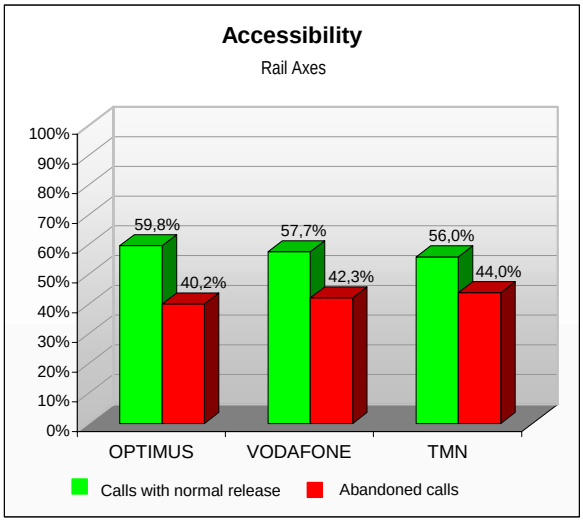
2.5 Rail Axes

Precision of the indicators, with a 95% confidence interval:

	OPTIMUS	VODAFONE	TMN
Accessibility	5,45%	5,50%	5,47%
Poor Audio Quality	2,67%	2,50%	2,84%
Fair Audio Quality	4,53%	4,45%	4,49%
Good Audio Quality	4,32%	4,40%	4,14%

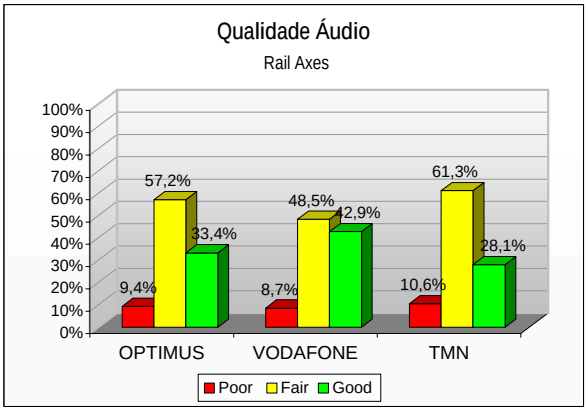
2.5.1 Accessibility

		Operator	OPTIMUS	VODAFONE	TMN
Calls made		Total	311	310	316
			100%	100%	100%
Routed calls		Total	243	251	246
			78,1%	81,0%	77,8%
		Abandoned conversation	57	72	69
			18,3%	23,2%	21,8%
		Normal release	186	179	177
			59,8%	57,7%	56,0%
Calls not routed			68	59	70
			21,9%	19,0%	22,2%
Abandoned calls		Total	125	131	139
			40,2%	42,3%	44,0%
	Causes	No service	18	15	14
			5,8%	4,8%	4,4%
		Congestion	74	39	41
			23,8%	12,6%	13,0%
		Radio link failure	20	40	27
			6,4%	12,9%	8,5%
		Others	13	37	57
			4,2%	11,9%	18,0%



2.5.2 Audio Quality

		Operator	OPTIMUS	VODAFONE	TMN
Calls with measurements		Total	458	485	452
			100%	100%	100%
Audio Quality (MOS)		Poor	43	42	48
			9,4%	8,7%	10,6%
		Fair	262	235	277
			57,2%	48,5%	61,3%
		Good	153	208	127
			33,4%	42,9%	28,1%



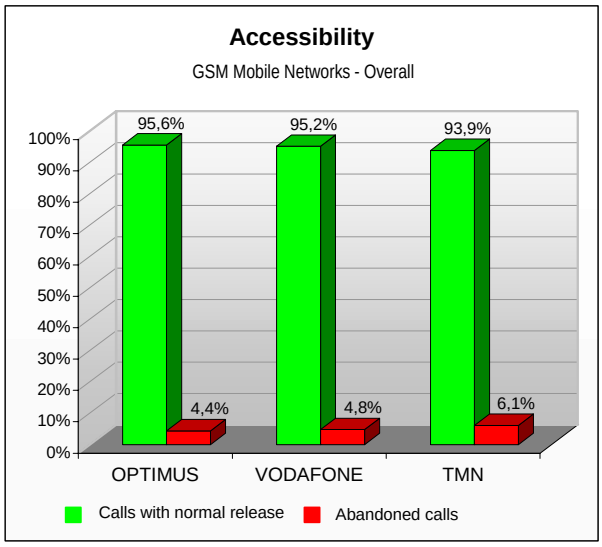
2.6 OVERALL

Precision of the indicators, with a 95% confidence interval:

	OPTIMUS	VODAFONE	TMN
Accessibility	0,52%	0,54%	0,60%
Poor Audio Quality	0,19%	0,18%	0,21%
Fair Audio Quality	0,88%	0,85%	0,90%
Good Audio Quality	0,88%	0,86%	0,90%

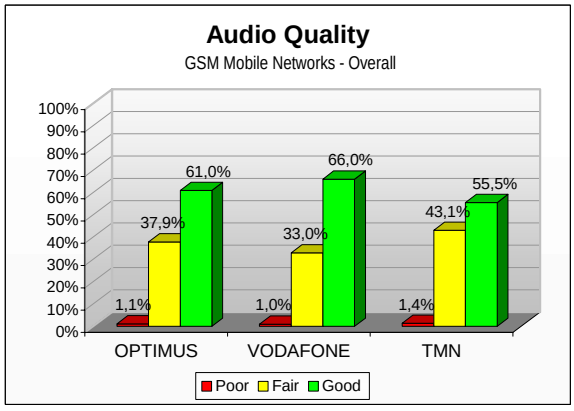
2.6.1 ACCESSIBILITY

		Operator	OPTIMUS	VODAFONE	TMN
Calls made		Total	6050	6049	6048
			100%	100%	100%
Routed calls	Total		5914	5891	5856
			97,8%	97,4%	96,8%
	Abandoned conversation		132	134	179
			2,2%	2,2%	3,0%
	Normal release		5782	5757	5677
			95,6%	95,2%	93,9%
Calls not routed			136	158	192
			2,2%	2,6%	3,2%
Abandoned calls	Total		268	292	371
			4,4%	4,8%	6,1%
	Causes	No service	19	15	15
			0,3%	0,2%	0,2%
		Congestion	144	114	141
			2,4%	1,9%	2,3%
		Radio link failure	55	70	65
			0,9%	1,2%	1,1%
		Others	50	93	150
			0,8%	1,5%	2,5%



2.6.2 AUDIO QUALITY

		Operator	OPTIMUS	VODAFONE	TMN
Calls with measurements		Total	11767	11731	11623
			100%	100%	100%
Audio Quality (MOS)	Poor		128	114	160
			1,1%	1,0%	1,4%
	Fair		4463	3869	5010
			37,9%	33,0%	43,1%
	Good		7176	7748	6453
			61,0%	66,0%	55,5%



2.6.3 COVERAGE

(Following pages)

MAINLAND PORTUGAL

OPTIMUS – PSTN

MAINLAND PORTUGAL

VODAFONE – PSTN

MAINLAND PORTUGAL

TMN – PSTN

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