





# Radio Coverage Analysis of a 4G Network in Ambato's Center

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**Abstract**—This study presents a radio coverage analysis of the 4G LTE network operated by Ecuador's National Telecommunications Corporation (CNT) in Ambato's Historic Center, a dense urban area with complex topography. Over a seven-day period, field measurements of the Reference Signal Received Power (RSRP) were collected along 13 primary and 19 secondary streets using two mobile devices—one mid-range and one low-end—equipped with the Network Cell Info Lite application. Both pedestrian and vehicular scenarios were evaluated, and compliance with the regulatory parameter SMA-QoS-9, established by Ecuador's Telecommunications Regulation and Control Agency (ARCOTEL), was assessed based on minimum power ( $\geq -100$  dBm) and location coverage ( $\geq 95\%$ ). Results revealed that measured coverage fell below the regulatory threshold, with average compliance levels of 84.71% for pedestrian data and 76.77% for vehicular data, while simulated results based on official base station parameters reached 100% coverage. A 2.43 dB discrepancy in RSRP was observed between pedestrian and vehicular measurements, attributed to Doppler effects, signal obstruction, and multipath propagation. The proposed low-cost and accessible methodology is shown to be effective for in assessing real-world LTE performance, enabling operators and regulators to identify critical coverage gaps and calibrate network simulators. These findings support service improvement strategies and provide a foundation for efficient 5G NR deployment in similar urban environments.

Link to graphical and video abstracts, and to code:  
<https://latam.ieeet9.org/index.php/transactions/article/view/9922>

**Index Terms**—Mobile communication systems, Radio wave propagation, Radio signals, Wireless networks, Urban environment, Quality of service, Simulation.

## I. INTRODUCTION

MOBILE connectivity has become essential in modern life, supporting communication, education, remote work, and access to information [1]. In Ecuador, the Ministry of Telecommunications (MINTEL) has emphasized the expansion of Advanced Mobile Service (SMA) networks in its 2022–2025 Universal Service Plan [2]. SMA enables the transmission of data, voice, and multimedia content, and is a key driver of services such as tele-education, telemedicine, and

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remote work, especially since the COVID-19 pandemic [3], [4]. These factors underscore the urgent need to strengthen fourth-generation (4G) networks and accelerate the deployment of fifth-generation (5G-NR) infrastructure, particularly in underserved rural areas [5].

The 4G LTE-A standard, part of the IMT-Advanced framework, is designed to provide mobile broadband services with high speed and performance, operating over IP-based connections to efficiently deliver voice, data, and multimedia content [6], [7]. Its effectiveness relies on network design and user mobility management [8]. However, as user density increases, inadequate network dimensioning can lead to coverage limitations and capacity congestion, adversely affecting performance [9], [10].

With the rapid advancement in the development of 5G networks, which builds upon 4G technology, it is important to assess whether the established expectations are being met. Therefore, there is an urgent need to analyze key parameters of the 4G network and its coverage [11].

The networks face various challenges, emphasizing the need to ensure uninterrupted communication, security, and performance [12]. Critical aspects such as Quality of Service (QoS) and security are essential to ensure the optimal operation of associated services [13]. In this context, the RSRP (Reference Signal Received Power) emerges as an essential parameter of LTE, providing key information about signal coverage and quality. Continuous monitoring and analysis of RSRP are imperative to maintain and enhance the efficiency and reliability of the network, ensuring an optimal user experience [14].

Prior studies have applied user equipment (UE)-based measurement techniques and spatial analysis to assess LTE coverage performance. These include evaluations using Minimization of Drive Test (MDT) data and comparative studies of empirical measurements versus propagation models [15], [16]. Other research has demonstrated the stability and repeatability of RSRP measurements in suburban environments [17], and validated the accuracy of the Walfish-Bertoni model for LTE signal prediction in Riobamba, Ecuador [18].

Other studies have examined LTE-A cellular network coverage by analyzing received signal strength (RSS), accounting for first-tier interference and frequency reuse schemes. The findings reveal significant signal degradation, with RSS dropping from -34 dBm at the cell center to -91 dBm at the cell edge, resulting in a corresponding decline in spectral efficiency from 4.3 to 0.5 bps/Hz [19].

Unlike prior LTE coverage studies that rely solely on simu-

lation tools or drive-test campaigns using calibrated equipment [15], [16], this study combines real-world user-level measurements with a simulation model based on actual base station data in a topographically complex urban environment. The main novelty lies in the dual-scenario approach—pedestrian and vehicular—using mid- and low-range smartphones to approximate realistic user experience in a dense Andean city. Furthermore, the study applies Ecuador's ARCOTEL SMA-QoS-9 regulation as an evaluation benchmark.

The present study aims to assess the current state of 4G LTE technology and its coverage in Ecuador, specifically within the historic center of Ambato, Tungurahua province. It concentrates on measuring the radioelectric parameters mandated by the ARCOTEL for evaluating service quality in 4G technology, offering both measured and simulated data.

Given the high demand and topographical complexity of urban centers in the Andean region—such as Ambato's historic center, which combines business, governmental, touristic, and residential activities—evaluating LTE parameters in such environments is critical. Networks that operate outside of regulatory and performance thresholds cannot fully exploit the capabilities of LTE technology. This situation also has implications for the efficient deployment of 5G NR, which relies on a robust 4G foundation. In this context, the present work introduces a practical and accessible methodology to assess LTE network compliance with local regulations, supporting operators in implementing service improvement strategies and providing realistic data for simulator calibration.

The ultimate objective is to evaluate the radioelectric coverage of CNT's 4G LTE network in the aforementioned area.

The rest of this paper is organized as follows: Section II delineates the methodology employed for measurements and simulations. Section III presents the results obtained. Finally, Section IV concludes the paper.

## II. MATERIALS AND METHODS

This section outlines the approach and tools employed to obtain the results, offering an insight into the equipment, data collection sector, schedule, tools, routes, and transmitter data.

### A. Equipment and Materials

#### 1) Hardware:

- Xiami Redmi Note 8 Pro: A mid-range device.
- Tecno Camon 18P: A low-end device.

#### 2) Software:

- Network Cell Info Lite version 6.7.4.: This app is comprehensive, offering mobile network and Wi-Fi monitoring tools that cover various networks, from 5G to GSM [20].
- Professional Propagation Software: A complementary tool used to evaluate field-measured values.
- Smart Measure App: used to estimate distances and heights based on trigonometric functions.

### B. Sector and Schedule

The sector for data collection was initially established in the historic center of Ambato. Fig. 1 highlights the area of

the historic center, with a perimeter of 4.22 km and an area of 0.95 km<sup>2</sup>. This sector was chosen because it comprises numerous high-rise buildings housing governmental entities, restaurants, parks, commercial areas, residential zones, educational centers, and more. Also, the area experiences a significant influx of users, varying in numbers depending on the hour and day of the week. Taking into account these reasons, this sector was chosen for the investigation.

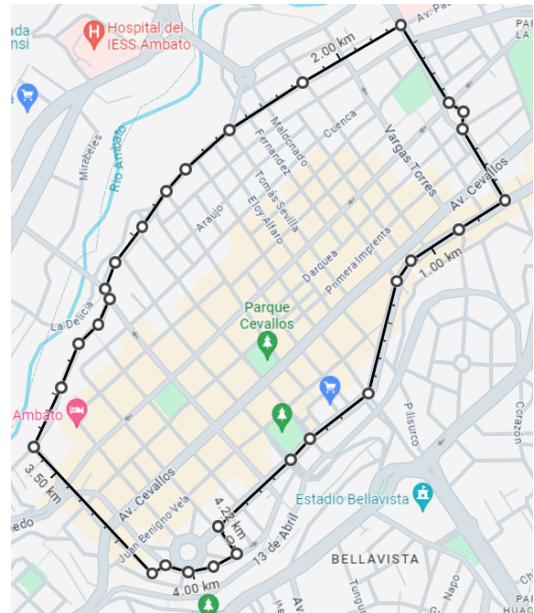


Fig. 1. Geographical area of Ambato's Historic Center selected for RSRP data collection.

Determining a specific schedule for data collection was also essential. The culture and customs of the city influence the daily number of visitors to this sector. For instance, on "fair days," there is a higher crowd, subsequently leading to increased usage and congestion of the cellular network. Typically, the majority of users consist of public and private employees, traders, and students who frequent this area.

To account for typical usage patterns, vehicular measurements were scheduled from 08:00 to 12:00, a period characterized by increased traffic due to work and school activities in the area. In contrast, pedestrian measurements were conducted from 12:30 to 17:00, when the sector shows higher foot traffic linked to tourism, park recreation, exercise, and commercial activities. This schedule was selected to reflect realistic temporal patterns of network usage, acknowledging that time-of-day variations may influence coverage quality.

### C. Tools

The chosen mobile application for the Android operating system was Network Cell Info Lite. Preliminary tests showed that the free version allows up to 200 measurements depending on the configured hop range. To gather a larger data set stored in a single file (.csv), the full version was acquired, allowing up to 1000 measurements. In addition, 4G connectivity was exclusively enabled in the mobile phone.

#### D. Routes

The measurement campaign was carried out in the urban environment of Ambato's Historic Center, specifically covering 13 primary and 19 secondary streets [21]. The evaluation was conducted in both pedestrian and vehicular scenarios, using two smartphones with different performance categories—one mid-range and one low-end. This sequential approach aimed to ensure a consistent daily route and to maintain data collection in an orderly and consistent manner and understandable for processing.

#### E. Measurements

The measurements were collected over seven consecutive days at various time intervals (morning, afternoon, and evening) to capture variations in network performance under different traffic and environmental conditions. The data acquisition was performed using the mobile application *Network Cell Info Lite*, which enables real-time monitoring of LTE parameters, including Reference Signal Received Power (RSRP).

It is important to note that while smartphones offer a practical and accessible means of collecting RSRP data, their measurements may be affected by device hardware, background processes, and limited calibration capabilities. Therefore, results obtained should be interpreted as indicative rather than absolute values.

The measurements started from the intersection of Francisco Flor and Avenida 12 de Noviembre and ended at Pérez de Anda and Lizardo Ruiz streets. Figs. 2 and 3 show examples of collected data for pedestrian and vehicular reception on the main streets, respectively.

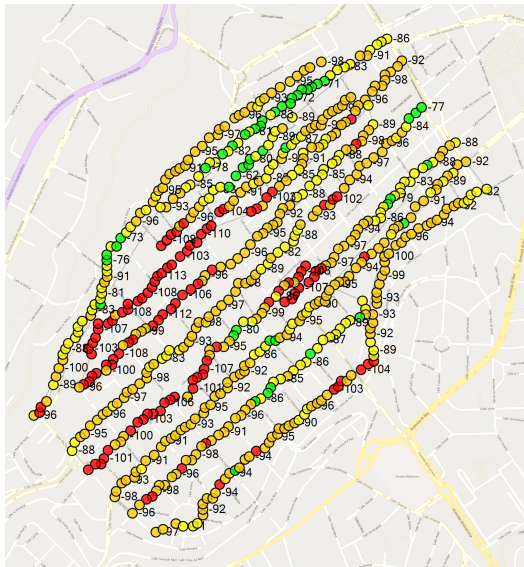


Fig. 2. Pedestrian Measurements on main streets, day 1.

Once the measurements on main streets were completed, the secondary streets measurements were made, as depicted in Figs. 4 and 5 for Pedestrian and vehicular reception, respectively. The route extended from the intersection of Lizardo Ruiz and Unidad Nacional streets to the intersection of Francisco Flor and Pérez de Anda streets.

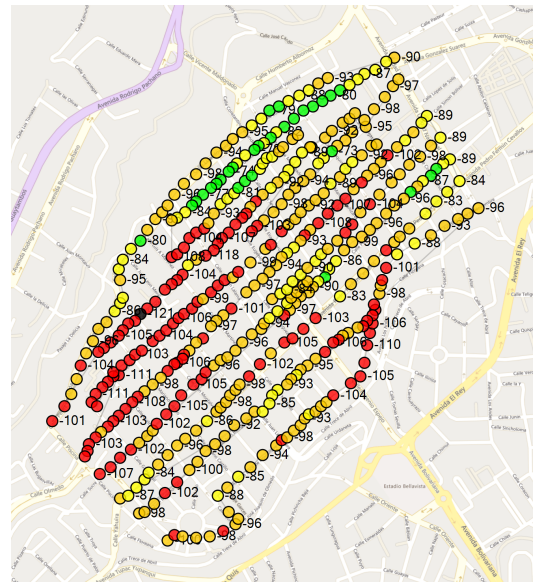


Fig. 3. Vehicular Measurements on main streets, day 1.

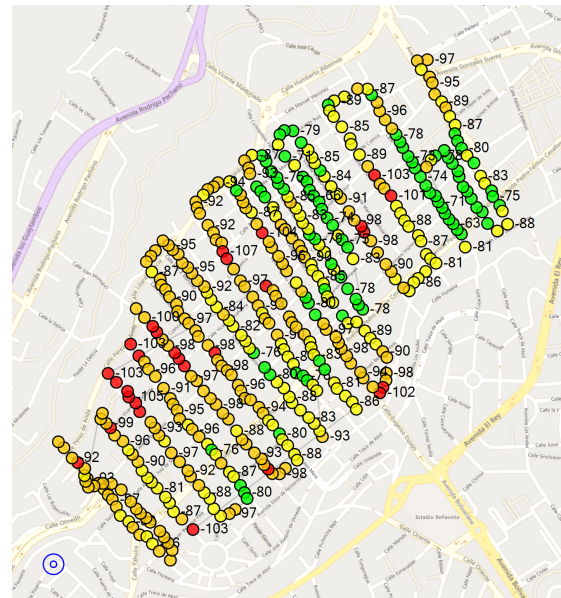


Fig. 4. Pedestrian Measurements on secondary streets, day 1.

#### F. Transmitters Data

An essential feature of the application is the detection of the eNodeB locations, visible in Fig. 6. Physical verification ensured the accuracy of this information; subsequently it was used in professional software.

In addition to location other BS parameters are required, such as: height, power, and azimuth. The Smart Measure mobile application determined height by using the device's position sensor or gyroscope. It calculates the height of an object, person, or building based on the device's inclination angle and the object's distance [22]. This app is freely available on the Play Store. Azimuth was determined by assessing the direction towards each transmitter's antennas. Fig. 7 demonstrate the approximate height of Radio Bases 1 (eNodeB1) with the Smart Measure app. Similar measurements determined the

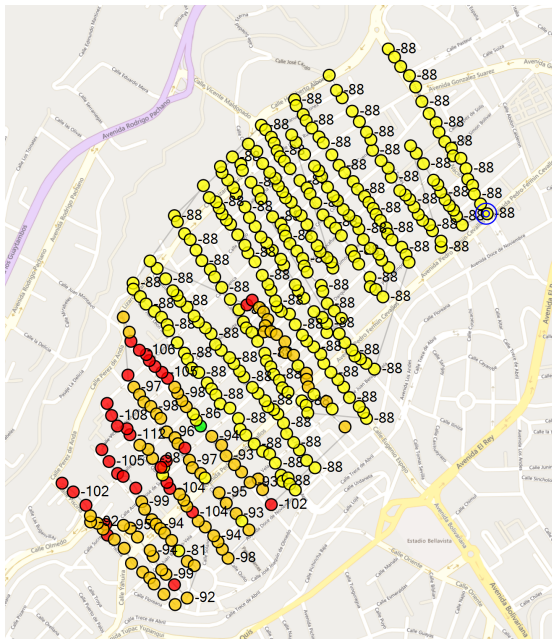


Fig. 5. Vehicular Measurements on secondary streets, day 1.

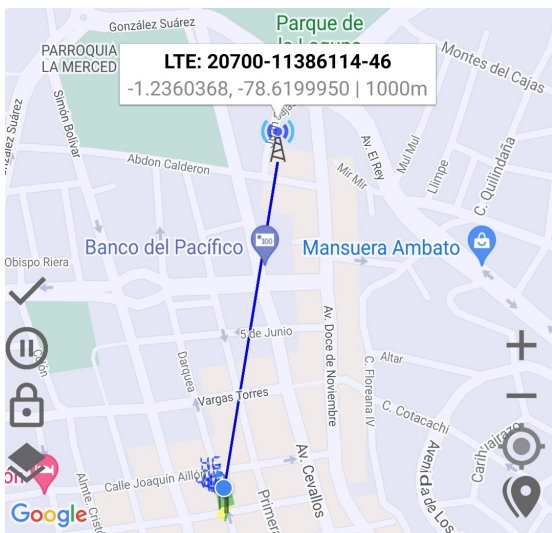


Fig. 6. Location of a radio base in Network Cell Info Lite.

heights of other radio bases.



Fig. 7. eNodeB1 Height Measurement with Smart Measure.

The transmission power for each transmitter was provided by documentary research, and are shown in Table I.

In Fig. 8, the transmitters are shown in professional software.

TABLE I  
LOCATION, HEIGHT AND POWER OF SIMULATED BASE STATION'S

Base Station	Latitude	Length	Height (m)	Power (dBm)
eNodeB1	-1.2340687	-78.6210706	19.2	20
eNodeB2	-1.2304.486	-78.6201355	10	15.2
eNodeB3	-1.2343.976	-78.6270402	17.6	15.2
eNodeB4	-1.2390.414	-78.6254815	23.4	20
eNodeB5	-1.2383.217	-78.6341460	32.5	15.2
eNodeB6	-1.2438.109	-78.6237679	26.1	15.2
eNodeB7	-1.2426.290	-78.6272775	47.5	15.2
eNodeB8	-1.2390.116	-78.6302313	26	18.2
eNodeB9	-1.2439.732	-78.6306816	23.8	15.2
eNodeB10	-1.2468.072	-78.6307168	6.2	15.2
eNodeB11	-1.2446.881	-78.6388533	12	15.2



Fig. 8. Distribution of the base station transmitters in the simulation environment using professional planning software.

G. Data Organization

The initial phase, involved organizing the collected data, maintaining a consistent process over the 7-day duration. For practicality, data was segmented according to each street within the historic center of Ambato, ranges from excellent, good, fair to poor [23] was selected as is shown in Table II outlines the RSRP parameter values indicating LTE signal quality. Moreover, data overlap at intersections between main and secondary streets was prevented. Details for the main street, Av. 12 de Noviembre, are presented in Fig. 9.

TABLE II  
LTE SIGNAL QUALITY PARAMETERS

	RSRP (dBm)	RSRQ (dBm)	SNR (dBm)	Reference colors	
Conditions	Excellent	≥ -80	≥ -10	10 to 30	
	Good	-80 to -90	-10 to -12	10 to 3	
	Fair	-90 to -100	-12 to -14	0 to -3	
	Poor(edge cell)	≤ -100	-14 to -17	-3 to -20	

Is important to note, that comparing the RSRP values obtained between the REDMI NOTE 8 PRO (mid-range) and the TECNO CAMON 18P (low-range) mobile devices, no substantial difference was observed (< 1 dB). Hence, REDMI



Fig. 9. RSRP Organized Data on AV. 12 DE NOVIEMBRE. Day 1.

NOTE 8 PRO mid-range device data were utilized for network analysis and evaluation.

#### H. Data Processing

Following the organization of the collected data, Figs. 10 and 11 show the processed histograms of RSRP measurements taken on the first day, both pedestrian and vehicular within the historic center of Ambato. Furthermore, Table III summarizes the percentage distribution of the measurements taken over 7 days, classified into excellent, fair, good, and poor values.

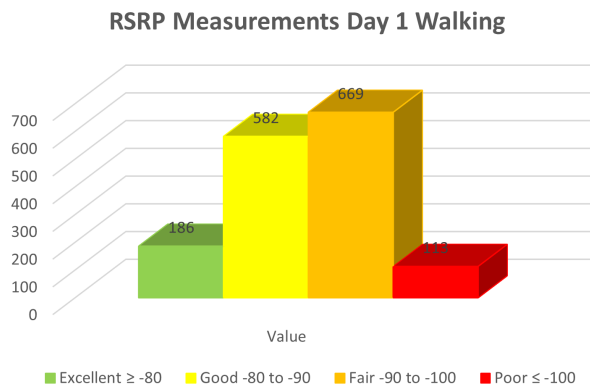


Fig. 10. RSRP (dBm) Measurement Histogram for day 1 and Pedestrian reception.

#### I. Data Analysis

According to Table III, there is a degradation in signal quality when measurements are taken inside a vehicle. This is due to the signal being attenuated by the vehicle's structure,

RSRP Measurements Day 1 Vehicle

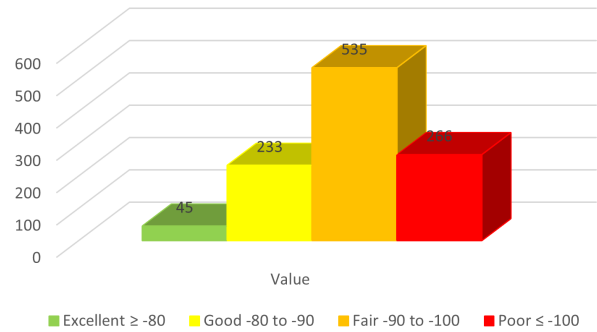


Fig. 11. RSRP (dBm) Measurement Histogram for day 1 and vehicular reception.

adding an obstacle to signal penetration. Vehicle speed also contributes to the degradation of the received signal due to the Doppler effect. This degradation pattern remained consistent throughout the 7-day measurement period.

TABLE III  
PERCENTAGE OF RSRP VALUES IN THE 7 DAY'S OF MEASUREMENT

		RSRP			
		Excellent	Good	Fair	Poor
Day 1	Pedestrian	12%	37.55%	43.16%	7.29%
	Vehicular	4.17%	21.59%	49.58%	24.65%
Day 2	Pedestrian	11.06%	33.17%	46.62%	9.15%
	Vehicular	4.92%	25.66%	48.11%	21.31%
Day 3	Pedestrian	9.64%	30.49%	43.84%	16.02%
	Vehicular	4.33%	25.51%	47.97%	22.19%
Day 4	Pedestrian	7.23%	26.75%	50.25%	15.76%
	Vehicular	4.35%	26.19%	46.94%	22.53%
Day 5	Pedestrian	4.28%	22.23%	53.99%	19.50%
	Vehicular	5.76%	26.19%	45.94%	22.09%
Day 6	Pedestrian	8.02%	26.44%	44.73%	20.80%
	Vehicular	5.19%	26.94%	42.34%	25.52%
Day 7	Pedestrian	4.12%	28.24%	47.79%	19.85%
	Vehicular	2.32%	23.55%	49.74%	24.39%

In addition to the consistent degradation observed in vehicular measurements, a daily variation pattern can be identified. Pedestrian data generally shows higher percentages in the "Excellent" and "Good" categories across most days. However, on Day 4, both pedestrian and vehicular measurements recorded similar values in the "Good" range (26.75% and 26.19%, respectively). Notably, on Day 5, the combined "Excellent" and "Good" percentage was slightly higher in vehicular measurements (31.95%) than in pedestrian ones (26.51%), suggesting temporal or environmental factors may have influenced signal propagation. These fluctuations may be attributed to dynamic factors such as network traffic load, atmospheric conditions, or user mobility patterns.

### III. RESULTS AND DISCUSSION

This section addresses the evaluation of CNT's 4G service performance in the Historic Center of Ambato, focusing on

the measured radioelectric parameter (RSRP).

**A. User Evaluation**

With the consecutive seven days measurements data, the RSRP was assessed to determine the operability level of CNT's 4G service in Ambato's Historic Center. This process involved calculating the average power values obtained on the streets within the area during the measurement days, as depicted in Figs. 12 and 13.

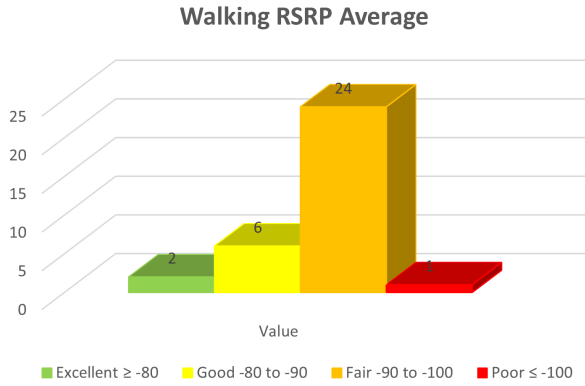


Fig. 12. Average RSRP values (dBm) in the Historic Center of Ambato Pedestrian.

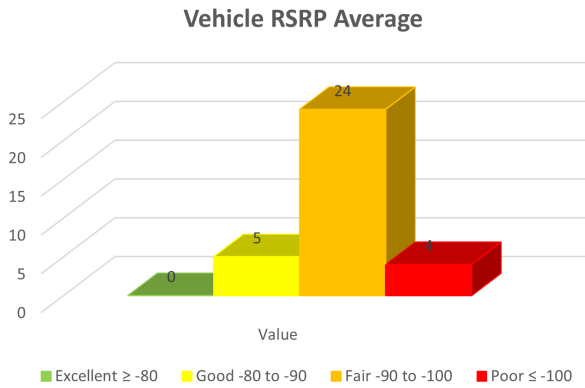


Fig. 13. Average RSRP values (dBm) in the Historic Center of Ambato from vehicular reception.

For vehicular reception, no streets achieved averages considered excellent within the 33 measured streets. Most RSRP averages of the 30 measurement streets fall between good and fair levels, represented with yellow and orange colour, respectively. Additionally, there's an increase in three streets with values below -100 dBm, classified as poor. These streets are Vicente Rocafuerte with -101.80 dBm, Juan León Mera with -100.04 dBm, and Quito with -100.10 dBm. The color-coded representation of the total RSRP averages for vehicular reception are presented in Fig. 14.

**B. Evaluation using the SMA-QoS-9 Parameter**

A regulation issued by ARCOTEL governs service quality, defining 12 quality parameters identified as SMA-QoS

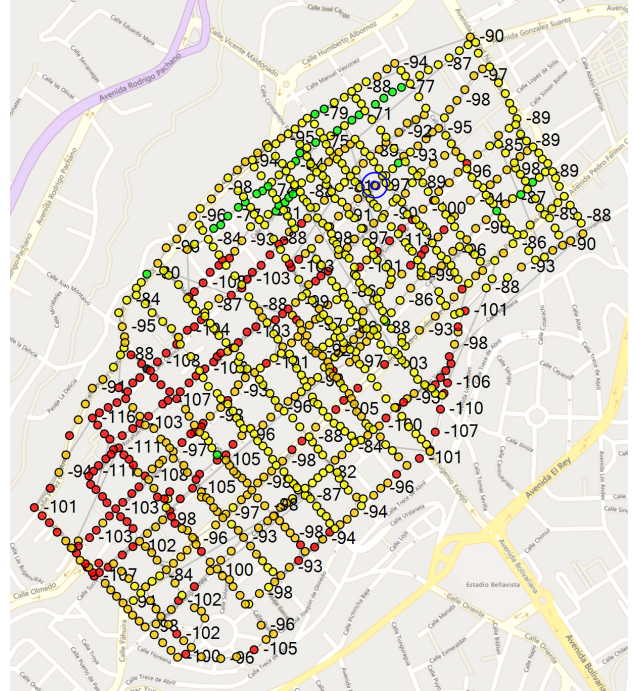


Fig. 14. Average RSRP values (dBm) of each street represented with colors for vehicular reception.

followed by a number [24]. This investigation evaluates the SMA-QoS-9 quality parameter, focusing on the minimum signal level for 4G technology in a coverage area. ARCOTEL oversees 4G service quality by analyzing RSRP values in a drive test, at a maximum speed of 60 km/h. The method used for measurements is known as linear binning, which involves obtaining the average coverage measurement (RSRP for 4G) sequentially, using a linear binning of 10 meters. These aspects, speed and linear binning, were achieved for measurements in Ambato's historic center. The minimum level required by ARCOTEL is specified as:

- $\%C \geq 95\%$  of the minimum signal coverage level, for each parish evaluated in the year.
- $\%C = 100\%$  of the minimum signal coverage level on roads, with respect to the expansion plan compliance for roads, if the provider had such an obligation [25].

Where, the coverage percentage ( $\%C$ ) is obtained using Equation 1:

$$\%C = \frac{n_s}{n} \times 100 \tag{1}$$

Where,  $n_s$  is the number of samples with signal level of the control channel on the terminal equipment greater than or equal to the minimum level,  $n$  is the number of valid samples, and  $\%C$  is the percentage of coverage for each parish or road, and by technology.

ARCOTEL's regulations specify the minimum signal levels in coverage, as detailed in Table IV. Where Rx Level represents the reception level in the control channel in idle mode for 2G networks, RSCP (Received Signal Code Power) indicates the received power after despreading in idle mode for 3G networks, and RSRP (Reference Signal Received Power) measures the power of the reference signal in 4G networks.

For LTE, due to its informational nature, the values specified in Table II were used for coverage calculations.

TABLE IV  
MINIMUM SIGNAL LEVEL IN COVERAGE FOR 2G, 3G, AND 4G TECHNOLOGIES

SOURCE: ARCOTEL, 2018 [25]			
Site	Rx Level (2G)	RSCP (3G)	RSRP (4G)
Measurement zone	$\geq -85 \text{ dBm}$	$\geq -85 \text{ dBm}$	Informative
Roads	$\geq -98 \text{ dBm}$ , technology independent		

The sample size includes all samples collected during the drive test in the parishes and/or roads under study. The number of valid samples  $n$  comprises those with geographic location references (latitude and longitude coordinates) [1].

The example shows the procedure for calculating the percentage of coverage  $\%C$  on the first day of measurements for pedestrian and vehicular reception, obtaining values of 92.71% and 75.35% respectively (see Equations 2 and 3).

$$\%C = \frac{1437}{1550} \times 100 = 92.71\% \quad (2)$$

$$\%C = \frac{813}{1079} \times 100 = 75.35\% \quad (3)$$

The coverage percentages of the CNT 4G network during the 7 days of measurements are shown in Table V, showcasing significant variations based on the day and the type of reception.

TABLE V  
COVERAGE PERCENTAGE OF CNT'S 4G NETWORK IN AMBATO'S HISTORIC CENTER [26]

Survey Day	Methods	$n_s \geq 100 \text{ dBm}$	n	$\%C$
Day 1	Pedestrian	1437	1550	92.71%
	Vehicular	813	1079	75.35%
Day 2	Pedestrian	1331	1465	90.85%
	Vehicular	831	1056	78.69%
Day 3	Pedestrian	1132	1348	83.98%
	Vehicular	845	1086	77.81%
Day 4	Pedestrian	1165	1383	84.24%
	Vehicular	784	1012	77.47%
Day 5	Pedestrian	1090	1354	80.50%
	Vehicular	797	1023	77.91%
Day 6	Pedestrian	1165	1471	79.20%
	Vehicular	788	1058	74.48%
Day 7	Pedestrian	1050	1310	80.15%
	Vehicular	716	947	75.61%
Average	Pedestrian	8370	9881	84.71%
	Vehicular	5574	7261	76.77%

The total coverage percentages for both Pedestrian and Vehicular measurements were 84.71% and 76.77% respectively, falling below ARCOTEL's minimum requirement. It's important to note that mobile phones were used for these measurements, suggesting the need to compare these results with professional-grade measuring equipment in future investigations. However, it gives a more realistic reception quality experimented by subscribers.

### C. Simulation Evaluation using SMA-QoS-9 Parameter

In the simulation, the coverage prediction was conducted based on the transmitter signal levels, employing a Signal Level Coverage Prediction approach. The operating ranges were established according to LTE standards, as depicted in Table II. Fig. 15 presents the resultant map of this prediction along with the histograms providing detailed visualization of the coverage by signal level.

The LTE-A coverage simulation employed the COST-231 Hata model, widely used for urban macrocells in sub-3 GHz bands. Although the digital terrain model and generalized clutter losses were considered, detailed urban obstructions—such as buildings—were not explicitly modeled, which may account for the more optimistic results compared to field measurements.

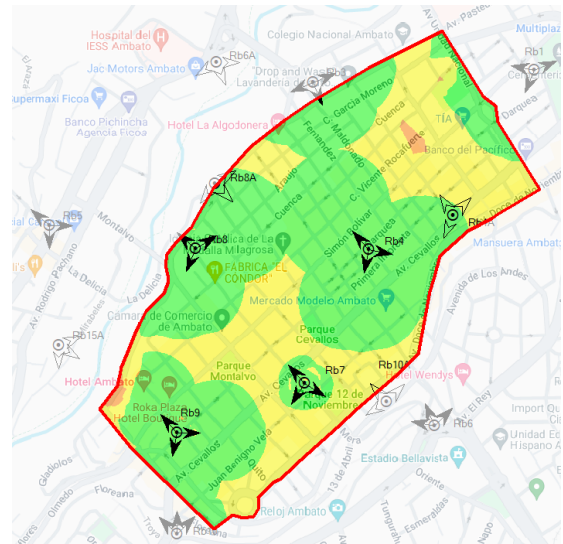


Fig. 15. Signal Level Coverage Pedestrian in Professional Software.

Analysis shows that in the simulated network in Fig. 16, RSRP values are predominantly distributed in the range of -80 to -70 dBm, constituting 66.99% of values classified as excellent. Furthermore, values between -90 and -80 dBm, categorized as good, account for up to 32.29%, while values between -100 and -90 dBm, considered fair, represent 0.728%. Notably, no values below -100 dBm were observed in the simulation.

These results demonstrate the potential of simulation tools to meet regulatory thresholds under idealized conditions. However, field measurements provide critical inputs to refine and calibrate these models, especially in complex environments. This reinforces the value of low-cost, user-based measurement strategies like the one presented in this study, which can help bridge the gap between modeled and real-world performance, guiding network optimization.

According to ARCOTEL's defined parameters, the evaluation determines that the network meets the required percentage ( $\geq 95\%$ ) of values equal to or greater than the minimum value ( $\geq -100 \text{ dBm}$ ). In the simulated network, all values surpass the threshold of -100 dBm, achieving a coverage percentage  $\%C=100\%$ . Here it could be noted the important of conduct

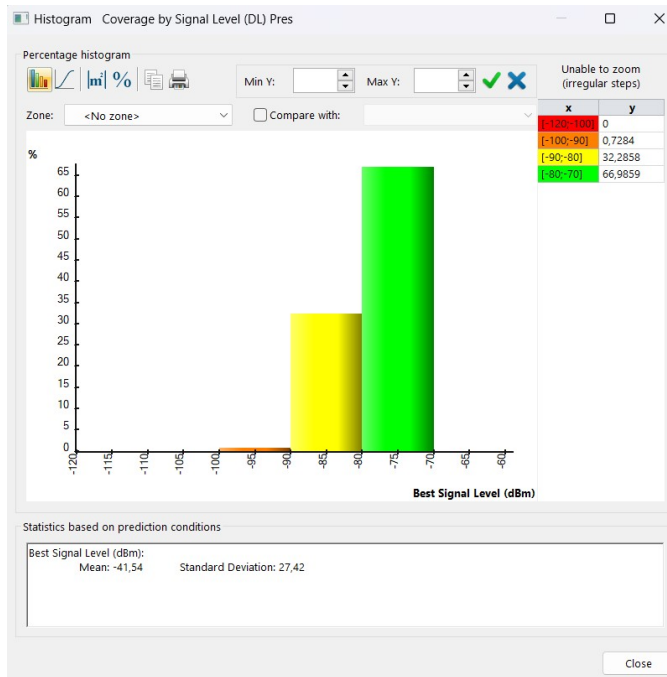


Fig. 16. Signal Level Coverage Histogram Pedestrian in Professional Software in percentages.

massive measurement campaigns to ensure the real accomplishment of the normative.

To contextualize the RSRP values measured in Ambato's Historic Center, results were compared with similar LTE studies. In Madrid, Kazmierczyk [27] reported that only 23.93% of measurements exceeded -83 dBm, while 15.88% were below -105 dBm, indicating notable signal degradation even in a major European city. In contrast, 84.71% of Ambato's pedestrian measurements were above -100 dBm. Likewise, a study at Universidad Privada de Bolivia found RSRP averages between -82 and -91 dBm for two operators [28], which aligns with Ambato's -91.61 dBm average. These comparisons support the validity of the present study and confirm that LTE signal variability is common in diverse urban scenarios.

#### IV. CONCLUSION

RSRP field measurements revealed a 2.43 dB reduction in signal strength when comparing pedestrian (-91.61 dBm) and vehicular (-94.04 dBm) reception, mainly due to Doppler effects, multipath propagation, and signal attenuation in indoor or obstructed environments.

Out of the 33 streets evaluated in Ambato's historic center, only two exhibited excellent LTE signal quality (RSRP  $\geq -80$  dBm), while most were categorized as good or fair ( $-100$  dBm  $<$  RSRP  $<$  -80 dBm), and three streets under vehicular conditions fell into the poor category (RSRP  $<$  -100 dBm), as defined by 3GPP TR 36.942.

The simulation of the LTE-A network coverage of CNT using professional software revealed RSRP values ranging from -80 to -70 dBm, with 66.99% being excellent, 32.29% falling within the good range (-90 to -80 dBm), and 7.28% considered fair (-100 to -90 dBm). No values below -100 dBm were recorded in the simulation.

According to ARCOTEL's technical standard for mobile network quality, which requires  $\geq 95\%$  of coverage above -100 dBm, the measured field values failed to meet this target—registering 84.71% for pedestrian and 76.77% for vehicular measurements—primarily due to the city's complex terrain.

The methodological approach applied in this research offers a practical alternative for evaluating LTE coverage using accessible tools and real-world data. While operators typically rely on professional monitoring systems, complementary field measurements—especially in high-demand and geographically complex zones—can inform immediate decision-making and reinforce planning strategies. Additionally, the measured data can serve as a baseline to calibrate simulation tools, improving network planning accuracy. Importantly, maintaining LTE networks within optimal thresholds is essential not only for current service quality but also to ensure an efficient and scalable deployment of 5G NR in both NSA and SA configurations.

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