Characterization and Evaluation of the Visual Impact of Mobile Communication Base Stations in the Urban Environment

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Abstract —Besides the increase of mobile communication services and providers in Peru, base stations (BS) have grown greatly without considering their visual impact. The characterization and evaluation of the visual impact from base stations to urban landscapes was carried out in the district of San Miguel, located in Lima, Peru. This district has a number of base stations suitable to conduct a pilot study. National and international regulations in force were reviewed, and the Manual for Camouflage of Radio Stations from Bogota DC, Colombia, was chosen as the basis for the visual impact evaluation. Then, a field study of mobile base stations located in the district of San Miguel was accomplished. After that, the matrices for evaluating the visual impact to each of the BS were applied. According to the evaluation, 12 BS (20.3 %) have a low visual impact, 42 BS (71.2 %) have a medium visual impact, and 5 BS (8.5 %) have a high visual impact. So, more than 90 % of the BS in San Miguel has low or medium visual impact.

***Index Terms*—**Visual impact, mobile base stations, urban landscape, visual fragility

I. Introduction

In April 2020, operators reported a total of 36,513 mobile Base Stations (BS), with more than 11,796 BS in Lima alone, followed by 1,850 BS [1] in Piura. The importance of mobile services increased due to the Covid-19 sanitary emergency, producing a massive growth in Internet consumption in our country in such a way that the telecommunication operators made estimations for the deployment of mobile Base Stations (BS) expected for 2021 in order to attend to this increasing demand by considering the following estimation variables: population, penetration rate, monthly data consumption, traffic by 3G and 4G technologies, evolution of the operator in the market, capacity per mobile Base Station (BS) and per operator.

The result was 36,513 BS expected for 2021, without considering the shared use of infrastructure among operators, the use of the same radiating elements (antennas), and the same supporting structure (towers) [1]. However, the growing insertion of BS in urban areas has caused displeasure in the communities that are increasingly sensitive to the quality of life aspects, due to the BS infrastructure. Likewise, OSIPTEL estimates that by 2025, 60,761 base stations will be required, which means that 36,695 additional antennas would have to be implemented in order to enjoy the benefits of the new 5G technology [1]. In Lima alone, more than 25,000 additional base stations would be required.

At present, our cities are more connected to the Internet. They are experiencing radical changes in how work, social interaction, and consumption are done.

There isn`t a detailed study in Peru related to the BS characteristics that generate visual impact in the urban landscape of our cities; therefore, this study aims to quantitatively evaluate the BS visual impact of the district of San Miguel as a pilot study based on their characteristics.

A. *Characteristics of Mobile Communication Networks and Their Base Stations*

Some of the main characteristics of the mobile communication networks are:

- Operation under the form of a cellular network (cells). Instead of using a high-power and high-range transmitter, the coverage area is subdivided into smaller areas called cells where the central element is the base station.
- Base stations are fixed installations interconnected with mobile phones through radio frequency (RF) electromagnetic waves and their own mobile network switch through microwave or fiber optic links.
- The antennas of the base stations are mounted on towers, poles, drinking water tanks, and other existing infrastructures, or distributed on the walls of the highest part of the buildings, as they require being placed at a certain height in order to have wider coverage.
- The mobile switching center (which can be composed of one or more interconnected switches) is the intelligent element of the network. Through it, the interconnection with other mobile networks is carried

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out for communication with other mobile subscribers, fixed telephone switches, and fixed subscribers.

Fig. 1 schematically illustrates the characteristics mentioned above.

- When someone calls by mobile phone, he/she is connected to a nearby base station. From the base station, the telephone call goes to the mobile switching center that connects us with any other mobile subscriber or land line subscriber.
- When the service is started in a determined area, usually there are only a few subscribers. As they increase, a greater number of BS will be required.

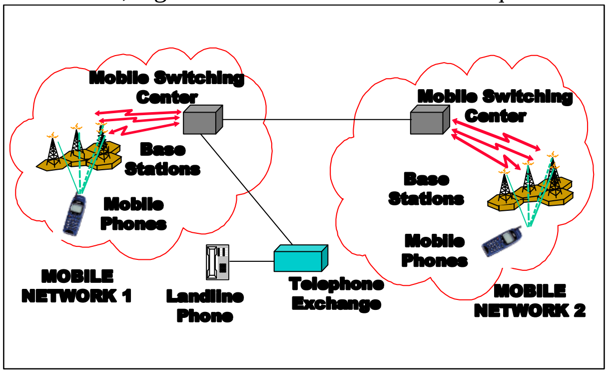

Fig. 1. Basic scheme of a mobile communication system [2] (V. Cruz, 2015)

Base Stations

They are radio stations for mobile communication networks.

Fig. 2 schematically illustrates the elements of a base station.

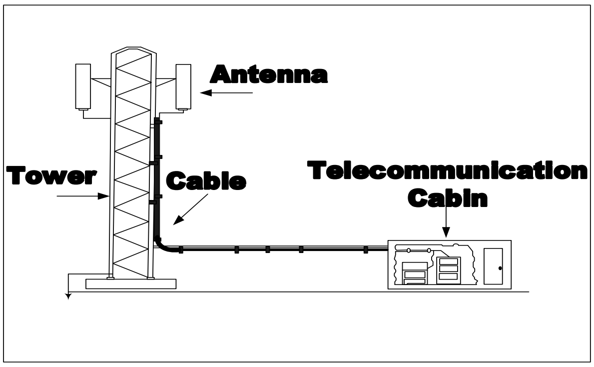

Fig. 2. General view of the antenna subsystem installation in a base station [3] (V. Cruz, 2006)

B. *Visual Impact*

The visual impact is the degree of discordance caused by an infrastructure [4] with respect to the natural or urban landscape. The solution for the visual impact is the integration of the element into the environment, especially in the case of places with great landscapes or monumental values.

According to Rivera [5], there are several physical health conditions caused by visual impact which are dependent on the vulnerability of each person, such as: stress, headache, distractions interfering with normal performance, and road accidents.

The visual impact perceived through the sense of sight exposes invasive aggressive stimulus to millions of people every day, especially in the cities; there are no filters or defenses against them [6].

A parameter that allows for the quantification of this impact is the Landscape Visual Fragility, which is an inverse function of the absorption capacity of alterations without loss of quality, when a use is developed on it. That is a way to establish its vulnerability.

Fig. 3 shows the components of the visual fragility concept.

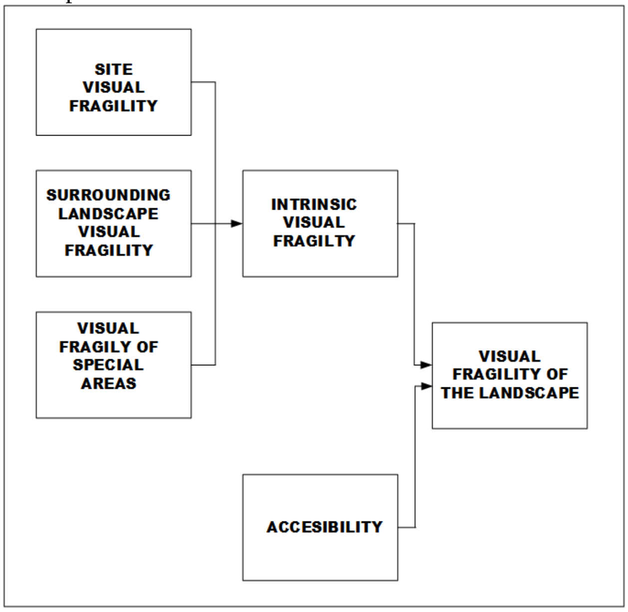

Fig. 3. Components of visual fragility [3] (V. Cruz, 2006)

The Visual Fragility of a Landscape is an inverse function of the absorption capacity of alterations without losing quality.

- The Visual Fragility of the Site considers the biophysical factors derived from the characteristic elements of each site, such as: the type of soil, the slope of the surrounding terrain, the vegetation, and the orientation.
- The Visual Fragility of the environment is constituted by visualization factors based on the configuration of the environment of each place; among the main ones is the visual basin or surface seen from each place.
- The Visual Fragility of the Area of Special Places includes the historical-cultural factors that tend to explain the character and shape of the landscapes based on the historical process that has produced them, weighing the existence of singular values within a landscape, according to the scarcity, traditional value, and historical interest, and are decisive for the compatibility of form and function of future actions in the environment. The weighted sum of these three factors results in Intrinsic Visual Fragility.

Observation Accessibility considers the height of towers, the distance and visual accessibility from roads and population centers, obtaining the Total Visual Fragility Index.

Elements of infrastructure which cause visual impact

- Cabins (standardized buildings), including walls, doors, floors, and roofs aimed to house BS equipment.
- Antenna system supports (masts or towers) in which it is possible to act on its dimensions, forms of support and design, as well as its wind bracing.
- Antenna systems that include the antennas themselves and the transmission line or waveguide.
- Mesh perimeter fences or walls used to delimit the space of a site where an BS is located.
- Roads to access BS located in rural areas.

Fig. 4 shows the main elements causing visual impact for a base station in the city of Lima.

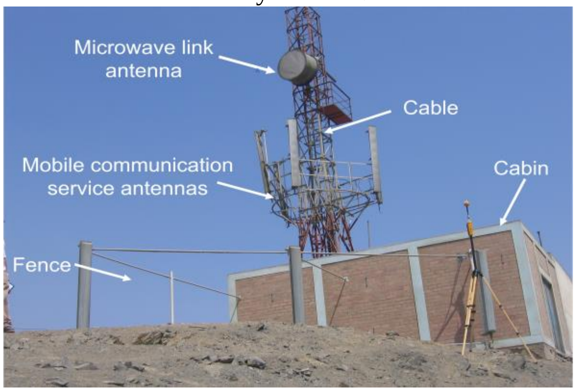

Fig. 4. Main elements of infrastructure causing visual impact [3] (V. Cruz, 2006)

The antennas can be mounted on towers on the roofs of the houses, attached to the walls of the houses, or in public spaces. The greatest impact occurs when the houses surrounding the installation are low profile, such as houses with one or two floors. In such cases, the towers or posts can have a fairly large obstructive effect if they are not properly camouflaged. They can also be located on buildings with more floors to generate less visual impact.

The BS antennas could be installed on a self-supporting tower, a guyed mast, or a monopole Tower. Guyed masts are usually made of steel or galvanized steel, and most of them are designed as a latticework structure (Fig. 5) [7].

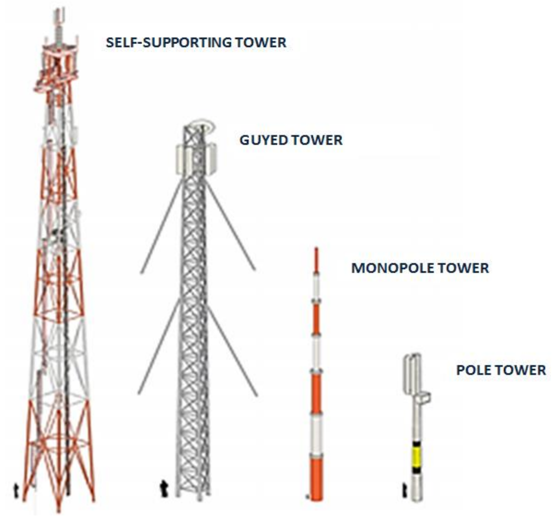

Fig. 5. Type of antenna supports. (CRCOM-Colombia, 2020)

The Mobile Infrastructure Project has been carried out to delivered 2G, 3G and 4G mobile connectivity through 75 mobile masts to 7,199 premises which previously had no mobile signal. Its objectives were to support economic growth in the United Kingdom (UK), including in rural areas, by improving the coverage and quality of mobile network services for consumers and businesses that live and work in areas of the UK where existing mobile network coverage was poor or non-existent [8].

The Department for Culture, Media and Sport (DCMS) of the UK in 2013 signed a contract with Arqiva to search and acquire mobile mast sites, then build and manage the sites. Arqiva [9] reported the key siting issues that would be properly considered in selecting a particular site. This issues could be included in the Visual Fragility of Landscape [3] and classified as follow:

The Visual Fragility of the Site

- Landscape character appraisal
- The height of the site in relation to the surrounding land
- The effect on the skyline
- The prominence of the site
- General topography and vegetation

The Visual Fragility of the Surrounding Landscape

- The relationship to neighbouring residential properties
- The relationship to existing masts and to other structures and buildings including cumulative impact
- The provision of landscape and other screening.

The Visual Fragility of the Area of the Special Places

- The presence of a valued natural or built environment
- Siting and design in sensitive townscapes and landscapes

This fact confirms the applicability of the Visual Fragility concept to evaluate the visual impact of mobile BS.

II. Methodology

A. *Regulatory Framework in Peru*

Before starting the visual impact evaluation on mobile phone base stations, the current regulations in Peru should be known.

Law No. 28295[10]: Its purpose is the distribution of mobile phone service operators on towers and buildings. In addition, it aims to share the entire mobile network in order to efficiently use the infrastructure for public use, mitigate the impact on the urban landscape, and promote the rational use of public space while reducing economic and social costs [9].

The third complementary provision of Supreme Decree No. 003-2015-MTC [11] and its amendment S.D. No. 004-2019-MTC [12] indicates the guidelines for installing antennas and communication towers to order the deployment, and to reorder the already installed telecommunication base stations. Besides that, the eleventh provision establishes the guidelines for installing antennas and telecommunications towers while considering the best national and international practices on Antenna Camouflage and Telecommunications Infrastructure for minimizing their visual impact.

B. Regulatory Framework in Colombia

In August 2017, the Mayor's Office of Bogota issued Decree 397 of 2017 [13], which establishes the procedures and the urban, architectural, and technical standards for the location and installation of radio stations used in the provision of ITC public services in Bogota DC. Other provisions were also issued, such as: The Manual of Camouflage of Radio Electric Stations for Bogota D.C. [14], as a technical input for operators and/or infrastructure providers.

To quantify the visual impact generated by telecommunications stations, factors such as the location of the station, the height of the elevation structure, the quantity and size of the radiating elements, among others, are considered. For that, it is necessary to evaluate the level of impact for a better choice of camouflage alternatives.

The Standard defines five evaluation matrices (Table I to Table V) which take into account the different impacts caused by the stations in the urban context. The first is for rooftop stations, the second is for stations at ground level, the third is for stations located in public spaces, and the fourth and fifth for stations with a permit exemption and, according to that, its low, medium, or high impact will be evaluated. Impact matrices are classified into:

Impact evaluation matrix of rooftop stations, which evaluates:

- Impact caused by the location of the station
- Impact caused by the elevation structure
- Impact caused by the number and size of antennas
- Impact caused by the equipment

Impact evaluation matrix of stations at ground level, which evaluates:

- Impact caused by the location of the station
- Impact caused by the structure
- Impact caused by the number and size of antennas
- Impact caused by the equipment
- Impact caused by building enclosure

Impact evaluation matrix of stations in public spaces, which evaluates:

- Impact caused by the location of the station
- Impact caused by the number and size of antennas

Impact evaluation matrix of exemptions attached to the point, which evaluates:

- Impact caused by the location of the station
- Impact caused by the elevation structure
- Impact caused by the number and size of antennas

Impact evaluation matrix of exemptions attached to the facade, which evaluates:

- Impact caused by the location of the station
- Impact caused by the elevation structure
- Impact caused by the number and size of antennas

TABLE I: IMPACT CAUSED BY THE LOCATION OF THE STATION

Impact to be measured		Impact (points)
Impact caused by the location in respect to a block	BS located at the back of the property, inside the block, has low impact: One (1) point. BS located near the façade of the property, inside the block, has a medium impact: Five (5) points BS located on a property which is adjacent to the block, has a high impact: Ten (10) points. BS located on a bigger property or block, has a low impact: One (1) point. BS located at the front of the property, set back by the garden, has a medium impact: Five (5) points. BS located on a property with double front, facing a road: The impact is high: Ten (10) points,	
Impact caused by the location in respect to the road system	BS located on an arterial road network, has low impact: One (1) point. BS located on an intermediate road network, has medium impact: Five (5) points. BS located on a local road network, has high impact: Ten (10) points.	

TABLE II: IMPACT CAUSED BY THE ELEVATION STRUCTURE

Impact to be measured		Impact (points)
Type of elevation structure	If the elevation structure is a truncated pyramid with a triangular base and a section larger than 3.0 meters, the impact is high: Ten (10) points. If the elevation structure is self-supporting with a square cross section between 1.0 and 1.5 meters, the impact is medium: Five (5) points. If the elevation structure is reinforced with a triangular or square cross section between 0.40 and 0.60 meters, the impact is low: One (1) point. If the elevation structure is a monopole type with a cross section between 0.60 and 1.0 meters, the impact is low: One (1) point.	
Percentage of elevation structure from the roof level of the highest	If the elevation structure has a percentage less than or equal to 25% of the height of the highest adjacent, the impact is	

border	low: One (1) point. If the elevation structure has a percentage between 26% and 50% higher than the roof level of the highest adjacent, the impact is medium: Five (5) points. If the elevation structure has a percentage greater than 51%, at the highest adjoining roof level, the impact is high: Ten (10) points.	
Additional elements of the elevation structure	If the elevation structure, regardless of its type, does not have additional elements (mobile platform for antenna support), the impact is low: One (1) point. If the elevation structure, regardless of its type, has additional elements (mobile platform for antenna support), the impact is high: Ten (10) points.	

TABLE III: IMPACT CAUSED BY THE NUMBER AND SIZE OF ANTENNAS

	Impact to be measured	Impact (points)
Visibility of antennas at a distance of ten (10) meters at pedestrian level	If antennas have areas smaller than 1.0 m2, the impact is low: multiply the number of antennas by one (1) point. If the antennas have areas between 1.0 and 2.0 m2, the impact is medium: multiply the number of antennas by five (5) points. If the antennas have areas greater than 2.0 m2, the impact is high: multiply the number of antennas by ten (10) points. If you intend to install more than fifteen (15) antennas, regardless of their dimensions, the impact is high: multiply the number of antennas by ten (10) points.	
Distance from the antennas to the elevation structure	If the antennas have an additional support less than or equal to 10-meter-long, the impact is low: one (1) point. If the antennas have an additional support between 1.0 and 2.0 meters long, the impact is medium: five (5) points. If the antennas have more than one additional support, regardless of their dimensions, the impact is high: ten (10) points.	

TABLE IV: IMPACT CAUSED BY THE EQUIPMENT

	Impact to be measured	Impact (points)
Visibility of the cabin at floor level from the street	If equipment is not visible, the impact is low: one (1) point. If equipment is visible, the impact is high: ten (10) points.	

TABLE V: IMPACT CAUSED BY THE BUILDING ENCLOSURE

	Impact to be measured	Impact (points)
Translucent mesh	If the enclosure is not visible from the public space or is visible but camouflaged, the impact is low: one (1) point. If enclosure is visible from the public space, the impact is high: ten (10) points.	
Masonry or other	According to materials, colors, and textures with the immediate adjacent, the impact is low: one (1) point. If it is not consistent in materials, colors, and textures with the immediate adjacent, the impact is high: ten (10) points.	

This matrix allows for objectively measuring the impact of radio stations located in the public space within its urban context. The resulting valuation is equal to or greater than 100 units, the visual impact of the station is classified as high.

If the total points of the impact matrices are between 40 and 99 units, the visual impact is understood as medium. If the total points of the impact matrices are less than 40 units, the visual impact is classified as low.

Identification of locations of mobile phone base stations to be evaluated

To carry out the study, the district of San Miguel was chosen. It has 210 base stations.

This district is located in the coastal area of Lima, in the northwestern part of the province. It is 50 meters above sea level and its coordinates are: South Latitude 12º 4’ 38.14”, West Longitude 77º 5' 34.33” (District Municipality of San Miguel, 2016). It 155,384 inhabitants [15]

Procedure for the evaluation of mobile phone base stations

Based on the Manual of Camouflage for Radio Electric Stations in Bogota D.C. (2017) [14] and considering the experience of the Visual Impact Evaluation carried out in Quito, Ecuador [16], the procedure was as follows:

Since a pilot project can consider a sample between 30 and 50 units [17], 59 stations have been chosen as a study sample. 37 were rooftop base stations, 21 were at public spaces and only 1 was al ground level.

The technical prospecting to define the conditions for the field study was carried out considering the Planning Guide for the Development of Telecommunications focused on the visual impact as well as in the development of telecommunications.

The location was obtained through the Open Signal application. Likewise, the characteristics and predominant land use in the area were verified. Finally, the type and design of the facilities was verified.

For the data analysis, the Impact Evaluation Matrix was used for each case.

III. Results

The results of the whole evaluation are shown in Table VI.

TABLE VI: SUMMARY OF THE VISUAL IMPACT EVALUATION

#	Evaluation Matrix	Latitude	Length	Visual Impact Value
BS 1	Public space	-12.060573	-77.079701	27
BS 2	Public space	-12.060816	-77.079447	42
BS 3	Public space	-12.060522	-77.078731	47
BS 4	Rooftop	-12.068349	-77.103571	18
BS 5	Public space	-12.069159	-77.098779	41
BS 6	Rooftop	-12.069131	-77.098327	68
BS 7	Rooftop	-12.070865	-77.098679	63
BS 8	Rooftop	-12.066134	-77.09753	61
BS 9	Rooftop	-12.067729	-77.099918	75
BS10	Rooftop	-12.064307	-77.100099	46
BS 11	Public space	-12.064661	-77.104197	32
BS 12	Rooftop	-12.074012	-77.100855	123
BS 13	Rooftop	-12.074012	-77.100855	122
BS 14	Rooftop	-12.078198	-77.08867	37
BS 15	Rooftop	-12.077678	-77.086137	72
BS 16	Rooftop	-12.077701	-77.086085	**431**
BS 17	Rooftop	-12.07718	-77.085239	61
BS 18	Rooftop	-12.077221	-77.085222	59
BS 19	Public space	-12.07846	-77.085052	26
BS 20	Rooftop	-12.07902	-77.07774	69
BS 21	Public space	-12.07976	-77.0767	41
BS 22	Public space	-12.08106	-77.07315	56
BS 23	Rooftop	-12.08186	-77.07204	84
BS 24	Rooftop	-12.08205	-77.07178	67
BS 25	Overland	-12.0835	-77.07445	**212**
BS 26	Rooftop	-12.08574	-77.07519	63
BS 27	Rooftop	-12.0851	-77.08109	43
BS 28	Rooftop	-12.08254	-77.08226	45
BS 29	Public space	-12.082816	-77.085456	55
BS 30	Rooftop	-12.08304	-77.08548	64
BS 31	Rooftop	-12.08434	-77.08288	91
BS 32	Public space	-12.08667	-77.08365	43
BS 33	Rooftop	-12.088622	-77.085551	84
BS 34	Rooftop	-12.09018	-77.08373	**559**
BS 35	Public space	-12.08697	-77.08379	13
BS 36	Public space	-12.0893	-77.08116	40
BS 37	Public space	-12.09101	-77.07791	40
BS 38	Rooftop	-12.09151	-77.07624	69
BS 39	Rooftop	-12.09022	-77.07617	80
BS 40	Rooftop	-12.09022	-77.07549	65
BS 41	Rooftop	-12.09145	-77.07893	32
BS 42	Public space	-12.09011	-77.08155	40
BS 43	Rooftop	-12.08453	-77.08912	60
BS 44	Rooftop	-12.08628	-77.09026	80
BS 45	Public space	-12.08828	-77.09003	56
BS 46	Public space	-12.07866	-77.09464	31
BS 47	Public space	-12.07816	-77.09571	41
BS 48	Public space	-12.07625	-77.10002	26
BS 49	Rooftop	-12.07754	-77.10095	91
BS 50	Rooftop	-12.07896	-77.10156	60
BS 51	Rooftop	-12.07752	-77.10433	84
BS 52	Rooftop	-12.07972	-77.10335	75
BS 53	Public space	-12.07546	-77.08221	71
BS 54	Public space	-12.07325	-77.08691	36
BS 55	Rooftop	-12.07078	-77.09087	36
BS 56	Public space	-12.07013	-77.09147	21
BS 57	Rooftop	-12.06973	-77.0928	49
BS 58	Rooftop	-12.07046	-77.09419	80
BS 59	Rooftop	-12.06946	-77.09152	92

The value of the visual impact for stations in the public space, obtained from the matrix, varies from 13 (BS 35) to 71 (BS 53), the average being 39.3. in Fig. 6 the visual impact of stations in the public space is shown.

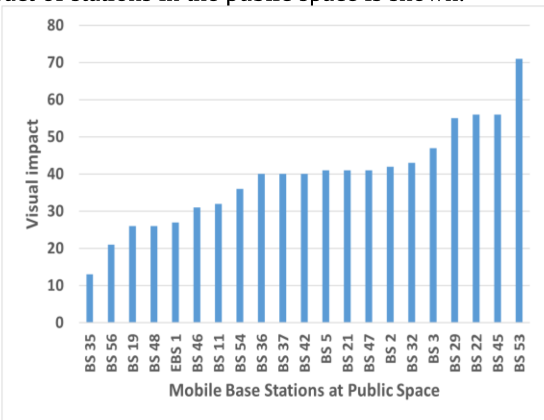

Fig. 6. Visual impact of mobile BS at public space

The value of the visual impact for rooftop stations, obtained from the matrix, varies from 18 (BS 4) to 559 (BS 34), the average being 90.8.

In Fig. 7 it can be seen visual impact of rooftop BS.

It means that the rooftop average (90.8) is more than double the average in public spaces (39.3).

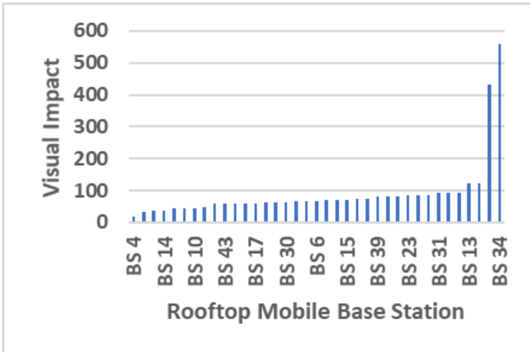

Fig. 7. Visual impact of rooftop mobile BS

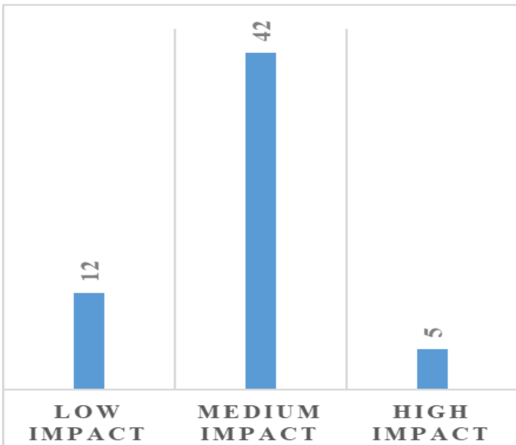

Fig. 8. Number of base stations per visual impact

Fig. 8 shows that out of a total of 59 base stations (BS), the majority of base stations (42 BS) offer a Medium Visual Impact, 12 BS present Low Visual Impact, while only 5 BS present High Visual Impact.

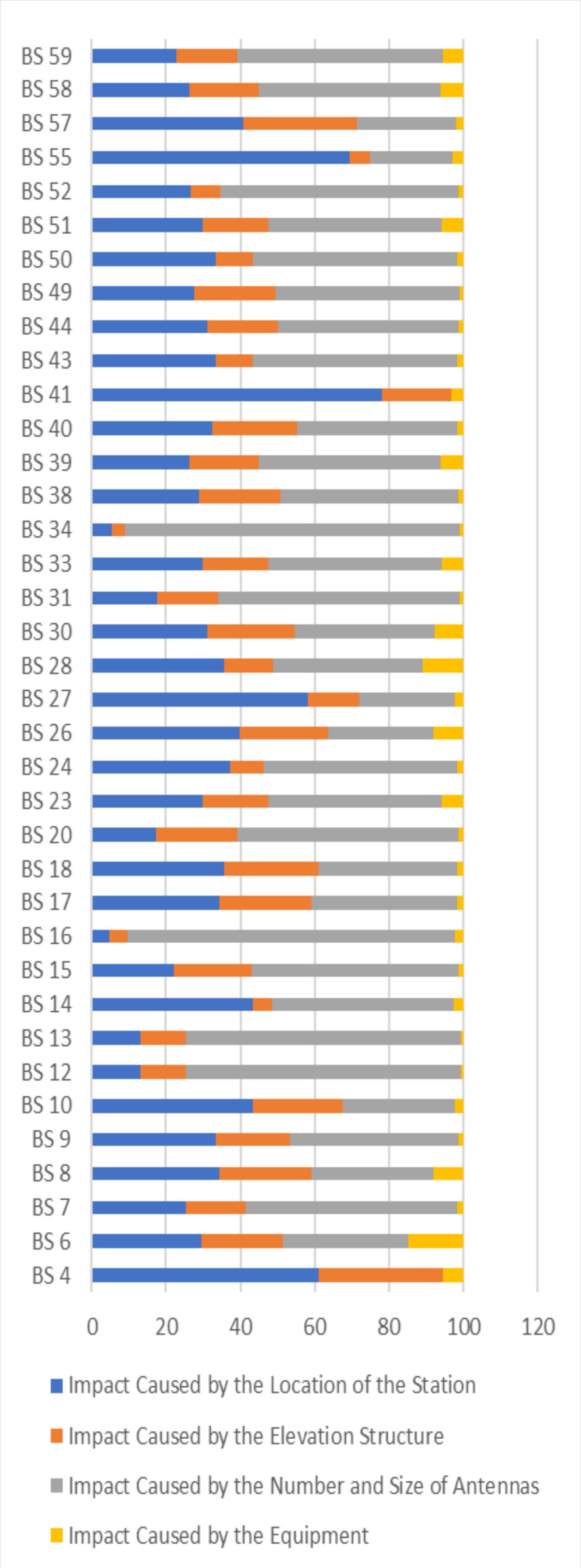

Fig. 9. Contribution per type of impact for rooftop BS (%)

The visual impact by component was analyzed separately for both rooftop base stations and base stations at public space, it could be observed from Fig. 9 and Fig. 10 that the main contributors to the total Visual Impact were the Impact Caused the Number and Size of Antennas and the impact Caused by the location of the Station.

- For rooftop BS 29 maximum contributions were due to antennas and 8 were due to location of the station.
- For base stations at public spaces 13 maximum contributions were due to antennas and 8 were due to location of the station.

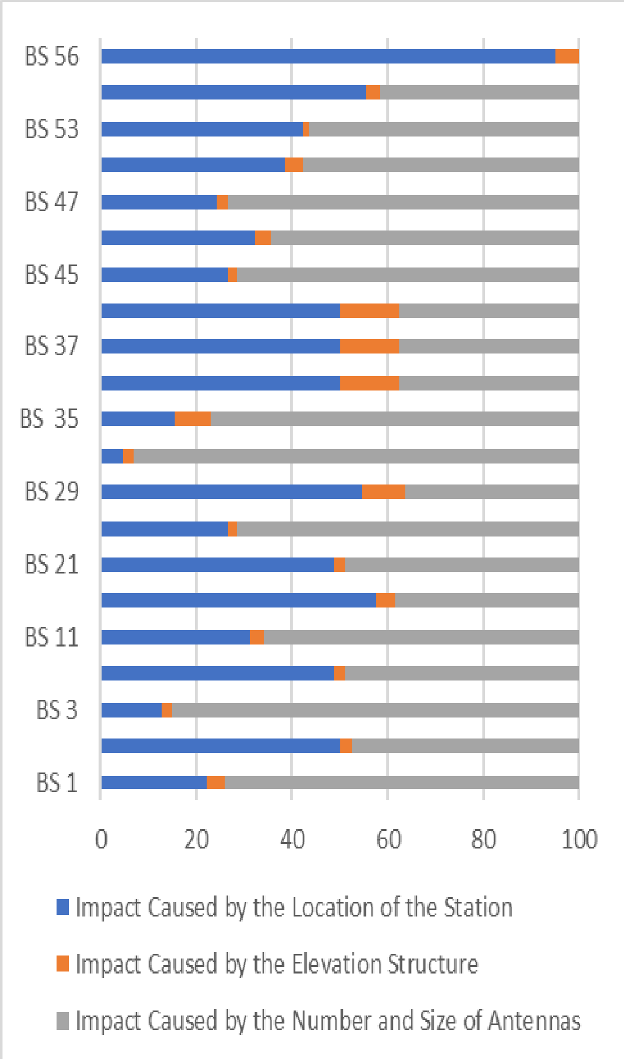

Fig. 10. Contribution per type of Impact for BS at public space (%)

The Impact Caused the Number and Size of Antennas is the main contributor to the total Visual Impact, this is the reason why it was carried out an analysis to know which of its component was prevalent. In Table VII and Table VIII is presented the results of this analysis.

- For rooftop BS 34 maximum contributions were due to visibility of antennas, 2 maximum contributions were due to distance to supporting structure and for 1 BS the contributions of the visibility and the distance of the antennas to the elevation structure contributed the same amount.

- For base stations at public spaces 7 maximum contributions were due to visibility of antennas, 7 maximum contributions were due to distance to supporting structure and for 6 BS the contributions of the visibility and the distance of the antennas to the elevation structure contributed the same amount.

TABLE VII: SUMMARY OF THE CONTRIBUTION TO VISUAL IMPACT OF ROOFTOP BASE STATIONS (%)

	Visibility of antennas	Distance of the antennas to the elevation structure
BS 4	50	50
BS 6	87	13
BS 7	89	11
BS 8	80	20
BS 9	97	3
BS 10	86	14
BS 12	66	34
BS 13	67	33
BS 14	83	17
BS 15	30	70
BS 16	50	50
BS 17	75	25
BS 18	77	23
BS 20	83	17
BS 23	85	15
BS 24	89	11
BS 26	83	17
BS 27	91	9
BS 28	83	17
BS 30	75	25
BS 31	76	24
BS 33	85	15
BS 34	50	50
BS 38	91	9
BS 39	85	15
BS 40	71	29
BS 41	50	50
BS 43	91	9
BS 44	85	15
BS 49	33	67
BS 50	91	9
BS 51	85	15
BS 52	71	29
BS 55	75	25
BS 57	85	15
BS 58	85	15
BS 59	86	14

TABLE VIII: SUMMARY OF THE CONTRIBUTION TO VISUAL IMPACT OF BASE STATIONS AT PUBLIC SPACE (%)

	Visibility of antennas	Distance of the antennas to the elevation structure
BS 1	50	50
BS 2	50	50
BS 3	75	25
BS 5	50	50
BS 11	52	48
BS 19	0	100
BS 21	50	50
BS 22	75	25
BS 29	50	50
BS 32	75	25
BS 35	0	100
BS 36	33	67
BS 37	33	67
BS 42	33	67
BS 45	100	0
BS 46	50	50
BS 47	100	0
BS 48	33	67
BS 53	75	25
BS 54	60	40
BS 56	50	50

IV. DISCUSSION

This paper analyzed visual impact of 59 EBC in San Miguel district, Lima, Peru and evaluated the magnitude and significance of the potential impact by selecting impact categories such as Low Impact, Medium Impact and High Impact.

A. Strengths and Limitations

This is the first study investigating the visual impact of mobile communication base stations in Peru. There is only a previous study on this subject published in South America which is a thesis carried out in Ecuador [15] that had a sample of 82 BS of which 17 BS (21 %) rated Low Impact, 74 BS (74 %) rated Medium Impact and 4 BS (5%) rated High Impact while in Peru the example was 59 BS, of which 10 BS (20.3 %) had Low Impact, 42 BS (71.2 %) had Medium Impact and 5 BS (8.5%) had High Impact. In general, the Ecuadorian results were similar to the ones of the Peruvian study but the High Impact BS were nearly twice those ones in the Ecuadorian study.

We also found The Mobile Infrastructure Project carried out in the UK that reported having used the same criteria for siting that were the basis for the matrices used in this evaluation [9].

One of the biggest limitation was the restricted working hours stablished in Peru because of the Covid 19 pandemic that extended the study time at least three additional months. Another limitation was the fact that the laser meter for tower height could not be used at daytime but only at night time.

B. Interpretation

The results of the study imply that it is necessary to stablish a better policy for visual impact management of mobile base stations in Peru including regulations and tools for evaluating this impact.

V. CONCLUSION

Peru has few regulations on visual impact management for mobile communication base stations; therefore, a Colombian Regulation was used to carry out the study.

This study proves that the characterization and evaluation of the visual impact for mobile base stations in Peru, and other countries, could be performed by using the matrices for evaluating the visual impact that are part of the Manual for Camouflage of Radio Stations of Bogota DC, Colombia.

The characteristics of the evaluated base stations are: location, size of the tower, number of antennas, equipment, and perimeter enclosures. These characteristics have been evaluated according to Table I-Table V.

According to the matrix evaluation, the visual impact of the base stations located in public spaces in the district of San Miguel, Lima, Peru, ranges from 13 (BS35) to 71 (BS53) and the average value is 39.3

The visual impact of the base stations on the over roof in the same area ranges from 18 (BS4) to 559 (BS34), and the average value is 90.8.

Comparing these two types of areas, the average visual impact from stations over the roof is more than twice that of the visual impact of stations in public spaces.

According to the evaluation, 12 BS (20.3 %) have a low visual impact, 42 BS (71.2 %) have a medium visual impact, and 5 BS (8.5 %) have a high visual impact. Therefore, more than 90% of the BS in San Miguel has a low or medium visual impact.

Conflict of Interest

The authors don't have any conflict of interest. All Authors worked for this paper.

Author Contributions

The authors Vanessa Vasquez, Victor Cruz and Maria Teresa Mendez carried out the general design of the paper and they also focus on the assessment of visual impact, Francisco Aguilar, Víctor Cruz and Mario Chauca focus on the mobile communications systems and Irma Solis focus in the Methodology. All authors review the paper.

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