TecnoLógicas

Telecommunications Network Infrastructure Sharing: An Assessment from Smart Cities Perspective

Compartición de infraestructura de redes de telecomunicación: una valoración desde la perspectiva de ciudades inteligentes

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Abstract

Cartagena de Indias is a Colombian tourist city whose historic center has been declared a World Heritage site. In recent years, the city has experienced significant expansion, capitalizing on the benefits derived from the sharing of the telecommunications network infrastructure (TNI). However, the impact of this infrastructure on the quality of life of citizens remains unknown. The aim of this research was to assess the impact of TNI sharing on the quality of life of citizens of Cartagena de Indias. The methodology consisted of four phases: a review of current regulations, the design of protocols and data collection instruments, data collection, and analysis of results. These phases were conducted using a quantitative exploratory approach, with a non-experimental and cross-sectional design. The results obtained were a list of characteristics describing the condition of TNI, which were used to assess the impact of TNI on quality of life, analyzing both the aesthetic impact on public spaces and the risks it poses to the physical safety of maintenance personnel, citizens, and the infrastructure itself. Finally, it was concluded that the main issue lies in the fact that the condition of most TNI not only negatively impacts urban aesthetics but also poses a risk of safety, affecting the quality of life of those who inhabit or visit the city. These findings highlight the importance of integrating the technologies and strategies characteristic of a smart city to improve the management and monitoring of TNI, optimizing both the safety and the urban experience.

Keywords

Public infrastructure, public security, resource sharing, smart cities, telecommunication network, urban planning.

Resumen

Cartagena de Indias es una ciudad turística colombiana cuyo centro histórico ha sido declarado patrimonio de la humanidad. En los últimos años, la ciudad ha experimentado una expansión significativa, aprovechando los beneficios derivados de la compartición de infraestructura de redes de telecomunicación (IRT). Sin embargo, el impacto de esta infraestructura en la calidad de vida de los ciudadanos sigue siendo desconocido. El objetivo de esta investigación fue hacer una valoración del impacto de la compartición de IRT en la calidad de vida de los ciudadanos de Cartagena de Indias. La metodología empleada comprendió cuatro fases: revisión de la normatividad vigente, diseño de protocolos e instrumentos de recolección de información, recolección de datos y análisis resultados. Estas fases se realizaron bajo el enfoque cuantitativo de carácter exploratorio con un diseño no experimental de tipo transeccional. Los resultados obtenidos fueron: un listado de características que describen el estado de la IRT que se usó para hacer una valoración del impacto de la IRT en la calidad de vida, analizando tanto la afectación estética del espacio público como los riesgos que representa para la seguridad física del personal de mantenimiento, los ciudadanos y la propia infraestructura. Finalmente, se concluye que el principal problema radica en que el estado de la mayoría de la IRT no sólo impacta negativamente la estética urbana, sino que además constituye un riesgo para la seguridad, afectando la calidad de vida de quienes habitan o visitan la ciudad. Estos hallazgos resaltan la importancia de integrar tecnologías y estrategias propias de una ciudad inteligente para mejorar la gestión y monitoreo de la IRT, optimizando tanto la seguridad como la experiencia urbana.

Palabras clave

Infraestructura pública, seguridad pública, compartición de recursos, ciudades inteligentes, redes de telecomunicación, planificación urbana.

1. INTRODUCTION

Smart cities are an evolving urban development concept that leverages digital technologies, communication technologies, and data analytics to create efficient service environments, utilizing artificial intelligence, robotics, and the Internet of Things (IoT) for managing urban resources and services [1], [2]. In this regard, according to [3], smart cities use technology to enhance the efficiency of their processes, improving economic development, sustainability, and the quality of life for citizens in urban areas. However, despite the significant contribution of technology in a smart city model, it must also consider people, emphasizing the need for an integrative approach that prioritizes human well-being in urban development [4]. Among the main advantages of smart cities is the promotion of economic growth by creating environments conducive to innovation and entrepreneurship, attracting talent and financial capital [5]. On the other hand, smart cities generate new conditions and employment opportunities, contributing to local development and reducing poverty rates [6].

The key components of a smart city include physical infrastructure, human and social capital, and advanced technologies such as IoT, artificial intelligence, and sensor networks [7], [8]. Thus, in the context of smart cities, information, and communication technologies (ICT) play a crucial role, as by integrating this infrastructure, smart cities can improve public services such as healthcare, transportation, and utilities, leading to higher living standards [2], [9]. Similarly, through ICT, smart cities contribute to improving quality of life, traffic management, the environment, and government interaction [10]-[12]. Specifically, the telecommunications network infrastructure (TNI) enables the integration of systems and services, enhancing their capacities and response times [13]. In order to reduce costs, avoid environmental implications, and prevent infrastructure duplication, regulatory entities from various states have established guidelines that allow electric infrastructure owners to share access to and use of their infrastructure in exchange for compensation [14]-[17].

In this same vein, the sharing of telecommunications infrastructure, especially in rural and emerging areas, contributes significantly to reducing deployment and operational costs, facilitating better coverage [18], [19]. In addition to reducing costs, infrastructure sharing enables operators to offer new services, expand coverage to remote areas, improve service quality, and generate higher revenues for the state [14]. Furthermore, infrastructure sharing allows operators to split the costs of expensive technologies, accelerating their implementation and improving operational efficiency [20], [21]. To ensure an organized implementation of infrastructure sharing, mechanisms, standards, and techniques have been established globally, and each country has defined regulations according to its own context [22], [23]. In the specific case of Colombia, institutions such as the Communications Regulation Commission (CRC), responsible for regulating communication markets, and the Energy, Gas, and Fuel Regulation Commission (CREG), responsible for regulating those services, have been created. Additionally, over the past three decades, numerous laws, decrees, and resolutions have been issued regarding infrastructure sharing for the provision of telecommunications services [14].

On the other hand, from the perspective of smart cities, there are various models to measure the maturity of cities [24], which address dimensions such as economic development, governance, the environment, habitat, people, and quality of life [25]-[31]. These maturity models provide a framework to assess the progress of cities in the implementation of ICT, as well as in the adoption of sustainable practices and effective governance [8], [32]. A maturity model can evaluate aspects such as technological infrastructure, data management, and citizen participation, which supports government entities in decision-making, prioritizing intervention areas, and allocating resources more effectively [33], [34]. In this regard, one of the key purposes of maturity models is to assist city leaders in identifying the strengths and weaknesses of their cities, thereby enabling specific interventions aimed at improving urban management [35]. Moreover, maturity models facilitate informed decision-making by providing clear benchmarks to evaluate current city capacities and identify areas for improvement [36]. Similarly, these models allow for the prioritization of resources in cities by obtaining critical information on the dynamics of supply and demand for smart city initiatives [37]. Likewise, the analysis of big data collected from the implementation of maturity models in cities contributes to the development of sustainable urban environments [32], [38].

It is important to note that these maturity models must be adaptable and capable of being contextualized to the specific needs of each territory, allowing for practical and effective implementation [39]. In this regard, the concept of a maturity model is multivariate, multidisciplinary, and influenced by several aspects: health, the fulfillment of basic material needs, safety, work, leisure time for personal activities, connection with nature, education and knowledge, well-being, among others [40]. From a psychological perspective, well-being is a subjective perception dependent on multiple factors, including the aesthetics of spaces [41], [42]. Thus, the architecture of buildings and the design of public spaces generate emotional responses in citizens, affecting their perception of well-being and, therefore, their quality of life [41]. Similarly, according to [43], pollution and the improper use of public spaces detract from the well-being of citizens.

While there are numerous benefits to the sharing of telecommunications network infrastructure (TNI) [16], [17], it is also a reality that the indiscriminate and disorganized deployment of such infrastructure affects the aesthetics of public spaces and can pose a safety risk to citizens [23] and maintenance personnel, as well as to the physical integrity of the infrastructure itself, as shown in Figure 1. In the specific case of the City of Cartagena de Indias, declared a national heritage site of Colombia through Article Four of Law 163 of 1959 [44] and a UNESCO World Heritage Site in 1984 [45], the benefits of TNI sharing are evident in the advantages provided to its inhabitants. However, there is also an observable impact on the aesthetics of urban spaces and safety due to the potential risks posed to TNI maintenance personnel and citizens, as shown in Figure 1.

The literature review identified multiple studies on the sharing of telecommunications network infrastructure (TNI), focused on cost analysis [15]-[17], [46], technical aspects [22], [23], or regulation [47], [48]. However, no work was identified that analyzes its impact from the perspective of citizens' quality of life as an integral dimension of smart cities [29].

Figure 1. Cartagena de Indias tourism sector photographs. Source: own work.

In this context, the aim of this work was to assess the impact of TNI sharing on the quality of life of the citizens of Cartagena de Indias. The scope of the assessment includes the risk posed to the physical safety of maintenance personnel, citizens, and the physical infrastructure itself, as well as its aesthetic impact on public spaces. The assessment takes into account the condition of the network infrastructure and the governance observed over it. The study's results provide useful insights for TNI managers, service providers, and regulatory entities to take appropriate measures within their responsibilities to improve the indicators affecting citizens' quality of life.

2. METHODOLOGY

To assess the impact of shared TNI on the quality of life of the citizens and visitors of the city of Cartagena de Indias, a quantitative exploratory study was conducted, with a non-experimental cross-sectional design, covering the month of December 2023. The research was carried out in four phases (see Figure 2). The first phase involved reviewing the current regulations, including standards, norms, and regulations to identify the aspects of TNI that affect quality of life. In the second phase, the protocol and instruments were designed to ensure the validity of data collection. In the third phase, fieldwork was conducted for data collection, applying the protocol and using the designed instruments. Finally, in the fourth phase, the collected data was analyzed, and the results were structured for publication.

Figure 2. Methodology considered. Source: own work.

The impact of shared TNI on quality of life is a consequence of the state of the infrastructure, the governance of this resource, and how citizen participation is included in that governance, as shown in Figure 3. The impact assessment is based on the percentage of the TNI that exhibits one of the following characteristics, assuming an underlying normality assumption as explained below. In terms of quality of life, the negative impact of the TNI on aesthetics (A) in urban spaces was assessed [41], [42], as well as its impact on safety [40], represented by the potential risk it may pose to maintenance personnel (MP), citizens (C), or the physical integrity (PI) of the infrastructure itself (see Table 1).

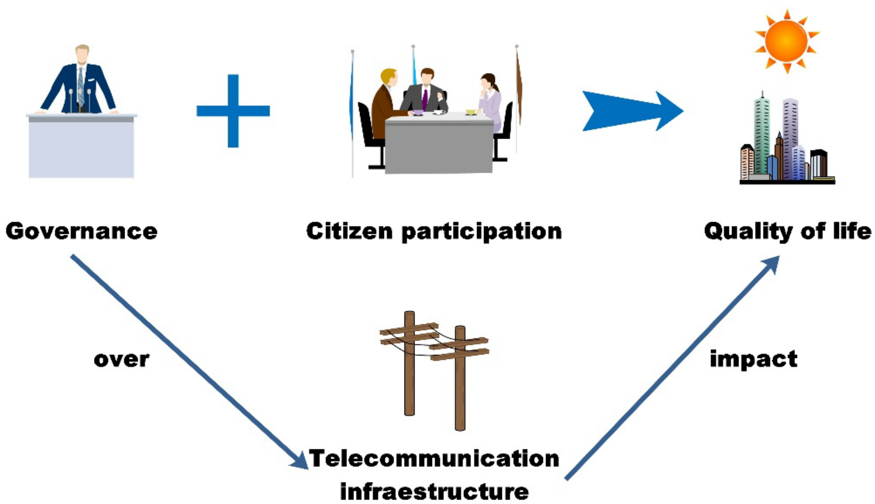

Figure 3. Conceptual framework of the variables. Source: own work.

Table 1. Relationship between the state of the TNI and quality of life. Source: own work.

State of the TNI	Quality of Life			
	Safety			A
	MP	C	PI	
Pole mechanical tension	X	X	X	X
Co-location with transformers	X		X	X
Diagonal crossings at corners	X	X	X	X
Reserves over spans and poles	X	X	X	X
Distance below the electrical network	X	X		X
Distance from network to ground	X	X		X

Regarding citizen participation (CP), the availability of information (AI) incorporated into the TNI, and the participation capacity (PC) provided by the state of this infrastructure were evaluated (see Table 2). Consequently, direct observation was used as the information collection technique. The population corresponds to the shared physical infrastructure of the telecommunications networks in the city of Cartagena de Indias, represented by the poles and wiring, which form the unit of analysis.

The observation was conducted on a non-probabilistic sample using the convenience sampling technique, as it is an exploratory study aimed at identifying preliminary trends regarding the impact of ITR sharing on the quality of life of the citizens of Cartagena de Indias. Additionally, neighborhoods belonging to the tourist sector were selected because they are directly related to the city's main economic activity and have experienced accelerated urban growth in recent years, which impacts infrastructure sharing. The sample corresponds to the poles and wiring in the following neighborhoods: San Diego, La Matuna, Getsemaní, El Cabrero, El Laguito, Castillogrande, and Bocagrande, as these are part of the tourist sector, are directly related to the city's main economic activity, and in recent years have experienced accelerated urban growth impacting the shared infrastructure.

Table 2. Relationship between TNI governance, citizen participation, and quality of life. Source: own work.

Governance of the TNI	CP		Quality of Life			
			Safety			A
	AI	PC	MP	C	PI	
Marking	X		X			
Presence of unused infrastructure		X	X	X	X	X
Elements attached to the pole		X	X	X	X	X
Cable bundle exceeding 30 mm		X	X	X	X	X
More than five fastening mechanisms on the pole			X	X	X	X
Pole pressured by vegetation		X	X	X	X	X
Cable inventory with visual inspection		X	X			X

In order to assure the content validity of the data collected, the state of the TNI (see Table 1) and the governance capabilities offered by the TNI (see Table 2) were evaluated based on the characteristics established in the international standards IEC 60652, IEC 61936-1, IEC 61784-5-11, BS EN 50423, IEEE STD 524, IEEE NESC, ANSI/IEEE C2, ANSI/TIA - 606-B, ISO/IEC 14763-2, ITU-T K.26, ITU-TK.66, ITU-T L.51, ITU-T G.781, ITU-T L.1700, ITU-T K.64, and ITU-T G.650; the national standards NTC 3278:2001, NTC 1329:2013, NTC 2050, RITEL, and RETIE; and the regulations established by CREG (070 of 1998, 140 of 2014, and 083 of 2020) and CRC (5050 of 2016 and 4545 of 2022).

In addition, based on these parameters and characteristics, a protocol for data collection was initially defined, which was validated through a pilot test conducted in a sector different from the sample area. This allowed refining the data capture form, framing all questions in a dichotomous format, omitting irrelevant information, and establishing observation schedules in two shifts: from 7:00 a.m. to 10:00 a.m. and from 2:30 p.m. to 5:30 p.m., as the climatic and visual conditions are optimal for observation and capturing photographs that ensure evidence. Similarly, it was determined that the best mode of transportation for the technical staff conducting the observations is by bicycle, and that the average data capture time per pole is four (4) minutes. All these improvements led to the enhancement of the observation protocol, specifying the aspects to observe, the manner in which information should be recorded, and the criteria for decision-making during the observation. In this way, the procedure was standardized, consistency was maintained, and biases in data collection were minimized. The accuracy of data recording was ensured through the use of Google Forms, which included thirteen mandatory dichotomous questions, one for each observed characteristic, to determine its presence or absence (see Tables 1 and 2). The data collection process was conducted by trained technical personnel in the telecommunications field, who were instructed on proper form completion to reduce interviewer bias. For the analysis of the collected information, descriptive statistics were used for each variable, identifying frequency distribution and measures of central tendency.

3. RESULTS AND DISCUSSION

Initially, the census of poles observed in the selected neighborhoods for the study is presented. Then, the results of the impact of the state of the TNI on quality of life are discussed, from the perspective of the risk it poses to the physical safety of maintenance personnel and citizens, as well as its aesthetic impact on public spaces. Subsequently, we address these same aspects but from the perspective of the governance of TNI, showing how citizen participation is enabled through the availability of information and the ability to access it. Later, we present the levels of impact of the TNI on quality of life, and in the final section, we analyze the findings.

In the seven (7) neighborhoods that make up the most touristic part of the city of Cartagena, a total of 1.82 poles were identified, of which 1.178 share telecommunications network infrastructure (see Table 3). Only 8 % (104 poles) are for exclusive use and therefore are not included in the study analysis. The results show that Bocagrande has the highest number of poles (46.96 %), followed by Castillogrande (14.27 %) and Getsemaní (11.23 %), while La Matuna has the fewest (1.25 %). The neighborhoods that make up the historical part of Cartagena are San Diego, El Centro, and Getsemaní, which account for one-fifth of the observed population (19.50 %).

Table 3. Number and percentage of poles per neighborhood. Source: own work.

Neighborhood	Sharing poles	% Sharing	Not sharing poles	% Not sharing	Total poles
Centro	43	3.35 %	23	1.79 %	66
Castillogrande	183	14.27 %	15	1.17 %	198
Bocagrande	602	46.96 %	24	1.87 %	626
La Matuna	16	1.25 %	6	0.47 %	22
San Diego	63	4.91 %	3	0.23 %	66
El Cabrero	59	4.60 %	16	1.25 %	75
El Laguito	68	5.30 %	9	0.70 %	77
Getsemaní	144	11.23 %	8	0.62 %	152
Total	1.178	91.89 %	104	8.11 %	1.282

The results of measuring the variables that represent the state of the shared TNI indicate that diagonal crossings are the most frequent issue (50.42 %) (see Figure 4), followed by cable spans and pole reserves (33.79 %), failure to maintain the required distance between the network and the ground (33.62 %), and coexistence with transformers (26.23 %). Although less frequent but still posing a risk to the safety of maintenance personnel, citizens, and the infrastructure itself, as well as impacting the aesthetics of public spaces, it was identified that 13.75 % of the poles have mechanical tension problems, and in 8.57 % of the cases, the 40 cm distance between the electrical network and the shared network is not maintained.

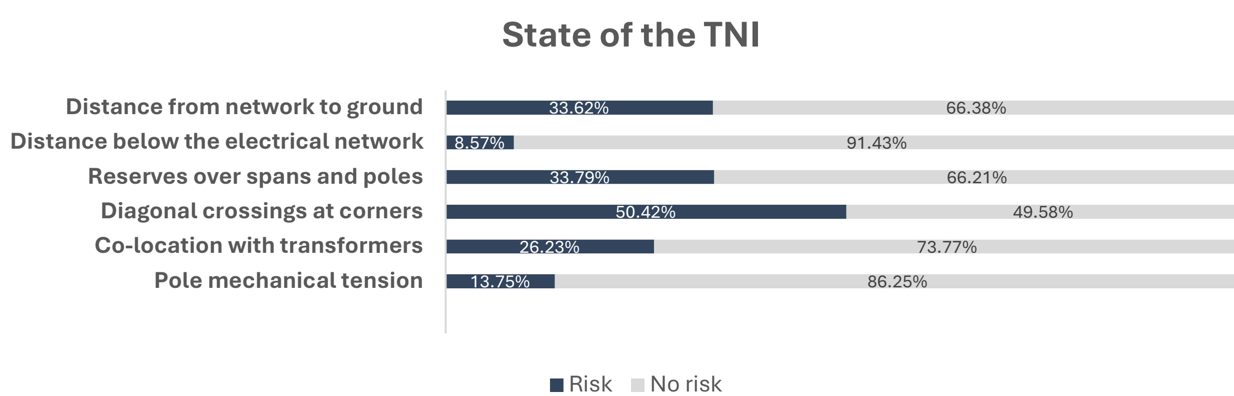

Figure 4. Assessment of the variables representing the state of TNI. Source: own work.

Among the variables analyzed that describe the state of the TNI, those representing the highest incidence in terms of risk to public safety, maintenance personnel, and the network infrastructure itself are: Pole Mechanical Tension (PMT), Coexistence with Transformers (CT), Diagonal Corner Crossing (DCC), failure to maintain the distance required by regulations from the power grid (DRG) and between the grid and the ground (DGG). The simultaneous occurrence of these variables increases the risk potential and consequently impacts quality of life. Thus, Table 4 presents the observed results of the concurrent incidences of these variables, relating the number of poles with their respective percentages, where the absence or presence of one, two, three, four, or five variables at the same time was evidenced. Although critical cases where more than three variables occur simultaneously do not exceed ten percent, it is still concerning that the majority of poles exhibit at least one or two risk factors. It is worth noting that these variables also affect the aesthetic aspect of public spaces, so their impact is not limited to safety alone.

Table 4. Concurrent incidence of safety risks as a consequence of the state of the TNI. Source: own work.

Number of concurrent incidences	PMT and CT		PMT, CT and DCC		PMT, CT, DCC and DRG		PMT, CT, DCC, DRG and DGG	
None	750	63.67 %	398	33.79 %	289	24.53 %	270	22.92 %
Some	385	32.68 %	524	44.48 %	446	37.86 %	437	37.10 %
Two	43	3.65 %	227	19.27 %	330	28.01 %	326	27.7 %
Three			29	2.46 %	97	8.23 %	108	9.17 %
Four					16	1.36 %	36	3.06 %
Five							1	0.08 %

From the governance perspective that reflects the state of the TNI, as shown in Figure 5, the results indicate that the most frequent issue is the presence of elements attached to the pole (68.59 %). It is also observed that in four (4) out of every ten (10) poles, there are cable bundles thicker than 30 mm (41 %), more than five attachment mechanisms on the pole (42.78 %), and unmarked elements (38.03 %). Although less frequent, still a concern, is the inability to inventory cables through visual inspection (25.21 %) and the presence of unused infrastructure (21.14 %). The risk with the lowest incidence was the pole being pressured by vegetation (12.99 %).

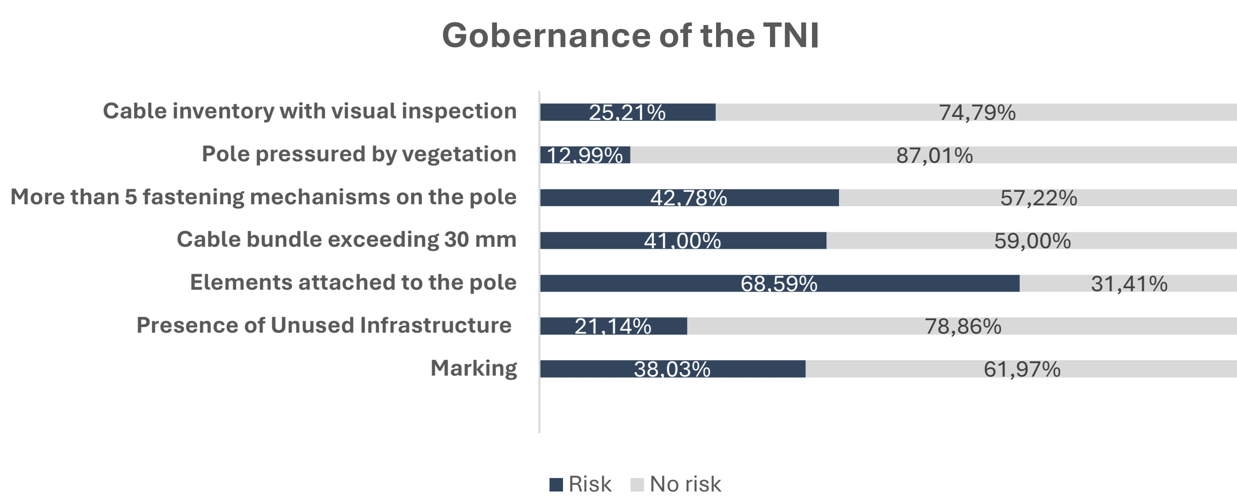

Figure 5. Assessment of the variables representing the governance of the TNI. Source: own work.

Among the set of variables analyzed that reflect the governance of the TNI, those that represent the greatest incidence of risk to public safety, maintenance personnel, and the network infrastructure itself are: Presence of Unused Infrastructure (PUI), Elements Attached to the Pole (EAP) exceeding 15 cm, Cable Bundles thicker than 30 mm (CBT), having more than 5 Pole Attachment Mechanisms (PAM), and the presence of Poles Pressured by Vegetation (PPV). The simultaneous occurrence of these variables increases the likelihood of risk and consequently affects the quality of life. Table 5 presents the observed results of the concurrent incidences of these variables, relating the number of poles with their respective percentages, where the absence or presence of one, two, three, four, or five variables at the same time was evidenced. It is noted that only one-fifth of the poles remain free from posing a safety risk, one-quarter represent at least one risk, and one-third pose three or more safety risks simultaneously. These variables also impact the aesthetic aspect of public spaces.

Table 5. Concurrent incidence of safety risks as a consequence of TNI governance. Source: own work.

Number of concurrent incidences	PUI and EAP		PUI, EAP and CBT		PUI, EAP, CBT, and PAM		PUI, EAP, CBT, PAM and PPV	
None	334	28.35 %	270	22.92 %	239	20.29 %	216	18.34 %
Some	631	53.57 %	422	35.82 %	320	27.16 %	296	25.13 %
Two	213	18.08 %	326	27.67 %	250	21.22 %	266	22.58 %
Three			160	13.58 %	238	20.20 %	227	19.27 %
Four					131	11.12 %	163	13.84 %
Five							10	0.85 %

On the other hand, citizen participation becomes possible when the TNI has available information, represented through marking mechanisms, whether on poles or cables, as identified in 61.97 % of the analyzed TNI (see Figure 5). Moreover, the capacity for citizen participation provided by the TNI depends on access to the information recorded in the marking of such infrastructure, which can be affected by the presence of unused infrastructure, multiple pole attachment mechanisms, the presence of elements attached to the pole, cable bundles thicker than 30 mm, and the presence of vegetation.

Consequently, the results obtained allow us to infer that the condition of the shared TNI and the governance observed over this resource enable limited citizen participation, as only slightly more than half of the resource has markings for identification, and access to this information depends on the previously mentioned variables.

To determine the impact that the condition of the shared TNI and its governance has on quality of life, from the perspective of urban space aesthetics and safety for maintenance personnel, citizens, and the physical integrity of the infrastructure itself, the risk posed by each pole for each of these aspects was assessed using the following measurement scale: None: When the evaluation of the pole's condition variables does not affect the aspect being observed. Moderate: If the evaluation of one, two, or three variables affects the aspect in question. High: If the evaluation of four, five, or six variables affects the referenced aspect. Critical: If the evaluation of more than six variables affects the mentioned aspect (see Table 6).

Table 6. TNI impact level results. Source: own work.

Aspect	Impact (Number of poles / Percentage)							
	None		Moderate		High		Critical	
Aesthetics	87	7.39 %	506	42.95 %	385	32.68 %	200	16.98 %
Safety MP	83	7.05 %	462	39.22 %	364	30.90 %	269	22.84 %
Safety C	104	8.83 %	565	47.96 %	364	30.90 %	145	12.31 %
Safety PI	102	8.66 %	598	50.76 %	411	34.89 %	67	5.69 %

Analyzing these results, it is observed that only a small percentage of the TNI (7.39 %) does not affect the aesthetics of public spaces (see Figure 6), while in the vast majority of cases, there is at least some impact, with 16.98 % of the poles being critically affected. A similar situation occurs regarding the risk posed to the safety of maintenance personnel, the public, and the physical infrastructure of the network, as less than 10 % of the poles pose no risk at all. In contrast, the results show that 90 % pose at least some risk, with one-fifth of them being critical for the safety of maintenance personnel (22.84 %), 12.31 % critical for the safety of citizens, and 5.69 % critical for the safety of the physical infrastructure.

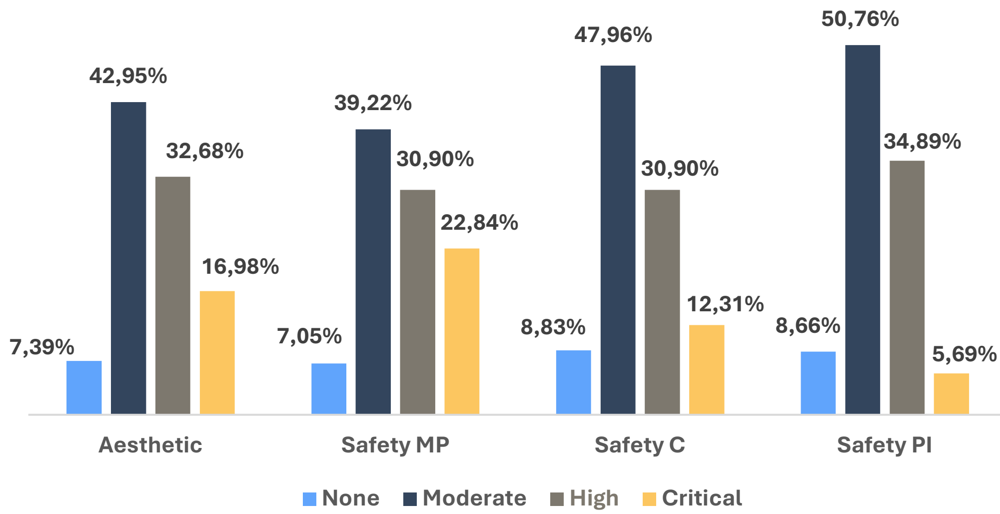

Figure 6. TNI impacts level on quality of life. Source: own work.

These results can be analyzed from the perspective of each stakeholder: the citizen, maintenance personnel, those responsible for the TNI, service providers, and the regulatory entities. For the citizen, it is clear that there is a latent risk to their safety, which unfortunately has become part of the landscape and is only noticed when critical cases occur, such as the one reported in the city's newspaper on May 30th of this year, which resulted in the loss of a person's life [49]. Another aspect affecting the citizen's quality of life is the impact that the shared TNI has on the aesthetics of public spaces, as they have also been forced to get used to, and thus accept, the disorder and unpleasant sensation caused by the presence of unused infrastructure, elements attached to poles, cable spans, and pole reserves, to mention a few of the variables observed in the study. Figure 7 provides evidence of the state of the TNI.

For the personnel responsible for the maintenance of the TNI, the results presented here make it clear that there is a latent risk to their safety when working on the TNI, given that only 7.05 % of the TNI does not pose any threat to their safety (see Table 6). Consequently, regulatory entities are tasked with ensuring compliance with national and international standards reflected in the variables observed in this study, and with applying the relevant measures to minimize the risk posed by the condition of the TNI, not only for the safety of citizens and maintenance personnel but also for the physical infrastructure itself. Similarly, regulatory entities must implement measures to prevent TNI from negatively impacting the aesthetics of public spaces, especially considering that this city has been declared a World Heritage Site, and its economy significantly depends on tourism.

Figure 7. TNI impact evidence. Source: own work.

In this study, quality of life was addressed as an integral dimension of smart cities [29], based on the underlying normality assumption that the state of TNI impacts urban aesthetics, safety, and citizen participation. Therefore, the management of this infrastructure contributes to determining the maturity level of a city. The obtained results serve as input for regulatory entities to design and validate public policies that help minimize the negative impact of TNI on urban aesthetics, the potential risks associated with infrastructure sharing, and that facilitate citizen participation in the management of this resource. For TNI stakeholders and service providers, these results are useful for validating the strategies, policies, mechanisms, plans, and actions they are implementing to manage this valuable infrastructure, which can lead to process improvements and cost reductions, particularly as they incorporate new technologies that enable them to perform this task more efficiently.

Given that an exploratory study was conducted, the results do not establish causal relationships; they only assess the potential risk or impact represented by each of the analyzed variables, without determining or quantifying a specific weight or degree of such risk or impact. Nor is it guaranteed that the study can be replicated, although the characteristics identified for the TNI can serve as references for similar studies. In the same way, the results cannot be generalized for the entire city of Cartagena de Indias, as they are limited to the tourist sector. Furthermore, the results reflect a perspective and bias from the technical aspect observed during the data collection process, which did not include social, cultural, or economic aspects of the citizens living in the neighborhoods that were part of the sample. Additionally, the perceptions of the TNI regulatory entities, infrastructure providers, or service providers were not directly involved. Finally, due to the application of a non-experimental, cross-sectional design, the results only reflect the state of the infrastructure at the time of data collection.

In contrast to the studies identified in the literature review, this research does not focus on enhancing TNI capabilities, reducing response times [13], cutting costs [18], [19,][23], or promoting sustainable and efficient use [14]-[17], [20], [21], nor does it propose models for TNI sharing [23]. This research is based on the concept of housing proposed by Rapoport, who defines it as a system of spaces organized according to the needs and values of a culture, determined by primary factors such as technology, which directly influences citizen security, lifestyle, symbolism, and aesthetics [50]. Therefore, the main contribution of this study lies in identifying some characteristics of shared telecommunications network infrastructure (TNI) that affect the aesthetics of public spaces, citizen security, and the potential for citizen participation in the governance of this infrastructure (see Tables 1 and 2). These findings serve as a reference for developing data collection instruments in studies aiming to assess the impact of TNI in other urban contexts. This, in turn, contributes to urban planning and design, understood as a "participatory, political, and integrative process that addresses and helps reconcile different interests regarding the form and functionality of the city from an appropriate urbanization perspective" [51].

4. CONCLUSIONS AND FUTURE WORKS

This exploratory study identified a list of characteristics describing the state of telecommunications network infrastructure (TNI), which were used to assess the impact of this infrastructure on the quality of life of citizens in Cartagena de Indias, from the perspective of smart cities, addressing dimensions related to security, citizen participation, and urban aesthetics. Based on the underlying normality assumption that the observed characteristics of the TNI impact citizen safety, maintenance personnel safety, the physical integrity of the infrastructure itself, and the aesthetics of public spaces, the main issue identified is that 90 % of the TNI presents some type of risk or negative impact on these aspects, which are integral to quality of life (see Table 6 and Figures 4 and 5). This is incompatible with the fundamental principles of smart cities, which aim to ensure the safety and well-being of their inhabitants through the use of advanced technologies. Therefore, it is recommended that the stakeholders responsible for the governance of the TNI use technologies such as the internet of things to monitor the variables identified in this study (see Tables 1 and 2) and analyze the collected data with data analytics tools and artificial intelligence to design and implement policies and action plans that allow for risk anticipation, improving the aesthetics of public spaces, citizen safety, and ensuring their participation in decision-making processes.

As future work, it is proposed to delve deeper into the analysis of each of the studied variables to assess their individual impact and determine which should be prioritized when implementing improvement measures based on the smart cities approach. This would allow for a more precise identification of the specific factors affecting urban aesthetics, security, and citizen participation capacity, facilitating the design and implementation of public policies. Additionally, it is proposed to conduct quantitative, longitudinal, and non-experimental study in the same population to observe and analyze the evolution of the variables over time. This would enable the stakeholders responsible for the governance of telecommunications network infrastructure (TNI) to make decisions to monitor changes in real time and dynamically adjust their intervention strategies, using advanced technologies such as data analytics, the internet of things, and artificial intelligence, which would contribute to more efficient management of urban resources.

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CONFLICT OF INTEREST

The authors declare that they have no financial, professional, or personal conflicts of interest that could inappropriately influence the results obtained or the interpretations proposed.

AUTHOR CONTRIBUTIONS

Martín Monroy Ríos: Literature review, Conceptual framework, Validation of the methodological aspects and Writing of the manuscript.
Iván Sanabria Forero: Literature review, Conceptual framework, Fieldwork.
Gabriel Chanchí Golondrino: Literature review, Conceptual framework, Manuscript review.

AI USAGE STATEMENT

In this work, the authors used DeepSeek solely to check aspects related to English spelling and grammar. Consequently, they assume full responsibility for the content of the publication.