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Perception of the Impacts of Urban Mobility Interventions in the Niterói Oceanic Region, Brazil

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Abstract: In a context of expansion and densification of cities, themes related to mobility and the improvement of the quality of life have aroused the interest of researchers and county managers. Using the case of the main urban mobility intervention in Niterói, the TransOceânica Road Corridor (CVT), this work aims to identify the perception of the population affected by the project in relation to the occurrence of the impacts predicted in the project planning phase, as well as to identify which of these impacts most influenced the standard of living and mobility of this population. The survey results showed that the respondents' perception of the impacts—as the change of air quality, the change of noise levels, the alteration of the local dynamics and neighborhood disturbance—did not confirm the scenario envisaged when planning the project.

Keywords: mobility; environmental impact; environmental feasibility study; urban traffic

1. Introduction

Urban mobility has been a central theme for city managers and planners in the metropolitan regions, being widely cited as one of the main challenges faced by cities [1]. It is intrinsically related to urban growth, with one enhancing the other. The vast majority of cities, especially those in developing countries, have experienced rapid and intense growth, often disordered, which impacts the configuration of roads and the characteristics of traffic. The tangled growth has provoked the appearance of peripheries as a solution for the population with less purchasing power, which increases the distances to urban centers. In this context, cities are usually dependent on road transport and, mainly, on private cars, which has made the construction of road corridors one of the most important undertakings in infrastructure projects.

According to Carter and Rushton [2], the transport system can be understood from six themes: (a) people or things being moved; (b) people who facilitate the movement of people and things, that is, the workforce; (c) vehicles; (d) physical infrastructure; (e) software and data infrastructure; (f) regulatory structure. Together, they form a system that, while facilitating the movement of people and things, can cause positive or negative impacts on society and the environment.

Several studies with different approaches have been developed, aiming to evaluate infrastructure projects and, to a greater or lesser extent, consider these themes [3]. In addition to assessing economic and social sustainability, they have also considered technological safety and attractiveness for living and businesses [4], focused on the evaluation of economic efficiency and environmental and social variables—such as CO_2 emissions, per-capita use of transportation energy, death injuries, accidents, residential population exposed to outside road traffic noise [5]—focused on the project operation stage to propose a system of indicators for assessing sustainability [6], evaluated the impacts of infrastructure projects [7] and developed a set of key assessment indicators for the assessment of sustainability performance that considers the three dimensions of sustainability.

Several studies have also addressed the impacts caused by infrastructure projects, such as, for example, those related to the influence on the natural and built landscape, air quality, environmental noise and safety [8–15]. These impacts influence the results of projects and the perception of society regarding their cost-benefit.

Changes in road systems affect the local population due to the effects of vehicle flow and the visual and locomotion barriers caused by the new characteristics and elements of the roads [16,17]. They can also cause changes in social patterns and the lifestyle of neighborhoods [16]. Furthermore, according to Pardo–Bosch and Aguado [18], the results of many infrastructures around the world have caused social rejection.

Regarding the influence of roads on the natural landscape, ecologists have focused on topics such as changing behaviors and habitats and changing plant communities, while architects have focused more on the visual qualities of the contrast between infrastructures and the natural landscape that accommodates them [8,9]. Regarding the urban landscape, roads are generally considered to be integrated with urban design, aiming at more attractive and visually comfortable places. In both cases, infrastructure, urban development and landscape must be combined to create a landscape of mobility [13].

Transport corridors also affect wild species and ecological systems [19], resulting in three main consequences: reduced landscape permeability, loss of habitat and increased habitat fragmentation [20]. Landscape permeability is related to the ability of species to move through the landscape [21]; habitat loss refers to the degradation of habitat quality, resulting, for example, in changes in the distribution of wild species and vegetation composition; and habitat fragmentation refers to the discontinuity in the spatial distribution of resources and conditions present in an area [22].

Regarding the air quality in cities, pollution has been a major challenge to be overcome [13], with transport being one of the main factors that contribute to air pollution in cities [23]. Karagulian [24], after analyzing cities in 51 countries, concluded that traffic emissions contribute 25% of the global averages of urban PM10 concentration, being the main source of urban levels of PM in regions such as India, Southwest Europe and Brazil. In large urban centers, tunnel construction has been used to redirect traffic away from the main roads, contributing to the improvement of ambient air quality [25–27].

Concerning environmental noise, road traffic is one of the main sources of noise, accounting for almost 67% of noise pollution in some cities, which, in addition to causing psychological and pathological effects, reduces the value of the property close to road corridors [28]. It is one of the main sources of dissatisfaction with the environment in residential areas [29,30].

Urban planning reflected in urban design has a strong influence on noise pollution in cities, since the volume and traffic conditions are associated with variables such as morphology, urban density, land use and street characteristics [12]. The main elements of the road corridors are the roads, flyovers and tunnels. Concerning tunnels, although a positive influence is attributed to their acoustic environment, there may be specific problems near their portals, which require studies of noise impact [31].

The road system also significantly influences the safety of the population, with direct consequences on health. Traffic accidents have short- and long-term effects, such as deaths, serious injuries and psychological, financial and everyday life damages, and it is estimated that they cause 38% of traffic deaths worldwide and will be the seventh leading cause of death in 2030 [32]. However, they are also the main means of access and escape in management plans for natural hazards, such as those caused by flash floods [33], and for post-disaster housing recovery [34].

A phenomenon associated with urban mobility is that urban growth and its resulting problems, such as congestion and air and noise pollution, encourage the search for housing in quieter places, far from urban centers. Consequently, work and leisure places, as well as the main trade centers and service areas, become more distant from homes, increasing the demand for quality public transport and the number of private cars. People want to move easily from one place to another and have quick and easy access to goods and services [35].

In the Brazilian city of Niterói, this fact occurred with the migration of the population to the regions of Pendotiba and Oceânica, previously characterized by temporary weekend and leisure residences, confirming the central axis of growth of Niterói, especially after the inauguration of the Rio-Niterói Bridge in 1974. As a result, these regions began to face everyday mobility problems, especially during rush hours. The concentration of the flow of vehicles towards Niterói's downtown, and also a large travel volume to the city of Rio de Janeiro, intensified the congestion on the main roads connected to the central area of the city.

Changes in the road system are mainly associated with public policies and the demands of society. Public policies translated primarily into land use, and occupation laws are influenced by the relationship between economic interests and the varied aspirations and needs of society due to cultural, political and geographical differences. Besides, the growing demands for more sustainable cities have also influenced road projects, which, while maintaining their main objective of improving mobility, must also incorporate solutions that minimize environmental impacts and meet the local characteristics of the population.

Several studies have addressed mobility management [36], converging with the concept of sustainable mobility. The concept of mobility is also intrinsically related to the concept of accessibility, in its broadest sense: (a) increasing the user's autonomy, mainly through the elimination of physical barriers and instruments that improve orientation in the urban space; (b) improving access by the local community to places of work and leisure and purchases of goods and services.

Historically, in a significant portion of Brazilian cities and developing countries, there has not been an adequate synergy between the regulation and practice of urban planning and the transport system, potentiating a constant dispute for the urban space between pedestrians, automobiles, buses, bicycles, etc. However, more recently, in Brazil, two legal instruments were essential to improve this context. The first was the City Statute [37], which promotes the dimensions of sustainability as a fundamental element of spatial planning, guaranteeing the right to sustainable cities [38], and determined that cities with more than 500,000 inhabitants needed to develop a transport plan [15]; the second was the National Policy for Sustainable Urban Mobility [39,40], influenced by society's demands for more efficient and sustainable urban services, enhanced by the increasing urbanization experienced by most countries [41]; and the third was the law that establishes the National Urban Mobility Policy [40], which incorporated the concepts of sustainable mobility when considering social inclusion, environmental sustainability, participatory management and the democratization of public space.

To improve traffic and the quality of public transport, the Improvement Plan for the Road System, Traffic and Public Transport was implemented in Niterói in 2010, based mainly on the guidelines contained in the National Policy for Sustainable Urban Mobility [39] and in Niterói's urban plans and guidelines [42–45]. Thus, in 2012, a series of interventions aimed at improving mobility in the city began, including the greatest urban mobility intervention in the history of Niterói: the construction of the TransOceânica Road Corridor (CVT), in the Bus Rapid Transit (BRT) modality.

The CVT's planning counted on the participation of the population through ten public hearings in neighborhoods directly affected by the project, in which the project and the Environmental Impact report were presented, clarifying doubts and collecting suggestions that made it possible to improve the report and the project.

The main objective of this work was to contribute to improving the effectiveness of road corridor projects based on the study of a real case of implementation of an important road corridor in a city with severe mobility problems. In this sense, we established an approach formed by two secondary objectives: (a) comparatively analyze the impacts foreseen in the planning phase of the CVT in relation to the perception of its occurrence by the directly affected population, in order to identify concordances and disagreements, as well as the reason for their occurrence; (b) research which variables considered for the elaboration of these scenarios most influenced the mobility and standard of living of this population.

In this context, and considering the results obtained, we summarized the main contributions of this research. The first is that the construction of road corridors has been an important strategy to solve mobility problems in cities, caused mainly by the circulation of an excessive number of vehicles. It is the case of the city of Niterói, which was identified by the Time Index 99 Travel (ITV 99) as having the most congested traffic in Brazil, in addition to having a high rate of vehicles per inhabitant (270,000 vehicles for an estimated population of 510,000 people). By studying the implementation of a road corridor in a city with an intense problem of urban mobility, we provide managers and city planners with information and conclusions that collaborate to increase the efficiency of this type of enterprise.

Several cities, especially those in developing countries, have characteristics similar to those of Niterói. This enhances the reach of the results of this study, which can help improve the road projects of those countries. Moreover, the implementation of road corridors requires environmental impact studies. Studying how the scenarios established at the time of these studies are evaluated by the population directly affected in relation to their occurrence can help improve the methodologies and premises used in these studies. This research also contributes to the existing literature, since few works on the subject provide conclusions based on real data.

2. Materials and Methods

Our approach involved five steps: characterization of the study area, bibliographic research, documentary research, survey and data analysis.

2.1. Study Area

The relief of Niterói, formed by massifs and coastal hills, significantly influenced the city's road system, making it challenging to adopt solutions that improve its mobility. An important project was the construction, forty years ago, of a 1.4 km tunnel connecting the neighborhoods of Charitas and Cafuba, to be opened in Serra do Preventório, considered an expensive and difficult construction project. During all this time, the population of Niterói yearned for the execution of this undertaking, which is the main symbol of the CVT, since, without its construction, the new road flow would not be possible. Thus, this has always been an ambitious urban mobility project, whose objective was to provide the neighborhoods in the ocean region with a road corridor of approximately 11.2 km that would improve the connection with the center of Niterói and the city of Rio de Janeiro [46,47].

Until the construction of the tunnel, passengers traveling between the Oceanic Region and the center of Niterói necessarily passed through Largo da Batalha, overloading the road system in that region, especially during rush hours. It took about 18 km to leave the Oceanic Region and reach the neighborhood of Charitas, while with the new corridor this route became 9.3 km (Figure 1), with the offer of an exclusive lane for public transportation.

The project's Direct Influence Area (AID) consists of the boroughs that make up the Niterói Oceanic Region, namely: Cafubá, Itaipu, Santo Antônio, Maravista, Engenho do Mato, Jacaré, Camboinhas, Piratininga, Jardim Imbuí, Itacoatiara and Serra Grande; and also the boroughs of Jurujuba, Charitas and São Francisco, belonging to the Bahia Beaches Region. Thus, the project's AID is composed of 14 boroughs that will receive the project or are close to it, and will therefore feel the greatest effects of the project (Figure 2).

The boroughs that make up the project's AID have predominantly residential characteristics. According to the last two censuses by the Brazilian Institute of Geography and Statistics, the growth in the new corridor's regions of influence was 6% to 8% per year, showing the highest population growth in the city. This is because these regions are the most promising in the city for economic activities related to leisure, tourism, construction and the real estate market; they are also where services and trade activities are most developed.

Figure 1. Current connection (before the construction of the Cafubá-Charitas tunnel) between the Oceanic Region and the central areas of Niterói and Rio de Janeiro. Source: SINERGIA, 2014 [48].

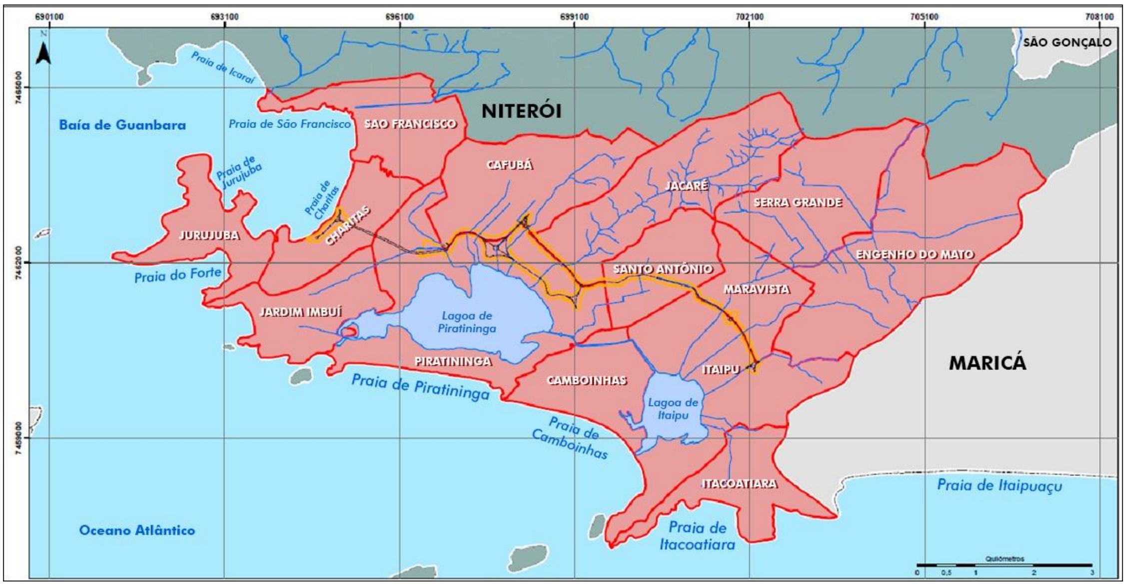

Figure 2. TransOceânica Road Corridor (CVT)'s Direct Influence Area; Source: AGRAR, 2014b [47].

Many IDA residents, as well as a third of Niterói's population, work outside the county [46,47], with Rio de Janeiro being the most attractive hub. However, the connection between the AID boroughs, the Niterói central area and Rio de Janeiro and the investments in public transport has not kept pace with the accelerated growth of the Oceanic Region, making daily commuting with a private vehicle necessary.

2.2. Bibliographic Research

We conducted extensive bibliographic research in the databases of Web of Science, Scopus and SciELO and on the website of the leading publishers of scientific journals, using the recommendations of the Preferred Reporting Items for Systematic Reviews and Meta-Analyzes (PRISMA). Initially, we searched for articles published in the last ten years, aiming at the best representation of the state of the art on the subject. We used the following keywords: urban mobility, urban mobility plan, sustainable mobility and sustainable urban mobility, resulting in 4798 articles. After that, we performed an exploratory reading of titles and abstracts, aiming to identify the articles that had some evidence or information on the theme and eliminate the repeated articles. This resulted in 298 articles, which were submitted to selective reading, aiming to verify if the contribution to the research was proven, resulting in 78 articles. These articles were read in full, and 58 articles were used. Table 1 summarizes the main themes supported by these articles.

Table 1. Summary of the main themes supported by the consulted literature.

Themes	References
CVT project and relevant legislation	[37]; [39,40]; [42–47]
Infrastructure projects assessment	[2–7]; [14]; [18]
Social impacts of road traffic	[3,4]; [11]; [17,18]; [49]; [50]
Influence of the road system on the natural and urban landscape and the quality of the habitat	[8,9]; [13]; [16,17]; [19]; [20]; [21,22]
Influence of the road system on air quality	[4]; [13]; [23–27]
Influence of the road system and city morphology on noise pollution	[4]; [12]; [23–31]
Influence of the road system on population safety	[4]; [10]; [15]; [28]; [30–32]; [50,51]
Influence of the road system on urban mobility	[1]; [15]; [32–36]; [52,53]
Land use pattern	[8]; [12]; [38]; [53]
Data analysis	[37–41]; [48]; [54–58]

The documentary research was based on the following documents: the Environmental Impact Study and Environmental Impact Report (EIA/RIMA) developed for the project's Environmental Licensing process, documents focusing on expectations about the project's results, documents focusing on urban evolution and mobility scenarios in the cities and demand studies for the BRT Transoceanic System. The EIA/RIMA are multidisciplinary technical documents that present the results of the assessment of significant environmental impacts. All materials were assessed for authenticity, credibility, representativeness and meaning.

2.3. Survey

To carry out the survey, we used a questionnaire (Appendix A) containing demographic questions and questions related to the impacts anticipated in the planning phase of the enterprise and the respective scenarios identified in the documents obtained in the documentary research. The questionnaire was distributed by e-mail, social networks and WhatsApp for eight weeks. Table 2 presents the impacts considered in the survey, its conceptualization and the scenario defined when planning the project.

To determine the sample size, we used Equation (1) [49]:

$$n = \frac{\theta^2 \cdot p \cdot q}{e^2} \tag{1}$$

where

n = Sample size
θ = Confidence level chosen, expressed as the number of standard deviations
p = Percentage at which the phenomenon occurs
q = Supplementary percentage $(100 - p)$
e = Maximum allowed sample error

The relationship between p and q represents the degree of homogeneity of the population. Usually, an 80/20 ratio is used for homogeneous populations and 50/50 for heterogeneous populations. To consider the most unfavorable case, we used the 50/50 ratio. We also established a 95% confidence level (two standard deviations) and a maximum allowed sample error of 10%. Due to these values, the minimum sample size must be 96, which is smaller than the one used (350).

Table 2. Impacts considered in the survey, its conceptualization and the scenario defined when planning the project.

Impacts	Scenarios
Changes in the standard of living of the local population: changes in the value of real estate, increase of commercial and service activities and generation of jobs and income.	Positive impact: the improvement of mobility and accessibility conditions will make the region more attractive, generating opportunities for new business and employment, as well as the appreciation of properties, especially those bordering the CVT.
Change in daily life: changes in the dynamics of the use of public space by the users and their daily routine.	Positive impact: the spatial planning provided by the CVT will make the use of spaces more accessible and improve the coexistence between drivers and cyclists; the reduction in travel times provided by improved mobility will make it possible to carry out new activities.
Change in air quality: change in the emission dynamics of air pollutants and concentration levels.	Positive impact: the emission of atmospheric pollutants will reach levels lower than the current ones, since the project's aim is the improvement in urban mobility, encouraging the population to leave their private cars at home and use public transport; with the differentiated BRT concept, the main road and the vehicles connected to the system will enter the boroughs of the Oceanic Region, reducing the need for several bus lines for the same route and the travel time to the town of Niterói and the Charitas borough.
Change in noise levels: change in the dynamics of noise generation and intensity levels.	Positive impact: reinforcing the effect of improving air quality, the levels of noise and vibration will also be positive, since they originate from the same polluting source, which is mainly the circulation of cars.
Alteration of the natural landscape: changes in vegetation cover and relief.	Negative impact: the requalification of the roads in the road corridor and the suppression of areas for the implantation of the tunnel and the construction site can bring significant changes from the local landscape's point of view; in the construction phase, the suppression of vegetation, the movement of soil for the topographical readjustment of the land and the insertion of the temporary infrastructures necessary for the implantation of the enterprise will result in irreversible changes in the local landscape; in the operation phase, the impact in question will occur through the insertion of permanent infrastructures.
Alteration of the local dynamics and neighborhood disturbance: alterations caused by the attraction of new residents and commercial and service enterprises, and modification of the local dynamics of movement of people and vehicles.	Negative impact: the ease of access and improvements in mobility conditions will cause an increase in the flow of people seeking or crossing the region, which will change the local dynamics of the movement of people and vehicles, impacting the local population.
Change in mobility in the region: changes in the dynamics and intensity of traffic and in the offer of public transport.	Positive impact: the CVT will have exclusive bus lanes, with connections to the city and intercity bus networks that will operate within the new infrastructure. It will improve the connection between the area under study and the city of Rio de Janeiro through the integration of the CVT with the Waterway Terminal of Charitas.
Changes in the urban landscape: changes in the landscape as a result of the topographic readjustment of the land and the insertion of the elements that make up the permanent infrastructure, including those regarding its functionality.	Positive impact: the roads through which the system will pass, the adjacent roads and those that will receive the flow of vehicles that will use the tunnel will be revitalized; there will be pavement on the roads to facilitate drainage, bike paths to encourage non-motorized travel, the improvement of existing sidewalks respecting accessibility standards and the elimination of surface parking on the main road to prioritize non-motorized travel in the area.
Changes in population safety: changes in traffic accident rates.	Negative impact: there may be an increase in accidents due to the increased circulation of vehicles, the new morphology of roads and the encouragement of non-motorized transport, on foot and bicycles; enterprise users will have to get used to new traffic rules and space sharing with multiple users. It should be noted that circulation in the tunnel may also cause accidents with serious consequences for users.

2.4. Data Analysis

Tables 3 and 4 summarize the data used in the analyses. Variables P1 to P4 refer to demographic issues, variable Xo refers to the frequency of use of the CVT and variables X1 to X18 refer to the impacts foreseen in the project's planning phase. Variables X1 to X9 identify the occurrence of a certain impact (yes/no) and variables X10 to X18 identify whether the impact is positive or negative.

Table 3. Variables used to identify demographic data and CVT usage.

Demographic issues	Variable
Borough	P_1
Age	P_2
Sex	P_3
Schooling	P_4
Usage of the CVT	**Variable**
Evaluation if the respondent is a CVT user	X_o

Table 4. Variables used to assess respondents' perceptions of the impacts predicted in the project planning phase and whether the impact was positive or negative.

Impacts Foreseen in The Project Planning Phase	Variables Related to The Impact Occurrence (Yes/No)	Variables Related to The Type of Impact (Positive/Negative)
Changes in the standard of living of the local population: changes in the value of real estate increase of commercial and service activities and generation of jobs and income.	X_1	X_{10}
Change in daily life: changes in the dynamics of the use of public space by users and their daily routine.	X_2	X_{11}
Change in air quality: change in the emission dynamics of air pollutants and concentration levels.	X_3	X_{12}
Change in noise levels: change in the dynamics of noise generation and intensity levels.	X_4	X_{13}
Alteration of the natural landscape: changes in vegetation cover and relief.	X_5	X_{14}
Alteration of the local dynamics and neighborhood disturbance: alterations caused by the attraction of new residents and commercial and service enterprises, and modification of the local dynamics of movement of people and vehicles.	X_6	X_{15}
Change in mobility in the region: changes in the dynamics and intensity of traffic and in the offer of public transport.	X_7	X_{16}
Changes in the urban landscape: changes in the landscape as a result of the topographic readjustment of the land and the insertion of the elements that make up the permanent infrastructure, including those regarding its functionality.	X_8	X_{17}
Changes in population safety: changes in traffic accident rates.	X_9	X_{18}

To assess the reliability of the data collection instrument and the interviewees, we used Cronbach's alpha [38,41,50,51]. For the data analysis, we initially confronted each of the impacts forecast for the CVT with the respondents' perception of the occurrence of these impacts, aiming mainly to draw conclusions about possible disagreements. Then, in order to assess which impacts most influenced the standard of living and mobility in the region affected by the CVT, we used the classification tree technique using the Classification and Regression Trees (CART) algorithm [52,53], made available by the RPART package of R software [54]. Through this technique, we analyzed two models: Model 1, considering $X_1 \sim X_0 + X_2 + X_3 + \ldots + X_9$ to reveal which variables are most important in assessing changes in living standards, considering mainly the real estate valuation, increased commercial and service activities and generation of employment and income; and Model 2, considering $X_7 \sim X_0 + X_1 + \ldots + X_6 + X_8 + X_9$ to reveal which variables are most important in assessing changes in mobility in the region, considering mainly the generation of traffic on internal roads and the pressure on public transport.

3. Results and Discussion

The survey was applied to residents of the 32 neighborhoods affected by the project, which together have an area of 165 km^2 and 266,077 inhabitants. 350 people answered the survey, including users and residents, whose sample included surveyed respondents from 38 different neighborhoods of Niterói, out of a total of 52—with residents of Icaraí (17%), Itaipu (16%), Piratininga (10%), Camboinhas (7%), Cafubá (5%), Santa Rosa (4%) and Maria Paula (3%), while a small parcel was located in the north and east Zone of the city's Ocean Region (51%).

Regarding the profile of the interviewed, 52% (fifty-two percent) were male and 48% (forty-eight percent) were female. The majority (71.9%) had a graduate degree (14.3% a master's degree and 2.3% a doctoral degree). The dominant age groups were 39–45 years (31.5%) and 51–60 years (25.2%), followed by 32–38 years (14.3%), 46–50 years and above 61 years, corresponding to a percentage of 13.5%.

We initially calculated the Cronbach's alpha, whose value, equal to 0.7, was considered adequate. The survey has shown that 97.4% of the interviewed used the CVT, either sporadically (50%) or frequently (47.4%), and a minority of 2.6% had never used the CVT. Among those who used the tunnel often, the majority (80%) were residents of the Oceanic region

Table 5 and Figure 3 summarize the survey results about the perception of the occurrence of impacts. Among the impacts presented in the survey, the most perceived ones were the alteration in the region's microclimate (95.,1%), the change in mobility in the region (91.1%), the change in the standard of living of the local population (88.9%), the alteration of the local dynamics (87.4%) and the change in the urban scenery (87.4%). All of these were viewed positively by the majority. The less perceived impacts refer to changes in air quality (60.0%), changes in noise levels (62.9%) and changes in population safety, the last three seen negatively by the majority. Among the perceived impacts, those that were evaluated as the most positive were: increase of noise levels (75%), change in population safety (71%), change of air quality (71%), native scenery change (46%) and change in the urban scenery (33%).

Table 5. Summary of survey results.

For You, Did the Possible Impacts, Mentioned Below, Have Effects on The Area Under Discussion?				
Impact	**Answers**	**%**	**Impact**	
			+	**−**
X_1: Change in the standard of living of the local population	Yes No	88.9 11.1	74.2	14.7
X_2: Change in daily life	Yes No	74.9 25.1	63.7	11.2
X_3: Change of air quality	Yes No	60.0 40.0	17.7	42.3
X_4: Change of noise levels	Yes No	62.9 37.1	15.5	47.4
X_5: Change in the natural landscape	Yes No	77.1 22.9	41.3	35.8
X_6: Alteration of the local dynamics and disturbance of neighborhood	Yes No	87.4 12.6	63.3	24.1
X_7: Change in mobility in the region	Yes No	91.1 8.9	61.4	29.7
X_8: Change in the urban landscape	Yes No	87.4 12.6	58.7	28.7
X_9: Change in population safety	Yes	66.3	19.2	47.1

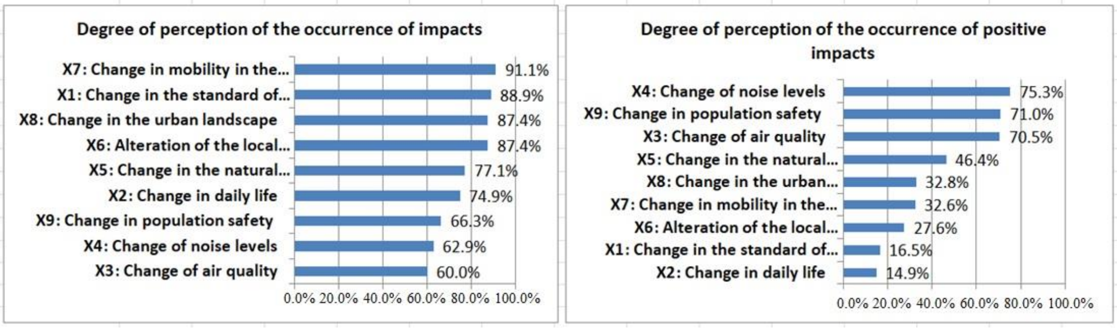

Figure 3. Degree of perception of CVT impacts.

When comparing the survey result with the scenario foreseen for CVT impacts at the time of the project planning (Table 6), it is possible to notice that the surveyed people did not confirm the scenario foreseen for the impacts of the change of air quality, change of noise levels and alteration of the local dynamics and disturbance of neighborhood.

Table 6. Comparison between the scenario foreseen for CVT impacts and the research results.

Questions	Impact	
	Predicted Scenario	**Survey Result**
X_1: Change in the standard of living of the local population	↑	↑
X_2: Change in daily life	↑	↑
X_3: Change of air quality	↑	↓
X_4: Change of noise levels	↑	↓
X_5: Change in the natural landscape	↓	↑
X_6: Alteration of the local dynamics and disturbance of neighborhood	↓	↑
X_7: Change in mobility in the region	↑	↑
X_8: Change in the urban landscape	↑	↑
X_9: Change in population safety	↓	↓

The survey results: ▬ confirmed the predicted scenario; ▬ did not confirm the predicted scenario. ↑ or ↑ Positive ↓ or ↓ Negative.

In summary, this research compares different perceptions: those that are translated into scenarios by the EIA and those that are translated into evaluation by the respondents. Regarding the results of the EIA, there is a debate about their effectiveness due to their being somewhat generalized. Besides, although it is noticeable that road projects, while providing economic benefits and improving the quality of life, also produce negative impacts on the local population [55], the reach, dimension, and nature of these impacts is influenced by the perceptions of this population [17]. It is this context of possible generalizations in the results of the EIA, associated with the degree of the population's capacity to perceive the impacts, that favors the occurrence of disparities between the predicted scenarios and the perception of their occurrence.

Regarding territorial dynamics, the initial expectation was that the CVT would provide greater accessibility to the Oceanic Region, enhancing the transformation of land use due to the increased demand for homes and commercial and service establishments, which was confirmed by the survey results. The literature about land use transformation also shows that development interventions, such as road projects, influence land use patterns and usually increase the values properties [55,56]. There was also an expectation of improving the urban landscape through aesthetic interventions and the reformulation of the circulation routes, making them more beautiful, safer and more comfortable, which was confirmed by the survey results. The improvement of the urban landscape is greatly influenced by the urban space management policies practiced by the municipalities. In the current municipal management, responsible for the implantation of the CVT, it has been possible to perceive the attention given to the visual and technical aspects of urban interventions in a context presented by Meurs [13], in which roads and landscapes are more combined than adapted.

Concerning socioeconomic dynamics, the initial expectation was that the spatial planning provided by the CVT would make the use of spaces more accessible, improve the coexistence between drivers and cyclists and free up time to carry out new activities, due to the reduction in travel times provided by the improved mobility. The survey results expressed people's satisfaction with the occurrence of this expectation. The use and compatibility of alternative means of transport and the improvement of the sustainability of urban spaces have been recurrent themes in the discussions on the improvement of the mobility and sustainability of cities [4,57], that have led highway projects to consider these aspects.

There was also an expectation that the increase in the flow of people seeking or crossing the region would modify the local dynamics of movement of people and vehicles, negatively influencing the local population. Several roads that would be used for the implantation of the CVT were in predominantly residential areas, with reduced the traffic of vehicles and pedestrians, some of them without pavement. Moreover, the mainly residential character meant that the circulation of people in the area was not intense, which caused the scenario regarding the change in the local dynamics of the movement of people and vehicles to be evaluated as having a negative impact. However, the changes caused by this dynamic were considered positive by the survey. We consider that two factors may have contributed to this result: the first concerns the increase in the feeling of security in a region with increasing crime rates, since the busiest streets contain criminal activity; the second is that several internal streets were paved, solving a chronic problem that the dwellers faced on rainy days.

Another expectation was that improved mobility would make the region more attractive, generating opportunities for new business and employment, as well as the appreciation of real estate, especially regarding properties bordering the CVT. The survey results expressed the interviewees' satisfaction regarding the occurrence of this expectation. Increasing the attractiveness of a region encourages the opening of new businesses and the improvement of the existing trade and leisure infrastructure [55], providing new jobs and better consumption alternatives.

Concerning the dynamics of urban circulation, the initial expectation was that the improvement of mobility due to the creation of a new route for the inhabitants of the Oceanic Region would reduce the travel distance to the main modes of transport and the congestion caused by joining the flow of vehicles from the Oceanic Region with the other flows that converged on Largo da Batalha. In addition, the CVT would contain exclusive bus lanes, with connections to the city and intercity bus networks operating within the new infrastructure, improving the connection between the area under study and the city of Rio de Janeiro through the integration of the CVT with the Terminal Waterway of Charitas. The survey results expressed the interviewees' satisfaction with the occurrence of this expectation. There was also an expectation of an increase in the number of accidents due to the increased circulation of vehicles, the new morphology of roads and the encouragement of non-motorized transport, on foot and bicycles. The survey results confirmed this expectation. The literature points out that an increase in the flow of vehicles and the alteration of the characteristics of the roads increase the number of accidents [55,58]. In addition, traffic rules were changed in the CVT, and the sharing of space between multiple users, in addition to enhancing the occurrence of accidents, must also have increased the feeling of insecurity.

Regarding the effects on the environment, the initial expectation was that the CVT would improve air quality by avoiding the emission of more than a thousand tons of carbon, due to the reduced flow of vehicles and traffic jams. For the same reason, there was also an expectation of a reduction in noise pollution. Several researchers associate road projects with increased air and noise pollution. Road traffic contributes 25% of the global averages of urban PM10 concentration in countries like Brazil [24] and accounts for almost 67% of noise pollution, causing dissatisfaction in residential areas [29,30]. The survey results did not confirm the predicted scenario, going against the literature. Some factors may have influenced the judgment: the suppression of vegetation may affect the propagation of sound and lead to higher air pollution, due to the association between vegetation and pollution reduction; the morphology and elements of the infrastructure may also be producing unforeseen consequences; and near the portal of the new tunnel there may be specific problems, such as reverberation. With regard to the natural landscape, the expectation was that the suppression of vegetation, mainly for the implantation of the tunnel and the construction site, and the topographical readjustment of the land would negatively influence the perception of the population. However, according to the research results, this did not occur.

The comparative analysis between the scenario and the respondents' perception can contribute significantly to the success of similar projects in the future. In Brazil, the premises considered for the construction of scenarios during the process of assessing the impacts of the project take effect when the Environmental Impact Study and the Environmental Impact Report developed for the project's environmental licensing process are developed. Normally, to identify these premises, the main focus has been to try to understand the aspects regarding what is tangible (data from the region, population, etc.), which is understandable. However, it is essential to give due importance to the information present in the existing literature.

Although the survey results were more convergent with the researched literature than the predicted scenarios, this difference does not mean that mistakes were made regarding the execution of the procedures established by the Brazilian legislation to carry out these studies, but mainly that the teams must consider other social participation mechanisms that make it possible to more accurately identify needs and expectations. Although the participation of society is promoted through a public consultation published by notice, the teams must consider other mechanisms of social engagement, such as the use of social networks. Moreover, we believe that Brazilian legislation needs to be more emphatic in this regard.

Regarding the identification of which variables most influenced the level of life and mobility, Model 1 (Figure 4) revealed that among the ten variables considered in the analysis, three were selected as the main variables related to changes in the level of life, seen positively by 83.5% of respondents (Table 2). The related variables refer to the perception of changes in local dynamics, the frequent use of the tunnel and the alteration of the landscape. The interval of 95% confidence for Model 1's accuracy ranges from 84% to 98%. Among those who perceive changes in local dynamics, there is a probability of 93% that they will see changes in the standard of living and 7% that they will not be aware of them. Among those who did not notice changes in the local dynamics, but who use the CVT, there is often a probability of 73% that they will perceive changes in the standard of living, against a 27% probability that they will not see such changes. Among those who do not observe differences in local dynamics or use CVT frequently, but observe changes in the landscape, there is a 60% probability that they will perceive changes in the standard of living against a 40% probability that they will not. People who do not recognize changes in the local dynamics or landscape and do not use CVT frequently are 67% likely not to see changes in the standard of living, compared to a probability of 33% that they will notice them.

Model 2 (Figure 5) revealed that among the 10 variables considered in the analysis, three were selected as the main variables related to changes in urban mobility in the Niterói region, viewed positively by 67.4% of respondents (Table 2). The related variables refer to the perception of changes in local dynamics, the frequent use of the CVT and changes in air quality. The 95% confidence interval for Model 2's accuracy ranges from 79% to 95%. Among those who perceive changes in local dynamics, there is a probability of 95% that they will observe changes in urban mobility and a 5% probability that they will not be aware of them. Among those who did not notice changes in local dynamics, but who use the CVT, there is often a probability of 88% that they will perceive changes in urban mobility versus a probability of 12% that they will not. Among those who do not perceive changes in local dynamics or use the CVT frequently, but perceive changes in air quality, there is a probability of 86% that they will perceive changes in urban mobility, against a probability of 14% that they will not notice them. People who do not see changes in local dynamics or air quality and do not use CVT frequently are 57% likely to miss changes in urban mobility, versus a probability of 43% that they will not.

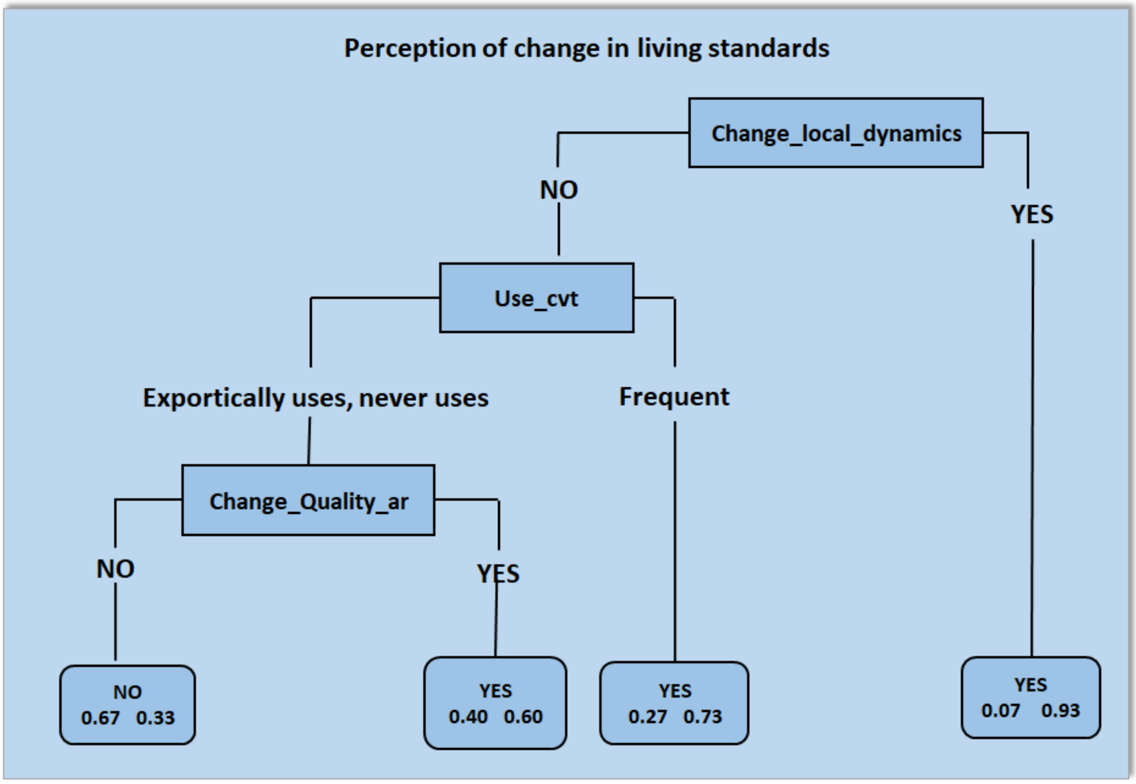

Figure 4. Tree of classification of the perception of the change in the standard of living of residents of Niterói after the implementation of the CVT. Estimated accuracy of 93%.

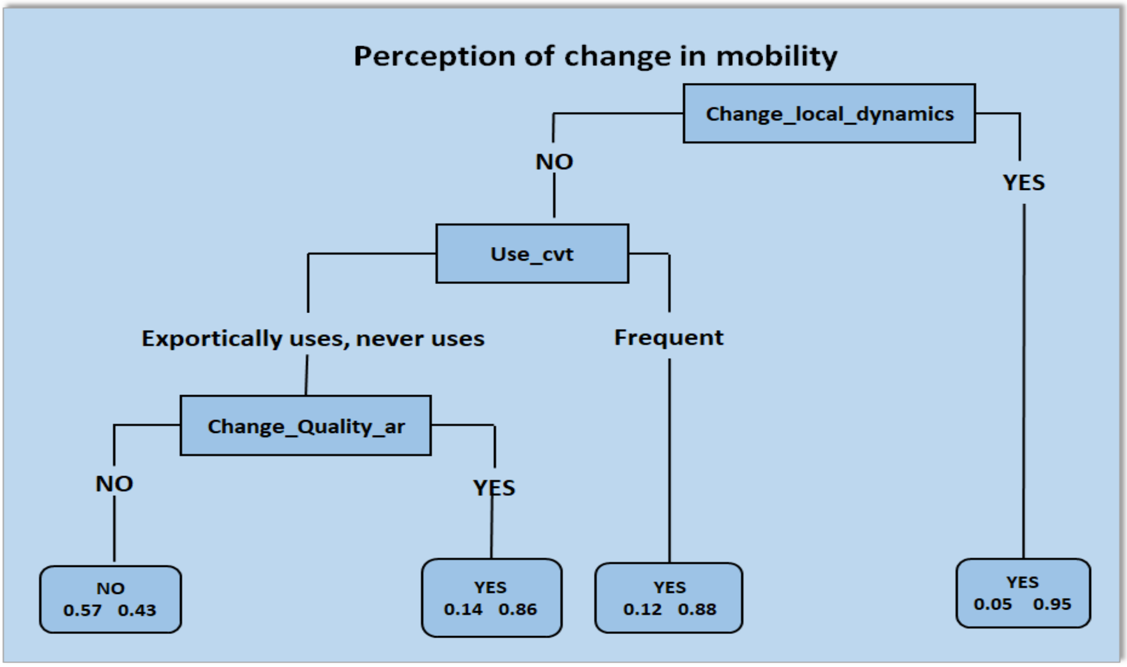

Figure 5. Tree of classification of the perception of the change in urban mobility after the implantation of the CVT. Estimated accuracy of 89%.

Models 1 and 2 reveal that the main variable that is positively related to the change in the standard of living and urban mobility in the region is the change in the local dynamics regarding the attraction of new residents, new commercial and service enterprises and more significant movement and flow of people. The change in this local dynamic was seen as positive by 72.4% of the region's residents (Table 2).

4. Conclusions

In this work, we identified the perceptions of the population directly affected by the CVT in relation to the occurrence of the impacts predicted in the initial phase of the project's operation, as well as which of these impacts most influenced the standard of living and mobility of this population.

The research showed that the positive scenarios foreseen by the environmental studies could already be perceived according to the assessment of the residents of the area directly affected. However, some of the expected impacts are perceived in a way that is contrary to the evaluations expected when planning the project—such as, for example, the change in air quality and the changes in noise levels, which, for most of the interviewed, were perceived negatively.

The model obtained by the classification tree technique identified the main variables involved in the perception of changes in the standard of living of the citizens who circulate in the Oceanic region of Niterói, who must be taken into account for the definition of public policies. It also showed that there is a probability that 67.4% of citizens will positively perceive the impact on mobility. This perception is mainly related to changes in local dynamics, air quality and the frequent use of the CVT.

We can conclude that, except for the effects of the project on air quality and noise levels, the CVT is well evaluated by residents and regulars in the area, contributing to the improvement of mobility and quality of life of those who live in, and attend, the Oceanic Region of Niterói.

This work has the characteristic limitation of studies that use the literature to support information and discussions, which is the risk that some relevant contribution has not been considered in the careful bibliographic research carried out. There is also a limitation often faced by qualitative studies that use a sample to draw conclusions about the population: the sample size. Although the sample used is statistically representative, we had difficulties in increasing the number of respondents willing to participate in the research.

As a result of this work, we suggest that a data survey be carried out, whose sample allows for a stratification by residents, workers in local commerce and users of local commerce.

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Appendix A

Questionnaire Used in the Survey

Evaluation of the perception of impacts arising from the transoceanic road corridor (CVT) by the population of the area affected by the project

1. Name (optional):
2. Borough:
3. Age:
4. Sex:
5. Education: Graduation ( ) Master's degree ( ) Doctoral degree ( )
6. You are a CVT user: **Frequent** ( ) **Sporadically** ( ) **Never use** ( )

7. Do you think that the implementation of the CVT generated significant changes (positive and/or negative impacts) in the region? YES ( ) NO ( ). If YES, these changes were: **POSITIVE** ( ) or **NEGATIVE** ( )
8. Do you think the CVT has improved traffic in the region? YES ( ) NO ( ). If YES, these changes were: **POSITIVE** ( ) or **NEGATIVE** ( )
9. Do you think that the implementation of the CVT generated significant changes (positive and/or negative impacts) in your daily life? YES ( ) NO ( ). If YES, these changes were: **POSITIVE** ( ) or **NEGATIVE** ( )
10. Did the possible impacts, mentioned below, generate effects for the region under discussion?

    (a) Change in air quality (dust/vehicular gases)? YES ( ) NO ( ) If YES, these changes were: **POSITIVE** ( ) or **NEGATIVE** ( )
    (b) Change in noise levels? YES ( ) NO ( ) If YES, these changes were: **POSITIVE** ( ) or **NEGATIVE** ( )
    (c) Alteration of the (natural) landscape? YES ( ) NO ( ) If YES, these changes were: **POSITIVE** ( ) or **NEGATIVE** ( )
    (d) Alteration of the local dynamics (attraction of new residents, commercial and service development, greater movement and flow of people)? YES ( ) NO ( ) If YES, these changes were: **POSITIVE** ( ) or **NEGATIVE** ( )
    (e) Change in mobility in the region (generation of traffic on internal roads, pressure on public transport)? YES ( ) NO ( ) If YES, these changes were: **POSITIVE** ( ) or **NEGATIVE** ( )
    (f) Change in the urban landscape? YES ( ) NO ( ) If YES, these changes were: **POSITIVE** ( ) or **NEGATIVE** ( )
    (g) Change in the population's standard of living (appreciation or devaluation of real estate, increase of commercial and service activities, generation of employment and income)? YES ( ) NO ( ) If YES, these changes were: **POSITIVE** ( ) or **NEGATIVE** ( )
    (h) Change in the safety of the population (vehicle and pedestrian accidents, levels of violence)? YES ( ) NO ( ) If YES, these changes were: **POSITIVE** ( ) or **NEGATIVE** ( )

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