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Longitudinal road infrastructure and coastal anthropization: a critical analysis of the impact of the Rio-Santos highway on the Atlantic Forest biome.

Longitudinal road infrastructures and coastal anthropization: a critical analysis of the Rio-Santos highway impact on the Atlantic forest biome

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Summary

This article analyzes the complex interactions between large civil engineering projects and the preservation of sensitive ecosystems, using the construction of the Rio-Santos Highway (BR-101) in the 1970s as a case study. Based on a theoretical foundation consolidated in French academia and Brazilian urban planning practice, it investigates how the longitudinal cut in escarpment areas of the Serra do Mar mountain range alters not only the local geomorphology but also triggers irreversible processes of real estate speculation and environmental degradation. The study uses the environmental impact analysis methodology developed at Université Paris VIII to assess the consequences of habitat fragmentation and the suppression of native vegetation. It concludes that road planning dissociated from a master plan for land use and occupation results in negative externalities that outweigh the immediate logistical benefits, requiring a revision of the paradigms of state intervention in coastal zones.

Keywords: Rio-Santos Highway. Environmental Impact. Regional Planning. Urbanism.
Atlantic Forest.

Abstract

This article analyzes the complex interactions between major civil engineering works and the preservation of sensitive ecosystems, taking the implementation of the Rio-Santos Highway (BR-101) in the 1970s as a case study. Based on a theoretical foundation consolidated in French academia and Brazilian urban practice, it investigates how the longitudinal cut in the escarpment areas of Serra do Mar alters not only the local geomorphology but triggers irreversible processes of real estate speculation and environmental mischaracterization. The study uses the environmental impact analysis methodology developed at Université Paris VIII to evaluate the consequences of habitat fragmentation and the suppression of native vegetation. It is concluded that road planning dissociated from a master plan for land use and occupation results in negative externalities that outweigh immediate logistical benefits, requiring a review of state intervention paradigms in coastal zones.

Keywords: Rio-Santos Highway. Environmental Impact. Regional Planning. Urbanism. AtlanticForest.

INTRODUCTION

The construction of transport infrastructure in regions of high ecological sensitivity.

This represents one of the greatest challenges in contemporary urban planning and geotechnical engineering.

This research stems from academic investigations initiated in 1976, as part of a master's degree at [institution name].

Université Paris VIII, focused on the impact of the Rio-Santos Highway on the environment. The objective

The central point is to dissect the dichotomy between economic development, advocated by integration.

national transportation via road networks, and the preservation of the natural heritage of the Atlantic Forest. The analysis

It transcends pure engineering, incorporating essential socioeconomic and urban planning variables for

to understand the transformation of the Brazilian coastal landscape.

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DEVELOPMENT

1. The Geomorphology of the Serra do Mar and Cutting Engineering

The geological complexity of the Serra do Mar mountain range presents Herculean challenges to engineering. road construction requires earthmoving operations that drastically alter the natural terrain profile. Construction of cut and fill slopes on steep inclines, typical of the northern and southern coast of São Paulo state. The people of Rio de Janeiro often ignore the hydrological dynamics of the local drainage basins. The waterproofing of the soil caused by asphalt paving accelerates surface runoff. resulting in erosive processes that destabilize adjacent slopes and compromise the very structure itself. Road safety. Technical analysis demonstrates that the containment solutions adopted are often based on highway paradigms from the 1970s, underestimated the intense rainfall in the region, generating a perpetual cycle of maintenance and degradation. In addition to physical instability, the Geomorphological alteration creates a visual scar in the landscape that fragments its continuity. Vegetation cover. The removal of biomass to open up right-of-way areas not only eliminates Plant specimens, but it disrupts ecological corridors vital for endemic fauna. The exposure From the ground to the elements, without the protection of the forest canopy, alters the local microclimate, raising temperatures and modifying soil moisture regimes. This phenomenon, studied from the perspective of Landscape ecology reveals that environmental damage extends far beyond the physical boundaries of The highway is affecting ecosystems kilometers away due to the silting up of waterways. and changes in the quality of water reaching estuaries and mangroves. The impact on the systems River transport is particularly critical, given that the highway intersects dozens of river basins that They flow into the ocean. The damming or diversion of small waterways for the construction of Culverts and bridges alter the speed and volume of water flows, impacting fish and flora. riverside. Excessive sedimentation, resulting from the erosion of unvegetated slopes, is deposited in floodplain areas and along the coastline, altering coastal bathymetry and water turbidity. Such Changes compromise coastal marine biodiversity, which is essential for the fishing economy. The handcrafted work of the Caiçara communities that inhabited the region long before the arrival of infrastructure. modern. The cutting engineering used on the Rio-Santos highway, therefore, must be understood not only not as a construction technique, but as a large-scale human intervention. The decision to tearing through the mountain escarpment instead of seeking less aggressive route alternatives, such as tunnels or Extended viaducts reflect a short-term economic rationale that disregarded costs. Long-distance environmental impacts. A comparative analysis with European highways in similar terrain. Studies conducted during training in France show that technologies with less impact were already in use. available, but were overlooked in favor of speed of execution and lower initial cost of work. From the perspective of road safety and environmental impact, the resulting geotechnical instability

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Interventions create areas of permanent risk. Landslides, rockfalls and
Runway subsidence is a direct consequence of a design that defied the laws of soil physics.
tropical rainforests can be damaged without proper precautions. Maintaining these structures requires constant interventions that...
They perpetuate environmental disruption, creating a state of "permanent construction" that prevents...
Natural regeneration of flora surrounding the highway. This scenario calls for a review of the regulations.
geometric and geotechnical design for roads in mountainous regions, prioritizing bioengineering of
soils. Finally, altered geomorphology serves as a vector for disordered human occupation. The
Disposal areas and service accesses created during construction invariably become...
starting points for invasions and precarious settlements. The altered topography facilitates the
installation of buildings in areas that would originally be inaccessible or unsuitable for the
housing. Thus, highway engineering acts as a physical catalyst for the urbanization of
risk, where the stability of the soil, already compromised by the road construction, is brought to collapse by
Housing occupation without sanitation and drainage infrastructure.

2. Habitat Fragmentation and Biodiversity Loss

The implementation of a linear infrastructure like the Rio-Santos highway acts as a barrier.
an insurmountable ecological challenge for several terrestrial species, resulting in population isolation and
in the loss of genetic variability. The "edge effect," a concept widely discussed in ecology,
This phenomenon manifests itself intensely along the entire length of the highway, where the dense, humid forest...
This gives way to secondary vegetation, which is drier and more vulnerable to invasive species. The penetration of
Sunlight and wind on the forest edges alter the floristic composition, favoring certain species.
Generalists are favored over specialists, impoverishing local biodiversity and reducing the...
Ecosystem resilience. Terrestrial fauna suffers from constant roadkill, one of the causes
more direct mortality rates for vertebrates in regions crossed by highways. The absence of passages
The lack of adequate wildlife in the original 1970s project transformed the BR-101 highway into a graveyard.
Linear for mammals, reptiles, and amphibians. In addition to direct mortality, noise and light pollution also contribute.
Traffic generated by vehicles creates behavioral exclusion zones, where animals avoid the
approaching the highway, effectively reducing the area of habitat available for feeding and
reproduction. This forced confinement to smaller forest fragments increases competition.
Intraspecific contamination and population stress. Water fragmentation is equally harmful. The works
Current art structures (sewers and culverts) are often not designed with mobility in mind.
aquatic fauna, creating steps or flow velocities that impede the migration of fish and
Amphibians. The disconnection between the upstream and downstream portions of rivers disrupts vital cycles of
Reproduction, affecting the entire aquatic food chain. Diffuse pollution, originating from oils and greases.
and tire residue washed by rain into bodies of water introduces toxic contaminants into

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pristine environments, with cumulative and long-lasting effects on aquatic biota. The introduction
The spread of exotic species is facilitated by the corridors opened by the highway. Invasive plants and animals
Non-native species use the right-of-way as a dispersal route, colonizing areas adjacent to it.
Native forest and competing for resources. Environmental enforcement, historically deficient, does not
manages to contain the spread of these species, which find in the environment disturbed by the construction the
Ideal conditions for proliferation. The loss of biodiversity, therefore, is not a one-off event.
linked to the initial deforestation, but a chronic and progressive process triggered by the operation.
continuous infrastructure. Studies conducted during a master's degree at Université Paris VIII indicate
that the economic value of this loss of biodiversity is incalculable. Ecosystem services
services provided by the Atlantic Forest, such as climate regulation, water production, and containment of
Slopes are degraded as biodiversity declines. The simplification of ecosystems
This reduces its capacity to respond to extreme events, making the region more susceptible to disasters.
natural resources. Paradoxically, the highway puts at risk the very natural heritage that attracts tourism.
The economic base of the post-road region. Mitigating these impacts requires the implementation of
Ecological corridors that reconnect forest fragments severed by the road. A
The construction of ecoducts, underpasses, and the reforestation of right-of-way areas are...
Urgent measures are needed to halt the loss of biodiversity. However, the effectiveness of these measures remains to be seen.
It depends on rigorous and continuous scientific monitoring, capable of assessing whether the populations
Are animals effectively using the passage structures, and is the native vegetation present?
managing to recolonize the degraded areas. Without this corrective intervention, the Rio-Santos Highway
It will continue to be a vector of local extinction.

3. Real Estate Speculation and Land Use Change

The opening of the Rio-Santos Highway served not only to connect cities; it
It commercialized the coastal territory, transforming traditional fishing lands and protected areas into assets.
high-value real estate. The accessibility provided by the automobile allowed the elite of
Large urban centers, such as São Paulo and Rio de Janeiro, provide access to previously isolated beaches.
triggering a boom in second-home construction. This phenomenon of "touristification" of
space resulted in the silent expulsion of traditional populations, who, pressured by
Due to rising land values and changes in their way of life, they sold their land and were pushed out.
to the outskirts of coastal cities or to the slopes of the Serra do Mar mountain range. Land subdivision.
In these regions, a predatory logic was largely followed, detached from any planning.
Sustainable urban development. Housing developments were approved and implemented without basic infrastructure.
sanitation, drinking water and waste collection, transferring a liability to the local public authorities.
The environmental and social impact is enormous. The excessive waterproofing of the soil in luxury condominiums and in

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Irregular settlements have exacerbated drainage problems, increasing their frequency and intensity.
Flooding in low-lying areas. Architecture imported from urban centers, unsuitable for the climate and
In contrast to the tropical landscape, it replaced vernacular architecture, homogenizing the landscape and erasing the
Local cultural identity. Real estate pressure is also evident in the verticalization of areas.
coastal areas and the occupation of beach and mangrove zones, ecosystems protected by law, but
Vulnerable to corruption and lack of oversight, the "sea view" has become a commodity.
valuable, justifying landfill, deforestation, and construction in permanent preservation areas. A
Urban planning analysis demonstrates that municipal Master Plans, often drawn up under strong
The influence of the real estate sector legitimized urban expansion into fragile areas, consolidating a
A dispersed and low-density occupation model that maximizes the consumption of land and resources.
natural resources. The road infrastructure, by inducing this type of settlement, created a dependency.
structural issues in individual transportation. The absence of an efficient public transportation system and
Integrated along the coast, it forces the use of the automobile for any journey, generating
Seasonal traffic jams that collapse the very highway that spurred its development. A
The tourist carrying capacity of beaches and cities is frequently exceeded, resulting in...
Degradation of environmental quality and deterioration of urban services during the high season.
This saturation cycle compromises long-term tourism attractiveness, creating a paradox where
Development destroys the foundations of its own sustainability. Land-use transformation.
It also brought acute social conflicts. The privatization of beach access and spatial segregation.
The conflict between gated communities and local residents' villages created a scenario of apartheid.
socio-spatial. The local population, often employed in low-skilled services in the sector.
The tourism and construction sectors face difficulties in accessing decent housing and infrastructure.
Public spaces are concentrated in upscale areas. Real estate speculation, therefore, acts as a...
A mechanism for income concentration and social exclusion, exacerbated by road infrastructure.
which selectively values the territory. To reverse this situation, it is imperative to implement
urban policy instruments that control speculation and promote the social function of
property. Ecological-economic zoning, the application of progressive property tax and the creation of
Special zones of social interest are tools that, combined with rigorous environmental monitoring,
They can regulate land use. However, the effectiveness of these measures depends on political will.
which has historically been superseded by the immediate economic interests associated with
The construction industry and predatory mass tourism.

4. Environmental Impact Assessment (EIA) Methodologies

The Master's thesis developed at Université Paris VIII was based on the application
pioneering Environmental Impact Assessment (EIA) methodologies, at a time when Brazil

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There was still a lack of robust legislation on the subject (prior to CONAMA Resolution 001/86). The approach
The French approach, characterized by Cartesian rigor and systems analysis, allowed for the dissection of the impacts.
direct, indirect, and cumulative effects of the highway. The interaction matrix, a central tool in this
methodology, cross-referenced the project's actions (deforestation, land leveling, traffic) with the
environmental components (soil, water, air, flora, fauna, population), revealing the magnitude and the
The importance of each identified impact. The analysis was not limited to physical and biological aspects,
incorporating the socioeconomic and cultural dimension as an integral part of the environment. A
The methodology adopted emphasized public participation and consultation with the affected communities.
elements frequently overlooked in Brazilian technocratic planning during the 1970s.
Identifying intangible impacts, such as the loss of cultural references and the disruption of ties.
Community-based research has shown that environmental assessment must transcend monetary quantification.
adopting qualitative criteria to measure human well-being and ecological integrity. One of
A crucial point of the methodology was the analysis of locational and technological alternatives. The study
This demonstrated that impact assessment should occur in the early planning phases, before the...
Decision-making regarding the final route. Comparison between different road corridors,
Considering the environmental costs of each option, it is essential to select the alternative with the lowest cost.
impact. In the case of the Rio-Santos highway, the ex-post analysis (carried out during or after the work) revealed that
Many of the design decisions were made without proper environmental considerations, resulting in...
damage that could have been avoided or mitigated with adjustments to the route or changes in techniques.
constructive. Predictive modeling, used to estimate the future impacts of the operation of
The highway expert warned of the risks of urban densification and long-term environmental degradation.
projections made in the 1970s, based on demographic and economic trends,
These findings were confirmed in the following decades, validating the EIA methodology as an instrument of
forecasting. The ability to predict future scenarios is fundamental for regional planning.
allowing the public authorities to adopt preventive measures for territorial planning and protection.
environmental impacts should be addressed before they become irreversible. The methodology also highlighted the
The importance of environmental monitoring and auditing. Impact assessment does not end with
The project is approved, but it must continue throughout the entire lifespan of the undertaking.
Monitoring environmental indicators allows us to verify the effectiveness of mitigation measures and
Make adjustments to the highway's environmental management. The lack of a continuous monitoring program.
The Rio-Santos highway contributed to the perpetuation of environmental problems and to the difficulty of...
accountability for damages caused. Academic experience in France has shown that AIA is
an indispensable political and technical tool for environmental governance. Its rigorous application
Transparency is a *sine qua non* condition for sustainable development. Transposing this...
Knowledge relevant to the Brazilian reality, however, requires the adaptation of methodologies to it.

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Tropical specificities and the country's institutional context. Strengthening environmental agencies.
and the technical training of professionals involved in licensing are fundamental steps for
that the EIA fulfills its role in safeguarding natural and social heritage.

5. The Conflict between National Development and Preservation

The planning of the Rio-Santos Highway was part of a historical context marked by
"Economic Miracle" and the National Security doctrine, which saw in the physical integration of
Territory is a geopolitical imperative. The ideology of development at any cost is hegemonic.
In the 1970s, nature was viewed as a resource to be conquered and exploited, and not as...
a system to be preserved. The Atlantic Forest, in this scenario, was seen as an obstacle to
progress, a "green barrier" that needed to be overcome by engineering to allow the flow of
goods and people. This developmental paradigm clashed head-on with the nascent
Environmental movements and the logic of environmental preservation. The urban planning analysis of this conflict.
This reveals that the development model adopted was exclusionary and concentrated in a way that favored concentration. The highway was...
designed to meet the interests of the automotive industry, the real estate sector and tourism.
elite development, marginalizing the needs of local populations and the environmental potential of the region.
The promise of progress and job creation, used to legitimize the project, materialized as follows:
precarious and seasonal conditions, leaving a legacy of social inequality and environmental degradation.
The wealth generated by real estate appreciation and tourism flowed out of the region, while the
Socio-environmental costs remained local. The tension between development and preservation.
This is also evident in land management. The creation of Conservation Units, such as the Park
The Serra do Mar State Highway was a belated response from the state to try to contain the advance of...
Urbanization induced by the highway. However, the lack of resources for implementation and
Monitoring of these protected areas, coupled with land pressure in the surrounding areas, generates conflicts.
Constant land use patterns. The highway acts as a pressure barrier on the park's boundaries.
facilitating the illegal extraction of natural resources (palm hearts, timber, hunting) and the irregular occupation of
its borders. The economic sustainability of the region depends, ironically, on the preservation of
The environment that the current development model threatens to destroy. Tourism, the main activity
The economic activity of the coast is based on the scenic beauty of the beaches and the forest. The degradation of quality
Water pollution, visual pollution, and biodiversity loss erode the region's natural capital, diminishing its value.
its attractiveness and competitiveness. The conflict, therefore, is not between development and preservation,
But it's a conflict between a model of short-term predatory exploitation and a model of long-term sustainable development.
Resolving this conflict requires a paradigm shift. It is
It is necessary to abandon the dichotomous view that opposes economy and ecology, adopting an approach
An integrated approach where environmental conservation is seen as the basis for economic development.

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Regional planning should prioritize activities compatible with the region's environmental vocation.
such as ecotourism, sustainable mariculture, and agroforestry. The infrastructure must be
Adapted to minimize impacts and promote ecological connectivity, transforming the highway.
from a vector of destruction to an axis of sustainable development. The academic experience
International research shows that it is possible to reconcile infrastructure and preservation, provided there is...
Integrated planning, social participation, and respect for the limits of ecosystems. Europe, with
Its high population density and historical human impact offer examples of territorial management where
The cultural and natural landscape is valued and protected. Brazil, possessing the greatest biodiversity in the world...
The planet has the responsibility and the opportunity to develop its own model of urbanism.
tropical, which harmonizes the need for infrastructure with the imperative conservation of its biomes.
unique.

6. Mitigation Strategies and Sustainable Regional Planning

Given the already established irreversible impacts and future risks, the management of the zone
The coastal area crossed by the Rio-Santos highway requires the implementation of robust mitigation strategies and...
An integrated regional plan. The first line of action should focus on environmental recovery.
of degraded areas. Soil bioengineering, using native vegetation for stabilization of
The slopes should replace the rigid concrete retaining walls, promoting the reintegration of the highway into the
landscape. The restoration of ecological corridors and the protection of springs and riparian forests are
fundamental to guaranteeing water security and regional biodiversity. In the urban planning context, it is
It is crucial to revise municipal master plans to contain urban sprawl. The definition
from rigid limits to horizontal growth, the incentive for densification in already consolidated areas.
and equipped with infrastructure, and the absolute prohibition of new occupations in risk areas and of
Preservation measures are urgent and cannot be postponed. Sustainable land regularization for communities.
The reforms to traditional and informal settlements must be accompanied by massive investments in
Basic sanitation and urban drainage, to stop the pollution of rivers and the sea. Mobility
Regional planning needs to be rethought to reduce dependence on individual transportation. Investment in
Quality public transport, cycle paths and maritime passenger transport can alleviate the pressure.
on the highway and offer sustainable alternatives for transportation. Traffic management, with
Access control in sensitive areas and ecological tolling can be used to regulate the flow.
Tourism and generate resources for environmental conservation. Road infrastructure must cease to be the
The single structuring axis of the territory, integrating into a multimodal transport network.
Regional governance is another fundamental pillar. The creation of intermunicipal consortia and the
Strengthening river basin committees allows for coordinated land management.
overcoming administrative fragmentation that hinders the solution of common problems. A

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active participation of civil society, universities and the private sector in the formulation and
Implementing public policies is essential to ensure the legitimacy and effectiveness of actions.
Environmental education should be transversal to all policies, fostering a culture of respect and
Valuing natural heritage. Tourism should be reoriented towards low-impact models and
High added value. Encouraging community-based tourism, scientific tourism, and observation tourism.
Nature conservation can generate income for local populations and fund conservation efforts. Certification
The environmental impact of tourist destinations and ventures can create a competitive advantage and attract a
A more informed public. The region's economy should be diversified, reducing its dependence on...
monoculture of sun and beach tourism and valuing socio-biodiversity products. Finally, the
Scientific research and environmental monitoring should inform decision-making. Implementation
from a regional observatory, capable of collecting, systematizing, and making available data on quality.
Environmental factors, demographic dynamics, and land use are fundamental to adaptive land management.
territory. Science, combined with traditional knowledge, can point the way to innovative paths for the
harmonious coexistence between society and nature. The Rio-Santos Highway, a symbol of a model of
Outdated development can become a laboratory for transitioning to sustainability.
where the mistakes of the past serve as lessons for building a more resilient and equitable future.

CONCLUSION

A detailed analysis of the impacts of the Rio-Santos Highway on the Atlantic Forest biome and the
The socio-spatial dynamics of the coastline confirm the thesis that large linear infrastructures, when
Implemented from a strictly engineering and developmental perspective, they generate environmental liabilities.
and social issues that are difficult to reverse. Academic training in Architecture and Urbanism at Mackenzie and the
Specialization in Urban Planning in France allowed for a multidisciplinary understanding of this phenomenon.
integrating physical, biological, and anthropogenic aspects. It becomes evident that the road functioned as a
A vector of uncontrolled urbanization, ecological fragmentation, and real estate speculation.
compromising the integrity of one of the richest and most threatened ecosystems on the planet.
The geomorphology of the Serra do Mar mountain range, challenged by the cut-and-fill technique, responded with instability.
Chronic, requiring perpetual maintenance and generating safety risks. System interruptions
Hydrological factors and the suppression of vegetation triggered erosion and siltation processes that
They affect everything from the slopes to the marine coastal zone. The loss of biodiversity, resulting from the effect
The effects of roadkill, accidents, and population isolation have impoverished the regional genetic heritage.
reducing the resilience of ecosystems to climate change and anthropogenic pressures. From
From a social and urban point of view, the highway accelerated the replacement of the Caiçara culture by the culture of...
summer vacations, promoting the elitization of the space and the marginalization of traditional populations.
Sprawling urban growth lacking sanitation infrastructure has degraded the quality of life and...

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The environment, creating a scenario of unsustainability. The lack of integrated planning transformed the landscape, homogenizing and decharacterizing it, which paradoxically threatens its very essence. The tourism activity that motivated the expansion. The Environmental Impact Assessment methodology, Studied at Université Paris VIII, it has proven to be an indispensable tool for identifying and predicting and mitigate these effects. However, its late or insufficient application in the context of the Rio-Santos highway. It limited its preventive potential. Experience shows that EIA should be incorporated into the phases. initial strategic planning factors, influencing the choice of layouts and technologies, and not just as a bureaucratic requirement for the licensing of already defined projects. The conflict between the The need for national integration and environmental preservation revealed the limitations of the model of Development strategy adopted in the 1970s. A short-term vision, focused on growth. The immediate economic focus disregarded the value of ecosystem services and social equity. Overcoming this conflict requires a new approach to regional planning, one that prioritizes... Sustainability at the heart of decision-making and recognizing the physical and biological limits of territory. The proposed mitigation strategies, such as the remediation of environmental liabilities, the Strict land-use planning and investment in sanitation and sustainable mobility are Urgent measures are needed to halt the degradation and promote the regeneration of the region. Participatory governance. Integrated development is fundamental to enabling these actions and ensuring the benefits of development. should be shared by the whole of society. Education and science have a crucial role in changing culture and the search for innovative solutions. It is concluded, therefore, that the Rio-Santos Highway is a A paradigmatic example of how not to intervene in sensitive coastal areas. The lessons learned This case study should guide future infrastructure interventions in Brazil and other countries. Tropical environments. Engineering and urban planning must evolve to work with nature, not against it. utilizing nature-based solutions while respecting the complexity of socio-ecological systems. The academic and professional legacy built from this research reinforces the conviction that The role of the architect and urban planner goes beyond designing forms and spaces; it involves responsibility. The ethics of planning resilient, just territories in harmony with the environment. The preservation of The Atlantic Forest and the quality of life in coastal cities depend on our ability to... transform this knowledge into effective public policies and planning practices. conscious.

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