Sustainability in infrastructure projects proposed for São Paulo state / Brazil and their vulnerability to climate change

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Abstract

Considering the scenario of climate change, in accordance with the latest reports of the Intergovernmental Panel on Climate Change (IPCC), it's possible to verify that the frequency of extreme climatic events tends to be higher, with potential consequences not completely known as of yet.

In this context, this article focuses on analyzing some environmental studies on infrastructure projects in São Paulo state, considering the different geomorphological compartments and their potential environmental fragilities in face of climatic changes.

Key words: climate change, infrastructure, environmental impacts assessment

Introduction

The studies on climate change present a change in the dynamics of the climate over the past few decades, whose models indicate a continuity in the times that follow, and this has been assumed in this article.

As per the first National Assessment Report (Relatório de Avaliação Nacional) - RAN1 of the Brazilian Panel of Climate Change (Painel Brasileiro de Mudanças Climáticas) - PBMC, the climate in Brazil will be warmer, with a gradual increase varying from 1° to 6° C by the year 2.100 in relation to the average temperature recorded at the end of the 20th century. In the South and Southeast regions of the country, an increase in rainfall is also expected.

The environment of São Paulo state

The predominant climate in São Paulo state is Tropical Atlantic, in areas with proximity to the coast, and Tropical Altitude, which prevails in the interior, in places of high altitudes. The average annual temperature ranges from 20° to 22° C. The annual precipitation average is around 1.400 mm, mainly concentrated in the summer. However, in the Serra do Mar Mountains the average is over 2.500 mm per year.

The state is located in the southeastern region of Brazil and presents diverse landscapes. According to ALMEIDA (1964), the state presents four major geomorphological domains, from east to west: the Coastal Plains, Atlantic Plateau, Peripheral Depression and Western Plateau, according to Figure 1 and Table 1.

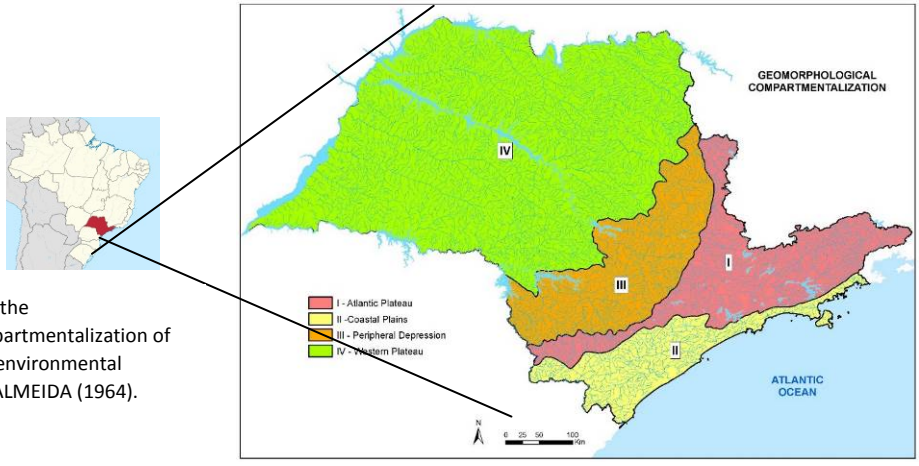

FIGURE 1 - Synthesis of the geomorphological compartmentalization of São Paulo state and its environmental fragilities according to ALMEIDA (1964).

TABLE 1 - Synthesis of the geomorphological compartmentalization of São Paulo state and its environmental fragilities according to Ross & Moroz (1997).

GEOMORPHOLOGICAL DOMAINS	GEOLOGICAL FORMATION	FRAGILITIES	SOCIOECONOMICS
Coastal Plains	Sandy Tertiary and Quaternary sedimentary rocks with levels of organic clay	Very high - subject to floods, shallow water table and inconsolidated sediment subject to constant accommodation, and high susceptibility to the undertows.	2 million people. Petrochemical industries, International trade Ports, coast resorts aimed at tourism.
Atlantic Plateau	Igneous and metamorphic rocks with relief of hills and mountains. Altitudes between 20 and 1000m. High slopes (> 40%). Tertiary sedimentary basins with sandy stones with low slopes.	Medium to high - strong erosive activities and high susceptibility to landslides. The sedimentary basins have medium to high fragility due to the potential of floods.	The most populous region of the state, with approximately 20 million inhabitants in the Metropolitan Region of São Paulo. Industries and services.
Peripheral Depression	Sedimentary rocks in the Paraná Basin of several lithology. Altitudes between 600 and 750m.	Low to medium - low erosive potential.	Region with important industrial poles and intense agricultural activity
Western Plateau	Sedimentary rocks of the Paraná Basin composed of sandstones and basaltic igneous rocks. Altitude between 500 and 600m.	Medium - greater stability in the processes of the physical environment. However, it has high susceptibility to linear erosive processes.	Predominantly agricultural and livestock activities with a focus on sugarcane used for ethanol production, in addition to orange, coffee and commodities.

Photos: Main geological, hydrological and climatic processes occurring in São Paulo state, which will undergo a change in its dynamics in the face of climatic changes.

Undertow

Landslides

Floods

Erosion

Strong Winds

In a rather general way, this table presents a picture of São Paulo state, and a scenario study of the projects that have been considered in this article.

The occupation history of this territory was marked by the transposition of the Serra do Mar Mountains, located between the Coastal Plain (Port of Santos) and the Atlantic Plateau (where the São Paulo metropolitan area is located). The escarpment of Serra do Mar has a slope of 800 meters and is an important route of connection between the industrial poles that have been developed in these regions. Its transposition has been carried out mainly by means of highways, railroads and pipelines, establishing the greatest economic flow of the country.

Infrastructure in São Paulo state

In Brazil, São Paulo state has the largest Gross Domestic Product – GDP - in the whole country, due to its industrial production, agriculture and services. It has a transportation infrastructure that stands out in relation to the rest of Brazil.

The state's 44 million inhabitants are scattered across a territory of 248.209 km ² with three cities containing populations of more than one million inhabitants. Namely, there are São Paulo, which is South America's largest metropolis with almost 11 million inhabitants. Additionally, there are also six cities with more than 500.000 inhabitants.

In this context, planners have considered the region of the macro metropolis of São Paulo state, which represents the largest and most complex urban system in the country. This area has been consolidated over the last ten years. At the end of this century's first decade, there were 173 municipalities in total which accounted for 73.3% of the total population as well as 82.7% of the state's GDP and 27.7% of the Brazilian GDP. The most urbanized area of the country, this immense region is a result of the unfolding of demographic, economic and urban dynamics.

Methodology

Despite the infrastructure mainly being installed during the 1960s and 1970s, and from its expansion and improvements implemented in the last two decades, it is still considered insufficient and obsolete for the continuity of the growth of the economy of the state and the country, and for the well- being of the population. To meet expected demand, it is necessary to expand and modernize the entire network for different modes of transportation.

In this way, this research was prepared to analyze which of the enterprises implemented in the last two decades in the state have in their preliminary environmental studies some approach or consideration regarding the new conditions predicted by global climate change.

The considered criteria to the research was:

- Selection of infrastructure projects in the last 20 years that were the subject of environmental studies to obtain environmental licenses;
- Identification of major transportation projects;
- Projects located in the different geomorphological compartments of the São Paulo State; and
- Selection of projects, among those selected, that the authors of of the paper had some technical participation in any stage of environmental impact assesment, or during the construction phase of the projects. Analysis of the expected environmental impacts and mitigation measures proposed in the studies.

Various Reports of Environmental Impact Studies were analyzed for modernization and deployment of highways (Rodoanel, Tamoios), improvements in public transportation system for urban trains, new subway lines (Linha 5 Lilás), new pipeline networks (GASPAJ) and implementation of underwater tunnels (Submerso Santos-Guarujá). The projects that are the objects of these studies are located in different environments of the state, being susceptible to different types of fragilities and vulnerabilities.

Although the analysis shows that enterprises with more modern projects and construction techniques are foreseen, and that new themes are being incorporated, the explicit approach on risks to climate change have not been realized. It is evident in the environmental studies that the analysis of the environment in an integrated way predicts the occurrence of surface processes in function of the behavior of the land and occupation. However, in none of them has their behavior in a future scenario under more severe climatic conditions been predicted, and as a result of the necessary design changes if there are significant changes in the dynamics of their particular weaknesses.

Based on the analysis of vulnerabilities defined by natural conditions and how the land was occupied, the IPCC wrote the 5^{o} report of Working Group II, focusing on the concepts of risk analysis.

The PBMC showed in the RAN1 that in the Southeast of the country, the projections indicate a relatively low temperature increase between 0,5^{o} C and 1^{o} C until 2040, with a 5% to 10% increase in rain. Between 2041 and 2070, trends of gradual increase of 1,5^{o} C to 2^{o} C in temperature and 15% to 20% in rainfall should be maintained. However, such trends should become even more pronounced at the end of the century, when the climate is expected to be between 2,5^{o} C and 3^{o} C warmer and between 25% to 30% rainier.

In this way, it can be considered that due to existing fragilities and with the increase of the occurrence of extreme events in a densely occupied region, more areas will be vulnerable and with a greater risk of accidents.

Considerations

Due to the fragilities of the environments in the state conditioned by the natural characteristics and the occupation of the land, the new enterprises are subject to the phenomena that may result in behavior alterations of frequency, intensity, comprehensiveness and significance.

In this way, it is possible to consider that:

- The Coastal Plain may intensify the processes of localized floods, salinization of groundwater, instability in building foundations, etc., due to sea level rises, elevation of the water table, liquefaction of the land and occurrences of undertows;
- The Atlantic Plateau may have an intensification of slope and flooding processes due to the increase in rainfall, which is already very high. In this way, the installed infrastructure would be subject to change in the vulnerability of wherever the it is located;
- In the Peripheral Depression and in the Western Plateau, the intensification of the processes of linear and superficial erosion can be predicted as well as of slides on the steepest slopes, in addition to floods located in the fluvial plains. As well as this, the increase in temperature may change the dynamics of agricultural production in the region.

Considering this framework, strategies and actions that will advance the generally resilient routes and infrastructures for sustainable development must be planned. Improving living conditions, the economy and environmental management, which must be implemented in the context of new environmental studies, is also recommended.

According PBMC (2014), the socio-environmental consequences of extreme events in Brazil in recent years reinforces the need for a national adaptation strategy in various sectors of economic activities.

Although international reports and scientific studies point to uncertainties in climate modeling, especially due to the difficulty of predicting socioeconomic aspects (GHG emissions, demography, technological development, among others), environmental studies for new developments in São Paulo state need to:

- Incorporate forecasts considering the predictions of increase occurrence of extreme events;
- Incorporate new design criteria for drainage systems, for security of structures, among others;
- Incorporate new systems of operational monitoring of infrastructure to increase the efficiency of forecasting actions and alert to the occurrence of these extreme events;
- To develop specific mitigation plans and contingency plans that incorporate new emergency operational procedures and protocols for harm reduction in natural disaster cases at the respective sites identified to withstand exceptional climatic events;
- Research and incorporate (even international) experiences of actions that increase resilience or responsiveness to extreme events;
- Apply globally a consolidated knowledge to international organizations such as the IPCC, UNISDR, to increase the engineering solutions of the infrastructure projects to be developed - incorporating future forecasts, testing and applying modeling in order to increase its accuracy.

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