The use of geotechnology as a new tool for external control

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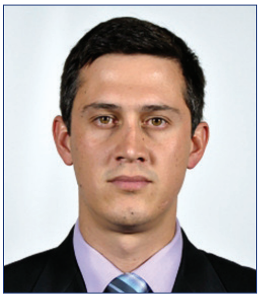

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SUMMARY

The goal of this study is to describe how the use of geotechnologies can become an innovative tool for external control, listing what are the main tools of geotechnology, enumerating the advantages of its implementation within the external control and describing a pilot project carried out in the Federal Court of Accounts of Brazil (TCU). Some important tools to support external control actions include the use of images from remote sensing (satellite, UAV and radars) with geoprocessing techniques, multi-criteria analysis applications for geographic information and Geografic Information System platforms (GIS) supporting all of these technologies. To check the efficiency of the multi-criteria analysis as an audit tool, a pilot test was carried out based on a model of a decision by multiple criteria coupled with geographic information systems directed to transportation planning. The study was conducted for the northern extension of the Norte Sul Railway – FNS, already scheduled, linking Açailândia/MA to the port in Barcarena/PA. The pilot results were very positive. The model proved to be simple and flexible. The results showed in graphics allow for an easy comparison view of the alternatives and of the most economical and efficient corridors. Furthermore, the model brings transparency regarding the data used, as well as adopted values and rules. The adoption of spatial multi-criteria analysis showed enormous potential for application in external control. The use of geotechnology tools has the ability to improve the performance of the external control, highlighting the increase of monitoring ability; expansion of the spatial and temporal scope of control; reducing travel costs; real-time monitoring of critical activities; increase the "feel" of control. Knowledge of geotechnology enables a more active external control by TCU, be it by increasing the tool proposition capacity to formulate public policies, be it by increasing the evaluation capacity of established public policies. In this sense, carrying out this pilot confirms the technical feasibility and the potential use of geotechnology multi-criteria analysis on these two dimensions. The next steps of this research include the evaluation of other geotechnologies and the evaluation of its incorporation as external control tools.

Keywords: geoprocessing, geointeligence, remote sensing, multi-criteria analysis, external control, audit of public works, evaluation of public policies.

1. INTRODUCTION

The implementation of a public policy (in particular those involving infrastructure projects) is usually complex and involves the analysis of a large amount of information from different fields: economic, social, legal, political-administrative and environmental (Rodrigue et al, 2006 ; Nobrega et al, 2012). Decision-making without consideration and appropriate integration of these factors leads to poorly designed policies that do not optimize the aggregation of value to society. This complexity is also reflected in the performance of audit courts, especially given the need to act efficiently, timely and effectively in assessing public policies. This demands, especially in the infrastructure area, the incorporation of technological advances, among others, to the improvement of control measures (Pereira, 2009).

Some of the technologies available which enable an improvement in the development and evaluation of public policies are the geotechnologies supported by Geographic Information Systems (GIS). They enable the processing of large amounts of information and enable the integration of economic, social, environmental and technical data in a geographical and temporal context. From a practical point of view, it is new and still under development, so its use as a control tool is still on its early stage.

This article describes geospatial tools that are likely to be used in supporting the audits of the TCU and reports the innovative works that are being developed in the search for geoprocessing tools that might be useful for external control. It features an innovative pilot project carried out at TCU, using multiple criteria and GIS analysis for assessment of rail alignment alternatives. Finally, the paper discusses the potential application of geointeligence in external control.

2. GEOTECHNOLOGY TOOLS AND THEIR USE IN DECISION-MAKING

Geoprocessing is the discipline of knowledge which uses mathematical and computing techniques for the treatment of geographic information and that has been increasingly influencing the areas of mapping, analysis of natural resources, transport, communications, energy and urban planning. Geotechnologies are a set of technologies for collection, processing, analysis and availability of geo-referenced information. Several technologies are encompassed in this design and we describe here those which recently had greater application: Remote Sensing (RS), which include the use of images (satellite and manned/unmanned aircraft) as well as multi-criteria analysis applications for geographic information and GIS platforms supporting all these technologies.

Geographic Information Systems (GIS) are systems that connect geographic information to databases containing other types of information. These systems allow you to perform complex analysis to integrate data from various sources and create geo-referenced databases. (Davis et al, 2001). The pooled data allow you to create thematic maps, in which various types of information can be overlaid and interpreted (Delgado, 2014).

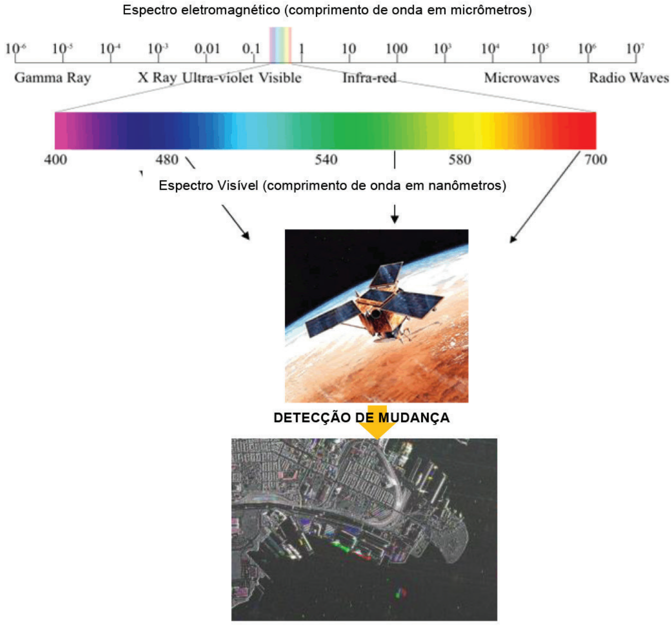
Remote sensing is the set of techniques that allows one to obtain information on targets on the earth's surface (objects, areas, phenomena). Remote sensing is not limited to photos with satellites, but includes any equipment that can sustain a sensor such as a camera, a radar or even a laser measuring device. Thus, the sensors can capture visible light or any other frequency from the eletromagnetic spectrum and can be installed in the hand of a person, a building, a satellite, an airplane or in modern UAVs (Unmanned Aerial Vehicles), commonly known as drones. Of course, the relative position between the sensor and the object to be observed may vary, resulting in a multitude of perspectives, which would allow different applications of the obtained images.

The progress of aerospace, the miniaturization of sensors and the popularization of UAVs have made it possible to obtain better quality images and increasingly lower costs. This effect, combined with the large number of softwares like GoogleEarth, gave a huge boost to the popularity of images of the Earth's surface and allowed the application of remote sensing for a multitude of purposes. As important tools of remote sensing for external control exercised by TCU, we can mention satellite images, radar images and images taken by the UAVs, summarized in the following text.

2.1 SATELLITE IMAGES

The satellites currently available on the market today are able to provide images with an extremely high level of detail. The location accuracy and excellent geometric quality turn these products into instruments with various applications for external control actions. Also called orbital images, they are used when the area of interest is relatively large, which impairs the cost-benefit of the aerophotogrammetric flight or UAVs and also when you need images regularly. Satellite images are also attractive because of the wider range of spectral bands such as infrared images, which allows for identifying in an automated manner the

Figure 1:
Satellite Images and highlight changes in detection of colors



source: geo-airbusds.com

type of terrain or vegetation cover, for example. High resolution satellite images already compete in price and applications with photogrammetric aerial images, and are important sources of digital data for GIS in order to constitute a geographic database allowing the performance of variousanalysis.[1]

One of the products that offers many applications is the detection of changes, which is the recognition of changes in patterns characteristic of certain features at any given time. In practice, periodic images are used where the areas where there have been changes are "painted" or marked with different colors (Santos et al, 2005). The choice of data to be used in this process should list the type, the sequence of events so that they can support the control and the inspection of a particular region (Steininger 1996).

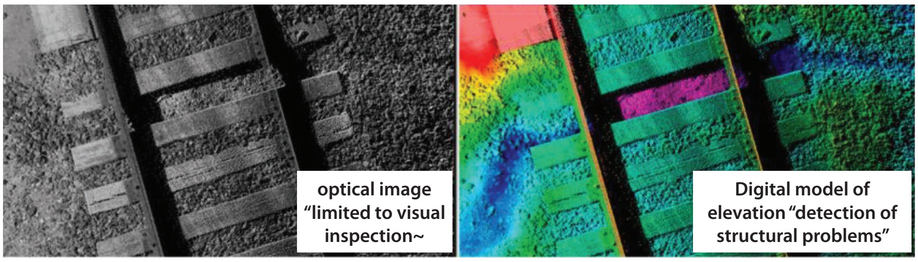
Under external control, the use of satellite images allows various actions ranging from the monitoring of areas or activities of interest (agriculture, construction, developments, settlements, areas of preservation and indigenous), which can be done through pictures updated daily, to data extraction contained in the images by means of specific software for interactive analysis activity and manipulation of raw images for subsequent interpretation, such as the creation of Digital Elevation Models and extraction of contour lines, from images.

2.2 PROFILING LASER IMAGES

Profiling laser images, known as LiDAR (light detection and ranging) revolutionized geotechnology

Figure 2:
Application of tillering images: comparison between the simple visual inspection through photographs and detection of problems in the track superstructure.

adapted from www.jasonamarori.com)



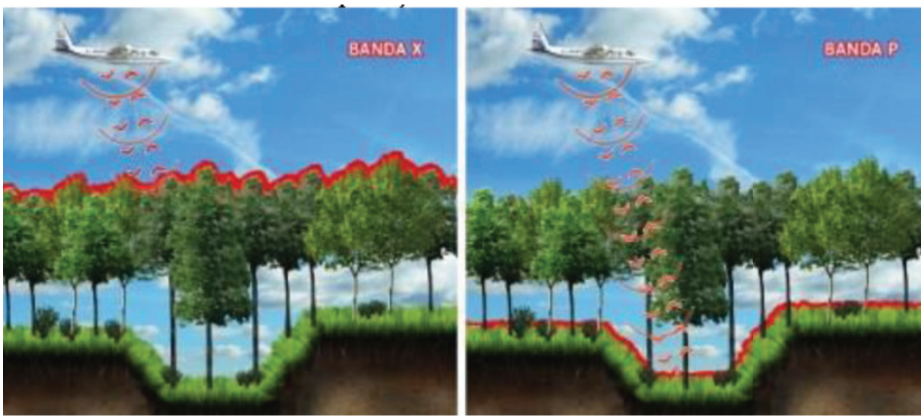


Figure 3:

Illustration of radar operation process highlighting the difference of the bands that allow the return signal on the surface of treetops or of the sign on the ground surface .

source: www.bradar.com.br

and are used as a way to collect data for the composition of topographic surfaces such as mining, cut and fill volumes, as well as three-dimensional measurement of objects installed on it, such as transmission lines and buildings. There are several companies of aerial photography in Brazil (with manned aircraft) that have such a system. Due to the quality, speed and accuracy in measurements, this system has gained more and more space in infrastructure projects and in monitoring.

The LiDAR is a sensor that emits pulses in the optical spectrum (usually laser) which, when they reach the surface to be mapped, are reflected, partly returning to the emission source. The system measures the time difference between the generation of the outgoing pulse and when it receives the reflected signal, and calculates the distance between the sensor and the surface. The pulse interaction with different targets on the surface causes lags in the signal, enabling the distinction and classification of different patterns on the surface.

2.3 IMAGES OF SYNTHETIC APERTURE RADAR (SAR)

The synthetic aperture radar (SAR) operate in the microwave range of the electromagnetic spectrum. Traditionally sensors operate in bands X (shorter wavelengths), L (intermediate waves) and P (longer wavelengths), these with the power to penetrate the vegetation cover, allowing the creation of digital terrain models with greater accuracy compared to traditional methods. The operative radar images in P band does not suffer interference or obstruction from the trees, which reduced considerably the margin of error in the execution of projects in which the highly accurate knowledge of the topography is very important, as in the precise study of flood area in a dam before construction.

SAR images are often used when: [1] the area of interest is constantly covered by clouds; [2] you need to precisely raise the altitude of a forest cover of the region; [3] it is required to map the region overnight; or [4]you need to monitor variations in the surface of the ground over time (Bradar, 2015). SAR sensors can be embedded in satellites or larger aircraft when it needs finer resolutions. There are commercially available orbital products with resolutions of tens of meters to a meter. It is noteworthy that the SAR images, by its natural non-optical signal and the required processing, display different characteristics than of an aerial photograph, and as such require unique methods of analysis and interpretation

2.4 UAV / DRONES

Unmanned aerial vehicles (UAV), also known as drones, are unmanned aircraft that can have autonomous control or be controlled remotely and manually. They are usually equipped with different systems such as cameras, sensors, communications equipment, among others. (Barrios et al, 2007). Currently, the use of UAVs is growing both in the military and in civil areas, especially when human operation is unnecessary, wasteful, repetitive or dangerous, especially in remote or small areas where the use of conventional photogrammetry makes work execution uneconomical.

The UAVs are being used in various fields of study such as archeology, geology, environmental monitoring and of accidents, monitoring of engineer-

Figure 4: UAV employment illustration for overflight on highways and the possible problems that technology can help identify before, during and after the execution of a project.

ing works for military purposes and aerophotogrammetric mapping. The systems allow, with moderate accuracy, the development of photogrammetric processes for correcting images and three-dimensional terrain measurement.

The UAV is an excellent tool for obtaining high-resolution images, low cost and high temporal resolution. These characteristics make it a quality alternative for the production of maps, Numerical Terrain Models (NTM) and high spatial resolution imaging.

Under the external control the UAVs have many applications, like the audits to follow linear jobs, such as railways, highways, canals and transmission lines. The use of UAV would allow the execution of aerial surveys, to the fullest extent of the job or at some particular point, with high resolution images and restitution of altimetry with point cloud generation of Digital Terrain Model (DTM) and contour lines , as illustrated in the following figure.

2.5 MULTICRITERIA ANALYSIS AND DEVELOPMENT OF PUBLIC POLICY

The objective of the evaluation of public policies is to help develop an eficient solution[2] that meets the goals of government action, considering possible alternatives for obtaining the desired results (HM Treasury, 2003). TCU has an important role, which is to charge public officials to make sure that public policies are adequately evaluated before its implementation, for the purpose of ensuring good use of funds. On the other hand, we must monitor and evaluate the

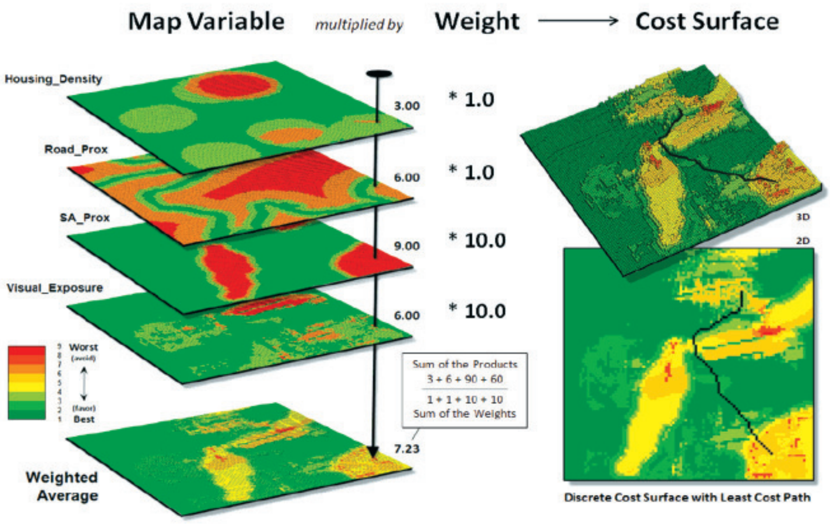


Figure 5: Multi-criteria analysis: maps integration process (Berry, 2009)

already implemented policies. The geospatial tools discussed here have great application in monitoring projects in progress or completed. In turn, the spatial multi-criteria analysis has application both prior appraisal (during the planning phase of a project) and in the evaluation after the policy is chosen.

One of the most used assessment tools for alternatives (and monitoring and evaluation of public policies) is the cost-benefit analysis. The basis of cost-benefit analysis is the monetization of costs and benefits. However, not always these costs and benefits can be easily monetized. In such cases, the multi-criteria analysis is an important tool to balance the benefits and costs of the impacts not monetized (London, 2009). It is a technique to aid decision-making about a complex issue, considering factors through weights, allowing them to choose alternatives according to different criteria and points of view. (Januzzi et al, 2009).

On the other hand, it turns out that, especially when it comes to infrastructure policies, environmental, agricultural or urban planning, much of the necessary information for decision-making are spatialized. With that comes the need to address the multi-criteria analysis in a spatial form - when it is used in combination with the geotechnology. The process allows a substantial reduction in analysis time, illustrates in the form of maps, graphs and tables, points out the areas of greatest viability (expected natural guideline for the implementation of infrastructure) and quantifies non-viable areas for the implementation of the work.

Therefore, the spatial multi-criteria analysis has great potential for the TCU, in areas such as evaluation of transport corridors, tracings of infrastructure works, great location for schools, daycares, hospitals and also in the monitoring of settlements, agricultural and of indigenous areas.

As it will be described below, a pilot work of space multi-criteria analysis has been conducted at the TCU, with the objective of evaluating the transport corridor linking Açailândia (extreme northern part of the Norte Sul railway) to the port of Barcarena (PA), seeking to ensure the best use of public resources.

3. THE PROJECT OF GEOTECHNOLOGY USE IN THE TCU

To be clear, there are numerous applications of geotechnology of which the control can benefit, especially:

- **Increased enforcement capacity:** the use of remote sensing imagery enables the automation of the inspection process, by providing a greater amount of systematized information in a smaller time frame, enabling broader evaluations of public policies or works;

- **Expansion of the spatial and temporal scope of external control:** with greater enforcement capacity becomes feasible to control a larger number of sites and at various times;

- **Reduction of travel costs:** the use of remote sensing is able to replace, in most cases, the auditor's visit to the place of inspection;

- **Real-time monitoring of critical activities:** certain activities that require more intensive monitoring by the control unit can be remotely managed in an efficient and timely manner;

- **Improvement of control planning:** the large amount of processed information that this technology enables, becomes a powerful source to plan the control actions;

- **Increase the "feel" of control:** with greater enforcement capacity and the expansion of the spatial and temporal coverage of the control agency's activities, the external control actions become efficient and timely resulting in a greater sense of control by the auditee;

- **Increased robustness and quality of public policy reviews:** with the use of spatial multi-criteria analysis, it is possible to evaluate and compare variables that are unquantifiable or that can not be monetized, allowing the control to evaluate more robust alternatives and choices of projects and policies, such as transport corridors, infrastructure works paths, location of schools, hospitals, and other public policies;

- **Transparency in the criteria used for the definition of policies or projects:** the provision of all data analyzed such as evaluation criteria and the choice of a project in a spatial database (GIS) (which can be combined or not to multi-criteria analysis tool) gives transparency to the adopted criteria and the relative weights used in decision making.

In this context, it emerged in the Coordination for Infrastructure Sector (COINFRA) of the Federal Court of Accounts of Brazil (TCU) a project to better assess the geospatial tools available in the market that are likely to be applied in external control and to formulate proposals for the structuring of technical units to incorporate the use of these tools . This work includes the completion of two pilots: the first, described below, which used the spatial multi-criteria analysis to assess the definition of a rail corridor. The second pilot, still in progress, evaluates the use of satellites and remote sensing images for the monitoring of public works. The work has the support of the Center for Research and Innovation of the Capacity Development Institute (ISC).

3.1 USE OF MULTICRITERIA PILOT ANALYSIS IN A RAILROAD

To check the efficiency of the multi-criteria analysis as an audit tool, a pilot test was conducted in partnership with prof. Rodrigo Nobrega, from the Department of Cartography of the Institute of Geosciences of the Federal University of Minas Gerais (UFMG), who developed a decision model for multiple criteria, supported by geographic information systems, targeted to transportation planning.

3.1.1 Study Area

The study was conducted for the planned northern extension of the Norte Sul Railway - FNS, linking Açailândia-MA to the port in Barcarena-PA. The port of Espadarte is also being planned in this same reagion, east of Barcarena. The knowledge generated and the results obtained can be used to analyze both the route to be proposed by the National Agency of Land Transport (ANTT) and Valec, and to assess the impacts of choosing one port or another. In order to maximize the capture of socioeconomic and environmental diversity, and infrastructure diversity of the region which could influence the railway project, the study area was expanded to 250 kilometers east and west of the straight line connecting Açailândia and Barcarena.

Figure 6: Scenarios, variables and their rankings used in level 1 of the multi-criteria decision-making implemented for TCU study of the northern stretch of the Norte Sul Railway

Nível 1

SOCIAL-ECONOMIC	
Criteria	***Ranking***
Population	6
Agricultural GDP	3
Industrial GDP	1
Services GDP	5
GDP *per Capita*	6

MARKET	
Criteria	***Ranking***
Soy	3
Other grains	4
Iron Ore	2
Calcite/Phosphate/Kaolin	3
Bauxite	1
Other types of Ore	4

LOGISTICS	
Criteria	***Ranking***
Roads – density	3
Waterway	8
Mineral deposit	2
Railway	1

ENVIRONMENTAL	
Criteria	***Ranking***
Official Native lands	9
Native lands – on-going study	7
CU – Full protection	7
CU – Sustainable use	5
Cave	9
Settlement – African origin	7
Settlement	7
Mangrove	5
Native forest	5
Archeologic site	9
RPPN	9

PHYSICAL GEOGRAPHY	
Criteria	***Ranking***
Hydrography – density	5
Hydrography – distance	5
Declivity	9
Geomorphology	3
Soft foundations	9
Transmission lines	5
Pipes	5

3.1.2 Methodology

The used model of multi-criteria analysis simultaneously integrated 35 different variables (such as terrain slope, agricultural and industrial gross domestic product, road density and intermodal attractiveness, intersection of waterways, environmental protection areas) combined into 5 groups (marketing variables , logistics, socio-economic, physical and environmental), as shown in Figure 7.

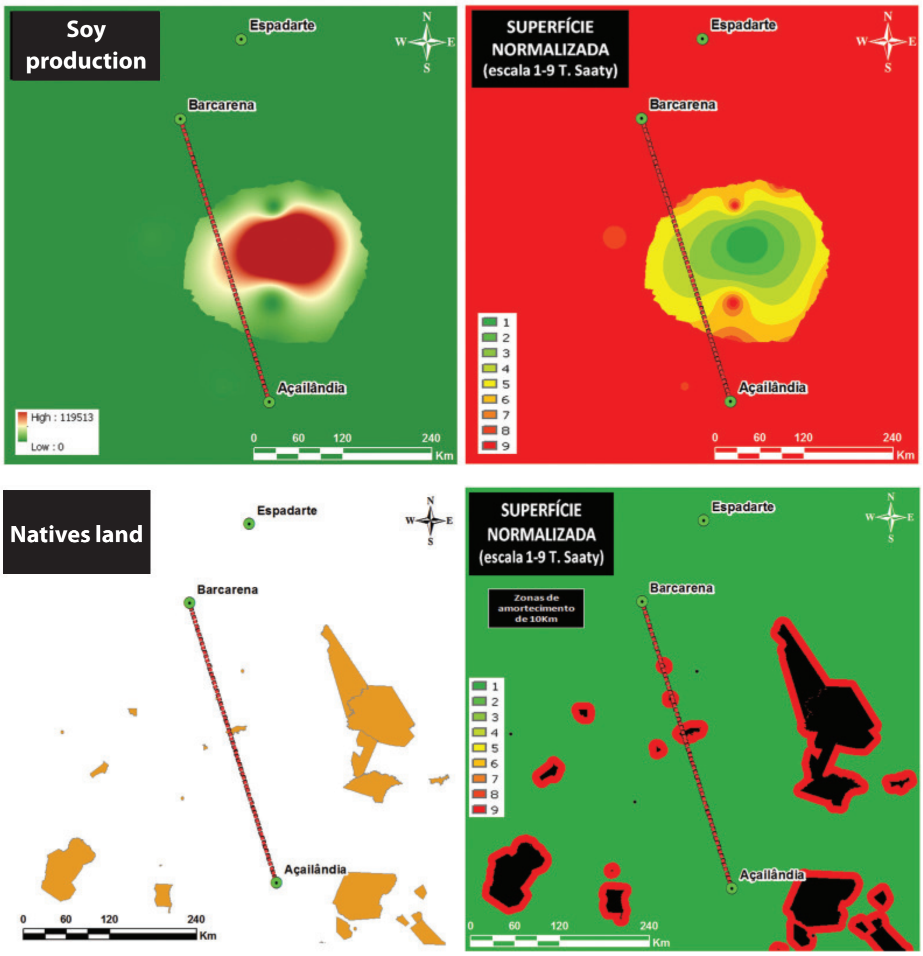
These variables were worked on a hierarchical procedure, where weights/points were given for each variable. The model defines whether these variables have attractiveness or repulsiveness to the railway line, as well as levels of attraction or repulsion. Thus, for example, stretches with steep slopes on the ground repel the route of the railway, as they result in a higher cost of construction, and points with high agricultural and industrial GDP attract the track as they may become points of interest for the construction of loading yards and freight. The adoption of weights was indirect and considered inputs in the range between 1 and 9, corresponding to the AHP model (SAATY, 1995). The strategy has always considered the degree of effort or potential cost offered for the railroad deployment for each variable. Lower values represent how attractive the model is (greater viability) and higher values represent repulsion (low feasibility or impossibility).

As a result, the model generates thematic maps (each variable is plotted on a map) and these maps are combined, following the example shown in Figure 5, in order to qualify and quantify the areas of highest feasibility for the implementation of the infrastructure.

The work was carried out in four steps: the gathering and processing of geographic data, pre-processing or adequacy of the data for entry into the mod-

Figure 7:

Examples of modeling of thematic maps used in the study of the rail segment between Açailândia-MA and Barcarena-PA



el, geographic modeling and finally the multi-criteria analysis for the creation of cost surfaces (or effort).

Data collection

At this stage we collected data that resulted in 35 distinct variables. These input data, without exception, come from public sources and were obtained without charge.

Preprocessing

In the preprocessing stage, the data listed above were prepared/modified to serve as input for the model. The first step was the geographical cut using the polygon of the study area. Some data, such as was the case with the digital elevation model, passed through the reverse process, forcing to compose a mosaic to fill the polygon. Once in line with the study area, the data were worked to generate thematic maps: the spatial mapping of information.

Geographic modeling

The geographical modeling of this study was based on the model proposed by Nobrega (2009). The procedure consists in handling information of each thematic map so that they can be processed and analyzed together.

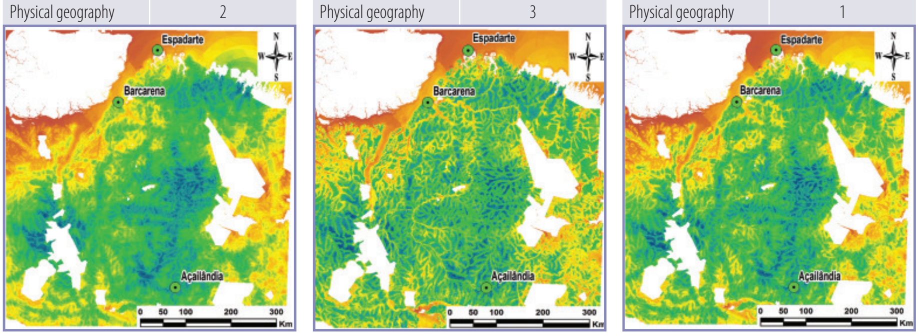
The initial challenge of modeling is the general understanding of the problem and how each thematic map entry will be treated to achieve the proposed objective. In this sense, the necessary steps are: [1][3] establishing rules for modeling (weights/points) each thematic map and [2] normalization of values.

In short, for the establishment of the rules, the data of each map are analyzed and processed as to contain qualitative data (nominal, categorical) and qualitative data (interval, ordinal), allowing them to be described in the same number and dimensionless scale so that they can be further processed together. This process can be developed in two ways:

Full scenario 1	
Criteria	ranking
Social-economic	2
Market	4
Logistics	2
Environmental	1
Physical geography	2

Full scenario 2	
Criteria	ranking
Social-economic	1
Market	1
Logistics	1
Environmental	2
Physical geography	3

Full scenario 3	
Criteria	ranking
Social-economic	1
Market	1
Logistics	1
Environmental	1
Physical geography	1



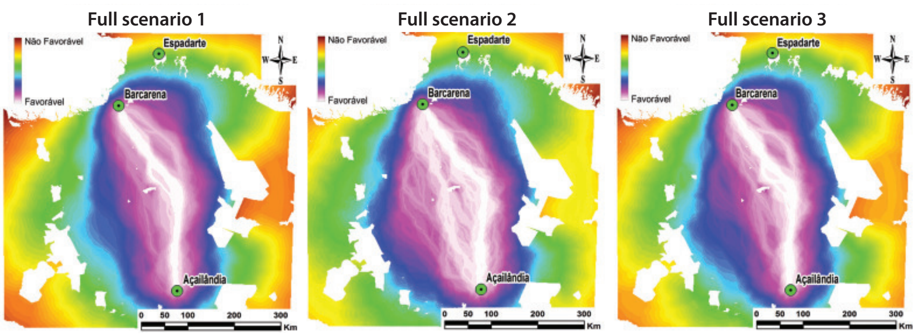


Figure 8: viability of corridors linking Açailândia-MA and Barcarena-PA. White and pink areas represent greater viability to the railroad deployment.

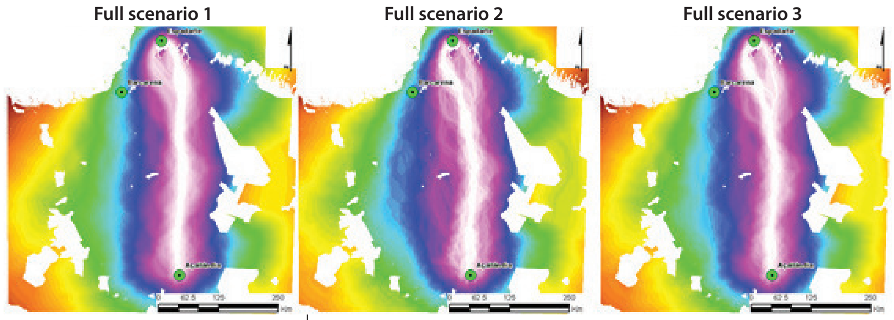


Figure 9:

Feasibility corridors linking Açailândia-MA and Porto Espadarte-PA. White and pink areas represent greater viability for railroad deployment

Processing of an interpolation surface, density map or indices (as slope maps): when using the mass center of the city and the farming attribute (eg, soybeans). The resulting surface will be divided into 9 classes as dimensionless production. The allocation of factors, called AHP - Analytic Hierarchy Process) will be inversely proportional to the value of production. The higher the production, the lower the AHP factor and respectively greater the attractiveness of the area for the corridor. The lower the production, the greater the AHP factor and greater stress to the operating corridor.

Definition of restricted areas: for example, the polygon of the indigenous area will be treated as restrictive mask. In this case, a 10Km buffer was created for the polygon and assigned the AHP factor = 9 for the area contained in the buffer. The rule prevents the occupation of indigenous areas, and hampers the occupation of the area surrounding the indigenous land.

3.1.3 Results

Once the five effort surfaces of the scenarios were established, these were integrated into the second level of the hierarchical process, for which it was established three integrated scenarios, which corresponds to the resolution of the sensitivity analyzes to model their corridors feasibility. Similarly to level 1, the hierarchical level 2 processing generated three new integrated level surfaces (Figure 8), used in their calculation of corridors (Figure 8 & 9).

Although different, the results of the three scenarios showed convergence in the passage/corridor to connect the two points. The areas identified as having the greatest viability for installation of the railway infrastructure suffered deviations caused by the repulsion of areas with environmental constraints. In its lower reaches, corridors showed great adherence for logistics, socioeconomic and marketing logistics to connect, in an almost straight line, the towns of Açailândia-MA and Paragominas-PA. The choice was also supported in maximizing geology and geomorphology, reducing the number of river crossings and of the intersection of high potential areas for soft soils.

Although the initial purpose of the work has been the use of a geographic intelligence model to calculate and represent alternative corridors for the Norte Sul railway between Açailândia-MA and Barcarena-PA, there was also a concern to include in the model the Espadarte Port, whose main appeal is the deep draft, compatible with the new traffic demand expected after the expansion of the Panama Canal. Figure 9 illustrates the model results including the Espadarte Port.

Similarly to the results illustrated in Figure 8, the convergence of the results in the lower half can be explained by the attraction of logistics, marketing, socioeconomic and physical variables. Overall, the behavior of the three corridors was very similar, except south of Espadarte Port, for which the model presented two corridor options in an attempt to minimize environmental impacts by intercepting mangrove areas and saturated soil.

3.2 MODEL ASSESSMENT

The pilot results were very positive. The model proved to be simple and flexible as it allows the rules to be molded dynamically, including the participation of performers and their opinions considered in weights for creating scenarios. The graphical results allow for an easy comparative view of the alternatives and corridors that best meet the established criteria. Furthermore, the model brings transparency regarding the data used as well as adopted values and rules. All information (quantitative and qualitative) are properly registered in the system in the form of maps and tables, allowing a reproduction of the study.

The result of the corridor connecting the two points was consistent as expected. As there is still no trace design for this rail, the results of this multi-criteria analysis can be used in the future to assess proposals of layouts to be presented by the ANTT. When assessing the project, the model may also provide valuable information - with the view of several different scenarios - for the choice of location of the port.

The pilot work of spatial multi-criteria analysis has shown enormous potential for application in external control. The tool expands the way in which the analysis is currently done, when only geographical variables are considered. The tool allows evaluation of the choices of public policies as a whole, since it expands the number and type of variables considered and summarizes in a graphical result, unquantifiable variables or that can not be monetized. This tool enables the assessment of location (schools, kindergartens, hospitals and other enterprises) and optimal route for linear works (roads, railways, canals, transmission lines, etc.). With so much potential, there is the possibility of direct application in the areas of construction, education, environmental, health, among others. Moreover, there are many customizations that could be developed and especially the possibility of monetizing the variables and thematic maps, to generate financial surfaces to be compared.

4. CONCLUSION

One of the main responsibilities of the TCU is the evaluation of public policies, in order to bring benefits to the country and society. However, examination of public policies, particularly investment in infrastructure, is intricate and involves the integrated analysis of economic, spatial, environmental, social and technical data. This complexity demands innovation and the incorporation of technological advances. One of the tools available and that has great application in the performance of appraisals and monitoring of project implementation is the Geographic Information Systems (GIS) and geotechnology because they have the ability to process large amounts of information and allow its integration in a spatial context.

Several technologies are encompassed in this design, including the use of Remote Sensing (RS), which includes the use of images (satellite and manned/unmanned aircraft) as well as multi-criteria analysis applications for geographic information with GIS platforms supporting all these technologies.

To check the effectiveness of this instrument as a way to promote a more active and innovative external control, the Coordination for Infrastructure Sector (COINFRA) is developing a project to explore the systematic use of geotechnology in external control. For this, two pilot projects are underway in the railway area: one with use of multi-criteria analysis for railway track assessment and the second still in the initial phase which evaluates the use of satellite images, in addition to UAVs, to follow-up public works.

The first pilot was the application of spatial multi-criteria analysis for the evaluation of the best rail corridor to connect Açailândia/PA to Barcarena/PA. This prototype used a model that integrates the process of multi-criteria analysis with a geographic information system (GIS), allowing the ranking, prioritization, selection and refinement of preferred alternatives. The spatialized multi-criteria analysis is an important tool to weigh the benefits and costs of impacts including those that can not be easily monetized. To evaluate the best corridor/strip of the railway track, it was considered 35 variables, grouped into 5 groups (marketing, logistic, socio-economic, physical and environmental variables). The model defines whether these variables have attractiveness or repulsiveness to the railway line, and set the levels of attraction or repulsion. Variables were worked in a hierarchical process of multi-criteria analysis and point to a great strip where the railway should be located. The process allowed substantial reduction in analysis time, illustrated the results and solutions in the form of maps, graphs and tables, pointed out the areas of greatest viability (expected natural guideline for the implementation of infrastructure) as well as non-viable areas for implementation of the work. In addition, this tool increases the robustness and quality of public policy assessments - and gives transparency in the criteria used for the definition of public policies.

Geotechnologies have been established as an improving tool performance of the Brazilian Public Administration. Knowledge of geotechnology facilitates a more active external control by the TCU, either by increasing the tool proposition capacity to formulate public policies, either by increasing the evaluation capacity of established public policies. In this sense, the realization of this pilot confirms the technical feasibility and the potential use of geotechnology multi-criteria analysis on these two dimensions. The next steps of this research include the evaluation of other geotechnology and evaluation of its incorporation as an external control tool, including in terms of structure to support the control departments in the use of geotechnology systematically, through training partnerships with specialized companies, training of auditors and even a possible creation of its own structure within the body.

NOTES

1 Images of the US Landsat satellite photograph the Earth's surface with spatial resolution of 30 meters and are available for free. In 2012, the Ministry of Environment (MMA), made available to federal agencies, images of the RapidEye satellites with a resolution of up to 5 meters. In 2015, the Ministry of Planning and Budget (MOP) conducted a record of price for the acquisition of satellite images from satellites Pleiades 1A / 1B and Spot 6/7, which provide images with resolution up to 0.7 meters. There are still images from other civil sensors with submetric resolutions, and that can be acquired from commercial representatives in a simple manner. Once acquired, the image becomes part of the project database and serves as spatial and temporal reference to supply analysis, eg measuring and monitoring the evolution of a project.

2 According to the TCU (in Performance Audit Manual Brasilia,. 2012, p. 12.): "Efficiency is defined as the ratio between the products (goods and services) generated by an activity and the costs of inputs used to produce them in a certain period of time, maintained the quality standards."

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