Applications of Power Rail Track Program to Tracings of Brazilian Railways

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Abstract: In Brazil, the use of software and applications in railway geometric designs is rare. Currently, after the division and privatization of the national rail network, the concessionaires who assumed the administration, are investing in modernization, recovery and extension of this transport model to make it more efficient. The PIL (Program of Investment in Logistics) has generated growth of the sector in response to the amount of investments, greatly enhancing the load capacity and optimizing the geometric design, which would allow speeds of 80 km/h. Based on this information, the objective of this research is to verify the software applications of Power Rail Track Program of Bentley Systems, Inc. for geometric designs in future deployments of railways in Brazil. This software is based on numerical calculations, including roller adjustment by the least squares method to calculate and choose the best alignments, and regression tools, to a fast and effectively optimization of various parameters of the geometry for a future or existing railway. Different variables that allow you to optimize the geometric design are analyzed, considering several optional alignments and complex restrictions present in geometric design, taking into account variables such as circular curves, transition, tangents and rays. The software regression tools include curvature diagrams identifying points and curves, tangent and spirals. The analysis results are presented quickly and points can be added or deleted from the regression analysis, providing improved tracing. The software also allows to detail the elements of the executive project of the railway line such as rails, joints, turning points, waypoints and others. The result of this study has shown that the application of the Power Rail Track Program generates significant cost savings in time and increases in productivity, providing greater opportunity to optimize the geometry and reducing geometric design costs.

Key words: Geometric design, railways, optimization, software, geometric tracing.

1. Introduction

The PIL (Program of Investment in Logistics) is responsible for building and improvement of 11,000 km of railway large gauge (1,600 mm), optimizing the geometric design, and would allow speeds of 80 km/h.

The railway really stands out as one of the main means of transport and terrestrial locomotion throughout the world, either for cargo or passengers. Their use, both in the urban context as in the connection of cities, states, countries and even continents, allows the realization of various activities directly and indirectly related to the development of a society, being directly linked to its economic growth.

The need for massive and quick transportation has presented itself since the beginning of the 19th century, with the purpose of improving the way to carry commodities. Lately, the technological advances allowed the innovation of equipment and the use of new energy sources for the operation of machines, while maintaining the original displacement idea of fixed rails stated in a geometric design project. Such advances have emerged, among other reasons, from the need for increased speed in the displacement between regions, as well as the increasing concern to improve mobility, safety and welfare of users [1].

Currently, technological advances in rail equipment requires that the geometric design of the railways must be of excellent quality, ensuring speed and safety in the performance of services and movements of persons and commodities.

Although Brazil is one of the countries with the
highest development on the global stage in recent decades, it has been showing serious infrastructure problems due to an uneven distribution in the transport sector, with high concentration in the road system, having airports and highways operating above its capacity, and possessing limited transportation alternatives. According to the ANTF (Associação Nacional dos Transportadores Ferroviários (in English: National Association of Railway Transporters)), the volume of loads transported on railway lines in Brazil increased 1.8% in 2013, growing from 481 million tons in 2012 to 490 million tons [2].

Due to the lack of investments in the rail sector, much of the Brazilian rail network has become inoperable or even inexistent, resulting in a great reduction of qualified manpower and academic training in the sector. As a consequence, the studies regarding the rail geometric project were also directly affected. In this context, it is important to rescue the norms, publications, advances and experiences adopted in other countries with solid railway traditions, to incorporate these concepts into our academic formation.

The main objective is to analyze the different variables that allow to optimize the geometric design using the Power Rail Track Program and so, to direct the decisions to select the best alignment by becoming an effective and efficient work, involving the different parameters which cover the alignment both horizontal and vertical of the railway geometric design, in addition, to provide a theoretical base about the geometric design parameters associated with railway norms that are already consolidated in other parts of the world. And then the secure parameters and comfort can be implemented in future railways in Brazil using the Power Rail Track Program.

2. Justification

The study brings together various information about the geometric design parameters for railways: checking software applications (Power Rail Track of Bentley Systems, Inc.); and the use of the program to geometric designs in future deployments of railways in Brazil; and improving of the traces, as well as yield and optimization of projects.

Alignment of project rail is a very complex process. In this process, the engineers often face a wide variety of factors and a great number of alternatives. They need to select an economical option, based on topography, soil conditions, socioeconomic factors and environmental impacts such as air pollution and noise.

The need to improve the geometric design and generate efficient railway model could ensure greater transmission capacity, due to the fact that high tonnage charges are preferably transported by rail, particularly when it is necessary to travel a long distance.

When analyzing the software that allows to get the best solution for tracing a route railway, one must consider several factors that provide benefits to the comfort of the user, such as the socio-economic impacts and effects that compromise the environment. Due to the huge amount of variables (alternative alignments) and several complex constraints, drawing a good design is necessary to evaluate the different variables that intervene in it, which are considered potentially a big problem [3].

The railroad designed must also satisfy the constraints of demand of passengers and commodities. Therefore, some restrictions and operational requirements must be considered in the railway project. It is known that a track consists of horizontal and vertical alignment. On the horizontal alignment, the main considerations may be land acquisition and other costs, dependent on the alignment of the location. For vertical alignment, the most significant factor is probably the cost of earthwork. Some restrictions as super elevation in circular curves or transition should be considered within horizontal alignment. For vertical alignment, the maximum gradient is a significant restriction parameter [4].

It is important to know several models of software for geometric design of the railway, with a visual and user-friendly interface which contains a database and
saves the information needed to resolve the problem in the best way possible. This allows minimization of the total cost, which is obtained by the sum of the supplier’s cost, user cost and system costs.

When discussing the most important elements for the development of countries and regions, we must necessarily consider the importance to have an efficient transport system. The railways, according to its features that generate high efficiency, established itself as a vehicle for economic transformation, assuming an important strategic role in the composition of the transportation network.

The first European railways were essential for the marketing of manufactured goods in the mainland markets and also for the movement of raw materials derived from commodities’ exporting countries. Later, countries of industrial development such as Canada and the United States, as well as exporting economies, such as Argentina, South Africa and Brazil, made use of railway routes as a strategy for economic advance.

In this context, rail freight and passenger gains are prominent as mechanisms of growth and economic development. Thus, the study aims to evaluate the development of the Brazilian rail system. The rail technology has allowed unprecedented decrease in mobility costs, reduced travel time, increased safety and reliability in the transportation of commodity and people.

The efficient design of a geometric trace in transport infrastructure is reflexed in the economic portion, reducing the value of the transportation taxes of goods, offering greater competition in domestic and international market, and increasing the country’s economic development. In several countries, due to the high implementation and maintenance costs, the railways often needed the government subsidies to continue operating after the spread of highways.

From the 1970s, the great interference of public administration in the railway sector in Brazil and other countries showed signs that the high costs and the low efficiency made the railway’s existence limited. This could be associated to the current model of operation. The private sector participation in the management, construction and operation of rail services, generates efficient management of resources and the possibility of competition [5].

In some instances, the environmental concerns can become the most critical factors in the railway project. Although it is difficult to incorporate the social and environmental costs to the overall cost of a railway. It is necessary to quantify and consider this cost as possible in the evaluation of different alternatives [4].

In Brazil, as a guarantee of the right to an ecologically balanced environment for all, it was set the mandatory environmental impact study for the development of works or potential and significant activities which may cause degradation of the environment, such as required by Article 255, IV of the Federal Constitution of 1988 [6].

It is important to clarify that the Federal Constitution of 1988 in Brazil, in the Article 8, II, provides that the National Council of Environment—CONAMA (in Portuguese: Conselho Nacional de Meio Ambiente) make the realization of the environmental impact study for works and activities, public or private, which cause environmental degradation [7].

The environmental impact study represented a huge progress in the Brazilian legislation, with a preventive character in the preparation of rail projects, a tool that contributes to the implementation of the project.

This same resolution determines the presentation of the study and report of the environmental impact of railways, considering that the rail project have artworks which can significantly modify the environment. Santos [8] considers that the assessment of the impacts require qualitative and quantitative interpretation of the ecological exchanges, social, cultural or aesthetic environment.

It is important to highlight that the implementation cost of any mode of transport has been influenced by the infrastructure, in other words, by the construction, skilled labor, technical material, signaling system
chosen and others.

The social costs will be paid, directly or indirectly, by the society, which can be pollution, noise and maintenance.

The Table 1 presents some of social costs show us that the road transport has accentuated results when compared with other modes. In the case of railways, there are high costs of implementing and maintenance.

To implement any of modal transport, it is necessary to consider the influence of the variables because it may result in positive and negative aspects.

The advantage of rail transport is the high capacity to transport passengers and cargo, and the number of stations and extension. However, it is important to consider the high costs of implementing and maintenance.

So, it can be said that in assessing the impacts generated by the implementation of railways, it is necessary to consider the ecological, social and cultural variables that can be either positive or negative for the environment or the population.

It can be said that the optimization of rail alignments includes different categories of costs which will determine different alignments settings. For example, costs dependent in length tend to choose an alignment in a straight line while the costs dependent location tend to choose an indirect alignment. The optimal alignment feature will be balanced between the different types of costs [3].

3. Development

The Brazilian railway network has achieved in 2012, 30.129 km long, including urban train passengers [9]. The value is below the peak observed in the early 1960s, when the total mileage of railways arrived in 38.287 km, but is greater than the number in the 1980s, when the existing network has achieved just over 28.942 km. Currently, the density of the Brazilian railway network is just over 3.3 km of rail line by thousand square miles of territory [9].

The reduction in the rail network was an attempt to eliminate damaged roads and uneconomic railway sidings. Approximately 8,000 km of railway lines have been disabled since the 1960s. In addition, it was attempted to reduce the deficit that the sector imposed on the budget of the union and avoid generalized scrapping of the network due to the lack of funds for investment. Fig. 1 shows the evolution of the extent of Brazilian rail infrastructure since its foundation to the present day.

In 1992, it began the transfer of the operational control to private enterprise. The concession incorporated 12 different stretches totaling more than 28,600 km, or 94% of the existing network, with each line operated by an individual company.

The rest of the network included local lines, urban and touristic trains, totaling 1,400 km. Table 1 summarizes the current setup of the national railway system in accordance with the operator and the gauge.

The railway concessions have brought many profits for logistics and national economic structure. After the initial transition period, most of the railways watched a positive result from equity, after decades of negative closings of the Federal Railway Network S.A. (RFFSA: National Railway Network Corporation Anonymous Society).

Table 1  Social cost regarding the transport arrangements.

<table>
<thead>
<tr>
<th>Social costs</th>
<th>Air transport (%)</th>
<th>Rail (%)</th>
<th>Waterway (%)</th>
<th>Highway (%)</th>
<th>Total (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air pollution</td>
<td>2</td>
<td>4</td>
<td>3</td>
<td>91</td>
<td>100</td>
</tr>
<tr>
<td>Noise pollution</td>
<td>26</td>
<td>10</td>
<td>0</td>
<td>64</td>
<td>100</td>
</tr>
<tr>
<td>Land use</td>
<td>1</td>
<td>7</td>
<td>1</td>
<td>91</td>
<td>100</td>
</tr>
<tr>
<td>Construction and maintenance</td>
<td>2</td>
<td>37</td>
<td>5</td>
<td>56</td>
<td>100</td>
</tr>
<tr>
<td>Accidents</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>98</td>
<td>100</td>
</tr>
</tbody>
</table>

Source: CNT (Confederação Nacional do Transporte (in English: National Confederation of Transport)) 2013.
In order to understand the historical evolution of Brazilian railways, it is necessary to analyze national economic context, as well as the level of existing technology. The railways have emerged in Brazil during the coffee period, which prevailed in the second half of the 19th century to the middle of 1930. At the time, the economy was primarily agricultural and agro-export [9].

**Table 2**  Extension of existing networks in the Brazilian rail system

<table>
<thead>
<tr>
<th>Railways</th>
<th>Large (1.6 m)</th>
<th>Metrics (1.0 m)</th>
<th>Mixed</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>América Latina Logística Malha Oeste S.A.—ALLMO</td>
<td>-</td>
<td>1,945</td>
<td>-</td>
<td>1,945</td>
</tr>
<tr>
<td>Ferrovia Centro-Atlântica S.A.—FCA</td>
<td>-</td>
<td>7,910</td>
<td>156</td>
<td>8,066</td>
</tr>
<tr>
<td>MRS Logística S.A.—MRS</td>
<td>1,632</td>
<td>-</td>
<td>42</td>
<td>1,674</td>
</tr>
<tr>
<td>Ferrovia Tereza Cristina S.A.—FTC</td>
<td>-</td>
<td>164</td>
<td>-</td>
<td>164</td>
</tr>
<tr>
<td>América Latina Logística Malha Sul S.A.—ALLMS</td>
<td>-</td>
<td>7,254</td>
<td>11</td>
<td>7,265</td>
</tr>
<tr>
<td>Estrada de Ferro Paraná Oeste S.A.—FERROESTE</td>
<td>-</td>
<td>248</td>
<td>-</td>
<td>248</td>
</tr>
<tr>
<td>Estrada de Ferro Vitória a Minas—EFVM</td>
<td>-</td>
<td>905</td>
<td>-</td>
<td>905</td>
</tr>
<tr>
<td>Estrada de Ferro Carajás—EFC</td>
<td>892</td>
<td>-</td>
<td>-</td>
<td>892</td>
</tr>
<tr>
<td>Transnordestina Logística S.A.—TLSA</td>
<td>-</td>
<td>4,189</td>
<td>18</td>
<td>4,207</td>
</tr>
<tr>
<td>América Latina Logística Malha Paulista S.A.—ALLMP</td>
<td>1,463</td>
<td>243</td>
<td>283</td>
<td>1,989</td>
</tr>
<tr>
<td>América Latina Logística Malha Norte S.A.—ALLMN</td>
<td>617</td>
<td>-</td>
<td>-</td>
<td>617</td>
</tr>
<tr>
<td>Ferrovia Norte→Sul—FNS→VALEC/Subconcessão</td>
<td>720</td>
<td>-</td>
<td>-</td>
<td>720</td>
</tr>
<tr>
<td><strong>Subtotal</strong></td>
<td>5,324</td>
<td>22,858</td>
<td>510</td>
<td>28,692</td>
</tr>
<tr>
<td>Metrôs: São Paulo, Rio de Janeiro, Porto Alegre, Recife, Belo Horizonte, Distrito Federal, Teresina</td>
<td>216.5</td>
<td>71.7</td>
<td>-</td>
<td>305.6</td>
</tr>
<tr>
<td>Light vehicles on rails—VLTs (tramway): Cariri e Maceió</td>
<td>0</td>
<td>45.7</td>
<td>-</td>
<td>45.7</td>
</tr>
<tr>
<td>Trens urbanos: CPTM (São Paulo Trains Metropolitan Company), SuperVia, Central, João Pessoa, Maceió, Natal, Fortaleza, Trem suburbano de Salvador</td>
<td>474.1</td>
<td>180.4</td>
<td>-</td>
<td>671.5</td>
</tr>
<tr>
<td>Trens Turísticos e Culturais: Campos do Jordão/Corcovado/Outros</td>
<td>0</td>
<td>117.4</td>
<td>-</td>
<td>117.4</td>
</tr>
<tr>
<td>Trombetas/Amapá/Jari</td>
<td>68</td>
<td>35</td>
<td>-</td>
<td>297</td>
</tr>
<tr>
<td><strong>Subtotal—others</strong></td>
<td>759</td>
<td>450</td>
<td>-</td>
<td>1,437</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>6,083</td>
<td>23,308</td>
<td>510</td>
<td>30,129</td>
</tr>
</tbody>
</table>

In 1852, the Brazilian government established the Interest Guarantee Act (Decree No. 641), which allowed the granting of the construction and operation of railways given the low attractiveness of the projects for rails construction [10].

For that, it was important to ensure a minimum level of tonnage to be transported to endorse the return of the project. With all this measures, there was growing interest of the private sector in the construction and operation of railways. After that, there was a disordered and unplanned expansion of the network, resulting, for example, the use of different types of gauges in various sections, which precluded their integration.

In the early 20th century, the Brazilian economy went through a period of economic transition and social modernization, where the railroads played an important role. From the 1920s, the construction of roads was expanded to compete with the railroads for public funds and the transport of commodities and passengers. This represented loss of income for the railways and less investment in infrastructure for the sector. Despite these difficulties, during the 30 years that followed, from 1920 to 1950, the national railway network expanded by more than 8,000 kilometers [11].

What contributed to this process was not only the natural advantages of railways in land transport, but also the development, over time, of new technology that allowed the substitution of trains powered by steam for electric traction vehicles and later by diesel engines. Such technological evolution secured a substantial increase in the efficiency of the railway system.

The cost structure of the railway infrastructure display periods of relatively long renovation, stretching for about 40 years, taking into consideration that work with earthworks and foundations are investments that are not considered as cost elements after completion, and due to this, it needs to consider all the variables involved in the geometric design of the railway project.

In August 2012, the federal government announced the PIL (Program of Investment in Logistics). Among the actions under the program for the rail sector, there is the implementation of a new concession model. With the new concession structure, there will be a separation between the supply of activity of railway infrastructure and rail service. In this sense, the model presented by the federal government is significantly more complex than the current operating in this country. The private sector will participate in both supplying infrastructure and the railway transport service, but in both there will be a direct participation of the public entity [12].

On the other hand, the expansion of the private sector participation in railway infrastructure offering is a major breakthrough for the development of the transport sector in Brazil. The transfer of the obligation to invest in construction, maintenance and operation of the rail network will reduce the pressure on the public budget. Additionally, private sector expertise in the implementation and management developments will allow greater flexibility in the execution of works and efficiency in the operation of the railway infrastructure service.

4. Software Power Rail

The Power Rail Track is an application to be used for preliminary design and executive of a railway project. It offers the designer of the geometric regression analysis, geometric design based on several international standards, corridor modeling of the permanent track superstructure. It is used for projects involving subways, trams, commuter rail and high speed.

Power Rail Track is a comprehensive 3D rail design software application with built-in CAD (computer aided design) and GIS (geographic information system) for preliminary and detailed 3D design of rail infrastructure. Comprising of regression analysis, horizontal and vertical alignment and cant design, turnout placement to international standards, and rail corridor modeling, the software offers high degrees of automation to established industry workflows, delivering significant productivity improvements and
time savings for the design and maintenance of all types of rail projects, including metro and light rail, commuter rail and high speed rail [13].

The program is flexible, versatile and holds configurable tools for promoting productivity of a project, since it shares the same model of track geometry as Power Rail Airline—a Bentley application for designing power supplies traction, and tests all aspects of alignment. Power Rail Track allows users to optimize the horizontal and vertical geometry—a way to reduce project costs. It is fully functional for participation, placement and verification of design with project standards.

5. Features and Functions of Program

The program allows:

1. CAD capabilities: create and edit CAD elements; read, write, and reference DGN and DWG (Digital Wireless Network and AutoCAD Drawing Database) files; apply digital signatures; support multiple raster formats; support PostScript and HPGL2/RTL printing, shade renderings—wireframe to smooth;

2. edit survey fieldbook data (graphically and dynamically): change instrument set-up with automatic updating; add, modify, or delete points and chains; change codes and styles capabilities; import geometry or surface data in virtually any; upload data collectors for construction stakeout;

3. geometric design: use interactive geometry tools for immediate design visualization; use methods and principles specific to rail design and civil engineering; create horizontal by PI (points of intersection) method or by elements: lines, circular arcs (arc and chord definition); multiple spiral transition definitions, including clothoid, cubic parabola, blossom, biquadratic parabola); perform associative and dynamic editing of elements; maintain curve definition and tangency; create vertical by PI method or by elements: lines, parabola, circular arcs;

3. vertical clothoid transition spirals: edit, delete, or join geometric elements; check integrity for location and removal of discontinuities and resolution of tangent and non-tangent curves; assign and edit stationing automatically; annotate alignments, stations and COGO (geocoding coverage) points, precision PI definition; define curve sets parametrically; create multiple vertical alignments per horizontal alignment; review and report geometric elements; perform dynamic annotation; perform design checks dynamically or in batch processes; use curve and spiral calculators, display geometry as 3D elements [13].

6. Influence on Trace Geometric

The railways really stand out through the generation of lower environmental costs as a result of lower emissions and less environmental impact in the construction of infrastructure of rail commodity transportation. The security level is higher compared with road transport. Therefore, the risk of accidents involving third parties or their own locomotive is proportionately lower. This reduces the social costs of rail transport.

Improvement was conquered due to the considerable investments of concessionaires, essential to prevent a faster climb in the contraction of the network. From 1997 to 2012, private investment amounted R$33.9 billion, with an average growth of 79% per year, as shown in Fig. 2. At first the investments were focused on the recovery of the rail network and rolling stock. From 2000 until 2007, there was increased capacity and improvement in operating services of the existing rail network. However, the advances in the use of new
technologies for the geometric design are not evident, at least in Brazil.

Although public investment were used in the construction of the rail network, the railway system was not integrated. Due to delays in the design stages, bidding, implementation and construction, many of the projects submitted were not completed. In addition, about 5,500 km from the given rail network show low traffic density, which creates an inefficiency situation in rail transport [14].

Despite the investments in transport infrastructure, the resources available must still be expanded to achieve the railway transport freight and passenger demand in short and long term. The works proposed are corrective measures, and yet, insufficient to the adequacy of the Brazilian transport and encouraging national production.

As planned over by the PPA (Plano Pluri Anual (in English: Multi-Year Plan), US $39.6 billion was invested for railway infrastructure between 2013 and 2015. The goals presented by the PPA are: (1) the expansion of the railway; (2) the construction of access to harbors; (3) the adequacy of rail segments; (4) the ongoing maintenance of segments; and (5) the implementation of a new rail concession model. It should be highlighted that, despite the budgetary planning of the federal government, these targets were included in the PIL, which provides both the new concession model as the expansion and construction of 12 railroad tracks by the private sector.

The PIL of the federal government is a breakthrough for the transport sector, especially rail. The program’s actions aim at the expansion of the rail network capacity through the participation of the private sector in the construction, maintenance and operation of the rail network PPP (private public partnership).

Interventions are planned in 10,000 km of railways with an estimated investment of R$91 billion, of which R$56 billion should be applied in the first 5-year contract (Fig. 3).

In Fig. 3, it is possible to view the existing infrastructure and identify the sections that will be integrated into the Brazilian rail network by the PIL. It is noteworthy that among the PIL integrant projects, there are sections that, although existing, will be refurbished under the program.

Among the works presented, six are not in the PAC (Programa de Aceleração do Crescimento (in English: Growth Acceleration Program)), but, with the exception of rail access to the harbors of Santos and Salvador, they were already planned by the CNT Plan Logistics and Transport or the PNLT (in Portuguese: Plano Nacional de Logistica e Transporte) [12].

The execution of priority projects of the railroad model and the expansion of the railway for new concessions are important movements for the solution of the geometric design and transportation infrastructure in Brazil. However, despite the advances that these actions represent, it is essential for the transport system’s good performance that new technologies are implemented in the future development of railways projects.

Therefore, it is a good opportunity for improving the railway sector projects in the country. The new private sector participation model in the supply of infrastructure allows Brazil to benefit from private sector expertise in the execution of works and assets management. As a result, it is possible to enabling both speed of execution and an appropriate maintenance of infrastructure.

7. International Experience

Creating a world-class railway (Bentley Rail Track software; gINT; ProjectWise; Bentley Navigator and more): At crossrail, consistency is the key to saving time and effort and improving the overall quality of the asset. In this project, there are challenges faced; standards and workflows adopted; technology deployed; and benefits enjoyed as the crossrail team worked towards its vision of a fully-coordinated; 3D information model for construction; operations; and maintenance of railways for years to come; with
Fig. 3 The national government investment program (ANTF, 2014).

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>Ferroanel SP—Tramo Norte</td>
</tr>
<tr>
<td>2</td>
<td>Ferroanel SP—Tramo Sul</td>
</tr>
<tr>
<td>3</td>
<td>Acesso ao Porto de Santos</td>
</tr>
<tr>
<td>4</td>
<td>Lucas do Rio Verde—Uruaçu</td>
</tr>
<tr>
<td>5</td>
<td>Uruaçu—Corintos—Campos</td>
</tr>
<tr>
<td>6</td>
<td>Rio de Janeiro—Campos—Vitória</td>
</tr>
<tr>
<td>7</td>
<td>Belo Horizonte—Salvador</td>
</tr>
<tr>
<td>8</td>
<td>Salvador—Recife</td>
</tr>
<tr>
<td>9</td>
<td>Estrela d’Oeste—Panorama—Maracujá</td>
</tr>
<tr>
<td>10</td>
<td>Maracujá—Mafra</td>
</tr>
<tr>
<td>11</td>
<td>São Paulo—Mafra—Rio Grande</td>
</tr>
<tr>
<td>12</td>
<td>Açailândia—Vila do Conde</td>
</tr>
</tbody>
</table>

- Passages in study/evaluation
- PAC (Annual Growth Program) running
- Mesh present
21 km of twin-bore tunnels; interchanges with the existing over- and under-ground rail networks. The scale and complexity of this project makes it truly awesome [15].

Hyderabad Metro Rail Project: As the capital city of Andhra Pradesh, India, Hyderabad is a growing metropolis with a population of more than 8 million. The Government of Andhra Pradesh launched INR (Indian Rupee) 164 billion for Hyderabad Metro Rail Project as a public-private partnership to provide modern transport across three corridors covering a total distance of 72 km. L&T (Larsen & Toubro) Metro Rail (Hyderabad) Limited will implement the project on a design-build-finance-operate-transfer basis. Each of the three lines will have a centralized metro rail train depot. Trains will run on a communication based train control system, which includes driverless technology to enhance safety and increase the frequency of trains. Given the densely populated metropolitan area, L&T Construction will construct an elevated metro rail viaduct over 80 road junctions. Bentley’s Power Rail Track enabled the designers to complete an alignment design in a short time despite the multifaceted constraints [15].

RITES (Rail India Technical and Economic Service) Mechi Mahakali and Pokhara Kathmandu Electrical Railway in Nepal: Nepal is one of the world’s least developed countries due in part to poor transportation infrastructure. In association with Nepalese consultants, the Indian Government commissioned RITES to study the feasibility of constructing a $9.8 billion east-west railway. Passing through mountainous terrain and across deep river gorges, the 1,218-km alignment includes 154 km of tunnels and 401 major bridges. The integration of Bentley Map and Google Earth helped to identify locations for river crossings, tunnel portals and township connections. The team used MXRAIL and Bentley Rail Track to plan alternative alignments based on terrain, topography, development and other features. Detailed design, optimization and quantity estimating were also performed. The project was completed in eight months, saving about ten months and nearly $560,000 [15].

In Brazil, there is no relevant use for this program, although some companies may use as a reference, but in a very small scale.

8. Result and Discussion

Taking into account the points that need to be evaluated in the geometric design of railways, the Power Rail Track Bentley Program allows to involve a wide array of factors and a great number of alternatives to evaluate and select the most promising alignment or the one that is closer to the ideal. In the geometric design (tracing), the software offers improvements in horizontal and vertical alignment, setting different cubic parabolas that detail various geometric variables such as entry radius, exit radius, length, angle, tangent entry and exit and other horizontal curves variables and its corresponding transition.

Another software application is the validation of pre-regression data, where is possible to select points and classify the data without needing to be ordered, generating curvature diagrams, allowing to see the locations that may have questionable data inside the alignment, and allowing changes and reducing errors, which reduce time and cost of the project in the future.

With reference to horizontal alignment, it allows a quick regression including, in the first, passing an automatic regression that contains lines, circular arcs and spirals, solving long and straight stretches. The vertical regression is similar to the horizontal, including two options: the standard lifting and the lines lifting.

The program allows the improvement of regression with a single element or multiple alignments, while observing the differential values and the parallel exchange of previous regression, showing the offsets for each element and for all the elements, giving the possibility to edit and review regression.

Sometimes, the spirals with transition designs can replace a series of compound curves with either fixed
length segments or matching up and using standard elements, such as: the multi-element standard, doing regression analysis, more limiting. The calculations made by the program are in international units according to standard and international railway terminology.

The horizontal design is integrated by different variables which allow to have an optimized design, accepting mixtures of types of transitions based on equilibrium equations, alternate speeds and user-defined transitions with the possibility to see the performance and safety of the track.

Additionally, the program allows to simulate the single and double landslides, the change of routes and tangential land non-tangential railroad crossings, using various methods to achieve various standards of the railroad industry. It has applications that allow the design of connections and to edit them.

9. Conclusions

The program has multiple applications in the geometric part that support significantly the development of a better quality of the rail geometric design. However, who uses the program must have extensive knowledge in the geometric part and skill in taking decisions for the election of the best path, minimizing time and, most importantly, creating an efficient work with high quality.

The program allows to have millimetric results and all the calculations are done inside the international standard norms as well as the railway terminology. Finally, it comes a need to optimize this program, taking into account several factors including in the railway project some steps, such as a viability study, then, project planning, construction, and at last, stages of operation and maintenance.

The most sensitive costs to be considered in the design of a railway alignment are the right of way and land acquisition, costs that change with distance and land uses. Due to the geometric characteristics of a railway, such as slope and curvature, that can affect the operation and maintenance costs, these costs should be considered based on the planning project phases of a railroad. Being able to introduce these tools in Bentley’s program will be very useful when choosing the best alignment of the railway.

To get a great railroad alignment, one should also consider the usage costs, such as the cost of travel time (including access time for the train station, the waiting time at the station and travel time in the train), and the cost of accidents. All these costs depend on the distance in the travel and the characteristics of the railway geometric design.

References


