

# The Feasibility Study for Establishment of Passenger Rail in the Metropolitan Region of Belo Horizonte / Brazil

Marcelo Franco PORTO  
School of Engineering, Federal University of Minas Gerais  
Belo Horizonte, Minas Gerais, Brazil

and

Luiz Carlos de Jesus MIRANDA  
Nilson Tadeu Ramos NUNES  
Cássio E. dos SANTOS Jr.  
School of Engineering, Federal University of Minas Gerais  
Belo Horizonte, Minas Gerais, Brazil

## ABSTRACT

The rail transportation, either of passengers or cargo, is essential to the country's economic growth. Due to a number of factors, in particular, severe mobility problems experienced by large cities and a demand for urban transport systems and suburban high capacity transport on rails going through a period of recovery with new investments being announced both for the construction of new railway sections, as for reclamation and re-adaptation of existing railway networks. In this context, the liability of decades without investment, necessitates a rational use of available resources and agile enabling to country develop projects for the sector rapidly and consistently. This paper presents a proposal that aims to make it easier to review and registration of a railroad. The proposal is obtain a film at 360 ° with a spherical vision camera Lady Bug (6 cameras) from Point Grey Research, a Sony Full HD Camcorder and a Sony High Resolution camera with integrated GPS system. The images collected will be stored in a georeferenced database in a computer system developed for this purpose which will be able to contain the record of all events by the slice, generating reports with data, pictures and location map. Applied to the specific case of metropolitan region of Belo Horizonte/Brazil. The data obtained in the study of railway network BHMR and surroundings, were used to subsidize the State Government, through the Agency for Development of the Metropolitan Region of Belo Horizonte, in assessing the feasibility of implementing transport passenger rail in this network.

**Keywords:** Infrastructure Engineering, Engineering Management, Spatial Analysis, Digital Image Processing.

## 1. INTRODUCTION

Rail transport in Brazil is experiencing a resurgence after decades with little or no investment, mainly in the construction of new roads. Due to economic growth in recent years, there has been an increase in government investment and private sectors of the rail industry, both in cargo as passenger. Only the federal government nods investments of \$ 45 billion over the next 25 years when it intends to build about ten thousand kilometers of new railways ( Ministry of Transport ) [1], which corresponds to more than one-third the length the current mesh. In addition to these investments, can be considered promising the creation of the EPL - Logistics Planning Company S/A, a company of the federal government in charge of strategic planning in the area of transport infrastructure.

There are investments to existing lines disabled or in poor condition, as well as incentives for redeployment of passenger transport in sections where only the cargo remained. These lines could play a strategic role in the mobility issue because they are in metropolitan regions or make the connection between cities large and medium-sized with a large demand for high capacity transportation.

## 2. HISTORICAL DEVELOPMENT

The railroads arrived in Brazil still in the Imperial period. A special law of 1852, which established the security interest on the capital invested in railway construction, besides other advantages is it possible to leverage the construction of the first railroads in Brazil. The first section, 14.5 km in length and gauge of 1.68 m, was inaugurated by D. Pedro II on April 30, 1854 [3].

The railways were developed at a good pace, in 1888 the country had 9200 km of railways built 9000 km and more under construction or study. Between the years 1905 and 1915 were built more than ten thousand kilometers of railways [3]. In 1922, the Brazilian railway has reached 29,000 km in length, dimensions very similar to today .

The initial policy of building railways left, however, negative marks felt until today. A wide variety of gauges is a hindrance to the operational integration between railroads today. Tracings extremely sinuous added to this huge variety of gauges (gauges 70cm to 1.68m with the largest) are harmful to operating speed and load capacity [4], in addition, requires the achievement of transshipment, both freight and passenger in the connection between extensions of different gauges. Another important negative mark is the fact that they created regional networks scattered and isolated preventing the integration of Brazil by rail [3]. After the peak, lived until 1920, the railways in Brazil began to decline with fewer investments, being passed over during the 50s and 60s in favor of highways, culminating in the extinction of RFFSA - Federal Railway S/A in 1999 after privatization of its lines .

Figure 1 shows the map of the current Brazilian railway, showing the existing railway lines to their utility beyond the lines currently under construction or planned your deployment. After privatization, the passenger was abandoned and the investments made only in the way in which the transport of cargo were profitable, leaving the remaining stretches of high economic and historical importance to the communities they served, as in the case of railway connecting Belo Horizonte to Ouro Preto [2] which is not operational, and much of its length, there is no longer the track superstructure.



The PDDI - Integrated Development Plan prepared by the State Government together with civil society points out the guidelines for transportation in the metropolitan region (re) placing the passenger rail as a strategic condition for solving problems and improving mobility accessibility to the entire population :

*" ( ... ) The conditions of access will only be extended with the dynamics of territorial integration and strengthening of the structure metropolitan network . In this context, it is recognized increasingly, the urgency of a rail system that (re) structured the whole system of passenger transport, currently restricted to cargo transportation. The railways should also enhance integration with other hub cities of Minas Gerais and the country." (PDDI 2011, page 282 ) [9]*

#### 4. THE TRAIN PROJECT DEVELOPMENT AGENCY BHMR

Project TRAIN (Rail Transport in the Metropolitan Region of Belo Horizonte) developed by the State Government through the Department of Metropolitan Management/Development Agency of the Metropolitan Region of Belo Horizonte, is due to a larger planning of the Government - the Integrated Development plan (PDDI) [9] of BHMR, presented in 2011. This plan is to take advantage of the railway lines to transport passengers and directly serve about 30 municipalities of BHMR and surroundings, a total length of 505 km.

To verify the feasibility, the Agency entered into an agreement with the UFMG - Universidade Federal de Minas Gerais, through the Department of Transport Engineering and Geotechnics, which would be in charge of the University a complete survey of the operating conditions of the entire rail network a radius of 150 km from the center of Belo Horizonte. The study conducted by team NUCLETRANS from the ETG/UFMG, aimed at general, characterize the current situation and analyze the use of the rail network to transport BHMR and around metropolitan and regional passenger to create a network of metropolitan rail transport more integrated and comprehensive.

The project also had the following specific objectives :

- Mapping in GIS format of the railway system in the BHMR and the area directly affected by the project;
- Evaluation of the physical and operational infrastructure and superstructure existing rail;
- Identification and assessment of rail beds that have potential for passenger rail, including sections that are not used for cargo transportation;
- Characterization of tracks domain and its immediate surroundings (identifying problems of invasion and/or obstruction of track);
- Identification of the current conditions of the main crossings in the municipalities directly affected by the railway line , with assessment of the comfort and safety of traffic affected.

To better organize the collected data and facilitate its analysis, the network is divided into three lots:

The Lot 1 is characterized by the loop that connects the towns of Sete Lagoas Divinópolis (currently operating to the entrance of Sete Lagoas). It is important to note that the urban stretch of Sete Lagoas, after the construction of a bypass that skirts the city, was deactivated and turned into the avenue. This lot is under concession to FCA.

The Lot 2 comprises the loop that connects the city of Barreiro Alberto Flores to the neighborhood in Belo Horizonte (operating), including the extension of Aguas Claras in Nova

Lima (excerpt nonoperating) . Most of this batch is under MRS concession.

The Lot 3 comprises the loop that connects the municipalities of Hafizabad Joaquim Murinho (operational) and Joaquim Murinho Miguel Burnier (operating) . At this point begins the nonoperating sections: east to Ouro Preto and north towards Sabara. Sabara line follows eastward to Santa Barbara, with operational only stretch to near Barão de Cocais. Also from Sabara, northwest, the line goes to Belo Horizonte to General Carneiro (not operating). The stretch of the General Carneiro to Horto is operational and is described in Lot 1. The excerpts included in the present document, were divided as it's showed at figure 2.

As for digital maps to be used in web GIS, these must be the same on the graphical environment, without any distinction. Therefore, the best way to analyze and represent likewise should provide the best form of interpretation and representation of information [13]. So it is necessary to teach Cartography for the visually impaired and accompany them throughout their learning process, for the reading and use of the map to be given in an optimized manner.

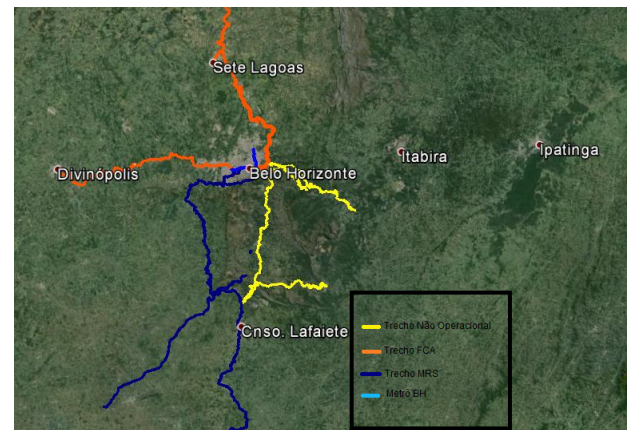


Figure 3.

Covered Excerpts – Source: Prepared by author

#### 5. EQUIPMENT AND METHODS

The field survey was carried out by inspection of images using equipment that generates images in 360°, with a resolution suitable for examination. In excerpts Betim-Divinópolis (FCA), Betim - Prudente de Moraes (FCA), Prudente de Moraes - Curvelo (FCA), Jeceaba - São João del Rei (MRS), Alberto Flores- Brumadinho - Barreiro (MRS), Ibirite - Tod (MRS), Juiz de Fora – Pedra do Sino (MRS) imaging equipment was used in a 360° recording geotagging from GPS data and pointer stored in spatial database ( PostGIS ).



Figure 4.

Railway vehicle with camera installed.  
Source: Prepared by author

To record the events detected in the images, we developed a computer system that allows the user to perform the registration of events, defined in the system database and detected in the images, characterize them and describe them with alpha-numeric data, which are connected to the respective image frames of the film where they are located. The system stores and manages to link this information with the images in the database. This developed system also allows automatic extraction is carried reports on the events section, generating reports with data, pictures and location map.

As a complement, were held footage and photos in high-resolution. This material, due to its characteristics, it is not georeferenced, but stored sequentially along portions of the data for reference. Imaging equipment used were spherical vision camera Lady Bug (6 cameras) from Point Grey Research, Sony Full HD Camcorder Sony camera and high resolution with integrated GPS system. The Figure 3 illustrates equipment spherical vision, spherical vision camera and rails.

## 6. FIELD RESEARCH

The teams walked the railroad tracks with the aim of raising the operating conditions of the roads with the help of the equipment listed in the previous item. The inspection and collection of images on the roads was made during time intervals provided by the utilities for the operating segments, which were done filming in 360 georeferenced. For non-operating sections, images were collected in full HD camera.

The major difference is not limited to film, but also with regard to materialization of the field reality, which, judiciously, review the images allows the passage many times as necessary in order to provide the maximum railroad engineer relevant information from images collected. The comments relating to a specific event are described only once. Thus, if the event will be repeated in other parts filmed, despite the need for correction, there will be no duplication of review.

For parts not operational, due to the difficulty of access to lines which are out of operation, the snippets Sabara - Barão Cocais, Miguel Burnier - Ouro Preto, Miguel Burnier – Barão de Cocais and extensions in the municipalities of Matozinhos, Sete Lagoas and Prudente de Morais had a different solution for lifting by images. Already parts of the inner handle Sete Lagoas and Extension of Aguas Claras in Nova Lima, although not operational, were registered by the imaging system 360°.

The survey was conducted through the events marking the route in Google Earth, through the launch of a polygon in the axis of the extinct likely via. Then the technicians were in the field, bike or on foot, to analyze site conditions and capture georeferenced images of events, according to the table defined in the system 's database, for further characterization in the laboratory of Nucletrans. It was necessary to develop a new computer system to allow the registration of such information in the database .

To register for elements of interest, applications were developed using the basic image of the Point Grey Research georeferenced spherical vision system. Thus, each element of interest are stored in a database containing information section, Latitude, Longitude (or other projection system, if necessary), frame, type of point of interest and description (if applicable). The database of final storage of alphanumeric data is the open source PostGreSQL with PostGIS.

The treatment environment and conversion of geographic data is Civil 3D that allows the manipulation of geometric data, georeferenced image manipulation and the internal module MAP, the manipulation of data from different datasources, analysis and eventual conversions projection systems formats. Figure 4 shows the screen display module for the analysis and registration of notable points .

All information generated was made available to the Agency Development Metropolitan as 360° videos generated in the passages, the database PostgreSQL/PostGIS in its latest version and can also be generated shape files (. Shp) and Google Earth (.Kml) which are generated directly from the database by another computing system developed and integrated into the site.

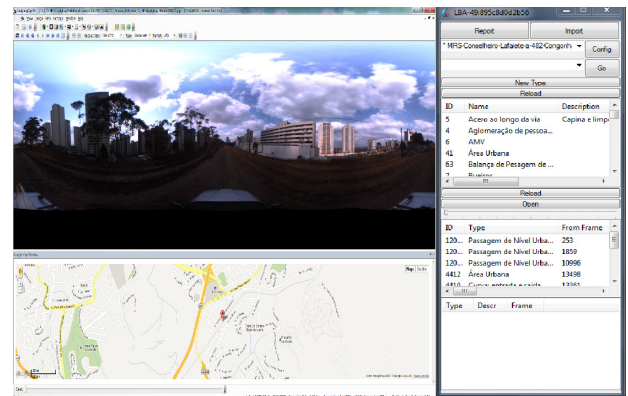


Figure 5.

Events Insertion Screen.  
Source: Prepared by author

## 7. RESULTS

In the inspections performed were identified meter gauge (1000 mm) and wide track (1600 mm), plus some excerpts operating with mixed gauges, used especially in cargo (BRINA 1988) [12]. This impedes the movement, since the failure to be able to change the motor meter gauge to wide and vice versa causes the need for transshipment of passengers at stations between adjacent gauges.

The fixing of the track, i.e. the way in which the rails are attached to TIES of wood or recycled material was one aspect observed. There were two types of fixing: the elastic (clamps) and rigid (nails and tirefonds direct on the rail).

Besides geometry, another point that caught the attention of researchers wear was observed in the billet rails. In general, it is accepted as the wear limit a loss of up to 25% of the area of the fetlock (BRINA 1988) [13]. The results of the inspection of the images showed problems in general recurrent in all sections.

To simplify the analysis, the extracts were separated according to the dealership and reports generated according to this classification (Figure 2). Were organized in FCA, MRS and excerpts not operational (NOP). The network under concession FCA includes links Divinópolis - Railway Station Eldorado and Eldorado - Sete Lagoas. The stretches of railway operating on meter gauge (narrow) or mixed, have elastic attachment and wooden TIES. The switches and crossings (AMV) operating with drive unit for maneuvering lockable spring. Lubrication track is embedded in Rail Vehicle (VF). Level crossings (PN) in urban areas have asphalt pavement and road signs. Where there transpose traffic with larger scale, it is necessary to adopt cancels and guardhouse for traffic agent. Found railing type TR-57 and TR-68. Across the range of urban area verified the existence of clandestine crossings for pedestrians transposition. Tracing the paths of FCA presents radius curves near the minimum, which makes the evolution of traffic in relation to speed and causes premature failure in railway superstructure, requiring the operator, the definition of a careful plan for preventive and corrective maintenance to provide adjustments and corrections of geometric features for alignment and leveling among others.

In the case of the superstructure of the roads in operation MRS and FCA, the anomalies found are concentrated on correcting the gauge, shortcomings in aligning and leveling the road race and AMV, rotten wooden TIES, excessive wear of rails, ballast out of compliance. In the case of the infrastructure, refers to embankment erosion, surface drainage system compromised portions of garbage in the rail located in urban areas and entering the bed rail.

The rail under MRS concession covers the southern part of the metropolitan region of Belo Horizonte, linking it to Sao Joao del Rei and Juiz de Fora. The route offers quality maintenance with regard to conservation of geometric characteristics of the track and control rail wear through lubrication billet, internal and external. Has broad gauge, operating in small patches in mixed gauge, elastic fixation. There is single points of slope erosion, in some places there is a commitment from the feedback of movement of trains. At these points there clogging ballast. The AMV's need interventions and control of wear safeguard quotas, with correction. Points were identified with invasion of the rail bed, rotten wooden TIES, rail erosion, trash from neighboring communities and wear of rails. Level crossings in urban areas in asphalt pavement with road signs. Urban stretches operate with high rates of vehicles crossing the railroad.

The excerpts are not operational degraded due to vandalism and the ravages of time without any maintenance for years. The main passage connects the towns of Ouro Preto and Sabara. There was disappearance of materials of railway superstructure, the rail bed occupancy by the community, and even in the transformation of local roads.

## 8. ANALYSIS

The study presents a new method of interpreting spatial information implemented on Google Maps for the visually impaired. The proposed model was implemented in C# language, in the framework .NET using the Google Maps API.

By using Google Maps, the prototype allows the user to have access to interactive maps of the world, leading to this type of user having a new dimension of experience with geographic information. Speak Mode, developed in the prototype allows the user to create mental models from spatial topological relationships observed in Google Maps. The implemented model of topological spatial relations proved effective in experiments with blind. The experiment revealed that the mental models generated by users is similar in most cases, models actual analysis. This study demonstrates the feasibility of using geotechnology teaching and the treatment of geographic information for the blind. It presents practical and efficient results for inclusion measures for the visually impaired.

The operating system has many barriers to release of the fleet, which can cause delays and cancellations of activities. For passenger transport, it is suggested the establishment of an independent pathway used for cargo, with autonomy of movement and maneuver, as well as construction of diversion in all stations deployed, providing the operation, routes auxiliary maneuvers in cases of damage the undercarriage.

In excerpts no-operating will need to redo the study outlined for improving the geometric design. Due to the state of degradation of infrastructure and superstructure, will be required to rebuild these parts of the whole system.

Finally, it is important to highlight the importance and the method used to generate a database of georeferenced information of the entire length of the stretch, allowing the issuance of reports concerning any occurrence on the roads. The results proved consistent and assertive as the registration of the network were evaluated and used by BHMR Development Agency to determine the feasibility of implementation of passenger rail. From this, the Agency has prepared proposals for PPP's (Public Private Partnerships) in which the excerpts have been tendered for PMI - Proposed Expression of Interest [14].

## 9. CONCLUSION

As in most industrialized countries the passenger rail plays an important role both internally to urban centers as in the connection between them, we have experienced a revival after years of neglect. With an array of transport based solely on motorized vehicles on tires, with the fleet of private cars growing at a rate much higher than the population, Brazilian cities live an immense mobility crisis, whose solution must rely on transportation projects on rails passengers.

In this context, the Metropolitan Region of Belo Horizonte paid a high price for not having a system of high transportation capacity to serve its more than five million inhabitants. Because of development characterized by a spatial concentration of activities and equipment, it created an asymmetry conditions of use and access to urban space that discourages population segments of lower income. The PDDI [10] provides for the participation of rail to ensure a link between the centralities, existing and proposed, in a network of compatibilizing BHMR infrastructure parameters to land use that is intended.

With the shortage of resources for the implementation of modern systems transpores, efficient alternative becomes the utilization of the existing structure of the extensive rail network linking various load municipalities of BHMR and surrounding cities.

This project has the importance of contributing simplifying the process of evaluation and registration of existing railroad tracks

presenting a new methodology and equipment for data collection. He is able to assemble a georeferenced database with all the events and occurrences of a railway section. With the completion of filming georeferenced the entire stretch at 360° is possible to analyze the conditions of the stretch in the laboratory, or field trip can be done in a shorter period, recording a range much greater detail and reducing the rate rework because, once done filming, any conference can be performed using up to them, it is not necessary to return to the field.

The methodology used was valid constituting an important tool to assess viability the implementation of passenger rail in the rail network MRBH.

For the future, it is an interesting improvement of the system as the coupling of sensors capable of taking measurements of some elements of the line, as the distance between the rails slips, your leveling, alignment, wear suffered, etc., determining thus its geometry. This could be achieved by laser sensors or spherical camera system could automatically recognize the elements in line and take your geometry from stereo images.

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