Environment for Analysis of Rural School Transportation: A Case Study in Espírito Santo/Brazil

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ABSTRACT

This project was developed in order to support public managers with the necessary tools to the enhancement of the rural school transportation system in Espírito Santo, Brazil. It was developed a virtual platform that enable the visualization of georeferenced data in a simple and intuitive way, making it suitable to the labor founded in the rural environment. It was established a methodology for the data treatment referred to the road network available in a GIS environment. Through the union of maps of territorial boundaries, school locations, students and route data available in a topology network format, the database became usable in the routes analysis. The methodology was validated by a case study of Vila Pavão County, in the state of Espirito Santo.

Keywords: Intelligent Transport Systems, Rural School Transport, Spatial Information, Geographic Information System.

1. INTRODUCTION

Data of the Brazilian scholar census [1] indicates that between 2003 and 2013 there was a reduction in the number of educational units available in rural areas resulting in a distribution of schools only in strategic central areas. As a reflection of this historical process nowadays students living in remote areas have to travel long distances to have access to schools. As an aggravating factor for this scenario, the road conditions and the spatial dispersion of these students increase the costs and affect the quality of the transportation services offered in these regions [2].

The Federal Constitution of 1998 establishes that the access to compulsory and free education is a subjective public right, and it is for the State to its provision [3]. The scholar transport must have its assurance guaranteed by the government [4]. To ensure not only access, but also the stay of students in schools, a scholar transportation system of quality is fundamental. This service becomes even more essential in rural areas, where the long distances between the students and the schools are more expressive. Thus, it is evident the social and economic relevance of the rural scholar transport in the educational development of a country [5].

In order to implement the distribution of resources and perform the necessary activities to the exercise of this duty, the State must contracts the providers of transportation services or the purchase of new vehicles to the provision of this service on its own. In both cases, it is mandatory to the government to observe the principles of the Law No. 8666/96, which establishes guidelines for the bidding process and guarantees the best use of the State funds [6].

Therefore, for a bid to fulfill its purpose, it is necessary the government to have a wide range of tools and data. Thus, it is possible to do an appropriated study related to the best solution for the rural scholar transport on its area, making possible the establishment of a reliable parameter for the analysis of the feasibility and the economy of the bidding companies proposals [7].

It was developed a study in the Federal University of Minas Gerais (Universidade Federal de Minas Gerais) in partnership with the Government of the State of Espirito Santo, to develop a solution for the abovementioned problem. For this, it was necessary a robust georeferenced database containing information related to the students, schools, vehicles, roads, routes and stops.

Various organizations and governors adopted the Geographic Information System (GIS) in order to make complex decisions in a quickly and safely way, saving time and money in data analysis [8]. These softwares are highly complex and there is a shortage of skilled labor to deal with this kind of technology, particularly in rural areas.

Considered the characteristics and needs of the rural areas and in order to obtain a way of facilitating the access to georeferenced data without the need of highly qualified professionals, it was created this project. It was intended to establish an interface that allows the access to necessary information to the study of resources allocation for the rural school transportation in a didactic and intuitive way, without the use of complex software, or that require intensive training prior to its utilization. As a case study, the Vila Pavão County (Espirito Santo, Brazil) was chosen.

3. PROJECT HISTORY

There are great efforts that are made by agents of public entities in order to improve the rural scholar transportation system in Brazil. However, there is the necessity of progress, especially in the development of technologies that contribute to the management of this service, particularly as regards the budgeting dedicated to rural transport.
There are 76 Counties in the state of Espírito Santo with students from the state network using Rural School Transportation. Mostly, the transport of students presents intuitively, which requires effective action from the State Government for its greater efficiency. The rural school transportation in Brazil is the result of a historical process by which the country passed.
The educational policy adopted over the years resulted in a reduction in the number of teaching units available in rural areas, focusing on other strategic areas. These measures distanced the students from schools locations, forcing them, often to cover long distances to have access to education. Besides, the conditions in these regions, such as poor roads, regions of difficult access, poor distribution of schools and spatial dispersion of students, hinder the provision of public transport. These factors reduce the quality of service and increase the cost of transport.

4. CORRELATED WORK

Geographic Information System (GIS) is a "set of programs, equipment, methodologies, data and people (user), perfectly integrated, in order to make possible the collection, the storage, the processing and analysis of georeferenced data, as wells as the derived production of its application". It is a fundamental tool in the transportation area, because it allows a better visual comprehension of the relation between all the data involved [9].
As well as the spatial visualization of data, trough GIS platform it is possible to verify if the project is consistent, identify possible vulnerabilities and repair them, and also simulate situations allowing an improvement in the decision-making process [10]. In transportation segment it is possible the supervision of road networks, vehicle routing, traffic control and tourist information system in complex areas as in municipal and federal planning using GIS.
For the study described in this paper it was used, within the GIS concept, the software: Autodesk Infraworks 360 and AutoCAD MAPS 3D, being both filled by a geographic database created in SQL structure in the PostGIS. Following, some correlated work in the study of routes and the use of georeferenced data are presented.
Holanda [11] aimed to organize and standardize all available data from Ceara Central (Brazil) in a GIS environment through the development of georeferenced database aiming the recovering of data, the improvement of the quality of the information and the possibility to generate new interpretations from existing data and products.
Silva [12] does as part of his work, a survey of the conditions under which the scholar transport is provided in 11 different countries, collecting data as daily cost per student, average age of the fleet, local legislation , maximum distance of the student and maximum waiting and travel times.
Lopes [13] search the assurance of the quality of the rural school transportation services through the establishment of an organizational structure that encompasses planning, management and control. It also define that this process requires that the manager rely on information related the registration of students, vehicles, schools and other items.
Cruz & Campos [14] expose the current state of art related to the use of GIS in the analysis of spatial data concerning the environment, transportation and land use. They establish that due to facility of analysis and visualization from maps and images generated by a GIS system, it is evident that one of the great capacities of the georeferenced data analysis is its manipulation to produce new information.
Rostami [15] uses GIS tools to propose a sizing model of the demand for public transport in rural areas of the state of New South Wales in Australia. For this, the author compares the vector paths of existing transportation in the area with the weighted profile of the residences of the rural area in a georeferenced form.
Nayati [8] sets out to answer the question of how to transport students in the safest, economical and convenient form possible. For this, the author creates a management system for georeferenced data able to obtain the best routes and to allocate the students collection points in an optimized and secure way.
GIS has been an excellent tool for route optimization.
Anavberokhai [16] used GIS and the multi-criteria analysis to determine a route between two points in Nigeria. The use of ArcGIS showed that this tool is reliable in the management, integration, performance of advanced analysis, modeling and operational data processing automatically, as well as the definitive display of results. The application of this method proved to be a process that demands less time and, consequently, generates less associated cost in a traditional planning method.
Winn[17], S. Panahi e M. R. Delavar [18] showed how the GIS platform could be used to create the shortest path to emergency vehicles like ambulances and fire trucks, based on Dijkstra's algorithm. The best path is defined as the route with the lowest cost determined by the applied impedance. It is believed that the dynamic routing based in cost attributes derived from data on historical travel time can help emergency vehicles to avoid congested areas and improve the travel time.
Araujo [19] used Data Envelopment Analysis technique to identify efficient and inefficient routes in the context of rural school transportation. Through a series of procedures, it was possible to evaluate routes based on operational cost and the identification of the sources that cause inefficiency.
In Dalumpines [20], data needed to search a transportation system area derived from GPS was automatically extracted using a group of GIS-based episodes reconstruction tools (GERT). This kit generates an entry for the modeling choice of route.
Sanches et al [21] considered two assessment criteria that reflect the quality of the service provided: the average level of accessibility of the students and the capacity of the vehicles, and the system operation cost. It allowed the access to the decision-maker to a wide range of alternatives, with diverse restriction levels, in order to define the most suitable system of routes to meet the needs of students in the rural area.
Sanches and Ferreira [10] conducted a study in São Carlos (São Paulo, Brazil) to rationalize the routes system of the rural school transportation. The study at hand allowed a reduction of 15% in the daily mileage with the development of more efficient routes, combined with the improvement in the quality of the service, limiting the maximum travel time to 60 minutes and respecting the capacity of vehicles. Furthermore, it was found that the graphic presentation provided by GIS facilitated the visual analysis of routes and the final adjustments necessary for the system consolidation.

Carvalho [22] used GIS with a different proposal. Instead of an optimization of the route, the author proposes an analysis methodology for choosing the best location for the construction of new schools in order to reduce the distance travelled by the students and teachers. However, it states that one of the requirements for the use of this methodology is the existence of qualified professionals for the use of GIS tools combined with mathematical operations.

Trough GIS it is also possible to do the analysis of pipeline routes that will bring to lower costs. In a study conducted by Kelly [23], several factors were considered to ensure the lower risk route, as the type of soil, the land slope and the factors of environment and social risk. A pipeline project in a straight line was taken as a baseline. Results indicated that the route optimized by GIS obtained a cost 38% cheaper than the project taken as a model. In the study developed by Huseynli [24] for the best path to a pipeline, the route generated by GIS demonstrated a 17% lower cost compared with a Euclidean route.

Yldirim V. et. al. [25] used the GIS concept to perform the optimization study of routes with linear engineering structures such as highways, pipelines, energy transmission lines and drainage systems through channels. Applying the available technology, it was managed to redefine the route of an existing highway in Turkey, reducing in 2km the length of it. They determined that the use of GIS brought a potential economy from 5 to 15%.

5. METHODOLOGY

This project has as his main objective to analyze Espirito Santos's scholar transportation as a way to implement a digital tool for optimization, management and rout control, as well calculate rural scholar transportation costs based in a geographic system information having as its reference today's rural scholar system transport implementation.

In this project there is also specific objectives which can be described in eight different marks to guarantee the entirety of the system. In following is presented those marks detailing.

1st Mark – Define and implement a computational environment for Transcolar ES system.

The computational environment for Transcolar ES system execution is implemented and effective. Two servers are being used as a production server, for an external use for Transcolar ES Website with an IP address number 150.164.49.166, and as a development server located at Transcolar & Nucletrans laboratories intranet. Both NAS 6 TB servers has each their own back-up system installed. Postgres, with PostGIS extension, is being used as system's database. The graphic interface was developed in PHP for the WEB environment. The routing routines were developed in C++ language while the cost routines were created in C# and javascript language.

2nd Mark – Create spatial database

Construct a spatial database to be used at Transcolar ES system which can be manipulated by public managers to contribute with a substantial improvement at the municipal and state rural scholar transportation system management. For each county it will be necessary to rearrange the highway network to the specific needs that is presented to Espirito Santo state.

3rd Mark – Develop and implement a management, optimization and rout control systems and calculate rural scholar transportation costs

Develop and implement a management, optimization and rout control systems and calculate rural scholar transportation costs. There are three independent and correlated systems. The first module includes Transcolar system website that allow the needed information to be register in the spatial database to optimize routs and cost calculation. This website contains interface to alphanumerical characters and a GIS plataform to analize and edit spatial information. The second module includes optimized rout generation system which reads database information and returns optimized routs report to this same database. Until now, six mathematic models have been developed and implemented. The third module receives optimized routs reports, analyze which vehicle it is the best choice to make each trip in each shift to minimize fixed vehicle costs and calculates, after it, the variable cost from a month trip. In this way, it can be found the right vehicle to make each trip and scale out the cost per kilometer or per student. As each vehicle transports state and municipal students, it can also determinate the percentage values which each government scope must contribute to support their own students transportation.

4th Mark – To promote nowadays routs system registering (2016)

It shall be registered in the website system all planned and executed trips to complete scholar transportation database, including municipal and state information. It is needed to be a standardization of the information to be correctly read and processed by the system. An effective loading of the data is extremely important to have a correct planning of working field.

5th Mark – Register, at GIS environment, all school and rural scholar transportation students from Espirito Santo (Figure 1).

To promote a georeferenced register at GIS environment of all school and rural scholar transportation students from Espírito Santo. For each student it has been requested the power supply identification code from their residence. After correlate those code numbers with geolocation points obtained with electricity power dealerships it is possible to georeferenced students location.

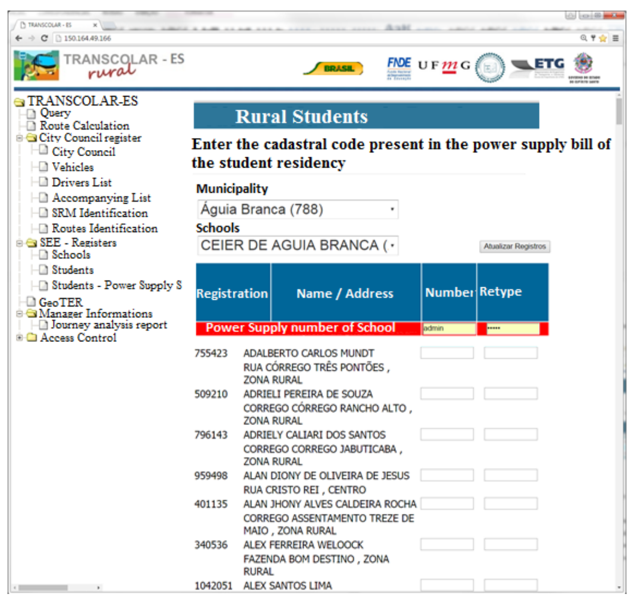

Figure 1: Input screen for student data

6th Mark - Registration of routes available for rural school transport.

It were inserted in the special database, information from state, federal and vicinal roads (Figure 2) to generate the updated road network, topologically correct and complete, in order to be used in optimization models.

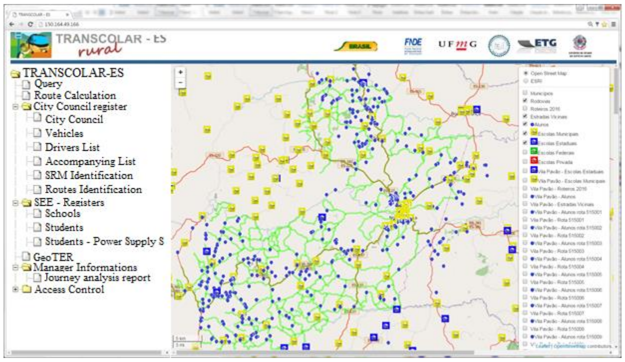

Figure 1: Spatial data

7th Mark - Develop cost spreadsheet model for rural school transportation

It was elaborated an Excel spreadsheet with the first version of the cost worksheet of the rural school transportation, adjusted to the singularities of Espírito Santo state. This worksheet takes into account all fixed and variable inputs relative to vehicle traffic and also operating costs. It shall be drawn up in spreadsheet form in order to facilitate explanation of the criteria and values and execution of calculations by the government and users. Once checked, it should be performed computational implementation to be added to the system, thereby generating the cost in an automatic way for every database and for other routes generated by the optimization.

8th Mark – Develop methodology for route optimization

There are two groups of research and development of mathematical models for Rural School Transportation. The teams are working in different research fronts that can lead to different results that may present more suited to different situations that arise. Both groups have developed over six computational models using heuristic solution to the problems presented.

6. DEVELOPMENT

To the development of this study, the County of Vila Pavão in the state of Espirito Santo (Brazil) was chosen as a case study for the methodology developed. Vila Pavão has 1,852 students enrolled in public schools, which is composed of 31 public schools [26] distributed in 433.257 square kilometers that make up the municipality [27].

The problem at hand is constituted by a group of students distributed spatially that must be transported from their residences to their respective schools with a route that allows the shortest travel time possible. These are the data to be considered as entries: the students, the schools, the vehicles and the available roads. From these data, it must be created a single network with the integration of all these elements.

Data acquisition

The points corresponding to the georeferenced location of each student were obtained with the help of visualization of the electricity bills, delivered by each student at the time of enrollment. The same process was done to obtain the geo-referenced location of each school. The County provided data about existing vehicles and involved agents. Moreover, at this stage some relations were implemented, such as the association of each student to their designated school and the association of each bus available to a capacity.

The routes performed by the current Rural School Transportation were collected via Global positioning System - GPS, starting with the installation of the information collection system in vehicles, which follow the designated routes. This information provides geographic position and also the time and hence the speed performed in each section.

Attention should be paid to the fact that the coordinates obtained by GPS satellite tracking refer to an internally consistent geocentric datum, the "World Geodetic System / 1984" - WGS-84), currently called G873. While GIS operate charter geographic coordinates, usually referred to a continental, national or local datum, with the state of Espírito Santo in position 24-S in the Universal Transverse Mecartor system [28].

Data processing

In order to supply the route algorithms in study with analyzable vectorized data, it was necessary to consider the treatment of the information contained in the georeferenced database. The graphic display of the data was performed using the AutoCAD MAP 3D and Infraworks software, which facilitated the identification of possible inconsistencies and errors in the stored data. Errors in data entry may go unnoticed when examined in tabular form, but are much more visible when shown on a map [10].

Through Autodesk Infraworks, the data can be viewed spatially, through the more diverse angles, enabling to check for inconsistencies that would not be displayed in the table. Obstacles on the route, for example, the terrain can influence significantly on the bus route, or walk path to be covered by the student, and this is a factor that does not appear when the data are released only in tables. Figure 3 shows the display interface provided by Infraworks, which can be observed data that need attention, such as roads sections without its vectorized layout and the overlapping of two schools, which may mean some inconsistency in the database.

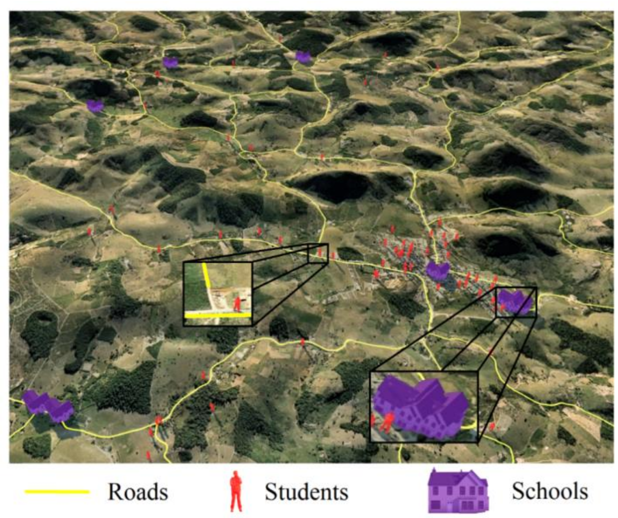

Figure 3: Spatial visualization of data on Infraworks and identification of inconsistences in the data.

A geographic database topology is, simply, a set of rules and properties that define the spatial relationships that shape and preserve the data [11]. In the case study of the best way to transport through routes, it is necessary an arc-node topology [29]. In this type of topology, the start and end points of each line will define the nodes and for each node, the incident lines will be stored. For each line, the start and end nodes will be defined, thus allowing the line to be associated with a transversal direction. This type of topology allows that, after each line is covered, to reach a node where can occur a change of the path for adjacent lines until all possible paths are covered and returning to the smallest route [30].

Through the manipulation of vector data it was possible to adapt the paths of the routes to the necessary topological rules. For fine-tuning the topological cleaning tool contained in AutoCAD 3D MAPS was used for which tolerances values can be supplied to the software to recompose the data correctly and automatically. However, this tool does not generate good results for the analysis of the grossest errors, since for these, it is necessary to define a very high tolerance, resulting in the adulteration of correct data.

Figure 4 shows how the AutoCAD 3D topological MAPS operates during the cleaning process.

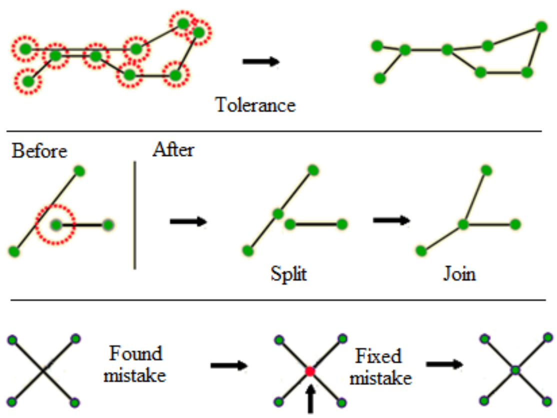

Figure 4: Edition of geographic features from topology rules. Source: Adapted from [31]

This analysis brings a more realistic view for the situation on site, which ensures greater reliability in the final product that it is the routing of rural school transportation. Figure 5 shows an image generated by AutoCAD MAPS 3D with the routes generates superimposed on the boundaries and points of interest.

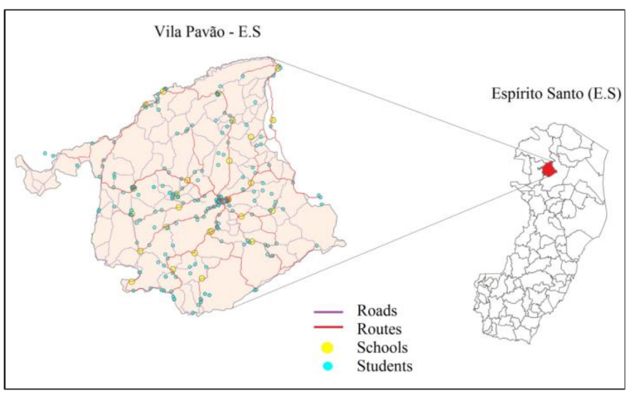

Figure 5: Visualization in 2D of the map with the routes, students and schools through AutoCAD Maps.

After analyzing and processing the data, a virtual platform entitled "Transcolar Rural – ES" was created to allow administrators to access and manage all data easily and intuitively. Through the site, it is possible to have access to all registered data, visualize spatially the location of each data and each generated route to transport students. Figure 6 shows the menu with all the information available on the website

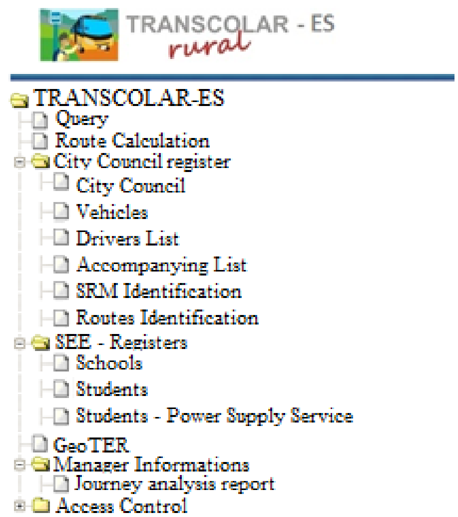

Figure 6: Menu of the virtual platform "Transcolar Rural – ES"

Figure 7 brings a route simulation. From the platform, it is selected a city and a school and all the vehicles available to suit the selected school are presented with the visualization of the route of each vehicle on a map, along with the relevant information, such as the vehicle capacity, the number of students that the vehicle is going transport, the total length in kilometer covered and the travel costs. This type of information visualization, through maps in conjunction with tables enables a clearer understanding of the routes of each bus, and, as a result, a better administration of the system.

Routes

City
Vila Pavão
Schools
EMUEF CORREGO DO MAROTO
Transcolar
School Name: EMUEF CORREGO DO MAROTO
Address:
Phone Number:
Quantity of Students:

Total Cost: ($)

ROUTES

	Journey	Shift	Vehicle Capacity	Transported Students	Departure/Arrival	Total Km	Km Student	Cost ($)
⦿	1	AM	11	4	Dep	120,4	71,6	120,3
○	2	AM	11	3	Arr	108,6	71,5	130,7
○	3	PM	11	4	Dep	120,4	71,6	120,3
○	4	PM	11	3	Arr	108,6	71,5	130,7

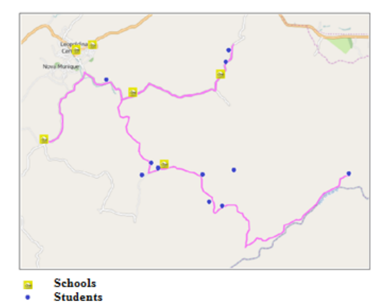

Figure 7: Visualization of the routes of the vehicles through the virtual platform "Transcolar Rural – ES"

4. CONCLUSIONS

This study aimed to make the treatment of routing data of rural school transportation more intuitive, as well as make available the analysis of the database required to the decision-making process related to the development of this service. In order to test the effectiveness of the study at hand, it was taken as a case study the city of Vila Pavao, Espirito Santo (Brazil).

Through a GIS platform, it was possible to treat the data through the georeferenced visualization of it. If the data were only in tables, inconsistences could not be identified and repaired so that the routing work can be fully implemented.

In addition, through the virtual platform created, the administrators of the Counties can also manage data in an intuitive way, without the need of GIS specialized professionals, which are scarce, particularly in rural areas, which is the focus on this work.

Because of this work, it was possible to provide proper tools for a more efficient management of the rural school transportation system. Through the utilization of the virtual platform, it will be possible to optimize the routes to be used and set reference prices more accurately for contracting services for this purpose.

5. REFERENCES

[1] Ministério da Educação, INEP -Instituto Nacional de Estudos e Pesquisas Educacionais - Censo Educacional 2013.

[2] Porto M. F. et al. Estudo do Transporte Escolar Rural no Estado de Minas Gerais – Terceiro Relatório. Universidade Federal de Minas Gerais. Minas Gerais: Belo Horizonte.

[3] BRASIL. Constituição (1988). Art. 208. Constituição da República Federativa do Brasil. Brasília, DF: Senado Federal: Centro Gráfico, 1988.

[4] BRASIL. Constituição (1988). Emenda constitucional n.º 59, de 11 de novembro de 2009.

[5] BRASIL. Ministério da Educação. FNDE – Fundo Nacional de Desenvolvimento da Educação. Cartilha Gestor Planejamento: Planejamento do Transporte Escolar Rural. 2010. Disponível em: http://www.fnde.gov.br/arquivos/category/131-transporte-escolar. Acessado em 21 de Julho de 2016.

[6] BRASIL. LEI Nº 8.666, de 21 de junho de 1993. Regulamenta o Art. 37, inciso XXI, da Constituição Federal, institui normas para licitações e contratos da Administração Pública e dá outras providências.

[7] BRASIL. Tribunal de Contas da União. Orientações para elaboração de planilhas orçamentárias de obras públicas / Tribunal de Contas da União, Coordenação-Geral de Controle Externo da Área de Infraestrutura e da Região Sudeste. – Brasília : TCU, 2014.

[8] Nayati, M. A. K. (2008). School bus routing and scheduling Using GIS. University of Gavle – Department of Technology and Built Environments. Master Thesis in Geomatics. Suécia: Gavle, 2008.

[9] Teixeira, A., Matias, L., Noal, R., & Moretti, E. (1995). Qual a melhor definição de SIG. Fator GIS, 11, 20-24.

[10] Sanches, S. P., & Ferreira, M. A. G. (2003). Avaliação do padrão de acessibilidade de um sistema de transporte de alunos da zona rural. In Anais do XVII Congresso de Pesquisa e Ensino em Transportes (pp. 931-942).

[11] Holanda. J. L .R. (2008). Desenvolvimento de um Banco de Dados Georreferenciado (SIG) para as Informações Geológicas Disponíveis do Domínio do Ceará Central. Universidade Federal do Ceará. CE. 2008.

[12] Silva, A. R. D. (2010). Metodologia para avaliação e distribuição de recursos para o transporte escolar rural.

[13] Lopes, E. P. (2010). Modelo organizacional para o transporte escolar rural nos estados e municípios brasileiros.

[14] Cruz, I., & Campos, V. B. G. (2005). Sistemas de Informações Geográficas aplicados à análise espacial em transportes, meio ambiente e ocupação do solo. Rio de Transportes III.

[15] Rostami, S. (2005). Application of the transport needs concept to rural New South Wales: a GIS-based analysis. University of New South Wales.

[16] Anavberokhai, I. (2008). Introducing GIS and Multi-criteria analysis in road Path Planning process in Nigeria: A case study of Lokoja, Kogi State

[17] Winn, M. T. (2014). A Road Network Shortest Path Analysis: Applying Time-Varying Travel-Time Costs for Emergency Response Vehicle Routing.

[18] Panahi, S., & Delavar, M. R. (2008). A GIS-based dynamic shortest path determination in emergency vehicles. World applied sciences journal, 3(1), 88-94.

[19] Araújo, C. E. F. (2009). Análise de eficiência nos custos operacionais de rotas do transporte escolar rural.

[20] Dalumpines, R. (2014). GIS-based episode reconstruction using gps data for activity analysis and route choice modeling (Doctoral dissertation).

[21] Sanches S. et al. (2016). Avaliação Multicriterial de um Sistema De Transporte De Alunos Da Zona Rural. Universidade Federal de São Carlos. SP. 2016.

[22] Carvalho, W. L. (2012). Metodologia de análise para a localização de escolas em áreas rurais.

[23] Kelly, A. (2014). GIS Least-Cost Route Modeling Of The Proposed Trans-Anatolian Pipeline In Western Turkey.

[24] Huseynli, S. (2015). Determination of the most suitable oil pipeline route using GIS least cost path analysis (Doctoral dissertation).

[25] Yildirim V, Nisanci R, Reis S (2006). A GIS Based Route Determination in Linear Engineering Structures Information Management (LESIM). XXIII FIG Congress Munich, Germany.

[26] IBGE (2016). IBGE Cidades. Instituto Brasileiro de Geografia e Estatística. Disponível em: http://cidades.ibge.gov.br/. Acessado em 22 de Julho de 2016.

[27] Cidades, I. B. G. E. (2010). Instituto Brasileiro de Geografia e Estatística.

[28] Bernardi, J. V. E., & Landim, P. M. B. (2002). Aplicação do Sistema de Posicionamento Global (GPS) na coleta de dados. DGA, IGCE, UNESP/Rio Claro, Lab. Geomatemática, Texto Didático, 10(31), 2002.

[29] Paula, M. Â. A. F. D. (2009). Estudo de roteirização de veículos empregando o TransCAD: contribuição para a distribuição urbana de cargas.

[30] Queiroz G.R & Ferreira K.R. (2006). Tutorial Sobre Banco de Dados Geograficos. Rio de Janeiro:Instituto Nacional de Pesquisas Espaciais-INPE, Ministerio da Ciencia e Tecnologia.

[31] Ferreira, N. C. (2006). Apostila de sistema de informações geográficas.Goiânia: Centro Federal de Educação Tecnológica de Goiás.