WCTR 2013 RIO

SELECTED PROCEEDINGS

AN APPLICATION OF VEHICLE ROUTING PROBLEM IN CHARTERED BUSES TO TRANSPORT EMPLOYEES USING GEOGRAPHIC INFORMATION SYSTEM

SALLES, ROSEMBERG S. - FEDERAL UNIVERSITY OF ESPIRITO SANTO, VITORIA, ES, BRAZIL
NETO, GREGÓRIO C. DE M. - FEDERAL UNIVERSITY OF ESPIRITO SANTO, VITORIA, ES, BRAZIL
CRUZ, MARTA M. DA C. - FEDERAL UNIVERSITY OF ESPIRITO SANTO, VITORIA, ES, BRAZIL

This is an abridged version of the paper presented at the conference. The full version is being submitted elsewhere. Details on the full paper can be obtained from the author.

ISBN: 978-85-285-0232-9

13th World Conference on Transport Research

www.wctr2013rio.com

15-18 JULY 2013
Rio de Janeiro, Brazil

AN APPLICATION OF VEHICLE ROUTING PROBLEM IN CHARTERED BUSES TO TRANSPORT EMPLOYEES USING GEOGRAPHIC INFORMATION SYSTEM

SALLES, Rosemberg S. - Federal University of Espirito Santo, Vitoria, ES, Brazil
NETO, Gregório C. de M. - Federal University of Espirito Santo, Vitoria, ES, Brazil
CRUZ, Marta M. da C. - Federal University of Espirito Santo, Vitoria, ES, Brazil

ABSTRACT

The chartered transport of employees in buses of Brazilian companies is an important alternative to public transportation, especially for companies located in places with deficiency transportation services, which are vulnerable to employees' delays and loss of productivity due to longer travel times. This article aims to develop a procedure for pickup and delivery of employees by a fleet of chartered buses with the support of a geographic information system by applying the vehicle routing problem for possible route optimization. For this purpose, TransCAD software is used for modeling and problem resolution. The procedure was applied to a case study in a large company in the Metropolitan Region of Vitoria City in Espirito Santo State. Four scenarios were created in order to analyze the efficiency of the routes in terms of distances and travel times.

Key-words: Chartered Transport, Vehicle Routing Problem, Geographic Information System.

INTRODUCTION

Among the many challenges presented nowadays by a consumer society, stand out the one of how to make transportation systems more efficient to meet the demands of people's displacement, especially in round trips to work.

Brazil's main cities live daily with serious problems urban mobility caused by the lack or deficiency of appropriate public policies to urban transport and land use, rapid industrialization, population density increase and credit facilities for cars purchase.

According to Lerner (2009), most cities in Brazil has grown explosively and disorderly, and the result, in relation to public transportation, has been the formation of a tangle of bus lines operating with great waste of time and costs. The trend is the aggravation of the problem with negative effects on productivity, urban environment and quality of life. He concludes: "nobody produces well after wasting time and energy to get to work."

This assertion is supported by the Institute of Applied Economic Research - IPEA (2002), whose study shows that travel times over 40 minutes from home to work have impacts on worker productivity in the order of 14 to 21%. This seems to be the major motivation of companies for investing in chartered transport to their own workers.

Due to the quantitative and qualitative deficiency of public transport evidenced by Brazilian workers every day, arises as alternative transportation, particularly for industry, the chartered transport. For Santos and Pinto (2003), this type of transport offers some advantages compared to public transport, such as: worker productivity increase, decrease in the number of absences or delays in service, invulnerability from public transportation system strikes, convenience and speed.

Despite the advantages that the chartered transport offers its users in relation to public transport, investments are necessary for keeping or increasing it’s efficient in terms of service level and economical feasibility, in order to ensure its competitiveness in a worrying urban mobility scenario. Among these investments, the use of georeferenced technologies that provides more efficient routes, called Geographic Information Systems (GIS) applied to Transport, appears as an important tool for managers and operators of those systems.

According to Verlangieri (1999), the routing based on georeferenced network allows to obtain routes with reduced travel times, mileage and number of vehicles used, with better utilization of vehicle capacity.

For Mapa and Lima (2005), the market has a reasonable number of softwares with transport applications. They are composed of logistics routines to facility location, vehicle routing and scheduling, monitoring and traffic control applications, transport supply and demand, and accident prevention.

In this article, the TransCAD software was used to develop a procedure for employees’ pickup and delivery from a large company in the Metropolitan Region of Vitoria City in Espirito Santo State that provides chartered transportation to its employees. The objective is to obtain more efficient routes in terms of distances and travel times.

LITERATURE REVIEW

Chartered transportation

According to Vuchic (2007), urban passenger transport modes are divided into three major groups: private, public and semi-public. The semi-public transport is the one that has intermediate characteristics between the private and public, such as: taxi, carpool, van rides and chartered vehicles, the subject of this article.

Quoting Lima (2001), the transportation by chartered bus in Brazil arose from the demands of large factories in the ABC region in Sao Paulo, who needed to provide round trip transportation for it's employees in different production shifts, located in places not always served by public transportation regular lines.

For Alvim (1995), the charter services are characterized as an intermediate form between the individual and public transport, as it is both, collective and personal - door to door service.

Geographic information system

According to Câmara et al. (1996), GIS is an organized collection of hardware, software, geographic and alphanumeric data designed to efficiently capture, store, update, manipulate, analyze and present geographically referenced information.

Quoting Viviane et al., (1994) and Silva (1998), GIS has been widely used in Transport Engineering, thus obtaining the name of GIS-T. The field for GIS-T is large, both in planning and transportation operation. Some applications of GIS in transportation, among the various existing, can be cited, such as: traffic monitoring and control, transport supply and demand, accident prevention, route optimization, monitoring and control of road operations.

For Ferrari (1997), the Geographic Information System can obtain benefits in three organizational levels: operational, management and strategic (Table 1).

Table 1 - Use of GIS in organizations

Level of organization	Benefits
Strategic	– Better Image (customers and partners); – Income increase; – New sources of income.
Management	– Administrative effectiveness with better information and tactical decisions: planning, management and resource allocation.
Operational	– Productivity gains; – Reduction or elimination of costs or risks; – Quality in tasks performing.

Source: Ferrari, 1997.

Vehicle routing problem

According to Golden et al. (1981), the Vehicle Routing Problem - VRP, belongs to a operational research category called "Network Optimization", where can also be found other classic problems such as: maximum flow, shortest path, transportation and assignment.

For Laporte et al. (2000), the VRP objective is to define vehicles roadmaps that minimize the total cost of service, each one starting and ending at the vehicles depot or base, ensuring that each customer is visited exactly once and the total demand of any route does not exceed the vehicle capacity.

According to the VRP classification proposed Bodin et al. (1983), the issue presented in this article is a classic knot coverage, with single or multiple bases, multiple routes, multiple vehicles with capacity constraint, time constraint and deterministic demand.

Software routing

According to Loureiro and Ralston (1996), the TransCAD software was one of the first GIS-T packages developed specifically to be used as a tool for planning, management, operation and transportation systems analysis. The TransCAD incorporates specific routines for solving logistics, operational research and transportation problems in general, such as: determination of routes with lower impedance between knots, trips distribution between zones, vehicles routing and scheduling, facilities location and resource allocation in networks.

For Brejon and Belfiore (2006), the benefits generated from using computerized vehicles routing procedures depends on the complexity of the problem, for example, a large number of customers and vehicles and routes with presence of time windows. There are many benefits achieved with computerized procedures, such as: (i) obtaining shortest routes; (ii) obtaining faster routes; (iii) lower number of vehicles employed; (iv) lower cost; (v) improvement in the operations performed; (vi) ability to perform sensitivity analyzes; (vii) better level of customer services.

URBAN MOBILITY IN THE VITORIA REGION

The metropolitan region of Vitoria - MRV, like other Brazilian regions, live daily with serious urban mobility problems, especially at rush hours, mainly characterized by thousands of people in round trips to work.

A FINDES[1] study in MRV identified the main aspects related to urban mobility of industry workers, such as geographical aspects, company profile, employee's profile, as well as the locomotion shaft and ways of these workers in their pendular displacements - constituted by round trips to work, which are presented below.

Geographical aspects

The MRV houses 46% of the total population of the Espirito Santo state, 57% of its urban population, concentrating 65% of the GDP. The MRV has an area of approximately 144 thousand hectares, representing 3.2% of the total area of the state, but the population density is more than nine times higher than the state average. The capital, Vitoria, is the smallest county in MRV and has the highest concentration of population: 3,065 inhabitants per square kilometer.

Companys profile

According to the FINDES study, the largest industrial concentration in MRV is in the Serra county (45.87%), followed by Vitoria (22.76%), Vila Velha (19.07%) and Cariacica (8.88%), as shown in Table 2.

Table 2 - Companies percentage distribution by size and county of operation

Company size		County of operation				Total
Number of employees	Company rating	Vitoria	Vila Velha	Serra	Cariacica	
1 - 19	Micro	2.72	2.11	2.02	2.37	9.93
20 - 100	Small	8.88	9.84	11.51	3.78	35.59
101 - 500	Medium	5.27	2.46	13.97	2.72	25.57
More than 500	Large	5.89	4.66	18.37	0.00	28.91
Total		22.76	19.07	45.87	8.88	100

Source: Euvaldo Lodi Institute, 2009.

Worker profile

Also according to the FINDES study, 10.28% of industrial employees works in scale, 18.19% develops their activities in shifts and the vast majority, 71.53% works in commercial hours. This information corroborate that industry workers moves in metropolitan region mainly in the so called peak hours.

The Table 3 reveals that the displacements of the industry workers (round trips to work) are mainly within the municipality of Serra (35.15%) and considerable between the counties of Vitoria and Serra (4.66%).

[1] Federation of Industries of the Espírito Santo State.

Table 3 - Relationship percentage between workplace and residence

County of residence	Workplace county					Total
	Vitoria	Vila Velha	Serra	Cariacica	Viana	
Vitoria	5.45	0.79	4.66	0.18	0.00	11.07
Vila Velha	2.46	12.92	2.37	0.62	0.09	18.45
Serra	7.73	0.53	35.15	0.26	0.00	43.67
Cariacica	6.59	4.39	3.43	7.29	2.02	23.73
Viana	0.53	0.35	0.26	0.53	1.32	2.99
Guarapari	0.00	0.09	0.00	0.00	0.00	0.09
Total	22.76	19.07	45.87	8.88	3.43	100

Source: Euvaldo Lodi Institute, 2009.

Transport ways for workers' displacements

The displacement method mostly used by industrial workers in their round trips to work in MRV, is the bus (58.96%), followed by displacement on foot and bicycles, which represents 22.67% of the total.

Adding to this number (22.67%) other means of displacements (car, motorcycle and others - 18.20%), implies a reasonable share of workers who do not use the public transportation system (40.87%), which could be a dissatisfaction with the services provided in this modal. In addition, 0.18% of industrial workers use chartered transport provided by their companies (Table 4).

Table 4 - Modes of transport percentage between home and work

Bus	Bicycle	On foot	Car	Motorcycle	Others	Companies chartered buses
58.96	12.65	10.02	8.44	4.75	5.01	0.18

Source: Euvaldo Lodi Institute, 2009.

Axis of workers' displacement

The daily flow intensity in the main roads of the metropolitan area, based on the public transport buses route can be observed in Figure 1. The displacement axis of the workers flow in the industry is concentrated in arterials pathways which corresponds to the Transcol[2] system trunk-lines.

Despite the workers' tendency to live in their work city or the company's preference to hire people who live closer to the workplace, this displacement shows great mobility of industrial workers' between counties. Therefore, it's clear that the main characteristic of the metropolitan region is its high degree of concentrating skilled labor availability. The metropolitan function is therefore condition of localization and logistic value to define industrial installation.

[2] Public transportation system managed by CETURB Company.

The city of Vitoria has the highest number of routes used for moving industrial workers'. The vast majority of the 600.000 vehicles fleet circulates through the main roads of the state Capital, which is already overloaded, reducing the average speed of vehicles to 20 km/h, mainly at peak times (LUZ, 2010).

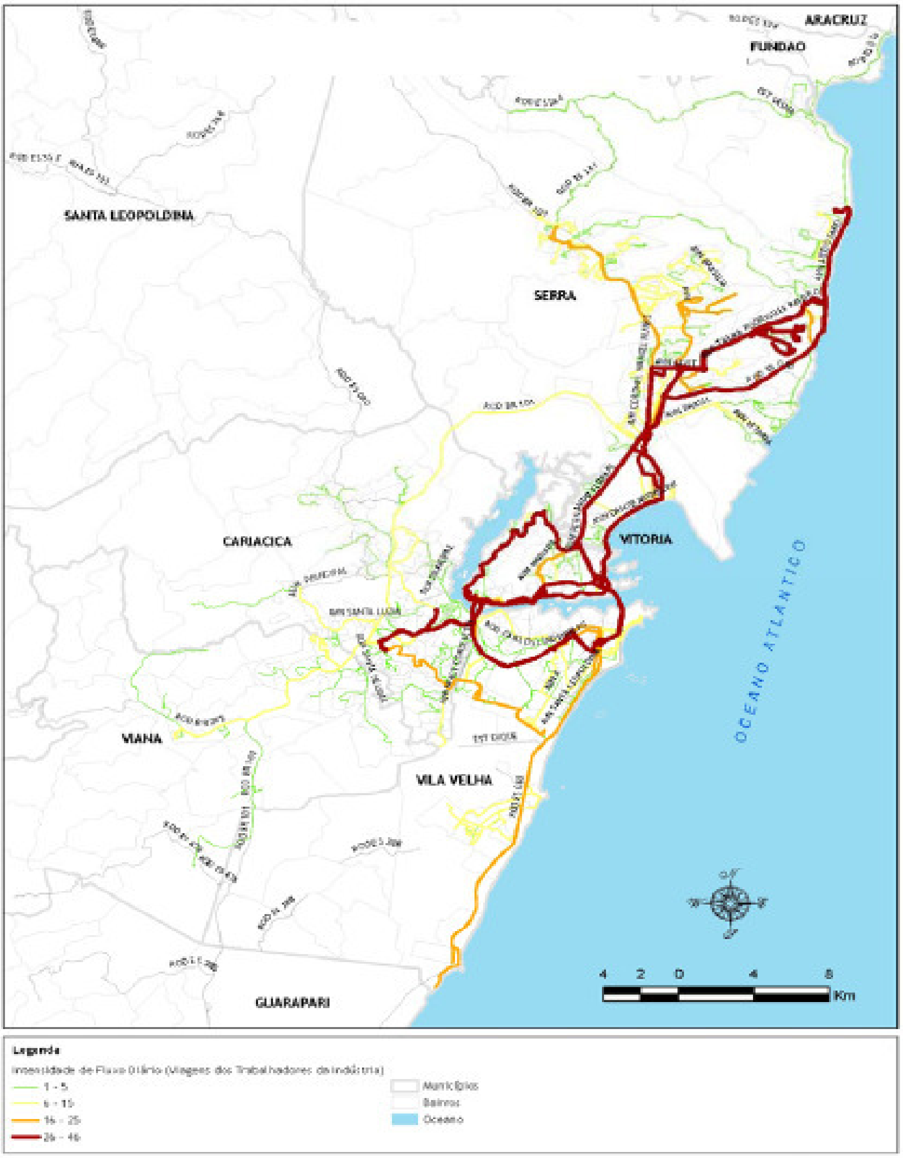

Figure 1 - Intensity daily flow of industrial workers' in the Vitoria region

The various aspects presented related to urban mobility of industrial workers' in MRV, demonstrates the importance of investments in the search for quality and efficiency of the transportations systems. Among these investments, we present the use of georeferenced technologies for building optimized routes that will bring benefits not only for managers and operators of the system through the economic prism, but also for its users, as it can for example, reduce travel times to round trips to work.

PROPOSED PROCEDURE

The proposed procedure is composed of five steps listed below:

1. The first step is to geographically delimit the region that will be used to apply the employee's pickup and delivery procedure.

2. The second step is performed to characterize the transportation demand for company's employees, through the selection of the user's sample that live and use the buses in the delimited region.

3. In the third step is to performe the data collection, data preparation and problem modeling using the TransCAD software routing module, according to the following steps: (i) the preparation of input data: create or obtain geographic files that show the routes and their directions, identify the locations of each base and stop points, data collect about demand and supply of the transport, among other characteristics. (ii) the creation of routing matrix: create a matrix file containing the distance or travel time between each stop.

4. In the fourth step, with the information collected in the previous steps, uses the TransCAD software to: (i) solve the problem of vehicle routing: develop efficient vehicles routes in accordance with the desired criteria; (ii) the presentation of results: generate reports and graphical visualization of the routing procedures results.

5. The fifth step is to, from the Base Scenario, define other alternative scenarios to be solved in order to analyze the results and choose the best solution.

PROCEDURE APPLICATION

Delineation of the study area

Vitoria is the capital of Espirito Santo State and is part of the MRV, along with the counties of Serra, Vila Velha, Cariacica, Viana, Fundão and Guarapari (PMV, 2011).

The county of Vitoria is organized into 83 neighborhoods and 8 administrative regional, among them the Region 8, formed by Jardim Camburi neighborhood. This region has a populational area of approximately 2.6 square kilometers and has an extensive road network with urban mobility characteristics typical of large urban centers. At peak times, there is an intense vehicles movement, causing traffic jams, such as in the Norte-Sul Avenue, one of the busiest routes for industrial displacement workers' between Serra county, location of the company object this case study, and the Vitoria county - Jardim Camburi neighbourhood, home to a significant number of employees of the same company as will be shown below.

Characterization of demand for employees transport

The object company of this article is one of 4 (four) large companies in the metropolitan region of Vitoria that provides chartered transportation to its employees. Along with the three other large companies, is offered chartered transportation for 10.880 employees, about 12% of all industrial workers (LUZ, 2010). The company selected to apply the procedure of pickup and delivering is responsible for transporting 4.037 employees, equivalent to 37% of this total.

The transportation of company's and some outsourced personal in their round trips to work is done by a charter bus company. This transport serves an average of 6.731 users per day, consisted by 60% of its own employees (4.037 users), and 40% of partner companies, (2.962 users). The chartered transport caters to employees in two schedules: Shift (6 a.m. to 6 p.m.; 6 p.m. to 6 a.m.; 2 p.m. to 10 p.m.) and Industrial (8:15 a.m. to 5:15 p.m.).

For this article will be considered only the company's employees who lives in the Jardim Camburi neighborhood and works in industrial schedule. Therefore the sample to be considered in the model consists of 314 employees, equivalent to:

1. 6.56% of the company's employees, which are 4.789;
2. 24.06% of all employees who lives in the Vitoria county, which are 1.305;
3. 15.79% of the employees working in industrial schedule, which are 1.989;
4. 39.5% of the total of employees that lives in the Vitoria county who work in industrial schedule, which are 795.

Data transport system for problem modeling

Location of the base

The base is the point of origin from where the buses depart to pick up the employees with company destination and deliver these same employees after workday ending.

The location of the base in this article varies according to the travel route. In the "home to work" route, the base can be any stopping point used as the starting point for employees' pickup operation with company's destination. The base can be single or multiple.

In the "work to home" route, the base is located in a geographical point within the company, called bus station. From there all buses depart for stopping points closer to employees' homes, according to previously established routes. Moreover, the bus station is the target location of every bus in the "home to work" route.

Location and employees' transport demand

The location and demand of employees who lives in the Region 8 - Jardim Camburi neighbourhood, and works in industrial schedule is known in advance through access to the studied company Human Resources database. This database has the address of each of the 314 employees selected for this study. Each employee is a unit to be serviced.

There were considered in the application of the model 58 pickup and delivery points. These stop points are the same used as urban public transportation stops in the region bounded by this study. The geographical location of these points, as well as the nomenclature used to encode them was obtained through access to the Vitoria's Departament of Transport, an initiative called Stop Point Program.

To fill the demand of the 58 boarding and landing points (stop points) of 314 employees, was used the stop point NODE_ID feature of the passenger layer, the one that has the exact location of each employees' home. This TransCAD feature was used to reduce as much as possible the route taken by the employee between his home and the stop point. On the subject company of this article, the maximum distance allowed between home and place of boarding and landing is up to 1 km.

Time of boarding and landing of employees

It was considered an average time of 9 (nine) seconds for each employee' boarding or landing. This time was determined through interview with the chartered transport company bus drivers. It is observed that the bus users, in this case, the employees, have usually no mobility problems and an age range between 18 and 55 years old.

For the fixed stoppage time, the one that is independent from the employees' demand was considered one minute per stop. This time includes the slowing and acceleration of the vehicle after the passengers' boarding and landing. This time was determined in the same way that the average time of boarding and landing of employees, by interviews with the chartered transport company bus drivers. Therefore, the total time of service for each passenger includes 1 minute per stop plus 9 seconds for boarding and landing, totaling 1 minute and 9 seconds per boarding or landing passenger.

Restrictions of schedules and travel times

In this article, the base opening hour is 7:00 a.m., due to the Jardim Camburi neighborhood closeness to the company. The base closing time is 8:00 a.m., since this is the standard time for the arrival of the buses in the company's bus station, where from that time on are provided the transshipments that will transport the employees to their respective sectors.

In the employees's trip from work to home, the opening time of the base is 05:20 p.m. This is the time when all the bus lines depart from the base (bus station) to stopping points close to employees' home. The closing time of the base was assumed to be at 06:20 p.m.

In relation to the employee's service hours, can be repeated the same conditions determined for the base, that is, in trip from home to work between 07:00 a.m. and 08:00 a.m. and in trip from work to home between 05:20 p.m. and 06:20 p.m.

In both cases, in round trips to work, the employees' travel time should not exceed 1 hour, which is the company's standard time in this case. This information was provided by the area responsible for the transportation system management of the company studied.

Vehicles

The total fleet responsible for the transportation of the studied company employees is composed of 77 buses, 5 of them reserves to attend any eventualities such as: delay, breakdown, maintenance or any other situation that requires a vehicle replacement. All 77 buses are of conventional type, with capacity for 43 to 45 seated passengers and an average age of 4.5 years.

In this article, it was considered a fleet of 7 (seven) vehicles with capacity for 45 seated passengers. This choice was made in order to attend 100% of the employees transportation demand in the Jardim Camburi neighbourhood that work in the industrial schedule.

The Table 5 summarizes the main data used for modeling and solving the vehicle routing problem applied in employees' chartered transport, in this case study.

Table 5 – Data transport system

Mode of operation	Base	Stop points + Base	Users	Vehicles	Time		
					Stop	Boarding/ Landing	Service Hours
Pickup	Single or Multiple	59	314	7	1 min.	9 s	07:00 a.m. to 08:00 a.m.
Delivery	Single	59	314	7	1 min.	9 s	05:20 p.m. to 06:20 p.m.

Roads

The georeferenced spatial data importation provided by the Jones Santos Neves Institute - IJSN (2008), was already in the extension recognized by the TransCAD software, the shape format. After importing these data into the TransCAD and the recognition of the map by the program, were created the following layers: counties, neighborhoods and streets, shown in Figure 2, containing the stop points and base(s) used.

After that was made a comparison between the roadway data base imported from IJSN and the geographic base available on the Vitoria city website, Google Earth and Google Maps. Some inconsistencies were found, such as, the absence of Miramar Avenue between Jardim Camburi and Fatima neighborhoods. To update, was used the TransCAD editing drawings tool (Map Editing).

The establishment of the transport network flow direction was based on Google Maps, on the chartered vehicles company' support, and on field research. This same procedure was done in the neighborhoods of Fatima, Carapina I, Helio Ferraz, Eurico Salles, Manuel Plaza and São Geraldo, due to their location being on the path between the researched company and the Jardim Camburi neighborhood. For this, was used the TransCAD Link Direction tool.

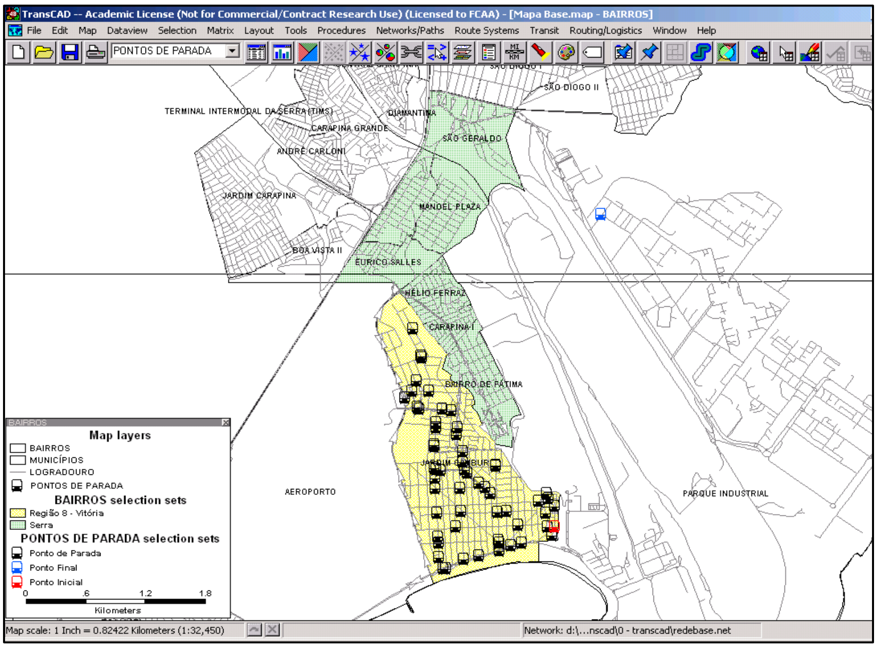

Figure 2 – Roads and stop points

Vehicle routing problem solving using the TransCAD software

In the stage of solving the vehicle routing problem it was used the TransCAD routing routine to create optimized routes for fleet vehicles. In this routine were employed the time windows to meet base and employees demand. Moreover, were introduced the restrictions of route time, stoppage buses time and time per employees' boarded and landed. That way, the generated routes will ensure that the buses stop will only happen during the available time window and that the generated itineraries include information about the buses stop time.

Among the four operation modes found in the routing routine with time windows by TransCAD, only two were used in the problem solving: pickup mode for boarding operations and delivery mode for landing operations. Were generated 7 (seven) routes, as shown in Figure 3, where was added a penalty in order to prevent the vehicle from returning on reverse gear.

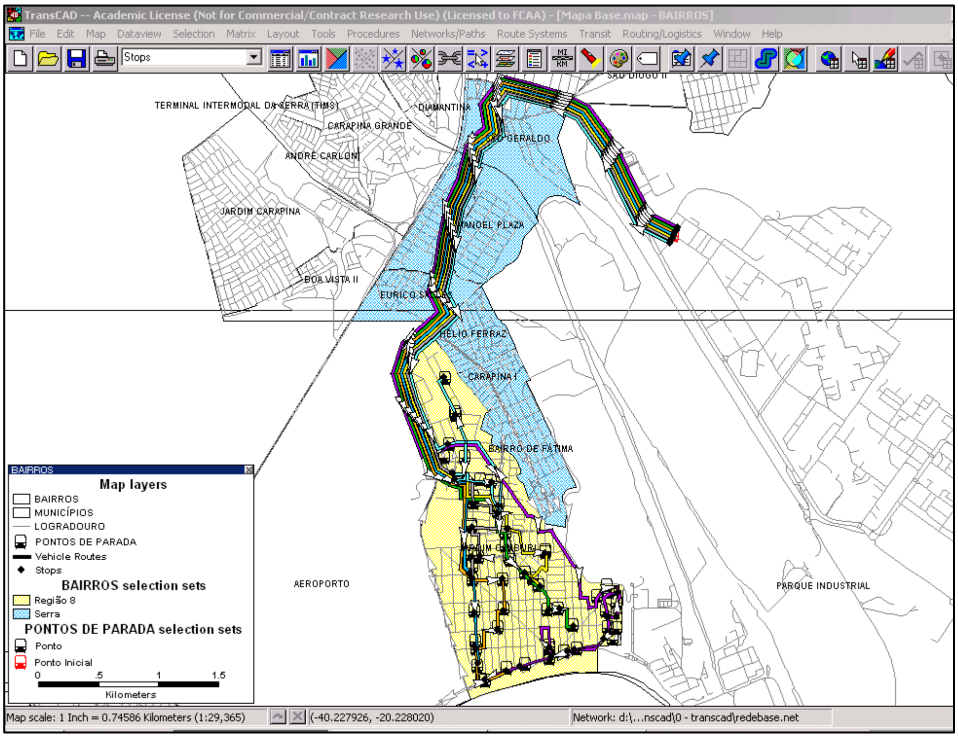

Figure 3 – Route map of the employee's delivery operation

Testing of scenarios

The Base Scenario presented until here, attempted to reproduce a similar situation to the current pattern of employees's pickup and delivery in their round trips to work, except for the fact that it attend the full demand of employees that lives in the bounded region, the Jardim Camburi neighborhood. On the other hand the other three scenarios presented below, seek to introduce constraints in order to identify the scenario that provides the best results in terms of distances and travel times:

1. Scenario 1: introduces the mandatory return of vehicles to the base for operating of employees's pickup and delivery, keeping the same parameters of time and vehicles capacity used in the Base Scenario;

2. Scenario 2: introduces the use of multiple bases for operating employees's pickup, without returning the vehicle to the base. It also keeps all the parameters of time and vehicles capacity used in the Base Scenario;

3. Scenario 3: introduces the use of multiple bases for operating of employees's pickup, with the vehicle's return to the base. It also keeps all the parameters of time and vehicles capacity used in the Base Scenario.

The main parameters and characteristics of each scenario are shown in Table 6, as well as their respective results are shown in Table 7.

Table 6 – Characteristics of the test scenarios

Scenario	Mode of operation	Base	Number of employees	Vehicles			Window service		Time restrictions		
				Type	Quantity	Capacity	Base	Employees	Route	Stop	Boarding/ Landing
Base	Pickup	Single without return	314	1	7	45	07:00 a.m. to 08:00 a.m.	07:00 a.m. to 08:00 a.m.	1 hour	1 minute	9 second
	Delivery	Single without return	314	1	7	45	05:20 p.m. to 06:20 p.m.	05:20 p.m. to 06:20 p.m.	1 hour	1 minute	9 second
1	Pickup	Single with return	314	1	7	45	07:00 a.m. to 08:00 a.m.	07:00 a.m. to 08:00 a.m.	1 hour	1 minute	9 second
	Delivery	Single with return	314	1	7	45	05:20 p.m. to 06:20 p.m.	05:20 p.m. to 06:20 p.m.	1 hour	1 minute	9 second
2	Pickup	Multiple without return	314	1	7	45	07:00 a.m. to 08:00 a.m.	07:00 a.m. to 08:00 a.m.	1 hour	1 minute	9 second
3	Pickup	Multiple with return	314	1	7	45	07:00 a.m. to 08:00 a.m.	07:00 a.m. to 08:00 a.m.	1 hour	1 minute	9 second

Table 7 – Results of the testing scenarios

Scenario	Mode of operation	Distance (km)		Time (hour)			Vehicles			Number of employees
		Route	Total	Travel	Service	Total	Type	Quantity	% Utilization	
Base	Pickup	8.98	62.9	1h03min.	1h31min.	2h34min.	1	7	99.7	314
	Delivery	8.6	60.2	1h00min.	1h31min.	2h31min.	1	7	99.7	314
1	Pickup	17.92	125.4	2h05min.	1h31min.	3h26min.	1	7	99.7	314
	Delivery	15.88	111.2	1h51min.	1h31min.	3h22min.	1	7	99.7	314
2	Pickup	8.25	57.8	0h58min.	1h31min.	2h29min.	1	7	99.7	314
3	Pickup	16.54	115.8	1h56min.	1h31min.	3h27min.	1	7	99.7	314

Comparison analysis between scenarios tested

Based on the testing scenarios presented above, comparative analysis will be made between them based on the results shown in Table 8.

Comparing Scenario 1, where the return of the base vehicle is required, with the Base Scenario, where there is no such obligation, we observe the increase of distances and total travel times for Scenario 1 compared to the Base Scenario in both modes of operation, pickup and delivery. These increases are explained due to the vehicles higher traveled distance to return to their base.

When analyzing the reason for the increase in the total travel times on the Scenario 1, higher than Scenario Base, was observed that it is a result of increased travel time of vehicles for mandatory return to their base. The service time remains unchanged, since there is no stop of vehicles when it return for base, due to the pickup operation of employees (trip for job) been completed.

In the comparison between Scenario 2, which introduces the use of multiple bases in the pickup operation of employees (without vehicles return to the base), and Base Scenario, that uses a single base to this same operation, it is shown that there is a decrement of distances and travel times for Scenario 2 in relation to the Base Scenario. The explanation for the decrement of the variables mentioned is the geographic distribution of vehicles, which reduce the distances from the starting stop points, which will start the pickup operation of employees in their trip for job.

In the comparison between Scenario 2 and Scenario 3, whose difference is the obligation of return vehicles to their respective bases in Scenario 3, it was found proportional increment in distances and travel times.

Regarding service time, considering the stop buses time and the time of boarding and landing of the employee, there was no difference among the scenarios tested. The explanation lies in the allocation of fixed times for each stop of buses (1 min.) and for each boarding or landing of employee (9 second), along with fixed employees demand (314).

There was no testing of different vehicles types or capacities to attend the demand of employees in the region bounded by the study. Therefore, there was no difference in the rate of vehicles utilization, which was 99.7% for all scenarios tested.

Considering the comparative analysis between scenarios and their modes of operation (pickup and delivery), the results indicate that the best alternative for the employees's transportation in their round trips to work is the combination of Scenario 2 for the pickup' operation, one that adopts multiple bases without returning the vehicle, with the Base Scenario for delivery' operation, one that adopts only one base, without the vehicle's return. This is borne out by the smaller distances and smaller travel times used in these operations.

From the operational point of view, the adoption of Scenario 2 implies that after the employees's pickup operation, the vehicles used should stay in an area geographically located within the boundaries of the company or close to it. Thus, the vehicles are already positioned geographically close to the starting point for employee's delivery operation, characterized as the Base Scenario, contributing for reducing vehicle operating costs with their displacement.

Likewise, the adoption of the Base Scenario implies that after the employees's delivery operation, the vehicles used should remain as close as possible to the initial points from which they will start the employees's pickup operation, characterized as Scenario 2, again contributing for reducing vehicle operating costs with their displacement.

Note that the adoption of the single base for employees's delivery operation is the only viable alternative, since employees are concentrated in a single geographical location, in this case, the company object of this study.

Table 8 – Comparative analysis of scenarios

Scenario	Mode of operation	Distance (km)		Time (hour)		
		Route	Total	Travel	Service	Total
Base	Pickup	8.9	62.9	1h03min.	1h31min.	2h34min.
1		17.9	125.4	2h05min.	1h3 min.	3h36min.
Diference		8.9	62.5	1h02min.	0h00min.	1h02min.
Base	Delivery	8.6	60.2	1h00min.	1h31min.	2h31min.
1		15.8	111.2	1h51min.	1h31min.	3h22min.
Diference		7.2	51.0	0h51min.	0h00min.	0h51min.
Base	Pickup	8.9	62.9	1h03min.	1h3 min.	2h34min.
2		8.2	57.8	0h58min.	1h31min.	2h29min.
Diference		0.7	5.1	0h05min.	0h00 min.	0h05min.
2	Pickup	8.26	57.8	0h58min.	1h31min.	2h29min.
3		16.5	115.8	1h56min.	1h31min.	3h27min.
Diference		8.28	58.0	0h58min.	0h00min.	0h58min.

CONCLUSIONS AND RECOMMENDATIONS

This article aimed to develop an employee’s pickup and delivery procedure for their round trips to work in chartered buses, modeled as a Pickup and Delivery problem using a GIS-T tool.

Among the various scenarios tested in the application of the proposed procedure, the scenario that is more efficient in terms of distance and travel times is the one that adopts multiple bases without vehicle return for employees's pickup operation (Scenario 2) and single base without vehicle return for employees's delivery operation (Base Scenario).

The procedure has reached 100% of employees's demand (314) in the region bounded by the study (Jardim Camburi Neighborhood) using a homogeneous fleet of vehicles (capacity for 45 seated passengers). This fact resulted in the generation of 7 (seven) routes with a 99.7% vehicles's utilization rate.

The travel times of the various scenarios tested showed results that not exceeded the pattern adopted by the company, which is a maximum of 1 hour. However, this problem may present itself in places geographically further from the case company, like on other MRV municipalities, for example, Cariacica and Vila Velha, which reinforces the importance of a computerized procedure to support the routes building.

The geographical location of the permanent area of the fleet, after the transport of employees in pickup and delivery operations is a factor that contributes to the reduction of vehicle operating costs, as it reduces the distances to the trip's start points.

Despite this article emphasis on the quantitative aspects that comes from routing model application, one should not ignore the qualitative aspects obtained by using a GIS-T in the transportation systems planning and operation, such as: spatial visualization of various attributes (demand location, routes and stopping points) and parameters changing flexibility (vehicles, time constraints, etc.) that enable the realization of new simulations.

Based on the same objectives that guided the execution of this article it’s possible to apply this procedure to other logistics physical distribution of people, such as urban and interstate public transport.

A more accurate routing procedure than the one proposed in this article can be obtained by including average speed and traffic light timing in the transportation network used to create the distance matrix. The difficulty lies in collecting this data and modeling the network aiming their inclusion.

As future work, it’s possible to expand the procedure proposed to cover a larger geographic area in MRV, which can result in a larger sample of workers in their commuting. Thus, the procedure could be more robust and have better results in terms of potential optimizations. However, the lack of georeferenced data containing the flow directions of pathways are a major challenge to be overcome, as it requires much effort and time to achieve.

REFERENCES

Alvim, B. G. (1995). Statistical analysis of socioeconomic and mobility factors which acts over the demand for charter bus services in the State of São Paulo. Thesis (PhD). University of São Paulo, São Paulo.

Brejon, S. R. C. and Belfiore, P. P. (2006). The importance of systemic approach to vehicle routing problems. Production Engineering Development and Research Magazine, São Paulo, n.5, p. 64 – 86.

Bodin, L. D.; Golden, B. L.; Assad, A. A.; Ball, M. O. (1983). Routing and scheduling of vehicles and crews: The State of the Art. Computers & Operations Research, v.10, n.2, p. 63-211.

CALIPER (2005). Routing and logistics with TransCAD 4.8, Transportation GIS software. USA, 2011.

Câmara, G; Casanova, M. A.; Hemerly, A. S.; Magalhães, G. C.; Medeiros, C. M. B. (1996). Geographic information systems anatomy. National Institute for Space Research – Image Processing Division, São José dos Campos, São Paulo.

Ferrari, R. (1997). Journey to GIS. Sagres publishing house, Curitiba.

FINDES. Federation of Industries of the State of Espirito Santo. Available in: <www.sistemafindes.org.br>. Access in: jan, 2011.

Golden, B.; Ball, M.; Bodin, L. (1981). Current and future research directions in network optimization. Computers and Operations Research, v.8, n.2, p. 71-81, 1981.

IEL (2009). Report of urban mobility for industry worker of the Vitoria Region. Euvaldo Lodi Institute, Vitoria, Espirito Santo.

IJSN (2008). Jones dos Santos Neves Institute. Available in: <www.ijsn.es.gov.br>. Access in: nov, 2010.

IPEA (2002). Applied Research Economical Institute. Available in: <www.ipea.gov.br>. Access in: jan, 2011.

Laporte, G.; Gendreau, M.; Potvin, J; Semet, F. (2000). Classical and modern heuristics for the vehicle routing problem. International Transactions in Operational Research, v. 7, n4/5, p. 285-300.

Lerner, J. (2009). Comparative evaluation of public transportation urban models. Curitiba, Paraná.

Lima, A. (2001). Passengers transport by chartered bus and passenger station. Magazine of Public Transportation, 24 year, n. 93, p. 27-32, 4th trimester.

Loureiro, C. F. G and Ralston, B. A. (1996). GIS as a platform for analysis of models network transportation. XI Congress of Research and Education in Transportation, ANPET, Rio de Janeiro, v.1, p. 138-146.

Luz, M. (2010). Urban mobility: alternatives to avoid chaos in traffic. Magazine Capixaba Industry. Vitoria: FINDES, nº 29, p. 12 -16, sep. - oct. 2010.

Mapa, S. M. S. and Lima, R. S. (2005). Geographic Information Systems (GIS) as a tool to support location and routing studies. In: XII SIMPEP, Bauru, São Paulo.

PMV (2011). Vitoria City Hall. Available in: <www.vitoria.es.gov.br>. Access in: jan 10th, 2011.

Santos, J. M. and Pinto, R. R. S. (2003). Charting: an attractive alternative to combat individual transport. XIV Brazilian Congress on Transportation and Traffic. CD-ROM.

Silva, A. N. R. (1998). Geographic information systems for transportation planning. Thesis, Department of Transportation, University of São Paulo, São Carlos.

Verlangieri, M. V. (1999). Distribution, a constant challenge. Available in: <www.guiadelogistica.com.br>. Articles and Cases. Access in: jan 22th, 2011.

Viviane, E.; Sória, M. H. A; Silva, A. N. R. (1994). Unpaved roads management and the use of geographic information systems. I Brazilian Congress of Technical Multipurpose Cadaster, Florianópolis, p. 118-126.

Vuchic, V. R. (2007). Urban Public Transportation: Systems and Technology. Prentice Hall, NJ, USA.