International Journal of Latest Engineering Research and Applications (IJLERA) ISSN: 2455-7137

Volume – 09, Issue – 02, February 2024, PP – 44-54

A New Vehicle Routing Problem: When Duration Constraints and Strategic Support Deposit Coexist

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Abstract: This article presents a new variant for the vehicle routing problem, called vehicle routing problem with duration constraints and support deposit (SD-DCVRP), identified from the route studies of a shipping company located in the Brazilian city of Belo Horizonte. This variant can be described as a VRP with two deposits, one with greater importance, from which all deliveries depart, but which has the characteristic of being peripheral, and a second deposit that has a centralized location in relation to other cities and that acts as support to the first. The goal of SD-DCVRP is to minimize total journey time and reduce the number of vehicles used. In this study, variations of existing mathematical models were proposed to solve the problem, considering that, for the situation studied, there are a small number of vertices. The data used for the tests were generated by a Monte Carlo simulation obtained from real data provided by the shipping company. The results obtained and the propositions conceived were considered to be relevant to both the scientific and the technical aspect.
Keywords: Transportation, VRP, centralized backing deposit, Monte Carlo's simulation.

I. INTRODUCTION

Brazil is a continental country with a huge commercial flow between its regions, but it lacks well implemented varied logistics modals. Therefore, there is a significant exploration of its road network in the country. Keeping this in mind, it's understood that logistics planning goes beyond its importance in serving institutions and their customers, being that it also serves as a differential factor in the market, which in turn makes decisions related to this area as strategic issues.

Currently, outsourcing logistics services has proven to be more prominent, by moving hundreds of billions of dollars and achieving a 43% growth in the Latin American market between 2010 and 2012 [1].

The National Transportation Confederation presented, in its 2017 road transport study, IBGE (Brazilian Institute of Geographic Search) data pointing to the road modal as "responsible for 55.2% of the GDP of the transport sector in 2014" and "for 12.7% of the GDP of the non-financial services sector", being predominant for the volume of income generated in the country that year [2].

Given such circumstances, logistics operators need to make sure that there is an operationalization capacity to maintain the competitiveness of the organization operating in this scenario. A mechanism for operationalization aid involves the mechanisms for routing vehicles from a given fleet to optimize the business resources made available in transport.

Cordeau et al. [3] reports the fact that vehicle routing is a complex study, which becomes more difficult in bringing the specificities of each routing situation and the volume of vertices analysed, proposing that the entire programming is limited to low values of the number of movements, in general, not exceeding 50 vertices, and that there is a significant evolution, since the 1960s, of heuristic models for the resolution of various VRP models. To understand the entire evolution of VRP in 50 years, the reading of Laporte is suggested [4].

Therefore, it is understood that, to understand the specificities of each company in the field, such tools need to be adapted to effectively achieve the strategic objectives of these organizations, considering all their particularities.

In this sense, the initial objective of this research sought to adapt mathematical models of VRP and apply entire programming to solve specific vehicle routing problems of a transportation and logistics company, considering that the problem identified for this company was not found in the literature. It was considered the basis of information of the company studied, but simulated scenarios were proposed randomly through the Monte Carlo simulation model.

II. LITERATURE REVIEW

The management of transportation routes are a decisive factor, regardless of whether logistics service is proper or outsourced, since the decisive factor falls on the ability to serve the customer, and in this sense, the appropriate routing is a factor for the right management of the supply chain. It is precisely this factor that can guarantee greater or lesser organizational competitiveness.

The vehicle routing problem (VRP) was proposed by Dantzig & Ramser in 1959, who presented an article with the first mathematical modelingin order to solve an appropriate way to distribute fuel and since then, the most diverse studies on VRP have been emerging and multiplying [5].

In this initial VRP model, there is a unique distribution center in which if you know the demands and if these demands, at first, cannot be decomposed and are routed by vehicles which always employ the same conditions of execution of labor, this being the only restrictive factor of the model. In this model, which can also be called capable vehicle routing problem (CVRP), the different limitations of the vehicles are considered, and it is expected that you can visit all the vertices only once, leaving and arriving from the same distribution center [6] [7].

However, due to the existence of other routing problems that do not systematically comply with the conditions described above, variations have been proposed over the years for these models.

One such variations is the Mixed Capacitated General Routing Problem with Time Windows (VRPTW) which, "consists in determining routes for the delivery of central warehouse products to consumers, respecting capacity constraints and time windows” [8]. The so-called time window is an exact period of time when the delivery man must arrive, remain and finalize the delivery for a given consumer[9].

Ciancio et al. [10] presents a variation of this variant of VRP, showing a specific study on the Mixed Capacity Routing Problem with Time Windows (MCGRPTW) that is a mixed graph, with uniquely positive vertices and edges in which the set of routes should be raised while respecting the time windows and vehicle capabilities to reduce costs.

Another variation is related to collection and delivery (VRPB). In general, it consists of serving consumers at the same time with material collections and deliveries without, at any point of the route, not exceeding the maximum limit of vehicle capacity [9].

In this variant there are also derivations. There are, for instance, studies on Vehicle Routing Problem with Simultaneous Pickup and Delivery (VRPSPD), where each node is associated with a pickup demand and another delivery demand and the transportation of products is carried out from the warehouse to the consumers and from the consumers to the warehouse, and also the so-called Vehicle Routing Problem with Pickup and Delivery (VRPPD), in which it follows the same parameters as the previous one, but that cargo transportation occurs from consumer to consumer [8].

It can be statedthat the problem of routing vehicles with duration restrictions - PRVLD, is a minimum variation in relation to the original problem, in which the total time of each route cannot exceed the value of a constant data, such as by completing the entire route within a specified time limit of work.

In addition to these aspects which were most commonly studied, other research reports other variations, such as the problem of routing asymmetric vehicles with limited heterogeneous fleet (AVRPHLF) [5], vehicle routing problem with cross-docking (VRPCD) [11], A mixed load capacitated rural school bus routing problem with heterogeneous fleet [12], cumulative vehicle routing problem (Cu-VRP) [13], rollon-rolloff vehicle routing problem (RRVRP) and two-echelon time-constrained vehicle routing problem (2E-RLP) [14], cumulative routing vehicle problems with limited duration (CumVRP-LD) [15], Vehicle routing with probabilistic capacity constraints.(CVPSD) [16], Line-haul Feeder Vehicle Routing Problem (LFVRP) [17], clustered vehicle-routing problem (CluVRP) [18], multi-trip vehicle routing problem with time windows and limited duration (MTVRPTW-LD) [19], among others.

The diverse studies mentioned above, however, do not exhaust all possibilities of searching for innovative mathematical solutions to the most varied transport problems. To comprehend all the evolution and various aspects studied over the years and understand their classification methods, the literature of Laporte [4] and Desrocheset al. [20] is suggested.

In this sense, this work aims to contribute to this vast literature, presenting a possible solution for a new variant: the routing of vehicles with duration restriction and support deposit.

III. IDENTIFICATION OF VRP VARIATION

For the application of the practical study, we sought the functionality of the processes of the Correia Martins Shipping company. Correia Martins is located in the city of Belo Horizonte (MG - Brazil) and has its storage and distribution center located in the ring road, presenting easy access to the main federal roads that pass through the capital of Minas Gerais state. It also has a support deposit located in the city of João Monlevade, which is about 100 km from Belo Horizonte and strategically located at the median point of the main route managed by the organization.

For this purpose, data collection was conducted for six months of work, between the dates of November 1, 2017 and April 30, 2018, with general information obtained from the database of the programs employed by the company for billing management and delivery control.

The company does pickups and deliveries of fractional cargoes, mainly in the state of Minas Gerais, serving more than 50 cities in the vicinity of Belo Horizonte, but has as its main route as the east route, which connects the metropolitan region of Belo Horizonte to the Metropolitan Region of Steel Valley.

The cities on this studied route spread for about 250 km from Belo Horizonte in the vicinity of the BR 262, BR 381 and BR 120 highways, with, however, a series of other roads with intermediate connections between the cities of this distribution axis. As a method to facilitate the comprehension of the network of paths that connect the cities of the East route, a general graph of the route is presented in Figure 1.

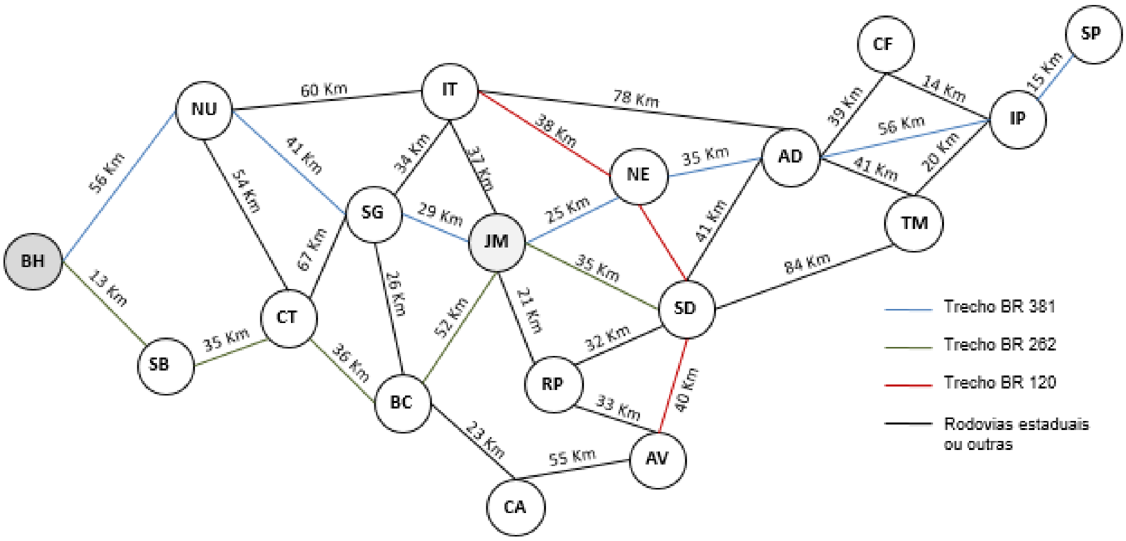

Fig. 1 - General graph of the route studied

As we can see from Figure 1, there is an emphasis on the city of Belo Horizonte, represented by the acronym BH, where the main deposit is located. The city is peripheral in relation to the total group of cities that make up the graph and is relatively distant from some cities of this axis. It is also possible to perceive another emphasis for a second city, João Monlevade (JM), where the support deposit is located and where its more centralized in relation to the other cities of this axis, which in turn favors the distribution from this point. However, for commercial reasons, all deliveries must depart from the main deposit.

Considering then, the general aspects of the studied Shipping Company, it is possible to determine the following points:

- The Shipping Company supply's, on the East route and for the period studied, to 17 cities with deliveries departing from a set of cities in the metropolitan region of Belo Horizonte;
- There are two distinct deposits: one main deposit in Belo Horizonte from which all deliveries depart, and another support deposit in João Monlevade (100 km from the first) to divide and redistribute any cargoes;
- When the volume of loads is large and requires such time that a vehicle departing from the main tank could not carry out the entire route, then this vehicle departs directly to the support tank, where the cargo is divided among other vehicles and from there are distributed to the other cities;
- The type of loading is called fractional load, not reaching the possible load limit of vehicles used for movement and also implying that the heterogeneity of vehicles does not interfere in the process;
- On the East route, in general, there is no simultaneous collection in relation to deliveries, and the collections usually made by another vehicle and in different periods of the day in relation to deliveries;
- There is no time limitation spent on each client, but there is time limitation for the route assembly;
- The routes used in delivery are, in all situations, two-way, so that the arches are regarded as a non-oriented feature. However, distance and time can be different between two locations in different directions.

Based on the information previously described, it is assumed that the variant that is closest to the problem studied is the problem of time-constrained vehicle routing problem (VRPDC) or similar, studied by several researchers [21], [22], [23] and [24] since all deliveries demanded must be made within a predetermined period.

On the other hand, it is known that more than one deposit exists, and there are specific studies for multiple deposits (MDVRP) (see: [25], [26], [27], [28], [29] and [30]).

However, it should be noted that the characteristics of the deposits are distinct both in terms of size and, mainly, in terms of utility and importance, so that necessarily all loads come out of warehouse 1, while warehouse 2 is kept available so that a second vehicle departs from there, reducing the distance traveled by this second vehicle and the time consumed for delivery, and therefore differing from the common form of the Vehicle Routing Problem with Multiples Deposits (MDVRP).

Considering the two basic characteristics mentioned above, the closest study is proposed by Crevier et al. [31] which considers within the problem of routing vehicles with multiple deposits the possibility of movement between deposits (The multi-depot vehicle routing problem with inter-depot routes- MDVRPI). However, the condition of moving between deposits is set so that a vehicle starts the route in each warehouse and ends in another, differing from the model proposed here.

Taking such conditions as a basis and having not found a specific variant for the indicated condition, a specific classification is proposed for this particular model of problem: Vehicles Routing Problem with Support Deposit and Duration Constraints (SD-DCVRP). The acronym was thus formulated so that it does not be confused with Vehicle Routing Problem with Stochastic Demand and Duration Constraints (VRPSD-DC) nominated in the studies by Erera et al. [32].

IV. STRUCTURAL ANALYSIS OF SD-DCVRP

The SD-DCVRP is the proposition of a new variant for the routing problem and, considering the particularities arising from the characteristics of the logistics processes of the company studied, the following properties should be considered:

- Have two deposits, being the first the most important, from which all the deliveries are departed (since the delivered products are collected in the city in which this deposit is located), and the second only with a supporting basis, from which the other vehicles depart;
- By logical condition of maintaining a support distribution center, it is understood that the main deposit is peripheral, having long distances in relation to certain customers, while the support deposit has a centralized location;
- Variations in fleet size and load capacity are not relevant factors for the problem, since, by delivering fractional loads, the volume is never exceeded;
- The time consumed for all deliveries cannot be exceeded considering a daily working limit of vehicles. In addition, a pre-stipulated time for deliveries in more than one establishment in the same city should be added.
- Whenever a vehicle that has departed from warehouse 1 and has to carry out a transfer to warehouse 2, the additional time pre-stipulated for that route should also be increased.

For the presented problem, this specific classification was determined. The determination for a new variant of the vehicle routing problem was considered, considering that the working condition exercised by the studied company did not fit any model presented in the most diverse studies on the subject, having peculiarities that required the proposition of this new variant.

V. ADAPTED MATHEMATIC MODELS

The computational complexity associated with the resolution of models with logistical characteristics requires that adjustments and simplifications be adopted. In this study, the existence of two deposits significantly impacted in the complexity of the resolution. The solution to this problem could be the dismemberment of the general graph into two or more subgraphs, each of which would represent only one distribution center.

However, because it is not a typical MDVRP, a small adaptation of the model needs to be performed in dismemberment. For greater understanding, it should be understood that, in the problem studied, two customer service situations may occur: the first situation is one in which the number of customers (vertices) is small, so that a single distribution centre would be sufficient, configuring it as a common problem of VRP with duration restriction. For this situation, the conventional model can be adopted.

The second hypothesis refers to routes that require a longer time than that available to be fulfilled, or that have a large number of cities (vertices) to be covered, situations in which the use of the two distribution centers would be necessary (main and support). In this case, the cities between the two deposits are divided and the model described in the sequence can be applied to the main deposit and the third model can be applied to the support deposit:

$$Min\, Z \sum_{i=0}^{n} \sum_{j=0}^{n} \mu_{ij} .\ x_{ij} \qquad (1)$$

s.t.:

$$x_{01} = 1, \qquad (2)$$

$$\sum_{i=0}^{n} x_{i0} = 1, \qquad \forall i \in \text{H} \qquad (3)$$

$$\sum_{j=0}^{n} x_{ij} = 1, \qquad \forall i = 1, \dots, n \qquad (4)$$

$$\sum_{i=0}^{n} x_{ij} = 1, \qquad \forall j = 1, \dots, n \qquad (5)$$

$$\sum_{i \epsilon S} \sum_{j \epsilon S} x_{ij} \le |S| - r(S), \qquad \forall S \subset H\ \{0\}, |S| \ge 2 \qquad (6)$$

$$\sum x_{ij} \left(\mu_{ij} + e_j . b_j\right) \le D \qquad (7)$$

$$x_{ijk} \in \{0.1\} \qquad (8)$$

Equation (1) presents the objective function focused on minimizing routing time. The expression pointed out in (2) that was altered in order to force the first displacement to occur between the distribution center and the first city of the graph, which, in the general context, is the support deposit. With this condition, situations that need the use of two deposits will use the first rout and will always happen between the main deposit and the support deposit; Expression (3) is the restriction used to ensure that the route always ends in the distribution center; Equations (4) and (5) defines the existence of a single route that starts at the depoist, traverses all vertices and returns to the ware house; Expression (6) focuses on the elimination of sub-routes, that is, it prevents the occurrences of routes that start and/or end in one of the vertices other than the deposit. Only inserted restriction that differ in relation to the conventional VRP model, expression (7), limits the total time of the route, already considering the time of overflow required for the client. Finally, expression (8) is the decision variable x_{ijk} - {0, 1}

The complement of the solution is due to the application according to the adapted model:

$$Min\, Z \sum_{i=0}^{n} \sum_{j=0}^{n} \sum_{k=1}^{k} \mu_{ij} .\ x_{ijk} \qquad (9)$$

s.t.:

$$\sum_{j=1}^{n} x_{0jk} = 1, \qquad \forall k \in \text{K}$$

$$\sum_{i=0}^{n} x_{i0k} = 1, \qquad \forall k \in \text{K}$$

$$\sum_{j=0}^{n} x_{ij} = 1, \qquad \forall i = 1, \dots, n$$

$$\sum_{i=0}^{n} x_{ij} = 1, \qquad \forall j = 1, \dots, n$$

$$\sum_{k=2}^{K} \sum_{j=1}^{n} x_{0jk} = k, \qquad \forall j \in \text{C} \qquad (10)$$

$$\sum x_{ij} \left(\mu_{ij} + e_j . b_j\right) \le D$$

$$\sum_{i \epsilon S} \sum_{j \epsilon S} x_{ij} \leq |S| - r(S), \qquad \forall S \subset H \ \{0\}, |S| \geq 2$$

$x_{ijk} \in \{0.1\}$

In this second set of equations, all symbols are equivalent to the ones of the previous model. The objective function, expressed in (8), has, like the rest of the model, an increase of the variable k representing the possibility of using more than one vehicle from this warehouse. Equation (9) points out that the number of routes departing from this warehouse is equal to the number of vehicles used, in which each vehicle is responsible for a route. The other restrictions resemble those presented in the previous model.

VI. COMPUTATIONAL RESULTS

It was considered that the use of the entire linear programming would be sufficient, since, for all situations, it was a graph with a relatively low number of vertices. For this purpose, the use of Solver was defined through the MS Excel software, with presumption of linearity and employing the simplex method for the resolution of the model.

By applying each of the scenarios to an entire linear programming model, the appropriate routing for each scenario was obtained. In each situation, initially, the number of vertices would determine whether or not there would be the need for the use of the support deposit. The maximum number of vertices established for the use of a single deposit was five, considering the vertex of the deposit itself. Every time this figure was exceeded, it would require the inclusion of the support deposit to exit on a second, or third or more routes. If the number of vertices allowed the use of a single deposit, but the total time of the route exceeds the limit established, then the dismemberment of the route would be suggested. Such a condition would determine the number of vehicles used.

The maximum time for the resolution of each scenario was set in 300 seconds, as well as the maximum number of iterations, set to 300 iterations. In no situation were such values reached. The results obtained for the first scenario group are presented in Table 1.

Table 1 - Set of results obtained from simulated scenarios

Scenario	**Vertices**	**Vehicles**	**Routes by vehicle (k)** *****Each acronym represents a city of the general graph	**journey time per vehicle (min)**	**Overflow Time (min)**	**Optimal end time (min)**
1	7	2	k1 : BH → JM → NE → IT → SG → BH	375	455	732
			k2 : JM → AD → IP → JM	237	277	
2	4	1	k1 : BH → AV → NE → IT → BH	418	478	478
3	4	1	k1 : BH → IP → IT → SB → BH	491	551	551
4	6	2	k1 : BH → JM → SD → AD → IT → BH	447	527	768
			k2 : JM → IP → JM	221	241	
5	3	1	k1 : BH → IT → JM → BH	310	350	350
6	5	1	k1 : BH → JM → AV → SD → IT → BH	463	543	543
7	4	1	k1 : BH → JM → IP → IT → BH	491	551	551
8	4	1	k1 : BH → AD → IP → TM → BH	483	543	543
9	5	1	k1 : BH → JM → RP → AD → IT → BH	436	516	516
10	5	1	k1 : BH → BC → JM → AD → IT → BH	470	550	550
11	9	2	k1 : BH → JM → RP → SD → IT → BH	390	470	480
			k2 : JM → NE → AD → IP → TM → JM	258	338	
12	10	3	k1 : BH → JM → SG → BC → NU → BH	349	429	513

			k2 : JM → IT → NE → SD → JM	291	371	
			k3 : JM → AD → CF → JM	222	262	
13	9	2	k1 : BH → JM → AV → IT → BC → BH	485	565	565
			k2 : JM → NE → AD → IP → CF → JM	253	333	
14	9	2	k1 : BH → JM → SG → BC → NU → BH	349	429	508
			k2 : JM → IT → NE → AD → TM → JM	286	366	
15	7	2	k1 : BH → JM → AV → NE → IT → BH	434	514	514
			k2 : JM → AD → IP → JM	237	277	
16	7	2	k1 : BH → JM → NE → IT → SG → BH	375	455	455
			k2 : JM → AD → IP → JM	237	277	
17	8	2	k1 : BH → JM → SD → SG → BC → BH	396	476	511
			k2 : JM → IT → IP → AD → JM	289	369	
18	9	2	k1 : BH → JM → SD → SG → CT → BH	379	459	519
			k2 : JM → IT → IP → AD → NE → JM	297	377	
19	8	2	k1 : BH → JM → SD → BC → SG → BH	345	425	513
			k2 : JM → IT → AD → AV → JM	291	371	
20	8	2	k1 : BH → JM → IT → SG → CT → BH	368	448	514
			k2 : JM → NE → AD → SP → JM	292	372	

In most scenarios presented in Table 1, as expected, there was a need to use both deposits, specifically in 11 scenarios. Thus, the default is two routes per scenario, as shown in Figure 2. However, there are eight scenarios with a single route.

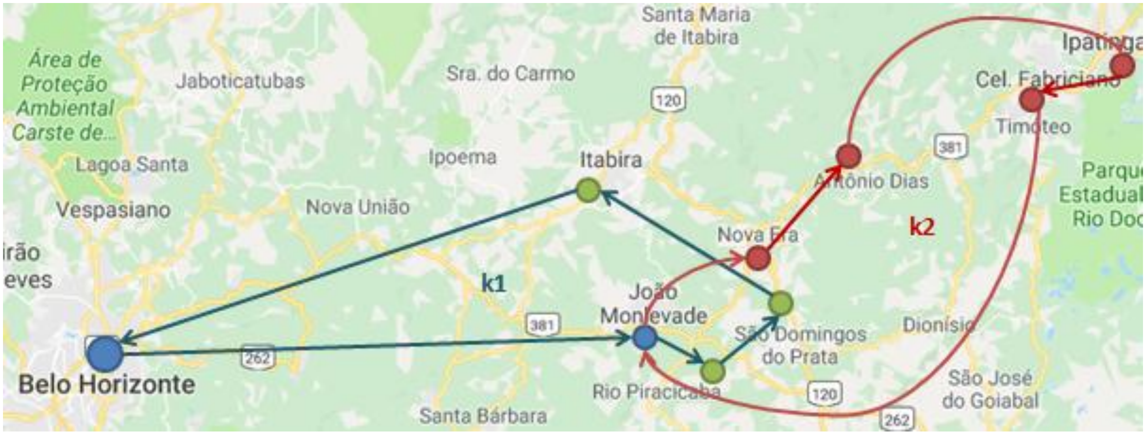

Fig. 2 - Graphic Representation of the Resolution of Scenario 11

Figure 2 generally represents the predominance of the use of main and support deposits and the use of two vehicles to comply with the routes identified through the simulation.

The exception regarding the number of vehicles employed was scenario 12, which, due to the number of cities, exceeds the time limit established and, as a result, had to work with three routes, as shown in Figure 3

.

Fig. 3 - Graphic Representation of the Resolution of Scenario 10

The relation of the routes in Figures 2 and 3 highlight the importance, including the geographical importance, of the support depot located in João Monlevade. The city, being approximately centralized in relation to the set of cities, favours the distribution process for situations with higher number of vertices.

The last highlight is the result of scenario 4, which, following the rule made in the programming that the four vertices closest to the main depot make up the graph for vehicle 1 (including the support depot, when necessary), This led to the creation of a second route with only one delivery, even under the condition that one of the cities on the first route is located just between the support depot and the city furthest from the starting point. A problem that can be tacitly corrected but depreciates the reliability of the routing mechanism employed and becomes a problem to be studied and repaired. It is worth pointing out that, although it did not achieve an optimal result in this scenario, the solution found nevertheless met all restrictions and would, in practice, serve the carrier's customers without loss. This scenario is represented in Figure 4.

At the end of the application of the integer linear programming in the resolution of the simulated scenarios, using the available computational resources and based on the adapted mathematical model, an acceptable result can be achieved, in which only one of the 20 scenarios did not obtain a satisfactory result, that is, 95% of the scenarios obtained valid and useful responses to the process.

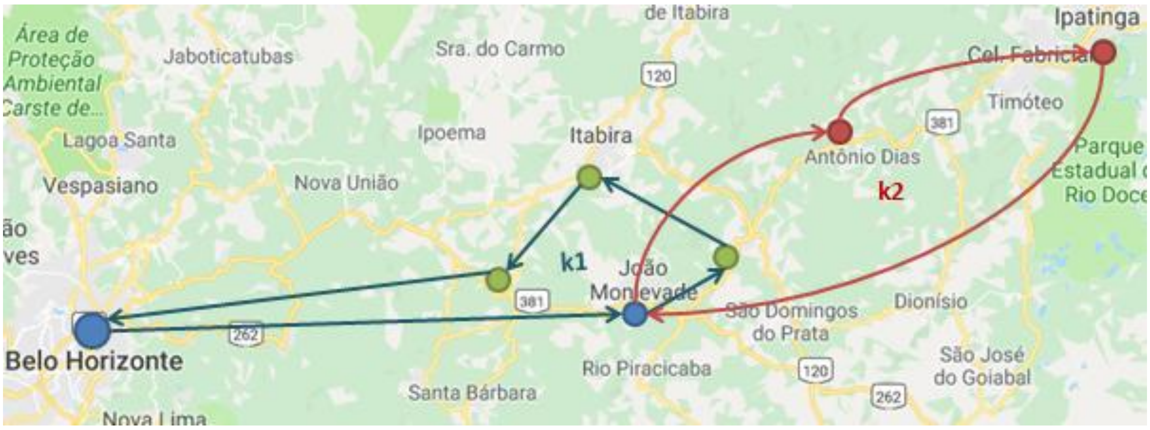

Fig. 4 - Graphic representation of the Resolution of Scenario 4

VII. CONCLUSION

This study aimed to present an analysis and logistic improvement through the routing of vehicles applied to a specific operating situation of a carrier that performs its activities in the state of Minas Gerais (Brazil). The relevance of the subject brought, although already widely approached, stands out for bringing specificities that significantly differ the problem from others already discussed in the most diverse studies on the subject.

While it was presented that there are different aspects of vehicle routing, in which each process of each organization can match a type of specific script, which in fact, indicates just how necessary it is to know existing mathematical models, as well as current techniques to solve these types of problem, mainly when dealing with problems of great complexity.

Once the theoretical aspects already studied about the broad subject were understood, the work sought the detailed identification of the work situation of the company targeted by the study.

The perception of the specific characteristics of service of this great route was paramount to bring the greatest relevance of this study by enabling the identification of a new variant for VRP: Vehicles Routing Problem with Support Deposit and Duration Constraints (SD-DCVRP).

The SD-DCVRP is similar, in some respects, to the routing of multi-deposit vehicles (MDVRP), since it has more than one distribution center available to the operational process. However, the SD-DCVRP presents as a peculiarity the difference in the level of importance between deposits, in which necessarily all goods must start from the main warehouse. In addition, there are only two deposits, one being main and one support. These conditions differ completely from the MDVRP, which makes no distinction of the importance of deposits, as well as the possibility of having a large number of related deposits.

The SD-DCVRP also has similarity with duration-constrained vehicle routing (LDVRP). However, in the case of this study the total duration of routes is influenced by the departure deposit and the sum of the number of deliveries to the same locality.

Thus, the insertion of the new variant is considered as a high-value proposition since it initiates an appropriate discussion and methods to solve a problem with very well delimited specificities. The variant adds up to the many other existing ones as a way to improve the logistics flow to a particular condition of operationalization.

While distinguishing the specific characteristics of this variant from the type of work performed by the carrier, it was assumed that these characteristics restricted operation under certain conditions. These technical constraints were paramount to determine the characteristic mathematical model proposed for SD-DCVRP resolution. Therefore, a specific mathematical model was created to meet this variant.

From the organization's data, simulated models of distributions were created, divided into two groups of ten scenarios each, the first being related to a current condition of care and the second as a strategic provision of care desired by the organization for brief future periods, totalling 20 simulations, to which they were submitted to the set of models mathematically adapted.

The computational study of each of the 20 scenarios, based on these models, allowed to optimize the total service time of the customers of this organization and establish, mathematically, the specific routes (simulated) to be travelled with the carrier's vehicles. In this study, it was noticeable that the number of localities involved is relatively small, which requires little computational effort for its resolution. This fact justifies the use of exact methods for solving problems. It is understood, therefore, that so far there is no need to apply heuristic or meta-heuristic methods for the resolution of the problem presented here.

Also in relation to computational resolution, it was possible to perceive that the limitation imposed by the combination of the mathematical model chosen and the tool used to solve the problem, the Solver of MS Excel, brought, among the twenty scenarios, a single unsatisfactory resolution that, although it meets all the requirements imposed and allows customer service within the appropriate deadlines, it would cause the unnecessary displacement of a vehicle in a given stretch of route. Nevertheless, the final response achieved a satisfactory result in 95% of the scenarios evaluated.

Therefore, this project when considered as a whole, is of great value to broaden the varied discussions of the vehicle routing problem, bringing a scientific gain to this field of study, besides creating a new mathematical model in the solution of a specific aspect. At the same time, it is considered a project that is widely valid in technical terms, since it made it possible to know in detail this specific type of movement, so that it may improve the distribution process carried out by the Shipping Company Correia Martins.

This study should also be treated as the principle of discussion and resolution of the problems presented here, and further studies should be developed about it, especially in order to present practical applicability to the organization, as well as to be the basis for use in routing resolutions for other organizations, but not ones limited to these proposals.

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