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VEHICLE ASSIGNMENT WITH PENALTY COSTS: A CASE OF MEXICAN FREIGHT TRANSPORT

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Abstract: The reduction of logistics costs is very important for Mexican companies, especially for those from freight transport industry. They must manage their operations efficiently and effectively to increase the revenue, which is reduced if trucks are not being productive. The objective of this research is to provide a model for a Mexican freight transport company, which lets the company reduce transportation costs, based on assignment models to make daily assignment programme of trucks. One particularity of the model being built is the fact that it will not only include general costs as in a Generalised Assignment Procedure (GAP), but also penalty costs caused by truck drivers. The main problem consisted in minimize the total cost of assigning 100 vehicles owned by the company to 10 routes (in which it was required to be transported molasse, and sand), considering that trucks cannot be assigned to some routes due to their characteristics, as well as they must assign different operators to the routes (which are classified as A, B, and C, depending on the characteristics like license type, performance, among others); thus, it was able to assign 100 operators with different characteristics to 100 different units required in 10 routes to satisfy market demands, achieving a reduction about 44.11% of current costs related to assignment, maintenance, idle time, penalty, and logistics costs.

1 Introduction

Freight transport is an important activity around the world, but particularly in Mexico, according to [1], road freight transport is accounting for 56% of the domestic and international freight transport. This activity plays an important role for the economy of the country. Many companies must deal with delays of their products by many issues, such as mentioned by [2], in which they are including natural disasters, road closing, road accidents, and others such as truck drivers time, vehicle age. It is important for the assignment to trucks and drivers to the routes consider different factors related to penalty costs, which results in the reduction of the company margin since prices are not able to be changed once the contract is signed. Thus, through this document we will propose a model to assign trucks weekly to help the company to assign and move the transport from one route to another to accomplish customer plans. One of the main problems for the company under study is the fact that 50% of the time is loss by operators, 40% due to maintenance and 10% due to external factors, which causes reduction of route productivity, which is about 60% average. With proposed model, it will be measured the impact of time in costs. By considering the penalty cost for maintenance or truck driver, it is expected to improve the delivery time and to fulfil the Estimated Time of Arrival (ETA) of each route, or at least, reduce the difference between ETA and real arrival time.

2 Freight transport

Logistics activities are core among companies, and, as established by [3], it is part of the value chain. Moreover, logistics function provides a link between supply and demand, product transformation and market of goods, as a result we deal with business complexity [4]. To increase supply chain productivity for freight transport companies, it is important to work with the distribution network on daily basis, it means, take in count the assignment of the driver to the truck, regarding the client and regarding the type of employee.

Assignment problem is a method to match “tasks” (jobs) with an “agent” (man, machine capacity, ant it is applied to vehicle assignment problems to minimize total assignment costs [5], one characteristics of these problems is the fact that the demand is not stochastic, like in this case, since they have to work with a monthly programme [6],

which is known in advance, but they have to programme the units in a way that the productivity was increased. Moreover, even though there are some algorithms as used by [7], everything depends on the problem, it means, what applies to one problem does not mean will apply to others or will impact in the same way.

Due to the high demand of logistics activities, in Mexico, Third Party Logistics (3PL) or outsourcing companies are important in states and Estado de Mexico, being large companies or small those who more uses this kind of service [8], which is critical for every company, since they put their products on the hands of other companies looking for benefits like [8]:

- Logistics operations flexibility.
- Concentration on business core activities.
- Improved expertise to market since secondary activities are carried by a third party.
- Cost savings from having their own trucks.
- Re-engineering of logistics processes.
- Access to new methods and technologies to develop core activities and involvement of all personnel.
- Risk reduction in transportation management.

3 Freight transport productivity factors

According to [9], there are some factors to take in count regarding truck utilization, which were related to vehicle capacity utilization, average speed, average lost time, average distance of transport, as well as the assigned route, which is important to make the right assignment. Identified as main factors affecting cost of truck operations [9,10]:

- Lorry size and its utilization (productivity).
- Use of Back-hauls (according to the demand).
- Empty running.
- Freight forwarding availability as well as other services.
- Traffic conditions.
- Road conditions.
- Social problems.
- Direct costs such as lubrication oil, labour costs, tires, vehicle maintenance, spare parts, and fuel.
- Quality management.

Other categories used for the optimization of the transport use are [11]:

- Profitability: Related with performance ratios, truck use, profits, use of outsourcing.
- Service quality: Objective's achievement, measurement of inconveniences, service levels, non-conformance.
- Equity: Service equity, client prioritization and segmentation, workload balance, collaborative planning.
- Consistency: Oriented to people, time consistency, delivery consistency, issues management.
- Simplicity: Separation, truck segmentation or service segmentation.
- Reliability: Expected cost or loss, probability of failure, risks management, truck driver management.
- External factors: Emissions, safety risks, social factors.

On the other hand, even though [9] and [12], mention these factors, they do not use or propose any model in which those factors are able to be used to improve truck productivity. Moreover, talking about Mexico, some problems related to transport products we have:

- Lack of road maintenance, having poor conditions of roads, producing productivity reduction.
- Lack of preventive maintenance to units, and more corrective maintenance.
- Lack of truck training.
- Truck drivers have inadequate maintenance and poor driving habits.
- Managerial and operational practices are not accurate, causing the delay and liberation of daily assignment programme for units.
- Measurement system was not accurate to measure the quantity of fuel used in each travel.

Despite the factors considered in the different models, we always talk about cost minimization or profit maximization, in terms of profits. However, time is an essential factor in products delivery by third party logistics, since we have some constraints like:

- Opening hours of load and unload depot.
- Closing hours of load and unload depot.
- Road closure because of social problems in any region or climate.

Those other factors cannot be controlled by the 3PL.

4 Vehicle Routing Problems

In order to solve vehicle assignment problems in which capacity constraints must be addressed (ensuring the minimum quantity required by the market is satisfied), whilst costs are minimised and truck drivers have to be assigned, it can be used the classical model of Vehicle Routing Problem (VRP), which can be found in the literature as many models adapted to different problems, as mentioned in papers [13] and [14]; however, none of them uses penalty costs as it was mentioned previously (even though time or distance can be considered as a cost). Regarding the literature review, in the Table 1 it is shown main factors considered by each model.

Table 1 Vehicle routing problems models

Paper \ VRP Model	**Classical VRP**	**Capacitated VRP**	**Asymmetric Capacitated VRP**	**Open Vehicle Routing**	**Simultaneous Pickup and Delivery**	**Mixed Pickup and Delivery**	**Multi-Depot**	**Multi-Depot with Mixed Pick Up**	**Heuristic**	**Time Windows**	**Stochastic**	**Time Dependent/ Periodic**	**Cross-Docking**	**Fixed Origin and Destination**	**Dynamic**	**Occasional Drivers**	**Fuel Consumption Minimizing**	**Emission**
Subramanian et al. [15]	X	X	X	X	X	X	X	X	X									
Korablev et al. [16]										X								
Haughton [17]											X							
Cordeao et al. [18]					X					X	X	X						
Huang and Liu [19]					X							X						
Vidal et al. [11]	X	X					X			X				X				
Yeun et al. [20]	X	X			X	X				X								
Christofides [21]	X	X				X	X	X		X	X	X						
Saint-Guillain [22]	X	X	X					X			X	X			X			
Archetti et al. [23]	X															X		
Nazari et al. [24]	X																	
Ghannadpour and Hooshfar [25]										X							X	
Caric and Gold [26]	X	X								X								
Lu, Zhang, and Yang [7]	X	X																
Londoño et al. [27]	X	X																
Haughton [28]		X									X							
Gendreay [29]	X	X								X								
Dahle et al. [30]	X	X													X	X		
Nagy et al. [31]						X												X
Frazzoli and Pavone [32]	X	X																
Guo et al. [33]	X	X	X							X	X							
Hanum et al. [34]	X	X					X	X		X								
IbrahIm et al. [35]		X																
Irnich et al. [36]		X	X	X	X	X	X	X	X	X		X	X	X				
Maleki et al. [37]				X														
Kara and Bektas [38]	X																	
Toro et al. [39]	X	X	X				X	X	X	X		X						X
Braekers et al. [40]	X	X	X	X	X	X	X	X	X	X	X	X	X					
Khodabandeh et al. [41]										X		X						
Bent and Hentenryck [42]											X							
Coene, [43]												X						
Pavone et al. [44]										X	X							
Hoogeboom et al, [45]	X	X								X								
Backer et al. [46]	X	X																
Ochoa-Ortiz et al. [47]	X	X																
Chepuri and Homem-De-Mello [48]											X							
Belachgar, [49]	X	X																
Kallehauge et al [50]										X								
Liñan-García [51]											X							
Ralphs [52]	X	X																

As it can be seen in Table 1, many models work in general way with constraints of time, capacity, pickup and delivery and routing. In fact, regarding models, according to [29] the more used VRP models according to 144 articles are (Figure 1): Capacitated Vehicle Routing Problem (CVRP), VRP with Time Windows (VRPTW), Heterogeneous VRP, Multi-Depot VRP, Backhauls VRP, Split Delivery DRP and Dynamic DRP. Which is what it was found in the literature review, but there are two models that were not considered previously like VRP with fuel consumption proposed by [25] and VRP with emissions proposed by [31] and [39]. Those late models are important, since they are not just focusing on time or a general constraint, but a constraint per unit or in a global way with environmental focus. It is important to highlight this since the models continue to use general costs, total times from one departure point to a destination point, time constraints, but they are not considering important factors that costs that can be caused by delays in the load centres, delays in destinations centres, delays due to operator undiscipline or due to truck failure due to it has to be send to maintenance, as well as the sending of the unit in advance to comply with preventive maintenance programs (in this company trucks have to be deviated from the current route just because the preventive maintenance was programmed with one day in advance, instead of being programmed at least with one week in advance to move units impacting the less possible the transport programme).

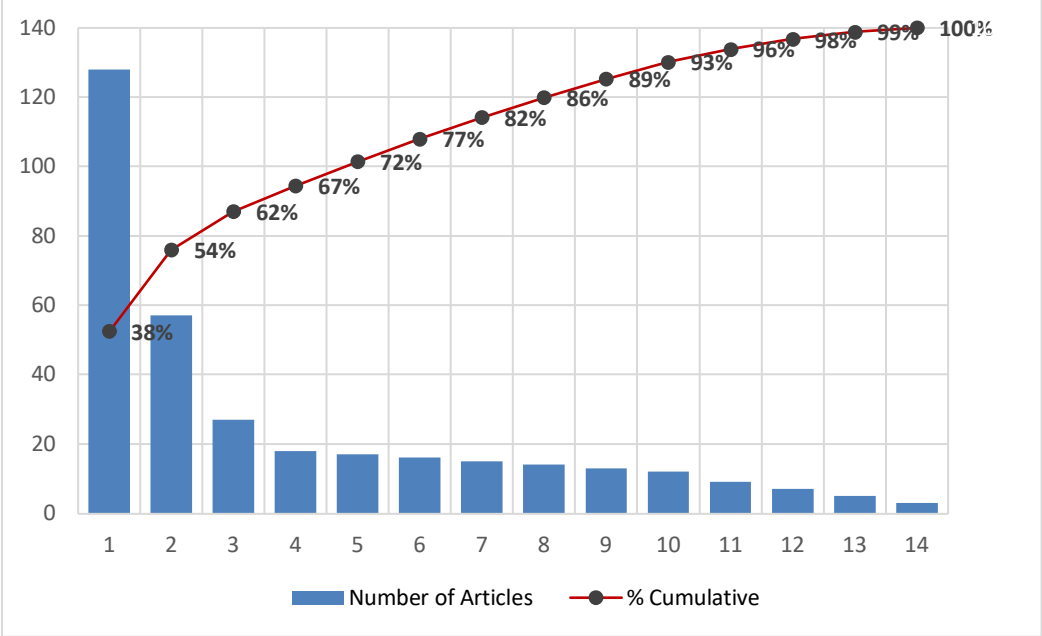

Figure 1 Most used VRP models in literature, own elaboration with data from [53]

As it can be seen, from literature, there are many variants of VRP models, but all of them works in general way with distances, costs, or revenues, in global way, without taking in count any penalties caused for transportation delay, being responsible mainly the truck driver. Moreover, this costs are not considered in some cases, since they only are focusing on distance optimization, when not necessarily the distance is proportional to the cost, since they are other factors as the fuel, which is spent depending on the route, it means, if the street has a slope, the effort required to move the unit will be greater and they will require more fuel than if the truck was operated in a plain road.

5 Methodology

The objective of this research was to help the company to create the daily programme of units assigned to the routes, using assignment on the vehicle routing problem considering costs of maintenance, for trucks assignment considering not a global unitary cost, but units costs of maintenance idle time, costs of truck driver idle time, as well as internal logistics costs, which will impact operations as reduce company profits. It helps to the organization to provide a better trucks assignment, reducing in the short-term these costs and in the long-term maintenance costs as well as the loss of customers due to lack of programmes fulfilment. Finally, it is compared the current assignment costs (for one day) to the costs related with the assignment using the mathematical model.

5.1 The Classic Vehicle Routing Problem

This problem parts from a Classic Vehicle Routing Problem (VRP). However, since trucks must stay in the same route going from an origin to a destination, the problem is simplified to an assignment problem in which it must be assigned trucks and operators to any route [30]. The general model for this problem is an assignment model, which is given by the direct costs (cd) – related to

unit wear, tires, toll payment, driver wage, fuel, insurance – and penalty costs – truck driver idle time (c_t), maintenance idle time (c_m), internal logistics costs (cl), caused by delays for the traffic department, and fine costs (cs), the following equations.

Objective function:

$$Min\ z = \sum\sum\sum c_d x_{ijk} + \sum(c_t + c_s)t_i + \sum c_m t_m + \sum c_l t_l \quad (1)$$

Subject to:

$$\sum x_{ijk} q_k \leq Q_k \quad \text{Route programme} \quad (2)$$

$$\sum x_{ijk} \leq O \quad \text{Operators available} \quad (3)$$

$$\sum x_{ijk} \leq U \quad \text{Trucks available} \quad (4)$$

$$x_{ijk} \geq 0 \quad \forall i \geq 0, \forall j \geq 0, \forall k \geq 0 \quad (5)$$

Where:

x_{ijk} = Binary variable representing the assignment of unit i to the driver j, to the route (6)

q_k = Quantity of product transported by the assigned unit (truck capacity) (7)

Q_k = Quantity of product demanded in route k (8)

O = Total number of operators available (9)

U = Total number of trucks available (10)

Since each operator has specific characteristics, costs depend on assigned operator and units available. The objective is to minimize the assignment cost for the company, taking in count penalties. Once the routes are stablished, it must be analysed if any of them are close enough to interchange operators or units and any programme can be completed faster or can be completed reducing costs, depending on the conditions.

5.2 The application of VRP model to a Mexican freight transport company

As the objective of this research is to define a model to assign vehicles to a route, it will be applied quantitative cross-sectional research because the sample is taken from one part in time [54]. For this study, data were collected from logs used in the company to record times of each unit, which are divided into: Departure time, Arrival Time to Load, Documentation, Departure Time from Load Centre, Arrival Time to Destination, Unload Time in Destination, Documentation Time, Available Time. All those times are arranged in a matrix to measure times from the origin to the destination and compare it with the Estimated Time of Arrival (ETA), which allows to see how much difference of time there are between planned and real times. Also, using the data from truck logs, it was obtained the driver performance.

To create the model, it was used a set of data of one day, it means, it is going to be created the programme for the units assuming 100 trucks are available, and they will be assigned to any route, and it was selected the most representative products which account for 80% of incomes. These data were selected since it is a planning period in which the company, and once units are assigned, it can be used the adapted VRP model to work with the units attending close routes without increasing costs meaningfully. Moreover, it is important to mention that origin and destination centres normally does not work on weekend, allowing units to be swapped between routes, unless the programme has been finished. The sample is representative, because we are going to use all the units that in this case are 100 and they are classified according to number of trailers they can pull, type of trailer, product to be transported, the capacity of the truck and the route that can be assigned due to vehicle aging (Table 2).

Table 2 Trucks classification

Number of Trucks	Trailers	Type	Product	Volume	Route	Classification
40	2	Tanker	Molasses	60	Any	A
25	1	Tanker	Molasses	30	Plain	B
15	2	Tanker	Molasses	60	Plain	C
20	2	Dump body	Sand	60	Any	A

Trucks Type A are the newest, requiring zero maintenance, Type B requires preventive maintenance (which is scheduled based on the kilometres travelled by the truck, established as 15000 kilometres) and type C requires corrective maintenance, whose hours where calculated based on the company standard work rates from the maintenance system (Table 3). Maintenance costs are given in Table 3.

Table 4 shows number of available Truck Drivers for each type, classification used by the company considering driver performance, type of license (which is considered when transporting dangerous material such as alcohol, which can be only transported by drivers A).

Table 3 Driver's classification

Truck Type	Maintenance($/Hour)	Required hours
A	0	0
B	250	5
C	750	24

Table 4 Driver's classification

Driver Type	Number of Drivers
A	50
B	40
C	10

To run the mathematical model, it was selected the 10 main client routes, which accounts for about 60% of the sales. And the programme for each one is shown in Table 5. "Routes A" are plain, and it can be used any kind of truck, Routes B are able to be assigned Trucks type A and B, and Routes C only can be assigned Trucks Type A.

Table 5 Routes and programmes

Route	1	2	3	4	5	6	7	8	9	10
Tons	500	500	400	600	550	650	120	240	300	120
Type	A	B	C	A	A	B	B	A	B	C
Product	Molasses	Molasses	Molasses	Molasses	Molasses	Molasses	Sand	Sand	Sand	Sand

To assign every unit to a driver and a route, there is a cost, as it was mentioned previously, which are shown in Table 6. Also, to differentiate the units of molasses from sand, it was used the letter M and S.

Table 6 Assignment cost for every route regarding truck and driver type

Truck	**Driver**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
MA	**A**	50	100	50	50	50	100	1000	1000	1000	1000
MA	**B**	75	50	50	75	75	50	1000	1000	1000	1000
MA	**C**	200	150	50	200	200	150	1000	1000	1000	1000
MB	**A**	50	75	150	50	50	75	1000	1000	1000	1000
MB	**B**	75	50	150	75	75	50	1000	1000	1000	1000
MB	**C**	200	150	150	200	200	150	1000	1000	1000	1000
MC	**A**	75	50	150	75	75	50	1000	1000	1000	1000
MC	**B**	50	25	150	50	50	25	1000	1000	1000	1000
MC	**C**	150	75	150	150	150	75	1000	1000	1000	1000
SC	**A**	1000	1000	1000	1000	1000	1000	75	50	50	50
SC	**B**	1000	1000	1000	1000	1000	1000	50	75	50	75
SC	**C**	1000	1000	1000	1000	1000	1000	100	100	100	100

6 Results and findings

According to the results obtained from running the problem by using Excel solver and GAMS, it was obtained the solution shown in Table 7, in which it is shown how many trucks of each type and driver type is assigned to each route. Assigning 5 trucks classified as Type A (tanks transporting volumes of 60 tons) that transport molasse to the route 1 using drivers type A, 5 units of this type to the route 3 and so on.

Table 7 Route assignment by truck and driver type

		Route									
Truck Type	**Driver**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
MA	A	5	0	5	6	7	1	0	0	0	0
MA	B	0	5	1	0	0	9	0	0	0	0
MA	C	0	0	0	0	0	0	0	0	0	0
MB	A	0	1	0	8	3	0	0	0	0	0
MB	B	0	0	0	0	0	0	0	0	0	0
MB	C	0	0	0	0	0	0	0	0	0	0
MC	A	0	0	0	0	0	0	0	0	0	0
MC	B	0	0	0	0	0	0	0	0	0	0
MC	C	4	3	1	0	1	1	0	0	0	0
SA	A	0	0	0	0	0	0	1	3	5	1
SA	B	0	0	0	0	0	0	1	1	0	1
SA	C	0	0	0	0	0	0	0	0	0	0
	TONS	540	510	420	600	570	660	120	240	300	120

As it is shown in Table 7, in some cases, the demand was satisfied and in other cases the demand was exceeded (Table 8 shows decoded results built by considering tables 2 – 6), for this kind of problems there is not an issue if the demand surpasses the transported quantity, since everything depends on the unit capacity, and it is not allowed to run any route with less product than the truck capacity.

Table 8 Units and type of drivers assigned by route

						Route									
TT	**PR**	**TR**	**Tons**	**Route**	**DR**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
MA	Mol.	2	60	Any	A	5	0	5	6	7	1	0	0	0	0
MA	Mol.	2	60	Any	B	0	5	1	0	0	9	0	0	0	0
MA	Mol.	2	60	Any	C	0	0	0	0	0	0	0	0	0	0
MB	Mol.	1	30	Plain	A	0	1	0	8	3	0	0	0	0	0
MB	Mol.	1	30	Plain	B	0	0	0	0	0	0	0	0	0	0
MB	Mol.	1	30	Plain	C	0	0	0	0	0	0	0	0	0	0
MC	Mol.	2	60	Plain	A	0	0	0	0	0	0	0	0	0	0
MC	Mol.	2	60	Plain	B	0	0	0	0	0	0	0	0	0	0
MC	Mol.	2	60	Plain	C	4	3	1	0	1	1	0	0	0	0
SA	Sand	2	60	Any	A	0	0	0	0	0	0	1	3	5	1
SA	Sand	2	60	Any	B	0	0	0	0	0	0	1	1	0	1
SA	Sand	2	60	Any	C	0	0	0	0	0	0	0	0	0	0
					TONS	540	510	420	600	570	660	120	240	300	120

Keys: TT: Truck Type TR: Trailers PR: Products DR: Drivers Mol.: Molasses

According to the values in Table 8, it is important to assign the right type of driver and truck to the route to reduce costs, if it is not done, costs start increasing due to penalties caused by maintenance, truck drivers, or other factors. The minimum cost found by running the model is shown in Table 9, which it can be observed that maintenance represents an important cost in the logistics process, as well as idle time cost, due to it is important to train drivers to reduce or eliminate those costs affecting the company incomes and profit.

Table 9 Assignment total cost

Costs	Current	Using the Assignment Model	% Reduction
Assignment	$278	$228	18.27%
Maintenance	$367,331	$195,000	46.91%
Idle Time	$123,981	$75,250	39.31%
Penalty	$13,957	$11,400	18.32%
Logistics	$3,232	$2,500	22.64%
TOTAL	**$508,779**	**$284,378**	**44.11%**

In this case, since the data from company is sensitive, there were used values representing costs of penalties; however, those costs are proportional to the current costs in the company; thus, it is important to make an alignment into the operations of the logistics and traffic department to reduce costs and increase revenues. Savings are calculated just for one assignment, showing the impact in those costs, but if it is considered that each month units are assigned at least 20 times (depending on the route), it would be shown the real impact that can be achieved by considering a mathematical model instead of just using trial and error techniques as currently it is done.

7 Conclusion and recommendations

For freight transport companies, it is important to develop a strategy to minimise logistics costs, since their main business is related to this activity, and it is the case of this Mexican freight transport company, for which it is important to consider costs incurred in operations to help the company to find out ways to reduce them. Hence, it was applied and adapted a vehicle assignment problem based on the classic vehicle routing problem to create the daily programme in which it was assigned the one hundred units, however, to apply the model in posterior days, assigned units should be removed from it, or add some constraints to avoid consider them. Moreover, with obtained results, it was confirmed the impact of low trucks productivity due to delays due to maintenance, idle time caused by the truck drivers or by delays on road from a source point to a destination point, which will cause additional costs or less incomes since the units will make less travels, causing those trucks cannot be assigned to other routes or programmes. The application of the VRP adapted to consider penalty costs shows a reduction about 44.11% of the total costs, which is important, since many of hidden costs of the company are due to lack of productivity due to short time in scheduling preventive maintenance programmes, idle time caused by the truck driver, delays caused in origin and destination centres, and also delays on road (caused, for instance, by weather conditions), which impacts to the company and it is reflected directly in the costs and incomes.

On the other hand, this research can be extended by taking in count different factors identified as those that cause more impact to the company, since in this case just were included the penalty costs, but there are other considerations that can impact the operations and work with the segregation of them, like the logistics costs (caused by the delay in the release of daily programme, lack of deposits of travel expenses to the truck drivers, delay in releasing load orders or purchase orders in fuel stations, among others). Also, further research can be developed by using the VRP model to move trucks between routes, considering a specific rout as starting point and incorporating it to others until it is assigned to the final circuit, if it is required because of operations.

References

[1] UNEP: Cooling Emissions and Policy Synthesis Report: Benefits of Cooling Efficiency and the Kigali Amendment, [Online], Paris, Nairobi and IEA, 2020.

[2] SANTOS, I.M., REIS, K.M.D., REPOLHO, H.M.V.: *Vehicle Routing Problem with Simultaneous Pickup-Delivery, Time Windows, Time Depend and Fault Probability: A Case Study on Liquefied Petroleum Gas Distribution*, XXXI Congresso Nacional de Pesquisa em Transporte da ANPET Recife, Vol. 31, pp. 2343-2355, 2017, https://doi.org/10.3141/2378-13

[3] PORTER, M.: *Competitive Advantage: Creating and Sustaining Superior Performance*, United States of America, Simon and Schuster, 1998.

[4] BARMAN, S.E., LINDROTH, P., STRÖMBERG, A.: Modeling and Solving Vehicle Routing Problems with Many Available Vehicle Types, *Proceedings in Mathematics & Statistics*, Vol. 130, pp. 113-138, 2014. https://doi.org/10.1007/978-3-319-18567-5

[5] NAUS, R.M.: Solving the Generalized Assignment Problem: An Optimizing and Heuristic Approach, *Informs Journal on Computing*, Vol. 15, No. 3, pp. 249-266, 2003. https://doi.org/10.1287/ijoc.15.3.249.16075

[6] BOONSAM, P., SUTHIKARNNARUNAI, CHITPHAIBOON, W.: *Assignment Problem and Vehicle Routing Problem for an Improvement of Cash Distribution*, Proceedings of the World Congress on Engineering and Computer Science, Vol II WCECS, 2011.

[7] LU, H., ZHANG, X., YANG, S.: A Learning-Based Iterative Method for Solving Vehicle Routing Problems, *ICLR 2020*, pp. 1-12, 2020.

[8] ARROYO, P., GAYTAN, J., BOER, L.: A Survey of Third-Party Logistics in Mexico and a Comparison with Reports on Europe and USA, *International Journal of Operations and Production Management*, Vol. 26, No. 6, pp. 639-667, 2006. https://doi.org/10.1108/01443570610666984

[9] KULOVIC, M.: *Freight Transport Performance Indicators, Example from Bosnia and Herzegovina*, College of Traffic Engineering, pp. 241-251, 2017.

[10] VELARDE, J.M., GARCÍA, S., LÓPEZ, M., BUENO-SOLANO, A.: Implementation of a Mathematical Model to Improve Sustainability in the Handling of Transport Costs in a Distribution Network, *Sustainability*, Vol. 12, No. 1, pp. 1-10, 2019. https://doi.org/10.3390/su12010063

[11] VIDAL, T., LAPORTE, G., MATL, P.: A Concise Guide to Existing and Emerging Vehicle Routing Problem Variants, *European Journal of Operational Research*, Vol. 286, pp. 286-287, 2020. https://doi.org/10.1016/j.ejor.2019.10.010

[12] MEHDIZADEH, A., CAI, M., HU, Q., YAZDI, M. A. A., KALEJAHI, N. M., VINEL, A., RINGDOM S. E., DAVIS, K. C., MEGAHED, F. M.: A Review of Data Analytic Applications in Road Traffic Safety, *Sensors*, Vol. 20, No. 4, pp. 1-19, 2020. https://doi.org/10.3390/s20041096

[13] HUERTA-MUÑOZ, D.L.: *The Flexible Periodic Vehicle Routing Problem: Modelling Alternatives and Solution Techniques*, Barcelona, Universität Politecnica de Catalunya, 2018.

[14] ARCHETTI, C., SAVELSBERGH, M., SPERANZA, G.: The Vehicle Routing Problem with Occasional Drivers, *European Journal of Operational Research*, Vol. 254, No. 2, pp. 472-480, 2016. https://doi.org/10.1016/j.ejor.2016.03.049

[15] SUBRAMANIAN, A., UCHOA, E., OCHI, L.S.: A Hybrid Algorithm for a Class of Vehicle Routing Problems, *Computers & Operations Research*, Vol. 40, No. 10, pp. 2519-2531, 2013. https://doi.org/10.1016/j.cor.2013.01.013

[16] KORABLEV, V., MAKEEV, I., KHARITONOV, E., TSHUKIN, B., ROMANOV, I.: *Approaches to Solve the Vehicle Routing Problem in the Valuables Delivery Domain*, 7th Annual International Conference on Biologically Inspired Cognitive Architectures, Vol. 88, pp. 487-492, 2016. https://doi.org/10.1016/j.procs.2016.07.469

[17] HAUGHTON, M.A.: *An Analysis of the Assignment of Delivery Routes to Vehicle Drivers in Stochastic Vehicle Routing Operations*, Second World Conference on POM, Vol. 15, pp. 11, 2004.

[18] CORDEAO, J.F., DESAULNIERS, G., DESROSIERS, J., SOLOMON, M.M., SOUMIS, F.: *The VRP with Time Windows*, Montreal, GERAD, The Vehicle Routing Problem, Chapter 7, Paolo Toth and Daniele Vigo (eds), SIAM Monographs on Discrete Mathematics and Applications, SIAM, Philadelpia, Pa., 2000.

[19] HUANG, C., LIU, Y.: Vehicle Routing Problem with Simultaneous Pickup and Delivery in Cross-Docking Environment, *Journal of Economics Business and Management*, Vol. 3, No. 1, pp. 60-66, 2015. https://doi.org/10.7763/JOEBM.2015.V3.156

[20] YEUN, L.C., ISMAIL, W.R., OMAR, K., ZIROUR, M.: Vehicle Routing Problem: Models and Solutions,

Journal of Quality Measurement and Analysis, Vol. 4, No. 1, pp. 205-218, 2008.

[21] CHRISTOFIDES, N.: The Vehicle Routing Problem, *Revue Française D Automatique Informatique Recherche Opérationnelle.*, Vol. 10. No. 6, pp. 55-70, 1976.

[22] SAINT-GUILLAIN, M.: *Models and Algorithms for Online Stochastic Vehicle Routing Problems*, INSA Lyon, 2019.

[23] ARCHETTI, C., FERNÁNDEZ, E., HUERTA-MUÑOZ, D.L.: The Flexible Periodic Vehicle Routing Problem, *Computers & Operations Research*, Vol. 85, No. September, pp. 58-70, 2017. https://doi.org/10.1016/j.cor.2017.03.008

[24] NAZARI, M., OROOJLOOOY, A., TAKAC, M., SNYDER, L.V.: *Reinforcement Learning for Solving the Vehicle Routing Problem*, 32nd Conference on Neural Information Processing Systems, Vol 31, pp. 9861-9871, 2018.

[25] GHANNADPOUR, S.F., HOOSHFAR, M.: *Multi-Objective Vehicle Routing Problem with Time Windows and Fuel Consumption Minimizing*, 5th International Conference on Operations Research and Enterprise Systems, Vol. 5, pp. 92-99, 2016. https://doi.org/10.5220/0005657900920099

[26] CARIC, T., GOLD, H.: *Vehicle Routing Problem*, Croatia, In-Tech, 2008.

[27] LONDOÑO, J.C., NARVAEZ, L.T., VASQUEZ, S., BRAVO, J.J.: A Strategy Based on the Open Traveling Salesman Problem to Solve the Vehicle Routing Problem with Backhauls, *Espacios*, Vol. 40, No. 28, pp. 7-13, 2019.

[28] IRNICH, S., VIGO, D.: *The Family of Vehicle Routing Problems*, Philadelphia, SIAM, 2014. https://doi.org/10.1137/1.9781611973594.ch1

[29] GENDREAY, M., TARANTILIS, C.D.: *Solving Large-Scale Vehicle Routing Problems with Time Windows The-State-of-The-Art*, Centre Interuniversitaire de Recherche, Montreal, 2010.

[30] JASIM, A.N.: A New Method to Solve Assignment Models, *Applied Mathematical Sciences*, Vol. 11, No. 54, pp. 2663-2670, 2017. https://doi.org/10.12988/ams.2017.78252

[31] NAGI, G., ARCHETTI, C., SPERANZA, M.G.: The Vehicle Routing Problem with Divisible Deliveries and Pick Ups, *Transportation Science*, Vol. 49, No. 2, pp. 163-431, 2013. https://doi.org/10.1287/trsc.2013.0501

[32] FRAZZOLI, E., PAVONE, M.: Multi-Vehicle Routing, Vol 99, No. 9, pp. 20, 2013. https://doi.org/10.1109/JPROC.2011.2158181

[33] GUO, Z., WALLACE, W.S., KAUT, M.: Vehicle Routing with Space- and Time – Correlated Stochastic Travel Times: Evaluating the Objective function, *INFORMS*, Vol. 31, No. 4, pp. 654-670, 2019. https://doi.org/10.1287/ijoc.2019.0906

[34] HANUM, F., HARTONO A.P., BAKHTIAR, T.: *On the Multiple Depots Vehicle Routing Problem with Heterogeneous Fleet Capacity and Velocity*, IOP Conference Series: Materials Science and Engineering, Vol. 332, 2017. https://doi.org/10.1088/1757-899X/332/1/012052

[35] IBRAHIM, A.A., ABDULAZIZ, R.O., ISHAYA, J.A.: Capacitated Vehicle Routing Problem, *International Journal of Research Granthaalayah: A knowledge Repository*, Vol. 7, No. 3, pp. 310-327, 2019. https://doi.org/10.29121/granthaalayah.v7.i3.2019.976

[36] KOVAKS, A.A., GOLDEN, B.L., HARTL, R.F., PARRAGH, S.N.: Vehicle Routing Problems in Which Consistency Considerations are Important: A Survey, *NETWORKS An International Journal*, Vol. 64, No. 3, pp. 192-213, 2014.

[37] MALEKI, F., YOUSEFIKHOSHBAKHT, M., IRAN, B.Z.: A Hybrid Algorithm for the Open Vehicle Routing Problem, *International Journal of Optimization in Civil Engineering*, Vol. 9, No. 2, pp. 355-371, 2019.

[38] KARA, I., BEKTAS, T.: *Integer Linear Programming Formulation of the Generalized Vehicle Routing Problem*, EURO/INFORMS Joint International Meeting, July 6-10, 2003.

[39] TORO, E.M., ESCOBAR, A.H., GRANADA, M.E.: Literature Review on the Vehicle Routing Problem in the Green Transport Context, *Luna Azul*, Vol. 42, pp. 362-387, 2016. https://doi.org/10.17151/luaz.2016.42.21

[40] BRAEKERS, K., RAMAEKERS, K., NIEUWENHUYSE, I.V.: The Vehicle Routing Problem State of the Art Classification and Review, *Computers & Industrial Engineering*, Vol. 99, pp. 300-313, 2015. https://doi.org/10.1016/j.cie.2015.12.007

[41] KHODABANDEH, E., BAI, L., HERAGU, S.S., EVANS, G.W., ELROD, T., SHIRKNESS, M.: Modelling and Solution of a Large-Scale Vehicle Routing Problem and Ge Appliances & Lighting, *International Journal of Production Research*, Vol. 55, No. 4, pp. 1100-1116, 2016. https://doi.org/10.1080/00207543.2016.1220685

[42] BENT, R., HENTENRYCK, P.V.: Dynamic Vehicle Routing with Stochastic Requests, *Proceedings of the Eighteenth International Joint Conference on Artificial Intelligence IJCAI*, Vol. 52, pp. 1362-1363, 2004.

[43] COENE, S., SPLEKSMA., F.C.R.: On a Periodic Vehicle Routing Problem, *Journal of the Operational Research Society*, Vol. 61, No. 12, pp. 1719-1728, 2010. https://doi.org/10.1057/jors.2009.154

[44] PAVONE, M., BISNIK, N., FRAZZOLI, E., ISLER V.: A Stochastic and Dynamic Vehicle Routing Problem with Time Windows and Customer

Impatience, *Mobile Networks and Applications*, Vol. 14, No. 350, 2009. https://doi.org/10.1007/s11036-008-0101-1

[45] HOOGEBOOK, M., ADULYASAK, Y., DULLAERT, W., JAILLET P.: The Robust Vehicle Routing Problem with Time Window Assignments, *Transportation Science*, Vol. 55, No. 2, pp. 275-552, 2019. https://doi.org/10.1287/trsc.2020.1013

[46] BACKER, B., FURNON V., KILBY, P, PROSSER, P., SHAW, P.: Solving Vehicle Routing Problems Using Constraint Programming and Metaheuristics, *Journal of Metaheuristics*, Vol. 6, No. 4, pp. 1-16, 1997. https://doi.org/10.1023/A:1009621410177

[47] OCHOA-ORTIZ, A., ORNELAS-ZAPATA F., MARGAIN-FUENTES, L., CEDILLO-CAMPOS, M. G., SÁNCHEZ-AGUILAR, J., JARAMILLO-VACIO, R., AVILA, I.: Capacitated Vehicle Routing Problems for PSS uses Based on Ubiquitous Computing: An Emerging Markets Approach, *Universidad Nacional de Colombia Sede Medellín Facultad de Minas*, Vol. 82, No. 191, pp. 20-26, 2015.

[48] CHEPURI, C., HOMEN-DE-MELLO, T.: Solving the Vehicle Routing Problem with Stochastic Demands Using the Cross-Entropy Method, *Annuals of Operations Research*, Vol. 134, No. 1, pp. 153-181, 2005. https://doi.org/10.1007/s10479-005-5729-7

[49] BELACHGAR, K.: *Vehicle Routing Problem with Distance Constraints and Clustering*, Capstone Project Final Report, Morocco, Al Akhawayn University, 2017.

[50] KALLEHAUGE, B., LARSEN, J., MADSEN, O.B. G., SOLOMON, M.M.: *Vehicle Routing Problem with Time Windows*, Denmark, Technical University of Denmark, 2006.

[51] LIÑÁN-GARCÍA, E., CRUZ-VILLEGAS, L.C., GONZÁLEZ-GONZÁLEZ, D.S.: Solving the Capacitated Vehicle Routing Problem with Stochastic Demands Applying the Simulated Annealing Algorithm, *Programación Matemática y Software*, Vol. 6, No. 2, pp. 36-45, 2007.

[52] RALPHS, T.K., KOPMAN, L., PULLEYBLANK, W.R., TROTTER, L.E.: On the Capacitated Vehicle Routing Problem, *Mathematical Programming*, Vol. 94, pp. 343-359, 2001. https://doi.org/10.1007/s10107-002-0323-0

[53] JAEGERE, N., DEFRAEYE, M., VAN NIUWENHUYSE, I.: *The Vehicle Routing Problem: State of the Art and Classification and Review*, Belgium, Faculty of Economics and Business; Leuven, FEB Research Report KBI_1415FEB Research Report KBI_1415, 2014.

[54] KOTHARI, C.R.: *Research Methodology: Methods and Techniques*, 2nd ed., New Delhi, New Age International Limited, 2004.

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