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Locating Nearby Delivery Zones in an Urban Logistics Context

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Abstract: In logistics engineering, the client satisfaction is one of the most important stakes that a provider has to overcome. Thus, many research focused on developing the tools required to guarantee the client satisfaction taking into consideration the optimization of the costs. In this research and in addition to that two concerns (client satisfaction and costs optimization), we will examine establishing new nearby delivery zones close to major retail and commercial precincts in a socio-environmental context. Two alternatives is then available, modeling the real life problem as multiple depot vehicle routing problem or using the uncapacited sing hub location problem. In this study, we showed that the second alternative stands good than the first. Then, nearby delivery zones would be implemented in cities. These delivery zones will occupy sections of curbsides space and alleys to provide space for carriers to park their delivery vehicles in a pre-booked space where they can load/unload products for the delivery/pickup to neighboring businesses walking or using rolling carts. Hence, carriers will avoid time windows restriction by making a single long stop in the nearby delivery zone instead of driving around the city center from one destination to another. In this study, we provide a mathematical formulation to this end based on the uncapacitated single allocation p-hub location problem, also, a Genetic algorithm approach is presented. The performance of the model and the metaheuristic was tested using the Australian Post (AP) data set.

Key words: Logistics, operations research, optimization, metaheuristics, AP, Genetic algorithm

INTRODUCTION

In logistics industry, carriers are aware of the additional costs induced on them by access time windows and they maintain an ongoing request for initiatives that might contribute to reduce them, one of which is the implementation of a system of urban mini-hubs. These mini-hubs are specific streets or areas where delivery vehicles are allowed to park, regardless of the access time window in order to complete the final deliveries on foot or using a handcart. This would represent longer delivery times, due to the need for longer displacements from the parked vehicle to the final destinations but it would also allow these vehicles to avoid the time window restriction by making a single long stop in the mini-hub instead of driving around the city center from one destination to another. Congestion, double parking and emissions would be reduced in the city center and carriers would in return be exempted from the time window restriction. It is important to stress the differences between urban mini-hubs and Urban Distribution Centers (UDCs). Whereas mini-hubs are simply specified sections of curb where delivery vehicles have to stop in order to make final deliveries, UDCs are transshipment points usually located in parking lots or similar premises close to the city center where delivery vehicles unload their goods which are then transferred to electric vehicles, managed by the municipality or by a third party for the final delivery to the shops. These UDCs, therefore, require investments and operational costs and have been tested in several European cities with the help of European research funds but proved economically unfeasible once, the public funding was over (Ambrosino *et al*., 2008). Besides issues like the management of the final deliveries and the assumption of responsibility for the goods were left unresolved, apart from the fact that carriers felt that they were losing presence in front of their customers. Finally, the consideration of urban hubs as consolidation and buffer points requiring certain infrastructure and operation leads to the introduction of a fixed cost figure associated to the installation and operation of a hub. In contrast, there are no costs associated to the implementation of mini-hubs, since, they only require the allocation of a given amount of curb space for logistic activities. These mini-hubs might complement the existing load zones but would ideally replace them, allocating a similar amount of curb space to fewer locations which could then be easily monitored for issues like vehicle

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rotation or security. Vehicle rotation could be guaranteed, for example, by implementing reservation systems to guarantee the availability of certain time slots at the mini-hub for every interested carrier. Moreover, the lack of security is one of the main complaints of drivers who are forced to leave their vehicles to complete a delivery but it is easier to guarantee it with a reduced number of mini-hubs than at all the possible parking locations that are used now a days. In case revenues were generated through the reservation system, they could well be used to pay for increased security at mini-hub locations. Preferential routes would be defined to enter and leave the mini-hubs and also the door would open for cooperation schemes whereby carriers delivering goods to different receivers in the same area of the city might find it convenient to associate and complete joint deliveries from the mini-hub. Depending on the allocation strategy of assigning the non-hub nodes to the hub nodes, there are two different classes of hub location problems: multiple allocation hub location problem and single allocation hub location problem. In the former, a nonhub node can be allocated to more than one hub of the net such as, this approach has applications in aviation industry where the main goal is to exploit the economies of scale obtained by using larger aircraft between hubs. In the latter, every non-hub node is allocated to exactly one hub node, this approach is applied in situations in which sorting at the source is not possible (or too costly), so that, all shipments are transported as a whole to the allocated hub. Finally, the implementation of a mini-hub system could also be carried out gradually in different areas of the city which would allow urban planners to modify or reconsider their characteristics as implementation problems arise or to discard the measure entirely before full-scale implementation is completed. The recommendation is then to start with a pilot implementation at a particularly dense and delimited area and then, if the results are positive, open one new mini-hub at a in logistics industry, carriers are aware of the additional costs induced on them by access time windows and they maintain an ongoing request for initiatives that might contribute to reduce them, one of which is the implementation of a system of urban mini-hubs. These mini-hubs are specific streets or areas where delivery vehicles are allowed to park, regardless of the access time window in order to complete the final deliveries on foot or using a handcart. This would represent longer delivery times, due to the need for longer displacements from the parked vehicle to the final destinations but it would also allow these vehicles to avoid the time window restriction by making a single long stop in the mini-hub instead of driving around the city center from one destination to another. Congestion, double parking and emissions would be reduced in the city center and carriers would in return be exempted from the time window restriction. It is important to stress the differences between urban mini-hubs and Urban Distribution Centers (UDCs). Whereas mini-hubs are simply specified sections of curb where delivery vehicles have to stop in order to make final deliveries, UDCs are transshipment points usually located in parking lots or similar premises close to the city center where delivery vehicles unload their goods which are then transferred to electric vehicles, managed by the municipality or by a third party for the final delivery to the shops. 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These mini-hubs might complement the existing load zones but would ideally replace them, allocating a similar amount of curb space to fewer locations which could then be easily monitored for issues like vehicle rotation or security. Vehicle rotation could be guaranteed, for example, by implementing reservation systems to guarantee the availability of certain time slots at the mini-hub for every interested carrier. Moreover, the lack of security is one of the main complaints of drivers who are forced to leave their vehicles to complete a delivery but it is easier to guarantee it with a reduced number of mini-hubs than at all the possible parking locations that are used now a days. In case revenues were generated through the reservation system, they could well be used to pay for increased security at mini-hub locations. 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Literature review

The p-hub median problem: Campbell produced the first linear integer programming formulation for the single allocation p-hub median problem. He formulated the problem with flow thresholds which he defined as the minimum flow value needed to allow service on a link. When flow thresholds are set to their maximum values, each demand node is assigned to a single hub and the formulation reduces to the single allocation p-hub median problem. Skorin-Kapov *et al.* (1996) O'Kelly and Miller (1994) and Ilic *et al.* (2010) stated that the LP relaxation of Campbell and O'Kelly (2012), O'Kelly and Miller (1992) and Contreras *et al.* (2009) formulation resulted in highly fractional solutions. They proposed a new mixed integer formulation for the single allocation p-hub median problem. The researchers showed that the linear relaxation is tight as it almost always yields integral solutions with the CAB data set. For those instances with non-integral LP solutions, the LP relaxation resulted in an objective function value <1% below the optimal objective function value. They obtained the optimal values by using CPLEX. To the best of our knowledge Skorin-Kapov *et al.* (1996) and Alumur and Kara (2008) presented the first attempt at optimally solving the single allocation p-hub median problem. Ebery Campbell and O'Kelly (2012) presented another formulation for the single allocation p-hub median problem that requires O(n) variables and O(n) constraints. This formulation uses fewer variables than all of the other models previously presented in the literature. However, in practice, the computational time required to solve this new formulation was greater than that required to solve the Ernst and Krishnamoorthy, (1999) and Ilic *et al.* (2010) formulation. The p-hub median problem is NP hard. Moreover, even if the locations of the hubs are fixed, the allocation part o f the problem remains NP-hard Kara and Contreras *et al.* (2011a, b). Clearly, the multiple allocation p-hub median solutions provide a lower bound on the optimal solution of the single allocation p-hub median problem. Using this idea, Campbell proposed two new heuristics for the single allocation p-hub median problem. These two heuristics, MAXFLO and ALLFLO, derive solutions to the single allocation p-hub median problem from the solution to the multiple allocation p-hub median problem. In these heuristics, the allocations are done according to different rules but location decisions are the same. Table 1 summarizes the studies on the single allocation p-hub median problem. In terms of required number of variables and constraints, Ebery (2001), O'Kelly (1992) and Ernst and Krishnamoorthy (1996) provides the best mathematical formulation. However, the best mathematical formulation in terms of computation time requirement is that of Ernst and Krishnamoorthy (1996) and Ilic *et al.* (2010). The most efficient exact solution procedure is the shortest-path based branch-and-bound algorithm presented by Ernst and Krishnamoorthy (1996) and Ilic *et al.* (2010). Up to now the largest set of problems that has been solved to optimality has 100 nodes. The most effective heuristic is the lagrangean relaxation based heuristic presented by Pirkul and Schilling, Skorin-Kapov *et al.*, (1996) and Campbell and O'Kelly (2012). And among the best metaheuristics are the tabu search heuristic presented in Skorin-Kapov and Skorin-Kapov and the simulated annealing heuristic presented in Ernst and Krishnamoorthy O'Kelly (1992), Campbell and O'Kelly (2012) and Ambrosino *et al.* (2008).

Multiple allocation: Campbell and O'Kelly (2012) was the first to formulate the multiple allocation p-hub median problem as a linear integer program. The researcher formulated the multiple allocation p-hub median problem also with flow thresholds and fixed costs as a linear integer program. Based on the model pesented by Campbell and O'Kelly (2012) Skorin-Kapov *et al.* (1996) presented a formulation resulting from a tighter LP relaxations and produced integral results in almost all instances using the CAB data set. For the cases when LP relaxation did not yield, an integer solution, the researchers employed an implicit enumeration search tree to obtain optimal solutions. This search tree normally involved very few tree nodes. Ernst and Krishnamoorthy (1999) proposed a new formulation for the multiple allocation p-hub median problem based on the idea that

Table 1: The studies on the single allocation

Years	Researchers	Notes
1987	O'Kelly	Quadratic integer program, HEURI, HEURI2
1990	Aykin	Procedureto find optimalallocations
1991	Klincewicz	Exchange heuristic
1992	Klincewicz	Tabu searhc and GRASP heuristics
1994b	Campbell	First linear integer formulation
1994	Skorin-kapov and Skorin-kapov	Tabu search heuristics
1995	O'Kelly Skorin-kapov and Skorin-kapov	Lower bounding technique
1996	Campbell	MAXFLO and ALLFLO heuristies
1996	Ernst and Krishnamoorthy	New formulation, simulated annealing heuristecs, B&B method
1996	O' Kelly, Bryan, Skorin-kapov and Skorin-kapov	New formulation for symmetric flow data
1996	Skorin-kapov, Skorin-kapov and O' Kelly	New mathematical formulation leading to tight LP relaxation
1996	Smith, Krishnamoorthy and Palaniswami	Modified hopefield neural network heuristic
1997	Sohn and Park	Two-hub location problem
1998b	Ernst and Krishnamoorthy	Shortest path based B&B alogrithm
1998	Pirkul and Schilling	Lagrangean relaxation heuristic
1998	Sohn and Park	New formulation for symmetric cost and allocation problem
2000	Sohn and Park	Three-hub allocation problem
2001	Abdinnour-Helm	Simulated annealing heuristic
2001	Ebery	New formulations for p = 2 and 3
2005	Elhedhli and Hu	Minimized congestion at hubs

they have proposed for the single allocation version by Ernst and Krishnamoorthy (1999). Ernst and Krishnamoorthy (1999), O'Kelly (1992) and Ernst and Krishnamoorthy (1996) showed that this formulation is more effective than the formulation of Skorin-Kapov *et al.* (1996), O'Kelly (1992), Ilic *et al.* (2010), Bailey *et al.* (2013) Boland *et al.* (2004) suggested that even though the formulation by Ernst and Krishnamoorthy (1999) results in faster computational times and requires less memory, it still suffers from weak lower bounds. In order to overcome this deficiency, the researchers identified some characteristics of optimal solutions to develop preprocessing techniques and tightening constraints. When they applied these to the multiple allocation p-hub median problem, the results indicate that tightening does significantly improve some of the results.

Uncapacited allocation: The Uncapacitated Single Allocation Hub Location Problem (USAHLP) with the hub-and-spoke network structure is a decision problem in regard to the number of hubs and location allocation. In a pure hub-and-spoke network, all hubs which act as switching points for internodal flows are interconnected and none of the non-hubs, (i.e., spokes) are directly connected. The key factors for designing a successful hub-and-spoke network are to determine the optimal number of hubs, to properly locate hubs and to allocate the non-hubs to the hubs. "The first mathematical model for the hub location problem" was given by O'Kelly (1992). He proposed a quadratic integer programming formulation for the problem of minimizing the total transport cost for a given number of hubs to locate (p-hub median problem). The following hub location literature mainly focused on the transportation cost objective locating both a fixed and a variable number of hubs. Important early studies are O'Kelly (1992), Ernst and Krishnamoorthy (1996, 1999) and Skorin-Kapov *et al.* (1996) where different kinds of hub and capacity constraints were discussed. On the heuristic side, recent successes are a neighborhood search algorithm of Ilic *et al.* (2010), a discrete particle swarm optimization of Bailey *et al.* (2013) and a Genetic algorithm by Topcuoglu *et al.* (2005). Contreras *et al.* (2011a, b) contributed much to the field: In Contreras *et al.* (2009), a Lagrangian relaxation approach is developed whereas Contreras *et al.* (2011a, b) considers Benders decomposition and Contreras *et al.* (2011a, b) uses a branch-and-price approach. For a more complete and also historical introduction, the reader is referred to Alumur and Kara (2008) and O'Kelly (1992).

MATERIALS AND METHODS

The uncapacited single allocation p-hub location problem: In this research, our main goal is establishing new nearby delivery zones close to major retail and commercial precincts as well as large stores in central city that individually or collectively attract and produce large number of daily freight vehicle trips while having limited space for maneuvering, parking and loading/unloading zones. These delivery zones will occupy sections of curbsides space and alleys to provide space for carriers to park their delivery vehicles in a pre-booked space where they can load/unload products for the delivery/pickup to neighboring businesses either walking or using rolling carts. The reserved spaces will facilitate easy parking, maneuvering and loading/unloading for the delivery vans and light trucks such as beveled edge sidewalk and inclined plane for enhanced material handling. Thus, our initiative will focus on small and independent retailers and businesses, taking into account they usually require frequent high-intensity and low-weight deliveries that are not optimized or bundled from various carriers. These receivers can negotiate collectively with suppliers that deliver similar products to their area and select a carrier that offer them the best service and cost. The carrier selected will deliver larger quantities in the same vehicle trip neighboring business as well as offering pick up services which will decrease the number of vehicles compared to using multiple carriers. The delivery zone will be available only to carriers that deliver consolidated deliveries to multiple receivers or perform multiple pick-up services close to the delivery zone via. a paid vehicle access permit. Only registered carriers will be able to reserve the delivery zone via. a mobile application that enables sending the booking details to receiving businesses via. either. This facilitates enhanced information visibility across the supply chain as businesses will be notified via. a mobile application once, the carrier reserves the delivery zone to deliver/pick up their products. The time-slots will be available for booking except during peak morning hours to encourage business to receiver deliveries throughout the day which will positively spread the freight demand generation and reduce congestion and parking during peak hours. Carriers will be able to modify their reservation in case, if they will not be able to reach the delivery zone on time, so that, other carriers can use it".

Mathematical formulation for the USHALP problem: Based on the hypothesis that consists of the known numbers of the nearby delivery zones (hubs), the single allocation of that hubs and the existence of enough nearby delivery zones to satisfy all the clients, the problem can be classified as an Uncapacitated Single Allocation P-Hub median Location Problem (USAPHLP). Thus, the following notation has been used in our mathematical formulation of the USAPHLP.

- C_{ij} = Cost per distance unit for the displacement of the carrier between the access point i and the nearby delivery zone j
- γ_{ij} = Induced cost per distance unit between two nearby delivery zones j and j'
- δ_{jk} = Cost per distance unit for the displacement of the handcart or the vanne from the hub to the client
- w_{ik} = The number of units of traffic sent from access point (origin) i to client k
- O_i = Total flow sent from the Origin i
- x_{ij} = 1 if access point i is allocated to the nearby delivery zone j. 0 else
- $z_{jj'}$ = 1 if the displacement between the hubs j and j' is occurred 0 else
- y_{jk} = 1 if the client k is delivered from the hub j 0 else

$$\text{Min}\sum_{i}^{n}\sum_{j}^{n} c_{ij}x_{ij} + \sum_{j}^{n}\sum_{j'\notin j}^{n}\sum_{k}^{n}(\gamma_{jj'}z_{jj'}+\delta_{j'k}y_{j'k})+\sum_{j}^{n}\sum_{k}^{n}\delta_{jk}y_{jk} \quad (1)$$

$$z_{jj'} \leq y_{j'k} \quad \forall j, k = 1, 2, ..., n \quad (2)$$

$$\sum_{j=1}^{n} x_{ij} = 1 \quad \forall i = 1, 2, ..., n \quad (3)$$

$$\sum_{j=1}^{n} x_{ij} = p \quad (4)$$

$$x_{ij} \leq x_{jj} \quad \forall i, j = 1, 2, ..., n \quad (5)$$

$$\sum_{k=1}^{n} W_{ik}x_{ij}y_{jk} = 0_i \quad \forall i, j = 1, 2, ..., n \quad (6)$$

$$x_{ij} \in (0, 1) \quad \forall i, j = 1, 2, ..., n \quad (7)$$

$$x_{jj'} \in (0, 1) \quad \forall i, j = 1, 2, ..., n \quad (8)$$

$$x_{jk} \in (0, 1) \quad \forall j, k = 1, 2, ..., n \quad (9)$$

The (Eq. 1) is to minimize the total transportation cost which is the summation of three costs. The first represents, the cost from the access points to the nearby delivery zones, the second describe, the cost induced when a displacement between the hubs occurs before the delivery and finally, the third is about the cost of transportation from the hubs to final clients. Equation 2 forces that if a displacement between two nearby delivery zones occurred, it has to be followed by a delivery to the clients. Equation 3 explains that each carrier has a single allocation of the nearby delivery zone, i.e., each non-hub node is allocated to a single hub. Equation 4 ensures that exactly p hubs are located. Equation 5 represents the flow conservation equation while Eq. 6 ensures that the nearby delivery zones are established for every distribution/ collection step, thus, avoiding direct transmission between access points and clients. Equation 7-9 define the binary variables used in the model.

Modeling the USAHLP as multiple depot vehicle routing problem: Since, our purpose stands for optimizing the total transportation cost with a respect of the demand constraints, i.e., all clients must be delivered. Hence, classical known approach which is vehicle routing can be used. Therefore, our USAHLP can be seen as a multiple depot vehicle routing problem by considering the depots as access areas and neglecting the p (number of hubs to be located) parameter. Thus, we will be able to conclude about the more suitable alternative (USAHLP or MDVRP):

$$\text{Min} \sum_{i\in t\cup j} \sum_{j\in t\cup j} \sum_{k\in K} C_{ij} x_{ijk} \quad (10)$$

$$\sum_{j\in t\cup j} \sum_{k\in K} x_{ijk} = 1 \qquad j\in J \quad (11)$$

$$\sum_{j\in J} d_j \sum_{i\in t\cup j} x_{ijk} \leq Q_k \qquad k\in K \quad (12)$$

$$U_{ik} - U_{jk} + Nx_{ijk} \leq N-1 \qquad 1,\ j\in J, \quad k\in K \quad (13)$$

$$\sum_{j\in I\cup J} x_{ijk} - \sum_{j\in I\cup J} x_{jik} = 0 \qquad k\in K,\ i\in I\cup J \quad (14)$$

$$\sum_{i\in I} \sum_{j\in J} x_{ijk} \leq 1 \qquad k\in K \quad (15)$$

$$\sum_{j\in J} d_i z_{ij} \leq V_i \qquad i\in I \quad (16)$$

$$\sum_{i\in I\cup J} (x_{iuk} + x_{ujk}) \leq 1 + z_{ij} \qquad i\in I, \quad j\in J, \quad k\in K \quad (17)$$

$$x_{ijk} \in (0, 1) \qquad i\in I, \quad j\in J, \quad k\in K \quad (18)$$

$$z_{ij} \in (0, 1) \qquad i\in I, \quad j\in J \quad (19)$$

$$U_{lk} \geq 0 \qquad i\in I, \quad k\in K \quad (20)$$

Sets:

I = Set of all access areas
J = Set of all customers
K = Set of all vehicles

Indices:

I = Access area index
j = Customer index
k = Route index

Parameters:

N = Number of vehicles
C_{ij} = Distance between point i and j, i, j∈I∪J
V_i = Maximum throughput at depot i
d_j = Demand of customer j
Q_k = Capacity of vehicle (route) k

Decision variables:

x_{ijk} = 1, if I immediately preceeds j on route k}
z_{ij} = {1, if customer is j allotted to depot i}
U_{lk} = Auxiliary variable for sub-tour elimination constraints in route k Mathematical Model

Genetic algorithm: A Genetic algorithm is a probabilistic search technique that computationally simulates the process of biological evolution. It mimics evolution in nature by repeatedly altering a population of candidate solutions until an optimal solution is found. The GA evolutionary cycle starts with a randomly selected initial population. The changes to the population occur through the processes of selection based on fitness and alteration using crossover and mutation. The application of selection and alteration leads to a population with a higher proportion of better solutions. The evolutionary cycle continues until an acceptable solution is found in the current generation of population or some control parameter such as the number of generations is exceeded.

Chromosome representation: For a better modeling, the chromosome should represent a set of nearby delivery zones to locate. Thus, we defined it as a vector of p genes where, p is the number of nearby delivery zones (supposed as known in the mathematical formulation) while the component of that vector represent the nodes and they are numbered from 1 to n. For p = 7 and n = 20, the following chromosome can be interpreted as the following: the hub number one is assigned to the node 4, the second to the node number 6 and etc.

4	8	3	17	11	13	8	5

Crossover operator: We used k-point crossover. It uses the random crossover point to combine the parents same as per 1-Point crossover. To provide the great combination of parents it selects more than one crossover points to create the offspring or child. The procedure first selects the two parents used for crossover and then randomly select K crossover points P1i to Pk-1i (i = 0-n-1). Two offspring are created by combining the parents at crossover point. In the given example, two crossover points are selected integer string from beginning of chromosome to the first crossover point is copied from one parent, the part from the first to the second crossover point is copied from the second parent and the rest is copied from the first parent (Fig. 1-3).

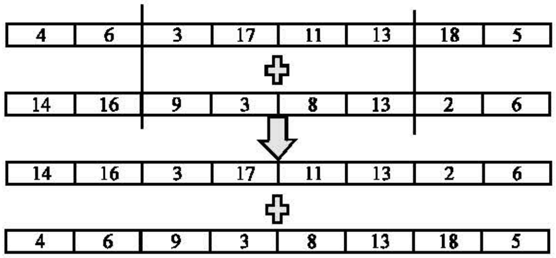

Fig. 1: The random crossover point to combine the parents same as per 1-point crossover

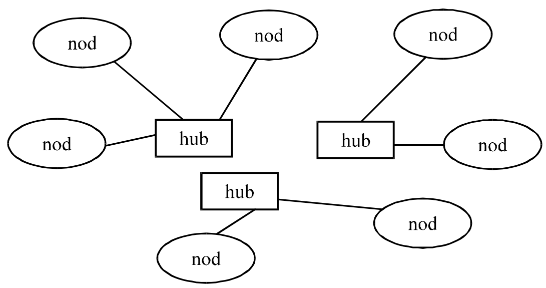

Fig. 2: Single hub allocation illustration

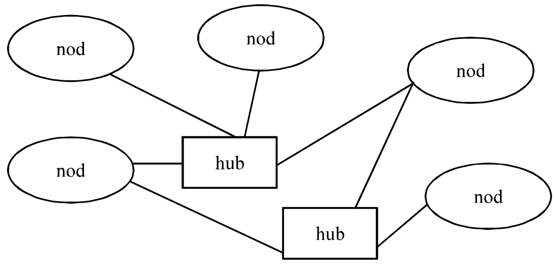

Fig. 3: Multiple hub allocation illustration

Mutation operator: First, we specified for each gene an upper and lower bound, then the mutation operator changes the value of chosen gene with uniform random value selected between our specified upper and lower bound for that gene.

Additional operators: The three remaining operators used by the Genetic algorithm are:

Selection operator: Probabilistic operator based on the fitness value for each individual. A probability of surviving to the next generation equal to 1 is assigned to the best individual and 0 to the worst one. The rest of the population is assign randomly selected gene is replaced by another number between 1 and n which is not already contained in the chromosome. As a result, the corresponding mini-hub is moved to another random location in the city center".

Restarting operator: When the average fitness of the population falls below 1.1 times the fitness value of the best individual, the population is restarted randomly, maintaining only the two best individuals.

Stopping criterion: The algorithm stops when the preset number of generations have been covered.

RESULTS AND DISCUSSION

The MDVRP is one of the pillars of the combinatorial optimization problems. Although, its large presence and importance for solving real-life problems, the MDVRP based approach is less satisfying than the USHALP one for our case. As shown in Table 2, we solved both of the mathematical models and concluded that the USHALP gave better results than MDVRP. For numerical tests, we use the Australian Post data set (AP) which can be found in the OR library and which is used frequently for different hub location problems. We use instances from 10-50 nodes and vary the number of hubs p from 2-5 and we generate. We used AMPL IDE for programming and solving solving the mathematical model. The suitable solvers for the first problem were IPOPT, GUROBI and COUENNE. Otherwise, we use CPLEX solver for the VRP Model. CPLEX was unable to provide a feasible solution due to Lagrangian relaxation reasons. Table 3 shows the results obtained, the first two columns are the n the number of access areas considered and the parameter p. The third column represents the objective function value for the USHALP mathematical model. The last column contains the values of the objective function for the presented MDVRP Model where n is the number of depot. Table 4 shows the calibration tests of the Genetic algorithm done, we concluded that the best configuration to use is about considering a population with a size equal to 150, a number of generation of 1500 and a mutation probability equal to 0.3. Table 5 contains a comparison between the results obtained by the exact method and the Genetic algorithm for the small and medium problem sizes. A correlation tests were also done to have an idea about the influence of the number of access areas, number of hubs (considered as dependent variable) on the fitness value. Table 6 resumes the results obtained. Figure 1 is the scatter plot of the fitness value depending on n and p variation.

The USAHLP approach that we used gave better results than the MDVRP. Calibration tests for the Genetic algorithm were done. We noticed that the parameter of algorithm was negatively correlated with the fitness value,

Table 2: The multiple allocation p-hub medium problem

Years	Researchers	Notes
1992	Campbell	First linear integer program
1994b	Campbell	New formulations, flow threshholds, fixed costs
1996	Campbell	Greedy-interchange heuristic
1996	Skorin-Kapov, Skorin-Kapov and O'Kelly	New mathmatical formulation leading to tight LP relaxation
1998a	Ernst and Krishnamoorthy	New formulation, B&B method, two heuristics
1998b	Ernst and Krishnamoorthy	Shortest path based B&B algorithm
1999	Sasaki, Suzuki and Drezner	1-stop problem
2004	Boland, Krishnamoorthy, Ernst and Ebery	Preprocessing and tightning constrainsts

Table 3: Results of the two models

N	p-values	Best lower bound found using the first formulation	Best upper found using the first formulation	Best lower found using the VRP Model	Best upper found using the VRP Model
10	2	14861.91	14861.91	15096.14	15096.14
10	3	14410.05	14410.05	14605.05	14605.05
10	4	11120.63	11120.63	11406.45	11406.45
10	5	10439.13	10439.13	10928.33	10928.33
20	2	15373.01	15373.01	15512.44	15512.44
20	3	14927.15	14927.15	15128.94	15128.94
20	4	14300.25	14300.25	14418.07	14418.07
20	5	13862.48	13862.48	14048.23	14048.23
40	2	17226.94	17226.94	17392.45	17392.45
40	3	16105.34	16105.34	16522.19	16522.19
40	4	15122.17	15122.17	15948.88	15948.88
40	5	13128.33	13128.33	13654.07	13654.07
50	2	17512.44	17512.44	17516.44	17516.44
50	3	16528.94	16528.94	16722.15	16722.15
50	4	16018.07	16018.07	16116.94	16116.94
50	5	15714.95	15714.95	17752.08	17752.08

Table 4: Paramaters used for the implementation of the CLM heuristic

Paramaters of the CLM heuristic	Utilization
k	Determines number of neighbor to be tracked
T	Threshold: Objective function
I	Problem Instance
S0	Initial solution, i.e, solution to be improved
Stopping criterion	Number of iterations or where local optimum is reached
Exploration rule	Solutions with best objectives/ solutions allowing best improvement
Feasibility	Test the feasibility of the solution

Table 5: Results given by ipopt versus the Genetic algorithm

N	p values	Lower bound	Optimal value of fitness	Execution time using exact method	Fitness value using hybrid GA with CLM heuristic	Execution time using GA with CLM	GAP (%)
10	2	14861.91	14861.91	8.91	14861.91	11.44	0.00
10	3	14410.05	14410.05	11.82	14410.05	15.66	0.00
10	4	11120.63	11120.63	13.11	11125.16	17.94	0.00
10	5	10439.13	10439.13	16.25	10439.13	21.15	0.00
20	2	15373.01	15373.01	13.25	15373.01	18.12	0.00
20	3	14927.15	14927.15	16.44	14927.15	22.06	0.00
20	4	14300.25	14300.25	17.59	14300.25	22.55	0.00
20	5	13862.48	13862.48	18.99	13862.48	23.44	0.00
40	2	17226.94	17226.94	18.16	17226.94	22.88	0.00
40	3	16105.34	16105.34	20.44	16105.34	26.15	0.00
40	4	15122.17	15122.17	53.13	15122.17	70.25	0.00
40	5	13128.33	13128.33	83.14	13128.33	92.36	0.00
50	2	17512.44	17512.44	69.25	17512.44	81.28	0.00
50	3	16528.94	16528.94	98.70	16528.94	112.45	0.00
50	4	16018.07	16018.07	120.15	16018.07	175.48	0.00
50	5	15714.95	15714.95	200.69	15714.95	288.24	0.00
50	7	16611.31	-	587.24	16940.22	743.64	1.98
75	2	15722.03	15722.03	316.45	15722.03	412.16	0.00
75	3	15494.49	15494.49	389.15	15494.94	455.78	0.00
75	5	16658.92	-	604.18	17012.09	798.29	2.12
75	7	17512.28	-	715.26	17897.56	945.87	2.20
100	2	16034.58	16034.58	314.59	16034.58	457.14	0.00
100	3	17264.29	17264.29	388.12	17264.29	498.36	0.00
100	4	17466.03	-	687.25	17845.05	745.21	2.17

Table 5: Results by IPOPT versus the Genetic algorithm

N	p values	Lower bound	Optimal value of fitness	Execution time using exact method	Fitness value using hybrid GA with CLM heuristic	Execution time using GA with CLM	GAP (%)
100	5	17622.09	-	726.94	18032.69	815.36	2.33
120	2	15948.36	15948.36	622.15	15948.36	709.64	0.00
120	3	17075.99	-	655.14	17443.13	723.21	2.15
120	5	18296.98	-	845.36	18745.26	1036.14	2.45
200	2	17303.66	-	1122.32	17746.64	1347.58	2.56
200	5	19531.02	-	1350.11	20105.24	1643.31	2.94

Table 6: Correlation tests between n, p and the fitness value

Variables	Correlation coefficient	Observation
Fitness value, n	0.92	Strength positive correlation
Fitness value, p	-0.60	Negative correlation

then, the best configuration was about considering a number of generation 1500, a population size of 100 and a mutation probability that equal to 0.3.

The complete local search with memory: Complete Local search with Memory (CLM) makes use of it by keeping track of the solutions visited by the heuristic and preventing it from searching their neighborhoods in the next interations. The heuristics uses a storage space set where the generated solutions are stored, this space is called memory. The size of the memory is the number of solutions that can be stored. It is used to maintain three lists of solutions. The first one, called LIVE, stores solutions that are available to the heuristic for exploration. A second list, called DEAD, contains solutions that were in LIVE at some stage and have already been explored. The third list, called NEWGEN is a temporary store for new solutions being generated by the heuristic during the current iteration. CLM starts with a given solution as input and puts it in LIVE. Sets DEAD and NEWGEN are initially empty. It then performs iterations until, the stopping rule is reached. At the beginning of each iteration, the heuristic picks a number of solutions (a paramater of the heuristic) from LIVE.

Each chosen solution is transferred from LIVE to DEAD and all its neighbors with objectives better than a threshold value (also paramater of heuristic) are generated. Each one of these neighbors is then checked for membership in LIVE, DEAD and NEWGEN. If it is a member of LIVE, then the solution has already been obtained by the heuristic and has not been explored yet (being less promising that the ones that are currently under consideration). If it is a member of DEAD, then the solution has already been generated and explored and we already know the solutions that are obtained by exploring it. If it is in NEWGEN, then it has already been generated in the present iteration. However, if the solution is not yet in any of the lists, it is a new solution which merits exploration and is put in NEWGEN. When all the solutions that were picked have been explored, the solutions in NEWGEN are transferred to LIVE and the iteration is complete. If LIVE is not empty when the stopping rule is reached, a generic local search is applied to the each of the members of LIVE and the locally optimal solutions, thus, obtained are added to DEAD. The best solution present in DEAD at the end of the generic local search procedure is returned by the heuristic.

To improve results given by our Genetic algorithms, an implementation of the CLM heuristic was done for each instance (n, p) the heuristic takes the solution given by the Genetic algorithm as an initial solution and start then the procedure described below taking into account those considerations:

Neighborhood: A 2-opt procedure: it consists of eliminating two edges and reconnecting the two resulting paths in a different way to obtain a new "tour". There is only one way to reconnect the paths that yield a different tour. Among all pairs of edges whose 2-opt exchange decreases the length we choose the pair that gives the shortest tour. This procedure is then iterated until no such pair of edges is found. The resulting tour is called 2-optimal.

Exploration rule: Choose k-best solutions from LIVE.

Stopping rule: Stop when LIVE is empty at the beginning of an iteration.

Other parameters: k = 2 , T is chosen to be the objective value of the solution being explored currently. At the end, a feasibility test is applied to the solution given from the DEAD set.

Algorithm 1; Complete local search with mwmory:

```
Start
LIVE<-S
DEAD←NULL SET
    While stoping rule is not satisfied
    Begin
```

```
NEWGEN←NULL SET
Integer choosen←0
While choosen <k and LIVE ! =NULL
  Begin
        Select solution s from the set of solutions LIVE
          Chosen++
          Add s to DEAD
          Remove s from LIVE
          generate N where N is the set of solutions
          neighbours to swith better
objective values
             for each element e of N
               Begin
               If n is not in LIVE or N is not in
               DEAD or N is not in NEWGEN
                   Begin
                     If size of memory< = number of
             solutions allowed to be
stored
                               Add n to NEWGEN
          else
                  For each element el of NEWGEN
                  Add el to LIVE
                  For each solution s in LIVE
                        Begin
                        Remove e from LIVE
                        Obtain el from e by applyin
                       2-point local search
                        Add el to DEAD
              End
    End
  End
  End
end
```

According to the comparison of the results of the algorithm Genetic with the exact method on the small and medium instances, we can conclude that the algorithm was performant regarding the optimality.

Here, it was about testing the correlation about the dependent variable n or p and the independent variable fitness function. Then, we can have a better preview about the variation of that three variables. Otherwise, this test shall be a preliminary for regression purposes (Fig. 4).

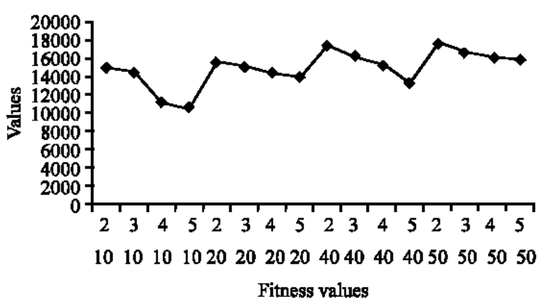

Fig. 4: Testing the correlation about the dependent variable n or p and the independent variable fitness function

CONCLUSION

Our study focused on a sustainable approach which is location nearby delivery zones in cities. Throughout the proposal, this approach seems to be encouraging in the optimization fields, since, its comparison with one of the most popular problems (MDVRP) gave satisfying results. Otherwise, one additional main gain of this new alternative is about avoiding the investment costs unlike the Ds and other "third party" costs such as parking lent or supplier-client's organizational costs.

Furthermore, that new urban engineering aspects may have good returns to the environment, since, the congestion, double parking and emissions would be reduced in cities. The application of this research has also a positive impact for city logistics growing, particularly in a developed nation such as Morocco where the logistics performance index is 2.38 with a scale varying from 1-5. In such country, establishing this kind of nearby delivery zones will also alleviate the traffic in the big cities especially where the road infrastructure remains poor.

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Significance statement: This research aims to examine establishing new nearby delivery zones close to major retail and commercial precincts in a socio-environmental context. Two alternatives are then discussed, modeling the real life problem as Multiple Depot Vehicle Routing Problem and the consideration of the uncapacited single hub location problem. These delivery zones will occupy sections of curbsides space and alleys to provide space for carriers to park their delivery vehicles in a pre-booked space where they can load/unload products for the delivery/pickup to neighboring businesses walking or using rolling carts. The performance of the model and the metaheuristic was tested using the Australian Post (AP) data set. We tried also to consider this problem on a sustainable approach by locating nearby delivery zones in cities. Also, by avoiding the investment costs and other "third party" costs such as parking lent or supplier-clients organizational costs. Thus, that new urban engineering aspects may have good returns to the environment, since, the congestion, double parking and emissions would be reduced in cities. The application of this research has also a positive impact for city logistics growing, particularly in a developed nation such as Morocco where the logistics performance index is 2.38 with a scale varying from 1-5. In such country, establishing this kind of nearby delivery zones will also alleviate the traffic in the big cities especially where the road infrastructure remains poor.

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