Vehicle Routing Problem with Regard to Simultaneous Pickup and Delivery, Time Windows and Workers Assignment on the basis of their abilities and Availability

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Abstract: The vehicle routing with simultaneous pickup and delivery, which considers simultaneous distribution and collection of goods to/from customers, is an extension of the capacitated vehicle routing problem (CVRP). In such matters, all the vehicles start moving from a central depot and stop working in the same center. Demands of each node should be served exactly once and only by one vehicle. All the customers' requirements must be met. In simultaneous pickup and delivery (VRPSPD), vehicles can perform pickup and delivery processes in each node simultaneously and the whole loading products should be returned to the central depot. In this paper, VRPSPD is considered with regard to hard and soft time windows. Some workers are applied to perform the pickup and delivery processes that they should be assigned to the vehicles depending on their abilities and also their availability. By considering pickup and delivery processes with time windows and allocation of workers, wider range of current issues in the real world will be included. We entitle this novel problem VRPSPD-TW-WA and propose a mathematical model to handle with it. Finally, the precision performance of the proposed model is assessed by solving some test problems via GAMS 24 software.

Keywords: Routing; simultaneous pickup and delivery; time window; worker assignment; penalty

1. Introduction

Nowadays, many companies are being required to satisfy more complicated customers' demand. Due to its importance, companies seek appropriate ways to meet the needs and reduce the total cost. General speaking, members in a supply chain such as suppliers, manufacturers and customers seek the highest efficiency simply for them, and do not consider the optimization of the whole system, in other words, they do not have systematic thought in order to increase the global optimization in the supply chain. Although optimization of only one member in supply chain improves its performance,it may have an adverse effect on the whole system. In order to reduce the total cost, it is indispensable to consider all supply chain members at the same time. VRP is one of the cases that pay attention to this subject.

The Vehicle Routing Problem (VRP) was first introduced by Dantzig and Ramser (1959)[1]. The problem is concerned with delivering goods to a set of customers with known demands through a number of vehicles with common features in order to meet all the needs and minimize the total cost. (A. serdarTasan, Mitsue

Gen)[2].An important assumption in the traditional vehicle routing problem (VRP) is that except for the distance, all road segments exhibit a homogeneous characteristic that has no impact on vehicle scheduling.

Capacitated Vehicle Routing Problem (CVRP) is an extension of VRP. In such matters, all the vehicles start moving from a central depot and stop working in the same center. It is not needed that all vehicles arrive at the central depot simultaneously andeach vehicle is used at most once.

Most studies have focused on the concept of VRP in point and there are huge studies which treat the vehicle routing problem in the supply chain. Details on VRP and its variants with formulation, and solution methods can be found in Toth and Vigo (2001)[3]. One of the variants of VRP is Vehicle Routing Problem with Time Windows (VRPTW). Several techniques have been developed for solving the VRPTW. There are four general types of exact solution methods: dynamic programming (Kolen et al., 1987)[4], Dantzig Wolfe (column generation), (Desrochers et al., 1992; Kohl et al., 1999)[5], Lagrange decomposition (Kohl and Madsen, 1997)[6] and solving the classical model formulation directly. The Dynamic Vehicle Routing and scheduling Problem withTime Windows (D-VRPTW) is a sort of the vehicle routing and scheduling problem with time windows, which is a typical route optimization technique employed in city logistics (Taniguchi *et al.*, 2007) [7].The objective of city logistics is to optimize the urban freight movement with respect to the public andprivate costs and profits (Thompson and Taniguchi et al, 2001) [8]. Optimal location of logistics terminals(Yamada *et al.*, 2001)[9] and cooperative delivery systems (Qureshi and Hanaoka, 2005)[10] are some of the citylogistics' schemes, aimed at the mitigation of the typical problems related to the urban freight transport. A routing system, in which complete or a part of input information (such as number and location of customers or travel time) is not available to the decision maker at the start, but it is revealed during the scheduling horizon (day of operations) is called Vehicle Routing and scheduling Problem with Soft Time Windows (VRPSTW),(Qureshi et al., 2012)[11].Qureshi*et al.* (2009)[12] developed a columngeneration based exact solution approach for the VRPSTW and efficiently solved instances up to 50 customers under various soft time windows settings. Recently, Qureshi*et al.* (2011)[13] extended it toincorporate the dynamic travel times and solve the D-VRPSTW. On the other hand, Vehicle Routing Problem with Hard Time Windows (VRPHTW) is another variant of VRPTW. In VRPHTW, customers can be served only during their time windows which are pre-specified,while in VRPSTW, they can be served at any time, but with penalty by not being in the time window. During thepast decades, literatures on VRPHTW have been actively published. Because of its heavy computational timerequired, however, only relatively small instances can be solved to optimality.

The Vehicle Routing Problem with Simultaneous Pickup and Deliveries (VRP-SPD) which considers simultaneous distribution and collection of goods to/from customers is an extension of CVRP.(Berbeglia et al. 2007)[14]conducted a comprehensive survey of Pickup and Delivery Problem (PDP) formulations and classified them into one-to-one, one-to-many-to-one, and many-to-many schemes. The Multiple Vehicle Pickup and Delivery Problem with Time Windows (MV-PDPTW) is a variant of the well-known vehicle routing problem with time windows (VRPTW).

Most studies focused on the advantages of VRP. Recently, there have been studies on actual issues of VRP to improve scheduling of the routes in the supply chain. It will be more desirable ifproducts can be produced and

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distributed at the right quantities, to the right locations, and in a distinct period of time, which results in minimal system wide costs while fulfilling customers' demand. This is why a model describes vehicle routing problem is treated in this study. Vehicle routing problem with simultaneous pickup and delivery and time windows is an extension of vehicle routing problem with simultaneous pickup and delivery that considers time windows too. This combination has not been discussed in literature.

The other supremacy of this study is hiring and allocating a set of workers to the vehicles to perform the pickup and delivery processes. Hereafter we remind this novel combination VRPSPD-TW-WA. Figure 1 gives a short summary of this combination.

The remaining part of this paper is organized as follows: In section 2, the problem description and the mathematical model are presented. A numerical example is given in section 3 and our conclusions are represented in section 4.

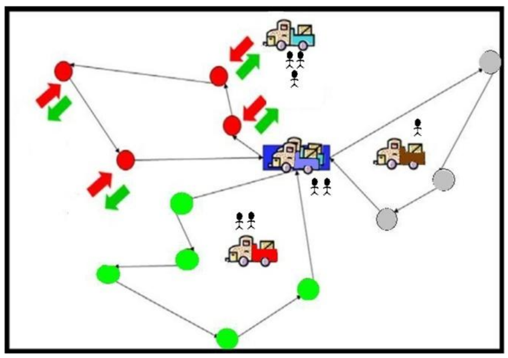

Figure 1:vehicle routing problem with regard to simultaneous pickup and delivery

For more details on the abbreviations used in this paper, the following explanations are supplied.

VRP: Vehicle Routing Problem
CVRP: Capacitated Vehicle Routing Problem
VRPTW: Vehicle Routing Problem with Time W020indows
D-VRPTW: Dynamic Vehicle Routing and scheduling Problem with Time Windows
VRPSTW: Vehicle Routing and scheduling Problem with Soft Time Windows
D-VRPSTW: Dynamic Vehicle Routing and scheduling Problem with Soft Time Windows
VRPHTW: Vehicle Routing Problem with Hard Time Windows
VRP-SPD: Vehicle Routing Problem with Simultaneous Pickup and Deliveries
PDP: Pickup and Delivery Problem
MV-PDPTW: Multiple Vehicle Pickup and Delivery Problem with Time Windows
VRPSPD-TW-WA: Vehicle Routing Problem with Simultaneous Pickup and Delivery and Time Windows and Workers Assignment

2. Problem definition

The model presented in this paper is a nonlinear programming model for routing vehicles and also allocating workers to the vehicles. It is assumed that a certain number ofvehicles with the same capacity are available forsimultaneous picking up and delivering goods to a set of customers. Each vehicle departs from central depot at most once and every departing vehicle should return to the central depot after its

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servicing trip. Each node is visited exactly once by exactly one vehicle.The cost and time required to move between all nodes have been set. Also the amount of goods that should be picked up or delivered in each node is specified. A time window is considered for each node. The time window constraint signifies that each customer should be served during a distinct period to prevent accruing any penalties. Each of per unit time earliness and per unit time tardiness has its own penalty.

To perform delivery and pickup processes, a set of workers with definite and different types of ability, wage and availability is assumed. This paper mainly aims at allocating workers to vehicles and also assigning the vehicles to routes so that all the customers' requirements arefulfilled and total cost of transportation, wage of workers and penalties are minimized. The allocated workers should have the ability to pick up and deliver the demands of customers that are assigned to them. The required time for going through each route should not exceed the available time of each of its allocated workers. Capacity constraints of vehicles must be considered. The following notationsare used throughout this paper:

Sets:

J: set of all nodes except central depot.
J_o: set of all nodes including central depot
V: set of vehicles
W: set of worker types

Input parameters:

Cap: vehicle capacity
d_j: delivery amount/weight/volume demanded by node j
p_j: pickup amount/weight/volume of node j
n: number of nodes except central depot
M: sufficiently large number
f_j: penalty of node j for per unit time tardiness
e_j: penalty of node j for per unit time earliness
tc_{ij}: transportation cost from node i to node j
t_j: length of visit in node j (t_0=0)
et_j: earliest admissible time for servicing node j without including penalty
lt_j: latest admissible time for servicing node j without including penalty
Aw_w: number of available workers type w
S_w: per unit time wage of worker type w
At_w: available time for each worker type w
npd_w: maximum amount/weight/volume of goods that each worker type w is capable to load or unload in a node
dt_{ij}: time for the vehicle to move from node i to node j
mw^v: maximum number of workers that can be settled in vehicle v
c_v: setup cost of vehicle v

Decision variables:

l'_v: load of vehicle v while leaving the depot

l_j: load of the related vehicle after servicing node j
a_j: arrival time at node j (a_0=0)
n^v_w: number of allocated worker type w to vehicle v
s_j: variable used to avoid sub-tours, can be interpreted as position of node j ∈ J in the route
x^v_{ij} : is equal to 1 if vehicle v moves from node i to node j and otherwise is equal to zero
n'^v_w :is equal to 1 if any worker type w gets allocated to vehicle v and otherwise is equal to zero
z_j : is equal to 1 if earliness occurs in node j and otherwise is equal to zero
z'_j:is equal to 1 if delay occurs in node j and otherwise is equal to zero

2.1. Mathematical model

$$Min \sum_{i\in J_o}\sum_{j\in J_o}\sum_{v\in V} tc_{ij}x^v_{ij} + \sum_{j\in J} e_j z_j\left(et_j - a_j\right) +$$
$$\sum_{j\in J} f_j z'_j\left(a_j - lt_j\right) +$$
$$\sum_{v\in V}\sum_{w\in W}\sum_{j\in J} x^v_{j0} n^v_w s_w\left(a_j + t_j + dt_{j0}\right) +$$
$$\sum_{j\in J}\sum_{v\in V} c_v x^v_{oj} \quad (1$$

Subject to:

$$\sum_{i\in J_o}\sum_{v\in V} x^v_{ij} = 1 \;\forall j\in J \quad (2$$

$$\sum_{i\in J_o, i\neq k} x^v_{ik} = \sum_{j\in J_o, j\neq k} x^v_{kj} \;\forall k\in J \;\; \forall v\in V \quad (3$$

$$\sum_{j\in J} x^v_{0j} \le 1 \quad \forall v\in V \quad (4$$

$$l'_v = \sum_{i\in J_o}\sum_{j\in J, j\neq i} d_j x^v_{ij} \;\forall v\in V \quad (5$$

$$l_j \ge l'_v - d_j + p_j - M\left(1 - x^v_{0j}\right) \forall v\in V, \;\; \forall j\in J \quad (6$$

$$l_j \le l'_v - d_j + p_j + M\left(1 - x^v_{0j}\right) \forall v\in V \;\; \forall j\in J \quad (7$$

$$l_j \ge l_i - d_j + p_j - M\left(1 - \sum_{v\in V} x^v_{ij}\right) \forall i,j\in J \;, \;\; j\neq i \quad (8$$

$$l_j \le l_i - d_j + p_j + M\left(1 - \sum_{v\in V} x^v_{ij}\right) \forall i,j\in J \;, j\neq i \quad (9$$

$$l'_v \le cap \;\forall v\in V \quad (10$$

$$l_j \le cap \;\forall j\in J \quad (11$$

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$$\mathrm{s_j} \geq \mathrm{s_i} + 1 - \mathrm{n}\left(1 - \sum_{v \in V} x_{ij}^{v}\right) \forall i, j \in J \qquad (12$$

$$a_j = \sum_{v \in V} \sum_{i \in J_o, i \neq j} (a_i + t_i + dt_{ij}) x_{ij}^{v} \; \forall j \in J \qquad (13$$

$$M\, z_j \geq \mathrm{et}_j - a_j \; \forall j \in J \qquad (14$$

$$-M\,(et_j - a_j) < M(1 - z_j)(a_j - et_j) \qquad \forall j \in J \qquad (15$$

$$\mathrm{M}(1 - z'_j) \geq lt_j - a_j \; \forall j \in J \qquad (16$$

$$-M\,(lt_j - a_j) < M\, z'_j (a_j - lt_j) \; \forall j \in J \qquad (17$$

$$d_j + p_j \leq \sum_{i \in J_o, i \neq j} \sum_{v \in V} \sum_{w \in W} \left(npd_w \;\; n_w^v x_{ij}^v\right) \; \forall j \in J \qquad (18$$

$$\sum_{v \in V} n_w^v \leq AW_w \; \forall w \in W \qquad (19$$

$$a_j + t_j + dt_{j0} \leq AT_w + M\left(1 - n'^{v}_{w} x_{j0}^{v}\right) \forall v \in V \;\; \forall j \in J \;\; \forall w \in W \qquad (20$$

$$n_w^v \leq M\, n'^{v}_{w} \; \forall v \in V \;\; \forall w \in W \qquad (21$$

$$n'^{v}_{w} \leq n_w^v \; \forall v \in V \;\; \forall w \in W \qquad (22$$

$$\sum_{w \in W} n_w^v \leq mw^v \; \forall v \in V \qquad (23$$

$$x_{ij}^{v}, n'^{v}_{w}, z'_j, z_j \in \{0,1\} \& n_w^v\,,\; s_j \geq 0: integer \; \forall v \in V \;\; \forall i, j \in J \;\; \forall w \in W \qquad (24$$

The objective function given in equation (1) is a nonlinear equation. It consists of several cost items as follows:

The first term representstransportation cost.The second term count’s an earliness penalty if the arrival time of the vehicle at a node is less than a customer's time window limit. The third term counts a tardiness penalty if the arrival time of the vehicle exceeds a customer's time window limit. The forth term represents the wage of workers. Computation of each worker's wage depends on the travel time of vehicle that the worker is assigned to.For each vehicle its traveltime uses summation of the followings: 1-the arrival time at the final node in its rout justbefore coming back to the central depot, 2- the length of the visit in that node, and 3- the time for the vehicle to return from its final visiting node to the central depot. Finallythe fifth term represents the setup cost of vehicles.

Constraint (2) ensures that each node is served exactly once and exactly by one vehicle. Constraint (3) ensures that for each node, same vehicle arrives at and leaves the node.

Constraint (4) expresses that each vehicle should notexit central depot more than once.Calculation of initial vehicle load is shown in constraint (5). Each vehicle's initial load is the accumulated demands of all nodes that aresupposed to be delivered by that vehicle. Constraints(6) and (7) balance the load of vehicle before and after servicing its first node in its rout. The load balancing between every other two consecutive nodes for each vehicle is shown in constraints (8) and (9). Constraints(10) and (11) impose capacity constraints. Constraint (12) ensures sub-tour elimination. The arrival time at a node is represented in constraint (13).Constraints (14) and (15) show that if earliness occurs, proportional penalty will be appeared in objective function and in the same wayConstraints (16) and (17) ensures penalty

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including if tardiness occurs. Constraint (18) shows that the amount/weight/volume of loaded and unloaded products in a certain node do not exceed the total ability of its assigned workers. Constraint (19) ensures that the number of workers of each type, servicing customers must not be greater than the number of available workers of that type. Constraint (20) represents that the travel time for each route should not be greater than the available time of the assigned workers. Constraints (21) and (22) show the state of worker allocation of each type in each vehicle. Constraint (23) represents the limitation of maximum number of allocated workers to each vehicle which usually depend on the vehicle structure or its capacity for labor force.
Constraint (24) shows the state of decision variables.

2.2. Linearization of the proposed model

The proposed model is a nonlinear integer programming model because of the nonlinear terms (2),(3) and (4) in the objective function and also constraints (13), (15), (17), (18) and (20). To linearize these nonlinear terms, following substitutive variables are used:

$Y_j = Z_j a_j \ \forall j \in J$

$B_j = Z'_j a_j \ \forall j \in J$

$H_{ij}^v = a_i X_{ij}^v \ \forall v \in V \ \ \forall i, j \in J$

$R_{ijw}^v = n_w^v X_{ij}^v \ \forall v \in V \quad \forall i, j \in J \quad \forall w \in W$

$U_{j0w}^v = n'^v_w X_{jo}^v \ \forall v \in V \quad \forall j \in J \quad \forall w \in W$

By considering these equations, the following constraints should be added to the mathematical model:

$Y_j \leq \ a_j + M(1 - Z_j) \quad \forall j \in J$ (26

$Y_j \geq \ a_j - M(1 - Z_j) \ \forall j \in J$ (27

$Y_j \leq \ M\, Z_j \ \forall j \in J$ (28

$B_j \leq \ a_j + M(1 - Z'_j) \ \forall j \in J$ (29

$B_j \geq \ a_j - M(1 - Z'_j) \ \forall j \in J$ (30

$B_j \leq \ M\, Z'_j \ \forall j \in J$ (31

$H_{ij}^v \leq \ a_i + M(1 - X_{ij}^v) \ \forall v \in V \ \ \forall i, j \in J$ (32

$H_{ij}^v \geq \ a_i - M\left(1 - X_{ij}^v\right) \ \forall v \in V \ \ \forall i, j \in J$ (33

$H_{ij}^v \leq \ M\, X_{ij}^v \ \forall v \in V \ \ \forall i, j \in J$ (34

$R_{ijw}^v \leq \ n_w^v + M\left(1 - X_{ij}^v\right) \ \forall v \in V, \ \forall \ i, j \in J, \ \forall w \in W$ (35

$R_{ijw}^v \geq \ n_w^v - M(1 - X_{ij}^v) \ \forall v \in V, \ \forall i, j \in J, \ \ \forall w \in W$ (36

$R_{ijw}^v \leq \ M\, X_{ij}^v \ \forall v \in V, \ \ \forall i, j \in J, \ \ \forall w \in W$ (37

$U_{j0w}^v \leq \frac{X_{j0}^v + n'^v_w}{2} \ \forall v \in V \quad \forall \ j \in J \quad \forall w \in W$ (38

$U_{j0w}^v \geq X_{j0}^v + n'^v_w - 1 \ \ \forall v \in V \quad \forall j \in J \quad \forall w \in W$(39

In addition to the changes in objective function, nonlinear constraints (13), (15), (17), (18) and (20) should be replaced by the following constraints, respectively:

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$a_j = \sum_{v\in V}\sum_{i\in J_o, i\neq j}(H_{ij}^v + (t_i + dt_{ij})\, x_{ij}^v)\ \ \forall j \in J$ (40

$-M\,(et_j - a_j) \leq \mathrm{M}(a_j - et_j) - \mathrm{M}(Y_j - z_j et_j)\ \forall j \in J$ (41

$-M\,(lt_j - a_j) \leq \mathrm{M}\,(B_j - z'_j lt_j)\ \forall j \in J$ (42

$d_j + p_j \leq \sum_{i\in J_o, i\neq j}\sum_{v\in V}\sum_{w\in W}(npd_w R_{ijw}^v)\ \forall j \in J$ (43

$a_j + t_j + dt_{jo} \leq AT_w + M(1 - U_{jow}^v)\ \forall j \in J$ (44

So the final mathematical model to handle with VRPSPD-TW-WA problems is as follows:

Min Eq (1) +

$$\sum_{j\in J} e_j\,(z_j\, et_j - Y_j) + \sum_{j\in J} f_j\,(B_j - z'_j\, lt_j) + \sum_{v\in V}\sum_{w\in W}\sum_{j\in J} R_{j0w}^v s_w (a_j + t_j + dt_{j0}) + \sum_{j\in J}\sum_{v\in V} c_v x_{oj}^v \quad (45$$

Subject to:

(2) – (12), (14), (16), (19), (21) – (44)

$U_{j0w}^v \in \{0,1\}$, $R_{ijw}^v \geq 0: integer$

, $Y_j, B_j, H_{ij}^v \geq 0$

$: real$ $\forall v \in V\ \ \forall i, j \in J\ \ \forall w \in W$ (46

Note that the forth term of the objective function is still nonlinear because of multiplying an integer variable (R_{j0w}^v) by a real one (a_j).

3. Numerical examples

The proposed model in this paper, coded in LINGO9 and runs on a core i5-4GB of RAM processor, has been solved for 2 types of small and medium sized instances and we will consider both of them.

In small size, VRPSPD-TW-WA problem is assumed with 5 customers, 3 vehicles, and 2 types of workers and it is considered with 10 customers, 4 vehicles, and 5 types of workers in the medium size. The other input parameters are randomly selected with uniform distribution on specified periods. All these parameters for the examples are shown in Table 1.

	Problem1	Problem2
Nodes	5	10
Vehicles	3	4
Capacity	200	50
Workers	2	5
	Uniform(100,250)	Uniform(100,250)
	Uniform(10,25)	Uniform(10,25)
	Uniform(0,50)	Uniform(10,30)

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	Uniform(0,50)	Uniform(5,20)
	Uniform(0,50)	Uniform(0,5)
	Uniform(0,50)	Uniform(0,100)
	Uniform(0,50)	Uniform(0,10)
	Uniform(0,100)	Uniform(0,20)
	Uniform(0,200)	Uniform(0,100)
	Uniform(1,5)	Uniform(1,5)
	Uniform(1000,5000)	Uniform(500,1000)
	Uniform(0,20)	Uniform(1,5)
	Uniform(10,30)	Uniform(10,15)
	Uniform(10,20)	Uniform(5,15)
	Uniform(1,10)	Uniform(1,5)

Table 1: input parameters

3.1. Output of the first instance

The optimal vehicle routes have been specified for the first example with the help of software and these routes are given in Table 2. The least possible cost for this routing problem is obtained 6252 monetary unit. Time taken to reach this optimum is closed to 869 minutes.

Vehicle	Rout	Travel time (time unit)
1	0 → 1 → 4 → 0	48
2	0 → 3 → 2 → 5 → 0	62
3	-	0

Table 2: optimal routes of vehicles

The total travel time of vehicles is given in the third column of above table. Also Figure2 shows depiction of this assignment. For example, after vehicle 1 had left the central depot, it served the first and fourth nodes and at the end, it came back to the central depot. It can be seen that each node is visited exactly once by exactly one vehicle.

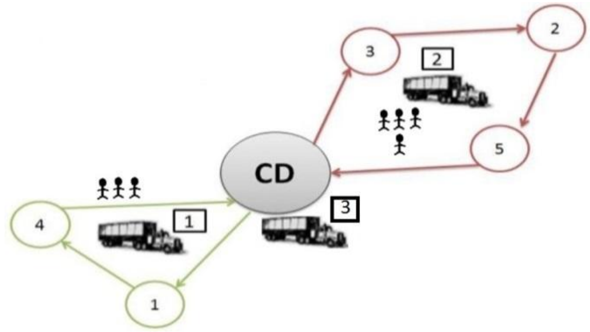

Figure 2:the depiction of the assignment of first instance

The optimal workers' assignment is given in Table 3. And the numbers in the table show the number of workers. For example, 1 worker of type 2 and 3 workers of type 1is assigned to vehicle 2, which results in total number of 4 workers .As can be seen in the results ,no worker is assigned to vehicle 3.On the other hand, there is no need to make use of vehicle 3. We can also see in table 2, there is no rout to be assigned to that vehicle. This means the results areperfectly matched.

vehicle / worker	1	2	3
1	2	3	0
2	1	1	0

Table 3: Workers assignment to the vehicles

Table 4 shows separation of costs:

Transportation cost	1420
Earliest cost	32
Latest cost	0
Wage cost	4750
Setup cost	50
Total costs	6252

Table 4: relevant costs

3. 2. Output of the second instance

After solving the second example with the help of software, the optimal vehicle routes have been specified and these routes are presented in Table 5. The optimal value of the objective function is equal to 9392 monetary unit. Solving this instance takes 1756 minutes for the software.

vehicle	Rout	Travel time(time

		unit)
1	0 → 2 → 9 → 0	57
2	0 → 1 → 10 → 6 → 0	69
3	0 → 8 → 5 → 7 → 0	74
4	0 → 3 → 4 → 0	53

Table 5: optimal routes of vehicles

The total travel time of vehicles is given in the third column of above table. Depiction of this assignment is given in Fig 3. For instance, vehicle 2 leaved the central depot. First of all, it servicednode 1, then node 10 and after that it serviced node 6. Finally, it came back to the central depot. It can be seen that each node is visited exactly once by exactly one vehicle.

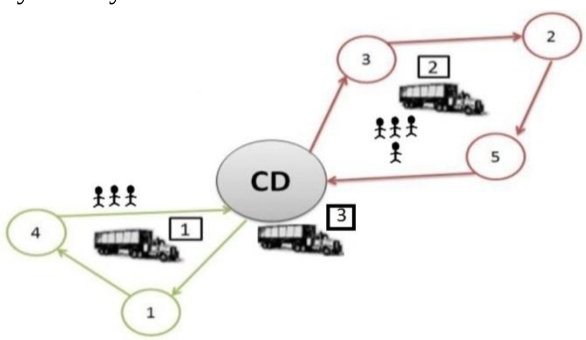

Figure 3:the depiction of the assignment of second instance

The optimal allocation of workers is given in Table 6. And the numbers in the table show the number of workers. For example, 4 workers of type 1 are assigned to vehicle 3 in the optimal solution.

vehicle / worker	1	2	3	4
1	2	1	4	1
2	0	0	0	1
3	0	0	0	0
4	0	2	0	0
5	0	0	0	0

Table 6: workers assignment to the vehicles

Also table 7 shows the transportation cost, tardiness and earliness penalties, wage of workers and also setup cost of vehicles for this example.

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Transportation cost	1650
Earliest cost	49
tardiness cost	121
Wage cost	7342
Setup cost	230
Total costs	9392

Table 7: relevant costs

4. Conclusions

This paper considers the vehicle routing problem with regard to simultaneous pickup and delivery as well as hard time and soft time windows. In order to make the proposed model more utilitarian, manpower/workers assignment is discussed too. The proposed model has been solved for small and medium sized instances in a reasonable solving time. It is obvious that whenever the size of problem increases due to the rapid growth in the number of constraints and variables, the time taken to solve the model increases dramatically. In such a manner it takes more than3 days to solve an example with 15 customers, 6 vehicles, and 5 types of workersrunning on a core i5-4GB of RAM processor.

Hence it is strongly recommended to provide and implement heuristic and meta heuristic methods for large sized examples to get to an even closed-optimal solution in a reasonable computational time. Therefor it can be a source of future research.

5. References

[1] Dantzig, G. B., &Ramser, R. H. (1959).The truck dispatching problem. ManagementScience, 6, 80–91

[2] A. SerdarTasan , Mitsuo Gen , A genetic algorithm based approach to vehicle routing problem with simultaneous pick-up and deliveries, Computers & Industrial Engineering (2012)

[3] Toth, P., & Vigo, D. (2001). The vehicle routing problem, monographs on discrete mathematics and applications. Philadelphia: SIAM.

[4] Kolen, A.W.J., Kan, A.H.G.R., Trienekens, H.W.J.M., 1987. Vehicle routing with time windows. Operations Research 35, 266–273.

[5] Desrochers, M., Desrosiers, J., Solomon, M.M., 1992. A new optimization algorithm for the vehicle routing problem with time windows. Operations Research 40, 342–354.

[6] Kohl, N., Madsen, O.B.G., 1997. An optimization algorithm for the vehicle routing problem with time windows based on Lagrangian relaxation. Operations Research 45, 395–406.

[7] Tagmouti, M., Gendreau, M., &Potvin, J. Y. (2007). Arc routing problem with time-dependent service costs. European Journal of Operational Research, 181, 30-39.

[8] Taniguchi, E., Thompson, R. G., Yamada, T., &Duin, R. V. (2001). City logistics: Network modeling and intelligent transport systems. Pergamon, Oxford.

[9] Yamada, T., Taniguchi, E., &Itoh, Y. (2001). Co-operative vehicle routing model with optimal location of logistics terminals.In E. Taniguchi, &R. G. Thompson (Eds.), City logistics II (pp. 139-153). Institute for City Logistics, Japan

[10] Qureshi AG, Hanaoka S. Analysis of the effects of cooperative delivery system in Bangkok. In: Taniguchi E, Thompson RG, editors. Recent Advances in City Logistics, Elsevier, Oxford; 2005, p. 59-73.

[11] Ali GulQureshi et al, A microsimulation based analysis of exact solution of dynamic vehicle routing with soft time windows ,Procedia - Social and Behavioral Sciences 39 (2012) 205 – 216

[12] Qureshi AG, Taniguchi E, Yamada T. An exact solution approach for vehicle routing and scheduling problems with soft time

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