CLARK WRIGHT SAVING ALGORITHM MODEL DEVELOPMENT FOR VEHICLE ROUTING PROBLEM WITH TIME WINDOWS

by Dewi Dian Retno Sari

Submission date: 20-Apr-2023 10:54AM (UTC+0700)
Submission ID: 2069995446
File name: 21pi-Clark_wright_saving_algorithm.pdf (4.64M)
Word count: 2569
Character count: 10534

0064

CLARK WRIGHT SAVING ALGORITHM MODEL DEVELOPMENT FOR VEHICLE ROUTING PROBLEM WITH TIME WINDOWS

ICLT 2009

Dian Retno, Dini Endah, and Anastasia L. Maukar
Industrial Engineering Department
Widya Mandala Catholic University Surabaya, Indonesia
Email: dini_endah@yahoo.com, dessi@mail.wima.ac.id

In this paper we proposed a developed Clarke Wright saving Algorithm for asymmetric capacitated with different capacity vehicle within the time window to overcome the lack of Clarke Wright saving algorithm with the subject of minimization travel distance.

THEORY

The objective of the savings method is to minimize the total distance traveled by all vehicles and to minimize indirectly the number of vehicle needed to serve all stops. The logic of the method is to begin with a dummy vehicle serving each stop and returning to the depot.

The Clarke Wright Savings algorithm as follows"

1. Label the customers as cities 1,2,…, n and let the warehouse be city 0.
2. Determine the cost c_{ij} to travel between all pair of cities and the warehouse i =0,2,..,n; j=0,..,n.
3. Select the warehouse as the central city
4. Calculate the saving $S_{ij} = c_{i0}+c_{0j}-c_{ij}$ for all pairs of cities (customer) i,j (i=1,2,…,n; j = 1,2,…,n; $i \neq j$
5. Order the savings, S_{ij}, from the largest to smallest
6. Starting with the largest savings, do the following:
   a. If the linking cities i and j results in a feasible route, then add this link to the route; if not , reject the link
   b. Try the next savings in the list and repeat (a). Do not break any links formed earlier, start new routes when necessary, and stop when all cities are on a route.

CLARKE WRIGHT ALGORITHM DEVELOPMENT

The proposed algorithm that has been developed as follows:

1. Input customer, customer demand, distance between customers, distance between depot and customer, the number of vehicles, vehicle's capacity, average velocity, time window, and loading-unloading time.
2. Calculate the *saving* $S_{ij} = c_{ik} + c_{kj} - c_{ij}$ for i = 1,2,3,…n, j = 1,2,3,…n, $i \neq k$, $j \neq k$, $i \neq j$.
3. Delete negative *Saving*
4. Sort vehicle capacity in decreasing order
5. For each vehicle:
   a. Delete path which accumulated customer demand in all nodes in the path exceeds vehicle capacity and total time spending for delivery bigger than time window.
   b. For each customer:
      1. Find the list of customer on the list of path.
      2. If there is customer in the list of customer then proceed to step 5.b.3. if not, go to step 5.b.4.
      3. Proceed with the next customer.
      4. Sequence the customer into the route then proceed 5.f
   c. Sort saving in decreasing order
   d. Schedule the path with the largest saving as a vehicle basic route.
   e. For each path:
      1. If there is a possibility for combine path with basic route, then proceed to step 5.e.2. If it is not, then proceed to step 5.e.3.
      2. Combine with basic route, reduce the vehicle capacity with the allocated customer demand for all nodes in the path.
      3. Proceed to the next path.
   f. Check vehicle capacity and total duration of vehicle trips
   g. Delete all paths from the first route
   h. Repeat step (a) to (g) for the next route
6. Calculate distance for all routes.

The above model will prioritize the largest vehicle's capacity to be firstly assigned. This is consistent to the greedy algorithm concept that tries to maximize profit (represented by 'saving') due to joining locations result. By assigning the largest vehicle's capacity first, more chance to join as many locations as possible to maximize saving.

NUMERICAL EXAMPLE

1 Input data

Input data for the this problem are distances between depot and customer and distance between customers, and customer demand shown as table 1 and table 2 below.

TABLE 1
DISTANCES BETWEEN CUSTOMERS AND BETWEEN DEPOT (0) AND CUSTOMERS (IN KM)

	0	1	2	3	4	5	6	7	8	9
0	0	15	20	19	9	16	12	8	16	19
1	16	0	12	30	28	20	7	14	11	13
2	25	10	0	17	11	15	15	14	32	16
3	13	31	11	0	7	18	3	25	25	25
4	14	21	9	11	0	8	4	11	24	13
5	13	18	13	15	5	0	9	20	19	14
6	11	6	12	5	3	7	0	21	17	13
7	10	12	15	22	13	22	18	0	11	11
8	14	12	30	29	25	21	15	13	0	28
9	20	10	15	20	19	9	16	12	31	0

TABLE 2
CUSTOMER DEMAND

Customer	1	2	3	4	5	6	7	8	9
Demand	30	18	27	25	21	19	10	20	17

It is assumed that:
a. Number of vehicles = 2
b. Capacity of vehicle 1 = 120 units
c. Capacity of vehicle 2 = 80 units
d. Average velocity = 40 kms/hour
e. Loading/unloading time = 2 minutes/unit.
f. Time window = 10.00 am-16.00 pm (6 hours = 360 minutes)

2 Calculate savings.

The calculation is used the formula:

$S_{ij} = c_{ik} + c_{kj} - c_{ij}$, for i = 1,2,3,…n, j = 1,2,3,…n, i ≠ k, j ≠ k, i ≠ j.

$S_{12} = 16 + 20 - 12 = 24$
$S_{13} = 16 + 19 - 30 = 5$
$S_{14} = -3$
$S_{15} = 12$
$S_{16} = 21$
$S_{17} = 10$
$S_{18} = 21$
$S_{19} = 22$
$S_{21} = 30$
$S_{23} = 27$
$S_{24} = 23$
$S_{25} = 4$
$S_{26} = 22$
$S_{27} = 19$
$S_{28} = 9$

$S_{29} = 28$
$S_{31} = -3$
$S_{32} = 22$
$S_{34} = 15$
$S_{35} = 11$
$S_{36} = 22$
$S_{37} = -4$
$S_{38} = 4$
$S_{39} = 7$
$S_{41} = 8$
$S_{42} = 25$
$S_{43} = 22$
$S_{45} = 22$
$S_{46} = 22$

$S_{47} = 11$
$S_{48} = 6$
$S_{49} = 20$
$S_{51} = 10$
$S_{52} = 20$
$S_{53} = 17$
$S_{54} = 17$
$S_{56} = 16$
$S_{57} = 1$
$S_{58} = 10$
$S_{59} = 18$
$S_{61} = 20$
$S_{62} = 19$
$S_{63} = 25$
$S_{64} = 17$

$S_{65} = 20$
$S_{67} = -2$
$S_{68} = 10$
$S_{69} = 17$
$S_{71} = 13$
$S_{72} = 15$
$S_{73} = 7$
$S_{74} = 6$
$S_{75} = 4$
$S_{76} = 4$
$S_{78} = 15$
$S_{79} = 18$
$S_{81} = 17$
$S_{82} = 4$

$S_{83} = 4$
$S_{84} = -2$
$S_{85} = 9$
$S_{86} = 11$
$S_{87} = 9$
$S_{89} = 5$
$S_{91} = 25$
$S_{92} = 25$
$S_{93} = 19$
$S_{94} = 10$
$S_{95} = 27$
$S_{96} = 16$
$S_{97} = 16$
$S_{98} = 5$

3 Delete negative saving.

S_{14}, S_{31}, S_{37}, S_{67} and S_{84} are deleted, because they have negative value.

4 Sort vehicle capacity in decreasing order.

Vehicle 1 has the largest vehicle capacity.

5 For each vehicle (vehicle 1)

a. Delete path with accumulated customer demand in all nodes in the path exceeds vehicle capacity and total duration exceed time window.

Customer demand

Node	Demand (unit)	Node	Demand (unit)	Node	Demand (unit)	Node	Demand (unit)
1- 2	48	2- 4	43	3 -7	37	5 - 7	31
1- 3	57	2 - 5	39	3 - 8	47	5 - 8	41
1- 4	55	2 - 6	37	**3 - 9**	**44**	5 - 9	38
1- 5	51	2 - 7	28	4 - 5	46	6 - 7	29
1- 6	49	2 - 8	38	4 - 6	44	6 - 8	39
1- 7	40	2 - 9	35	4 - 7	35	6 - 9	36
1 - 8	50	3 – 4	52	4 - 8	45	7 - 8	30
1- 9	47	3 – 5	48	4 - 9	42	7 - 9	27
2- 3	45	3 – 6	46	5 - 6	30	8 - 9	37

The accumulated customer demand in all nodes in the path is smaller than vehicle 1 capacity.

Delivery Time

Delivery time is calculated:
Time for S_{ij} = $(c_{ki}+c_{ij}+c_{jk})$ x 1.5 min/km + (demand customer i + demand customer j) x 2 min/unit
For node 1-2 (S_{12}) = ((15+12+25)x1.5)+(48x2) = 174 min

Saving	Time (min)	Saving	Time (min)	Saving	Time (min)	Saving	Time (min)
S_{12}	174	S_{34}	164	S_{56}	134	S_{78}	109.5
S_{13}	201	S_{35}	171	S_{57}	131	S_{79}	112.5
S_{14}	195.5	S_{36}	141.5	S_{58}	155.5	S_{81}	166
S_{15}	174	S_{37}	155	S_{59}	151	S_{82}	182.5
S_{16}	147.5	S_{38}	181	S_{61}	149	S_{83}	181
S_{17}	138.5	S_{39}	184	S_{62}	147.5	S_{84}	176.5
S_{18}	160	S_{41}	179	S_{63}	137	S_{85}	157
S_{19}	166	S_{42}	150.5	S_{64}	131.5	S_{86}	141
S_{21}	165	S_{43}	153.5	S_{65}	128	S_{87}	118.5
S_{23}	165	S_{45}	137	S_{67}	122.5	S_{89}	170
S_{24}	165	S_{46}	124	S_{68}	142.5	S_{91}	161.5
S_{25}	153.5	S_{47}	115	S_{69}	139.5	S_{92}	158.5
S_{26}	150	S_{48}	160.5	S_{71}	134	S_{93}	161.5
S_{27}	143	S_{49}	147	S_{72}	128	S_{94}	162
S_{28}	122	S_{51}	177	S_{73}	138.5	S_{95}	137.5
S_{29}	175	S_{52}	157	S_{74}	122.5	S_{96}	141
S_{31}	154	S_{53}	162	S_{75}	126.5	S_{97}	115.5
S_{32}	172.5	S_{54}	144.5	S_{76}	113.5	S_{98}	170

Duration of each saving does not exceed time window (360 minutes).

b. Find the customer is the remaining paths.
All customers (customer 1 to customer 9) are in the set of paths.

c. Sort savings in decreasing order
$S_{21}, S_{29}, S_{23}, S_{95}, S_{42}, S_{63}, S_{91}, S_{92}, S_{12}, S_{24}, S_{19}, S_{26}, S_{32}, S_{36}, S_{43}, S_{45}, S_{46}, S_{16}, S_{49}, S_{52}, S_{61}, S_{65}, S_{27}, S_{93}, S_{79}, S_{53}, S_{54}, S_{64}, S_{69}, S_{81}, S_{56}, S_{96}, S_{97}, S_{34}, S_{72}, S_{78}, S_{71}, S_{35}, S_{47}, S_{86}, S_{17}, S_{51}, S_{58}, S_{68}, S_{94}, S_{28}, S_{85}, S_{87}, S_{41}, S_{39}, S_{73}, S_{13}, S_{89}, S_{98}, S_{25}, S_{38}, S_{75}, S_{76}, S_{82}, S_{83}, S_{57}$

d. Schedule the path with the largest saving as vehicle basic route
S_{21}: 0-2-1-0 (used capasity = 48 unit, delivery time = 165 minutes)

e. Combine paths
S_{21}: 0-2-1-0 (used capacity = 48 unit, delivery time = 165 minutes)
S_{29}: x
S_{23}: x
S_{95}: x
S_{42} : 0-4-2-1-0 (used capacity = 73 unit, delivery time = 212 minutes)
S_{63}: x
S_{91}: x
S_{92}: x
S_{12}: x
S_{24}: x
S_{19}: 0-4-2-1-9-0 (used capacity = 90 units, delivery time = 241 minutes)
S_{26}: x
S_{32}: x
S_{36}: x
S_{43}: x
S_{45}: x
S_{46}: x
S_{16} : x
S_{49} : x
S_{52} : x
S_{61} : x
S_{65} : x
S_{27} : x
S_{93} : 0-4-2-1-9-3-0 (used capacity = 117 units, delivery time =345 minutes, total distance = 74 kms)

Vehicle 1 route is 0-4-2-1-9-3-0 with total used capacity 117 units, total delivery time 345 minutes, and total distance 74 kms. As remaining capacity of vehicle 1 (3 units) is smaller than the smallest demand customer (10 units), vehicle 2 will be used to cover the next route.

Then delete each path which has been scheduled in vehicle 1. The list of unscheduled route as follows:

$S_{56} = 13 + 12 - 9 = 16$
$S_{57} = 13 + 8 - 20 = 1$
$S_{58} = 13 + 16 - 19 = 10$
$S_{65} = 11 + 16 - 7 = 20$
$S_{68} = 11 + 16 - 17 = 10$
$S_{75} = 10 + 16 - 22 = 4$
$S_{76} = 10 + 12 - 18 = 4$
$S_{78} = 10 + 16 - 11 = 15$
$S_{85} = 14 + 16 - 21 = 9$
$S_{86} = 14 + 12 - 15 = 11$
$S_{87} = 14 + 8 - 13 = 9$

6 For each vehicle (vehicle 2)

a. Delete path for customer with demand bigger than vehicle capacity and total delivery time bigger than time window.

<u>Customer demand</u>

$S_{56} = S_{65} = 40$ unit
$S_{78} = S_{87} = 30$ unit
$S_{58} = S_{85} = 41$ unit
$S_{67} = S_{76} = 29$ unit
$S_{68} = S_{86} = 39$ unit
$S_{57} = S_{75} = 31$ unit

The vehicle 2 capacity is larger than all customer demand of each saving.

Delivery time

Saving	Time (min)	Saving	Time (min)	Saving	Time (min)
S_{56}	134	S_{67}	122.5	S_{78}	109.5
S_{57}	131	S_{68}	142.5	S_{85}	157
S_{58}	155.5	S_{75}	126.5	S_{86}	141
S_{65}	128	S_{76}	113.5	S_{87}	118.5

b. Find the customers in remaining set of paths. Cari *customer* di kumpulan *path* yang tersisa.
All remain customers (customer 5,6,7, and 8) are in the set of path.

c. Sort saving in the decreasing order.
S_{65}, S_{56}, S_{78}, S_{86}, S_{58}, S_{68}, S_{85}, S_{87}, S_{75}, S_{76}, S_{57}

d. Schedule the path with the largest saving as vehicle basic route
S_{65} : 0-6-5-0 (used capacity = 40 units, delivery time = 128 minutes)

e. Combine path
S_{65} : 0-6-5-0 (used capacity = 40 units, delivery time = 128 minutes)
S_{56} :x
S_{78} : x
S_{86} : 0-8-6-5-0(used capacity = 60 units, delivery time = 196.5 minutes)
S_{58} : x
S_{68} : x
S_{85} : x
S_{87} : x
S_{75} : x
S_{76} : x
S_{57} : 0-8-6-5-7-0 (used capacity = 70 unit, delivery time interval =242 minutes, total distance= 68 km)

Total distance

Total distance of vehicle 1 is 74 km and total distance of vehicle 2 is168 km. Total distance for both vehicles is 142 km.

EXPERIMENTAL RESULT

The inputs for experiment are as follows:
Number of customers: 5-10
1. Demand quantity : 25-75 units
2. Distance between Customer: 5-50 kms

Vehicle capacity: 250,125,and 70 units
Time Window : 6 hours
Average Velocity: 40 kms/hours
Loading/Unloading time: 1 minutes

The optimal solution using full enumeration is generated for comparing the development of algorithm's result and validating the developed algorithm. The result can be seen as table 3. It is shown that performance of algorithm that has been developed is 9.4%, on average, below the optimal solution

TABLE 3
EXPERIMENTAL RESULT

Replication	*Customer*	Vehicle	*With Algorihm* Computional Time	Distance	Optimal Computional Time	Distance	% below optimal
1	6	3	0.71"	109	2.57"	104	4.81%
2	6	3	0.61"	135	2.49"	131	3.05%
3	5	3	0.53"	153	0.86"	140	9.29%
4	9	4	0.64"	134	719':2"	105	27.62%
5	10	4	0.67"	218	1440':5"	209	4.31%
6	7	3	0.59"	187	15.74"	154	21.43%
7	8	3	0.58"	135	2':26.54"	131	3.05%
8	7	4	0.57"	99	1':12.26"	92	7.61%
9	6	3	0.54"	88	2.53"	86	2.33%
10	7	3	0.69"	143	16.64"	135	5.93%
11	7	3	0.62"	141	16.01"	120	17.50%
12	5	3	0.52"	108	0.90"	102	5.88%
				Average performance			9.40%

CONCLUSION

The performance of Clarke Wright Saving modification algorithm was 9.4%, on average, below optimal solution.

In this research, we provide infinite number of vehicles with different capacity, thus all customer could be served in the same day. For further research, the finite number of vehicle and the vehicle capacity constraints should be considered in the model.

REFERENCES

Ballou, Ronald H. (1998), Business Logistic Managemenr, 4th Ed. Prentice Hall International Inc.

Bodin et al, (1985), Routing and Scheduling of Vehicles and Crews, Pergamon Press ltd., Great Britain.

Boudali, Imen, et. al, (2005), "An Interactive Distributed Approach for the VRP with Time Windows", International Journal of Simulation, Vol. 6 No 10-11. pp. 48-59.

Endah, Dini et all, (2003), "Design and Application of Technology, Widya Mandala University Surabaya" Vol. 1 pp.10-17

CLARK WRIGHT SAVING ALGORITHM MODEL DEVELOPMENT FOR VEHICLE ROUTING PROBLEM WITH TIME WINDOWS

ORIGINALITY REPORT

7%	4%	5%	2%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	umexpert.um.edu.my Internet Source	2%
2	Submitted to Assumption University Student Paper	2%
3	"Innovations in Electronics and Communication Engineering", Springer Science and Business Media LLC, 2018 Publication	1%
4	Submitted to University of Southampton Student Paper	1%
5	Goyenechea Mayer Goyenechea Irene. "Revision taxonomica de generos Conopsis Gunther y Toluca Kennicott, Reptilia : Colubridae", TESIUNAM, 1995 Publication	1%
6	Setyo Rahaju, Dini Endah, and Dian Retno Sari Dewi. "An Approach to Dealing with Importance Weights of Customer Needs and Customer Dissatisfaction in Quality Function	1%

Deployment Optimization", Advanced Materials Research, 2014.
Publication

Exclude quotes	On	Exclude matches	< 1%
Exclude bibliography	On		