ADAPTING RESEARCH METHODS FOR SOLVING THE VRPTW TO REAL LIFE PROBLEMS.

EVOLUTION OF THE ALADIN METHOD AND IMPLEMENTATION TO A REAL LIFE CASE .

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Presentation outline

- Problem Analysis
- Model Development
- Results
- Conclusions

1. Problem Analysis

VRPTW characteristics

- Central depot and multiple customers geographically dispersed
- Depot with time window
- Customers with variable time windows
- Variable service times for customers
- Limited capacity for all vehicles
- Limited number of vehicles
- Euclidean distances considered
- Goal: Minimize total distance

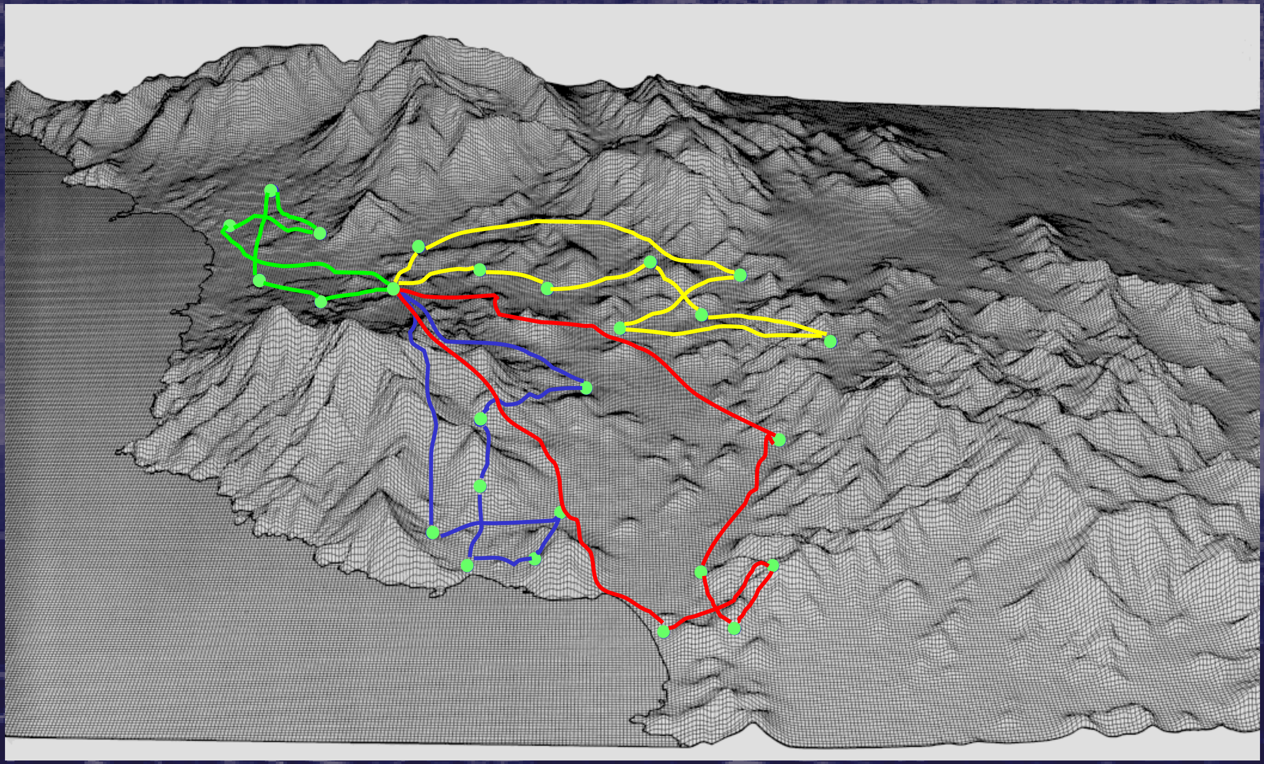
1. **Problem Analysis**

2. Model development

3. Results

4. Conclusions

The Vehicle Routing Problem with Time Windows



● Open Node

● Closed Node

1. **Problem Analysis**

2. Model development

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Mathematical Model for the VRPTW

$$\min \sum_{k\in V}\sum_{i\in N}\sum_{j\in N} c_{ij} x_{ij}^k$$

$$\sum_{k\in V}\sum_{j\in N} x_{ij}^k = 1 \quad \forall i \in N$$

$$\sum_{j\in N} x_{0j}^k = 1 \quad \forall k \in V$$

$$\sum_{i\in N} x_{i0}^k = 1 \quad \forall k \in V$$

$$\sum_{i\in N} x_{ih}^k - \sum_{j\in N} x_{hj}^k = 0 \quad \forall h \in N, \forall k \in V$$

$$\sum_{i\in N} d_i \sum_{j\in N} x_{ij}^k \le q \quad \forall k \in V$$

$$x_{ij}^k (S_i^k + t_{ij} - S_j^k) \le 0 \quad \forall i, j \in N, \forall k \in V$$

$$a_i \le S_i^k \le b_i \quad \forall i \in N, \forall k \in V$$

$$x_{ij}^k = (0{,}1) \quad i, j \in N, \forall k \in V$$

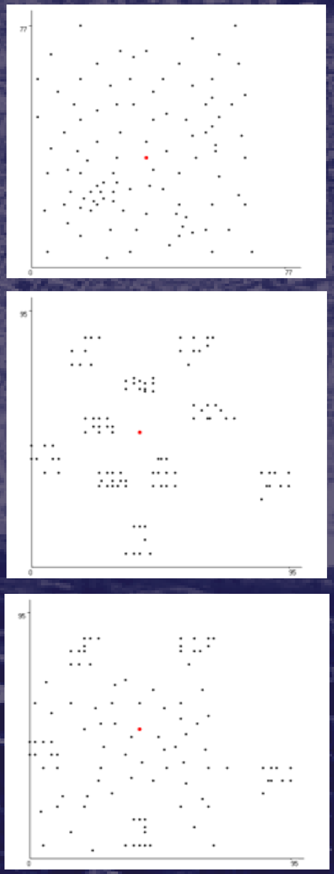
1. **Problem Analysis**
2. Model development
3. Results
4. Conclusions

Solution techniques for the VRPTW

- Heuristics
- Construction methods
    - Solomon (1987)
        - Savings methods
        - Gillett and Miller
        - Insertion I1
        - Insertion I2
        - Insertion I3
    - Potvin and Rousseau (1993)
    - Dullaert (2000 and 2001)
    - Ioannou et al (2001)
    - Bramel and Simchi-Levi (1996)

Solution techniques for the VRPTW

- Improvement Methods
  - Intra-route
  - Inter-route
    - Cyclic transfers
  - Antes and Derigs (1995)
  - Russell (1995)
  - Shaw (1997)
  - Cordone and Wolfer Calvo (1998)
  - Bräysis (2001)
- Meta-heuristics
  - Tabu Search
  - Simulated Annealing
  - Genetic Algorithms
  - Others



VRPTW

Solomon (1987)

2. Model Development

1. Problem Analysis

2. Model development

3. Results

4. Conclusions

Model characteristics

"Paralell construction of the routes in different phases, following different decision rules"

- Deterministic construction model
- Parameters inclusion
- Temporal and spatial criteria
- Basic rules: assignment, addition, single insertion and double insertion

Initial data

r103 - Bloc de notas

Archivo Edición Buscar Ayuda

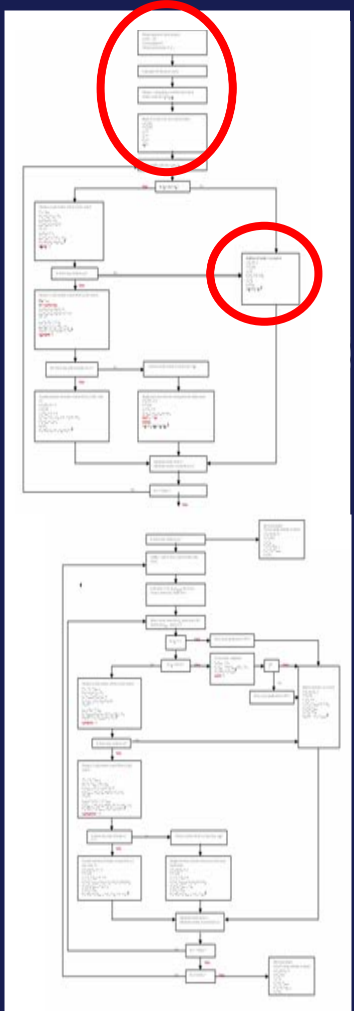
R103

VEHICLE

NUMBER	CAPACITY
25	200

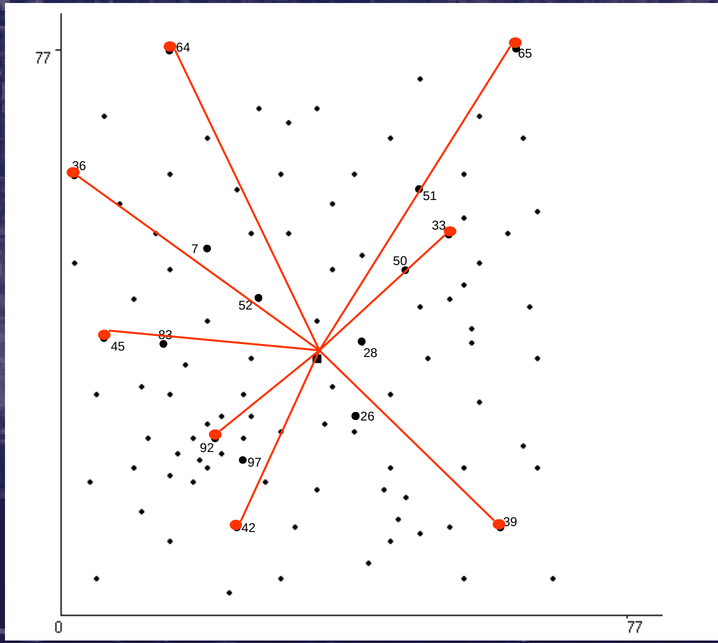
CUSTOMER

CUST NO.	XCOORD.	YCOORD.	DEMAND	READY TIME	DUE DATE	SERVICE TIME
0	35	35	0	0	230	0
1	41	49	10	0	204	10
2	35	17	7	0	202	10
3	55	45	13	0	197	10
4	55	20	19	149	159	10
5	15	30	26	0	199	10
6	25	30	3	99	109	10
7	20	50	5	0	198	10
8	10	43	9	95	105	10
9	55	60	16	97	107	10
10	30	60	16	124	134	10
11	20	65	12	67	77	10
12	50	35	19	0	205	10
13	30	25	23	159	169	10
14	15	10	20	0	187	10
15	30	5	8	61	71	10
16	10	20	19	0	190	10
17	5	30	2	157	167	10
18	20	40	12	0	204	10
19	15	60	17	0	187	10
20	45	65	9	0	188	10
21	45	20	11	0	201	10
22	45	10	18	97	107	10
23	55	5	29	68	78	10
24	65	35	3	0	190	10
25	65	20	6	172	182	10



Initial assignment rule

R103 *R=8, β=1.2 y γ=2*



tc_i

t_{0i}

$h_i = tc_i - t_{0i}$

Direct addition

$LR_k = [0, i]$

$CR_k = [i]$

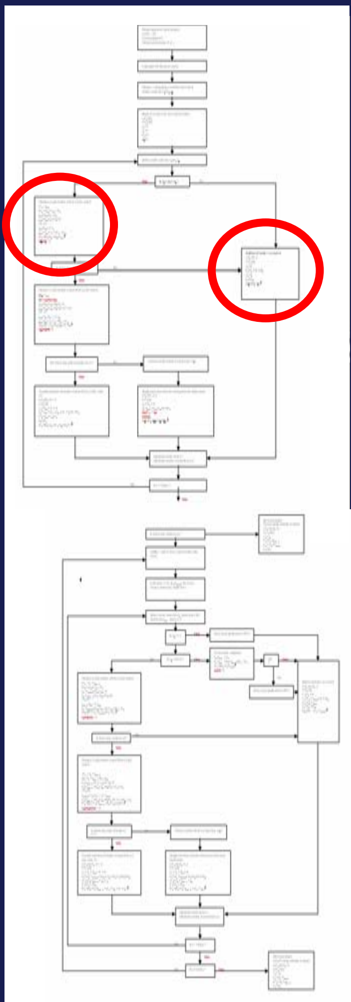
$c_k = d_i$

$tr_k = t_{0i} + ts_i + te_{ki}$

$D_k = t_{0i}$

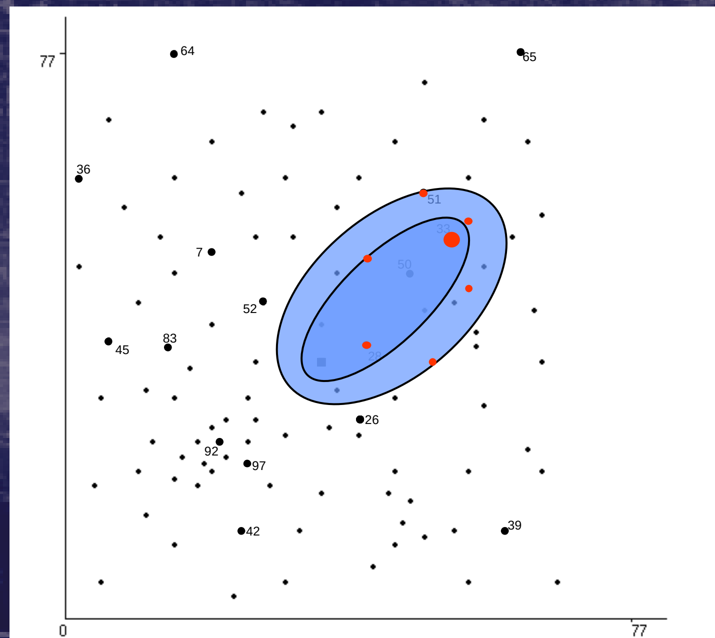
$E_k = te_{ki}$

$te_{ki} = [ta_i - (t_{0i})]^+$



Time gap analysis for possible insertions

R103 $R=8$, $\beta=1.2$ y $\gamma=2$ min $h_i=tc_i-t_{0i}$



L2 creation

$ta_m \leq t_{om}$

$ta_m + ts_m + t_{mi} \leq tc_i$

$t_{0m}+ts_m+t_{mi} \leq tc_i$

$t_{0m}+ts_m+t_{mi}+nh_i = tc_i$

$nh_i \geq 0$

$t_{0m}+t_{mi} \leq \beta \cdot t_{0i}$

$t_{0m} + t_{mi} + t_{i0} + te_{ki} \leq tc_0$

$te_{ki}=[ta_i-(t_{0m} + ts_m+t_{mi})]^+$

$d_m+d_i \leq q$

Direct addition

$LR_k=[0, i]$

$CR_k=[i]$

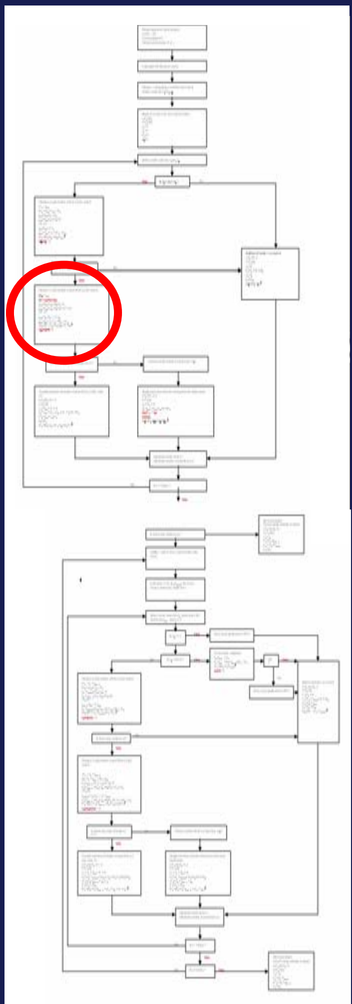
$c_k=d_i$

$tr_k=t_{0i} + ts_i + te_{ki}$

$D_k=t_{0i}$

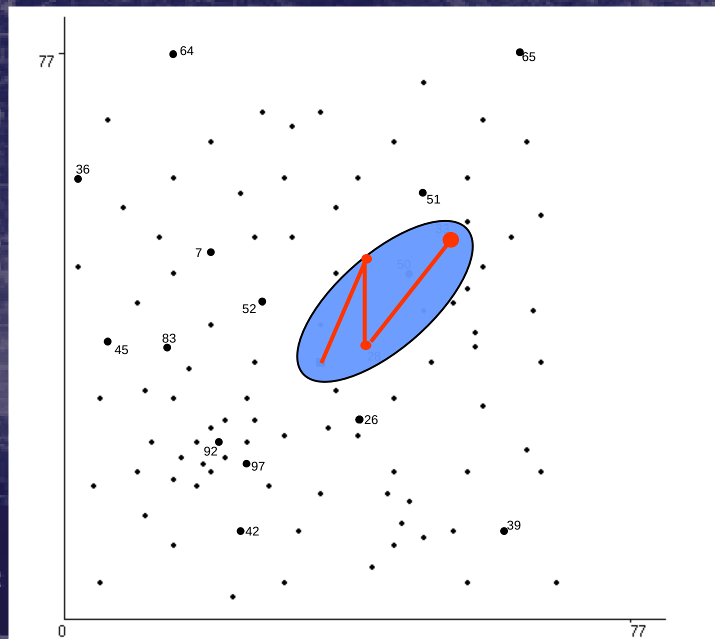
$E_k=te_{ki}$

$te_{ki}=[ta_i-(t_{0i})]^+$



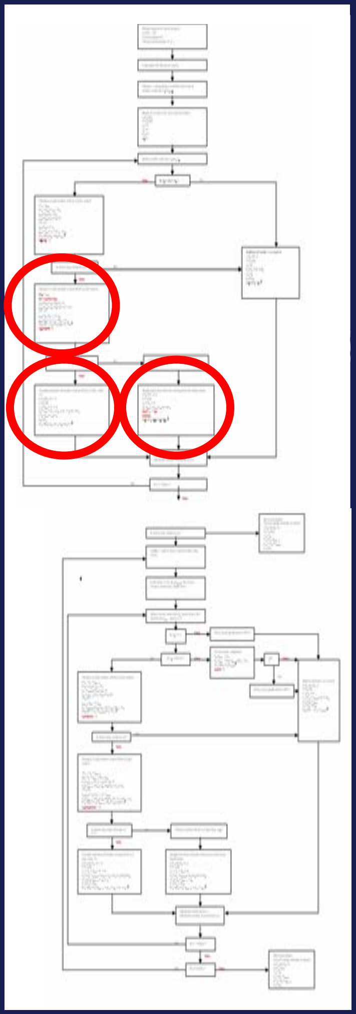
Double Insertion Requirements

R103 *R=8, β=1.2 y γ=2*



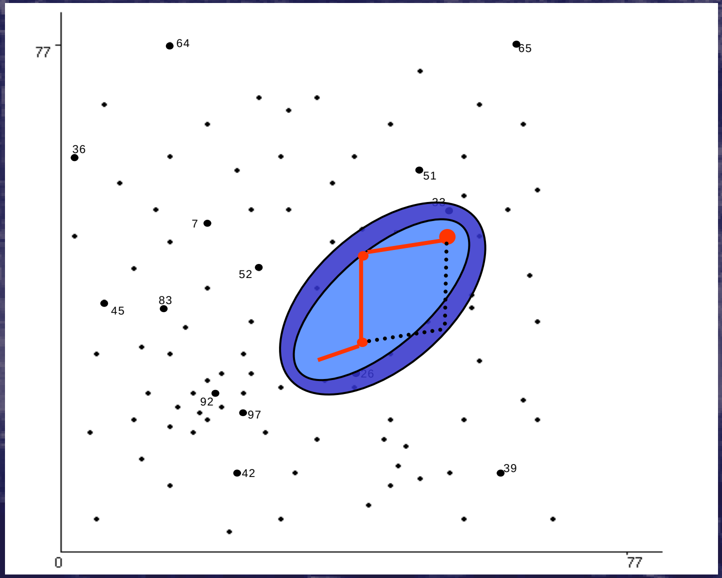
L3 creation

$$ta_m \le t_{0m}$$
$$ta_l \le t_{om}+ts_m+t_{ml}$$
$$t_{0m}+ts_m+t_{ml}+ts_l+t_{li} \le tc_i$$
$$t_{0m}+ts_m+t_{ml}+ts_l+t_{li}+nh'_i = tc_i$$
$$nh'_i \ge 0$$
$$t_{0m}+t_{ml}+t_{li} \le \gamma \cdot \beta \cdot t_{0i}$$
$$t_{0m}+t_{ml}+t_{li}+t_{i0}+te_{ki} \le tc_0$$
$$te_{ki}=[ta_i-(t_{0m}+ts_m+t_{ml}+ts_l+t_{li})]^+$$
$$d_m+d_l+d_i \le q$$



Double or Single insertion procedures

R103 *R=8, β=1.2 y γ=2*



L3 Creation

$ta_m \leq t_{0m}$

$ta_l \leq t_{om}+ts_m+t_{ml}$

$t_{0m}+ts_m+t_{ml}+ts_l+t_{li} \leq tc_i$

$t_{0m}+ts_m+t_{ml}+ts_l+t_{li}+nh'_i = tc_i$

$nh'_i \geq 0$

$t_{0m}+t_{ml}+t_{li} \leq \gamma \cdot \beta \cdot t_{0i}$

$t_{0m}+t_{ml}+t_{li}+t_{i0}+te_{ki} \leq tc_0$

$te_{ki}=[ta_i-(t_{0m}+ts_m+t_{ml}+ts_l+t_{li})]^+$

$d_m+d_l+d_i \leq q$

Double Insertion

$LR_k=[0, m, l, i]$

$CR_k=[i]$

$c_k=d_m+d_l+d_i$

$tr_k=t_{0m}+ts_m+t_{ml}+ts_l+t_{li}+ts_i+te_{ki}$

$D_k=t_{0m}+t_{ml}+t_{li}$

$E_k=te_{ki}$

$te_{ki}=[ta_i-(t_{0m}+ts_m+t_{ml}+ts_l+t_{li})]^+$

Single Insertion

$LR_k=[0, m, i]$

$CR_k=[i]$

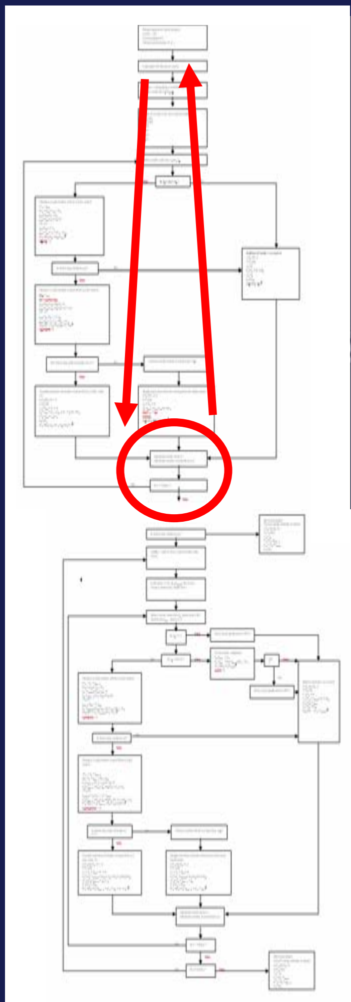
$c_k=d_m+d_i$

$tr_k=t_{0m}+ts_m+t_{mi}+ts_i+te_{ki}$

$D_k=t_{0m}+t_{mi}$

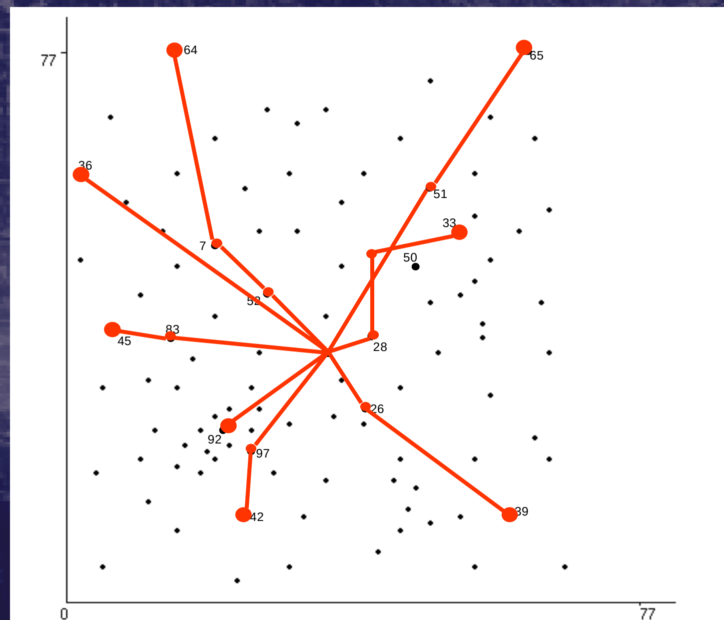
$E_k=te_{ki}$

$te_{ki}=[ta_i-[t_{0m}+ts_m+t_{mi})]^+$



End of first phase

R103 *R=8, β=1.2* y *γ=2*



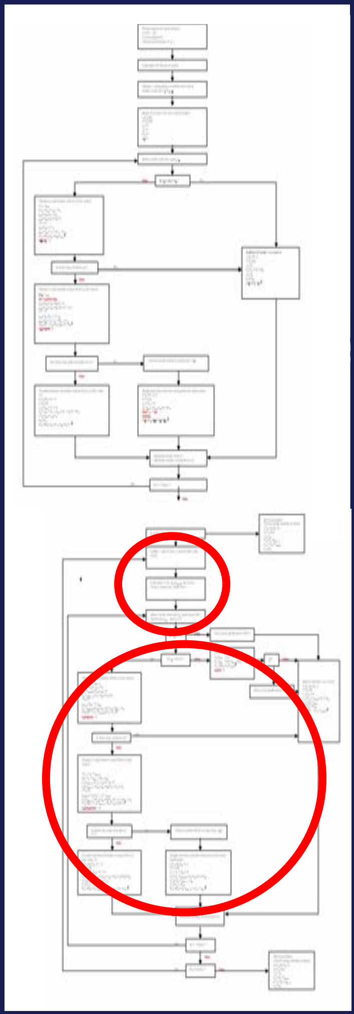
End of first phase

Routes uptdate

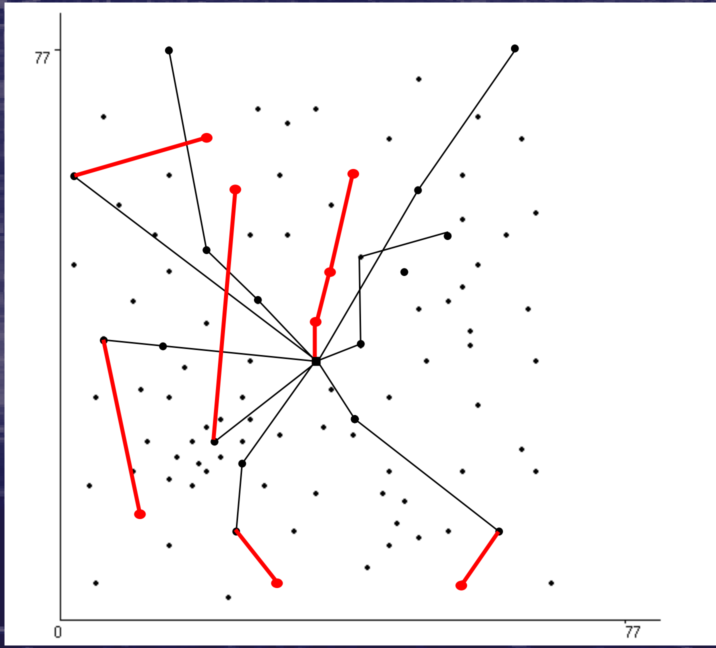
New selection of *R* nodes with

min tc_i

Second and further assignments



R103 *R=8, β=1.2 y γ=2*



min tc_i

Beginning of second and further phases

One by one all nodes are assigned to the nearest vehicles, given that these arrive on time.

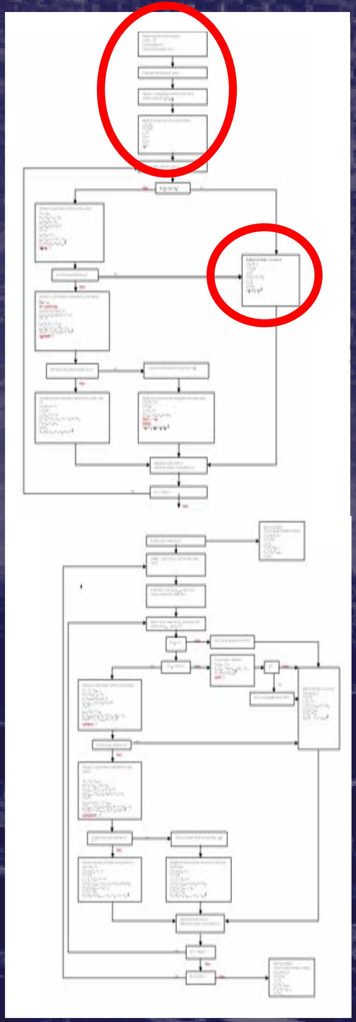
3. Results

Comparison with other construction methods

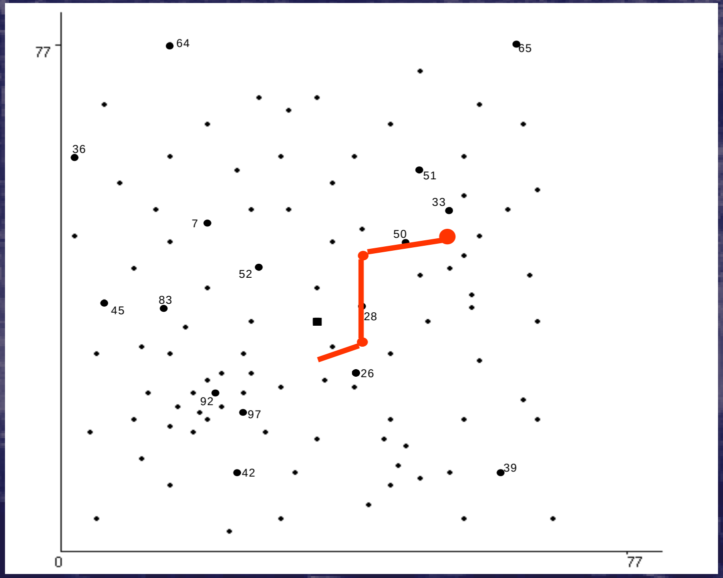
Method	R1		R2		RC1		RC2		C1		C2	
	Dist	NV	Dist	NV	Dist	NV	Dist	NV	Dist	NV	Dist	NV
Clarke and Wright Method	1499	16,60	-	-	-	-	-	-	976	11,70	-	-
Savings, waiting time limit	1517	15,10	-	-	-	-	-	-	987	10,70	-	-
Solomon I1	1437	13,60	1402	3,30	1597	13,50	1682	3,90	952	10,00	692	3,13
Solomon I2	1639	14,50	1471	3,30	1874	14,20	1798	4,10	1050	10,10	921	3,40
Solomon I3	1652	14,10	1475	3,40	1850	14,00	1816	4,00	1103	10,00	1073	3,50
Nearest Neighbour	1600	14,50	1472	3,40	1800	14,20	1755	3,90	1171	10,20	963	3,50
Gillet and Miller Method	1500	14,60	1449	3,20	1804	14,90	1736	4,00	941	10,00	712	3,00
Potvin and Rousseau (1993)	1509	13,30	1387	3,10	1724	13,40	1651	3,60	1343	10,67	797	3,38
Ioannu et al. (2001)	1370	12,67	1310	3,09	1512	12,50	1483	3,50	865	10,00	662	3,13
Guillén et al. (2004)	1955	26,00	1239	8,00	2247	21,00	1573	11,00	1955	25,00	1485	14,00

New Improvements

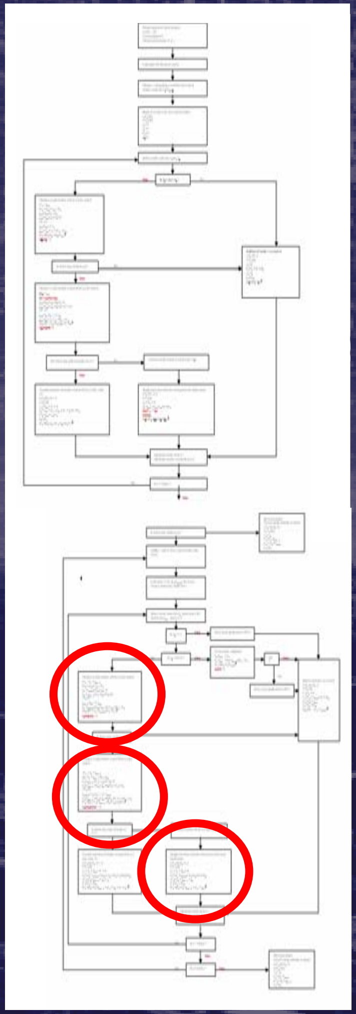
Initial assignment rule: Nodes chose one by one



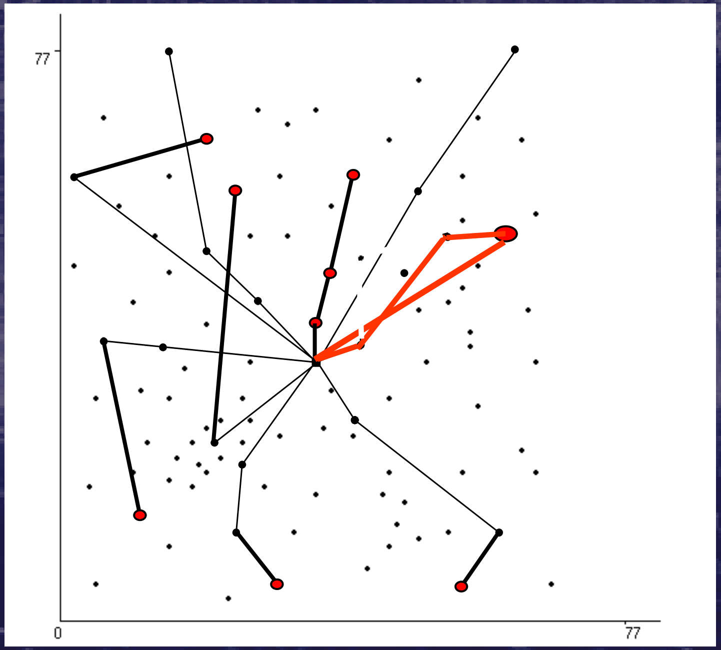
R103



Insertion with elimination of previosly inserted node



R103 *R=1, β=1.2* y *γ=2*



Comparison with other construction methods

Construction Methods	*R1*		*R2*		*RC1*		*RC2*		*C1*		*C2*	
	Dist	NV	Dist	NV	Dist	NV	Dist	NV	Dist	NV	Dist	NV
Clarke and Wright Method	1499	16,60	-	-	-	-	-	-	976	11,70	-	-
Savings, waiting time limit	1517	15,10	-	-	-	-	-	-	987	10,70	-	-
Solomon I1	1437	13,60	1402	3,30	1597	13,50	1682	3,90	952	10,00	692	3,13
Solomon I2	1639	14,50	1471	3,30	1874	14,20	1798	4,10	1050	10,10	921	3,40
Solomon I3	1652	14,10	1475	3,40	1850	14,00	1816	4,00	1103	10,00	1073	3,50
Nearest Neighbour	1600	14,50	1472	3,40	1800	14,20	1755	3,90	1171	10,20	963	3,50
Gillet and Miller Method	1500	14,60	1449	3,20	1804	14,90	1736	4,00	941	10,00	712	3,00
Potvin and Rousseau (1993)	1509	13,30	1387	3,10	1724	13,40	1651	3,60	1343	10,67	797	3,38
Ioannu et al. (2001)	1370	12,67	1310	3,09	1512	12,50	1483	3,50	865	10,00	662	3,13
Guillén et al. (2006)	1955	26,00	1239	8,00	2247	21,00	1573	11,00	1955	25,00	1485	14,00
Guillén et al. (2007)	1386	14,25	1096	5,27	1607	14,12	1293	5,87	925	10,66	705	3,50

Comparison with other improvement methods

Improvement methods	R1		R2		RC1		RC2		C1		C2	
	Dist	**NV**	**Dist**	**NV**	**Dist**	**NV**	**Dist**	**NV**	**Dist**	**NV**	**Dist**	**NV**
Thompson y Psaraftis (1993)	1367	13,1	1299	3,1	1534	13	1672	3,7	916	10	644	3
Potvin et al. (1995)	1381	13,33	1293	3,27	1545	13,25	1595	3,88	902	10	653	3,13
Russell (1995)	1317	12,7	1167	2,9	1523	12,4	1398	3,4	930	10	681	3
Antes y Derigs (1995)	1386	12,8	1367	3,1	1546	12,5	1598	3,4	955	10	717	3
Cordone et al. (1998)	1241	12,5	995	2,91	1408	12,3	1139	3,38	834	10	591	3
Zhu y Lee (1999) 2-int	1469		1330		1680		1700		965		780	
Guillén et al. (2006)	1955	26,00	1239	8,00	2247	21,00	1573	11,0	1955	25,00	1485	14,0
Guillén et al. (2007)	1386	14,25	1096	5,27	1607	14,12	1293	5,87	925	10,66	705	3,50

Comparison with other Tabu Search methods

Tabu Search	R1		R2		RC1		RC2		C1		C2	
	Dist	NV	Dist	NV	Dist	NV	Dist	NV	Dist	NV	Dist	NV
Garcia et al. (1994)	1320	12,9	1229	3,1	1483	12,9	1551	3,9	877	10	602	3
Potvin et al. (1996a)	1295	12,6	1186	3,1	1465	12,6	1476	3,4	850	10	594	3
Taillard et al. (1997)	1220	12,3	1013	3	1381	12,9	1199	3,4	828	10	589	3
De Backer et al. (1997)	1214	14,17	930	5,27	1385	14,25	1099	6,25	829	10	604	3,25
Schulze y Fahle (1999)	1268	12,5	1056	3,1	1396	12,3	1308	3,4	828	10	589	3
Tan et al. (2000)	1266	13,83	1080	3,82	1458	13,63	1293	4,25	870	10	634	3,25
Guillén et al. (2006)	1955	26,00	1239	8,00	2247	21,00	1573	11,0	1955	25,00	1485	14,0
Guillén et al. (2007)	1386	14,25	1096	5,27	1607	14,12	1293	5,87	925	10,6	705	3,50

Comparison with other Simulated Annealing methods

Simulated Annealing	R1		R2		RC1		RC2		C1		C2	
	Dist	NV	Dist	NV	Dist	NV	Dist	NV	Dist	NV	Dist	NV
Thangiah et al. (1994)	1227	12,33	1005	3	1391	12	1173	3,38	830	10	640	3
Chiang et al. (1996)	1308	12,5	1166	2,91	1473	12,38	1393	3,38	909	10	666	3
Tan et al. (2000)	1420	14,5	1278	3,64	1648	14,75	1641	4,25	958	10,11	766	3
Zhu y Lee (1999) SA	1422		1279		1657		1642		943		766	
Guillén et al. (2006)	1955	26,00	1239	8,00	2247	21,00	1573	11,00	1955	25,00	1485	14,00
Guillén et al. (2007)	1386	14,25	1096	5,27	1607	14,12	1293	5,87	925	10,6	705	3,50

Comparison with other Genetic Algorithms

Genetic Algorithms	R1		R2		RC1		RC2		C1		C2	
	Dist	NV	Dist	NV	Dist	NV	Dist	NV	Dist	NV	Dist	NV
Thangiah (1995a)	1300	12,75	1124	3,18	1474	12,5	1411	3,38	892	10	749	3
Potvin et al. (1996)	1296	12,58	1117	3	1446	12,13	1368	3,38	838	10	590	3
Berger et al. (1998)	1261	12,58	1030	3,09	1441	12,13	1284	3,5	834	10	594	3
Bräysy (1999b)	1272	12,58	1053	3,09	1417	12,13	1256	3,38	857	10	624	3
Homberger y Gehring (1999)	1226	12	1034	2,7	1407	11,5	1176	3,3	828,38	10	589	3,25
Gehring et al. (2001)	1217	12	961	2,73	1395	11,5	1139	3,25	828,63	10	590,3	3,25
Berger et al. (2000)	1221	11,92	975	2,73	1389	11,5	1159	3,25	828	10	590	3
Tan et al. (2000)	1314	14,42	1093	5,64	1512	14,63	1282	7	860	10,11	589	
Wee Kit et al. (2001)	1203	12,58	951	3,18	1382	12,75	1132	3,75	833	10	593	
Rahoual et al. (2001)	1362	12,92			1487	12,63			887	10		
Guillén et al. (2006)	1955	26,00	1239	8,00	2247	21,00	1573	11,00	1955	25,00	1485	14,00
Guillén et al. (2007)	1386	14,25	1096	5,27	1607	14,12	1293	5,87	925	10,66	705	3,50

4. Adapting research method to real life problems

Issues

- We need to adapt the distance matrix
- It is necessary to link the algorithm to GIS databases
- We need to locate every customer and link it to the nearest road milestone
- We need to coordinate the demands to the capacity of the vehicles
- These modifications allow the algorithm to solve real life problems

- We are now working with a business partner in order to validate the results
- The obtained results are pretty close to those provided by their software

- **NEXT STEP**: Improve the interfave and the interactivity with the user

Thank you !

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