Universitat Oberta de Catalunya

Greener Fleet Configurations for the Heterogeneous Vehicle Routing Problem with Multiple Capacities and Driving Ranges

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Outline

- ✓ Vehicle Routing Problem with Multiple Driving ranges (VRPMD)
- ✓ Capacitated Vehicle Routing Problem with Multiple Driving ranges (CVRPMD)
- ✓ Proposed solution method
- ✓ Analysis of the results
- ✓ Conclusion and future work

Vehicle Routing Problem with Multiple Driving ranges (VRPMD)

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Routing fleets with multiple driving ranges: Is it possible to use greener fleet configurations?

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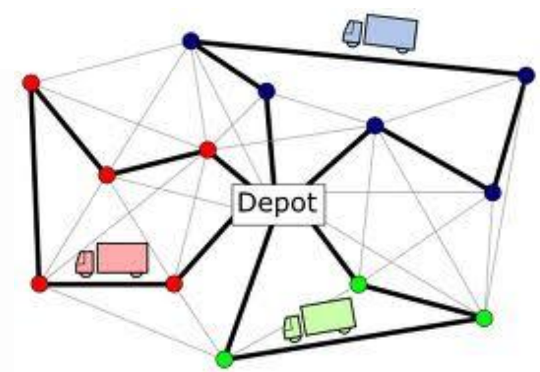
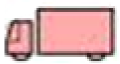
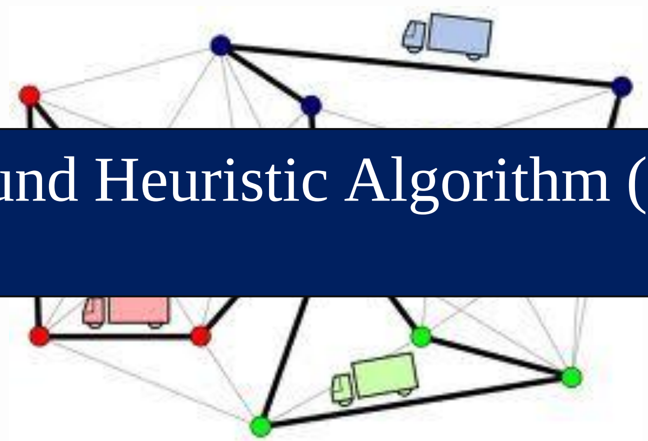


Vehicle Routing Problem with Multiple Driving ranges (VRPMD)

	Vehicle Type	Vehicle capacity	Vehicle driving ranges (distance unit)	Symbol
	ICEVs[1] and/or PHEVs[2]		No driving range limitation –Large	L
	EVs	Fixed to 100	200 – Medium	M
	EVs		100 – Small	S



Multi-Round Heuristic Algorithm (MRHA)

[1]Internal Combustion Engine Vehicles
[2]Plug-in Hybrid Electric Vehicles

Capacitated Vehicle Routing Problem with Multiple Driving ranges (CVRPMD)

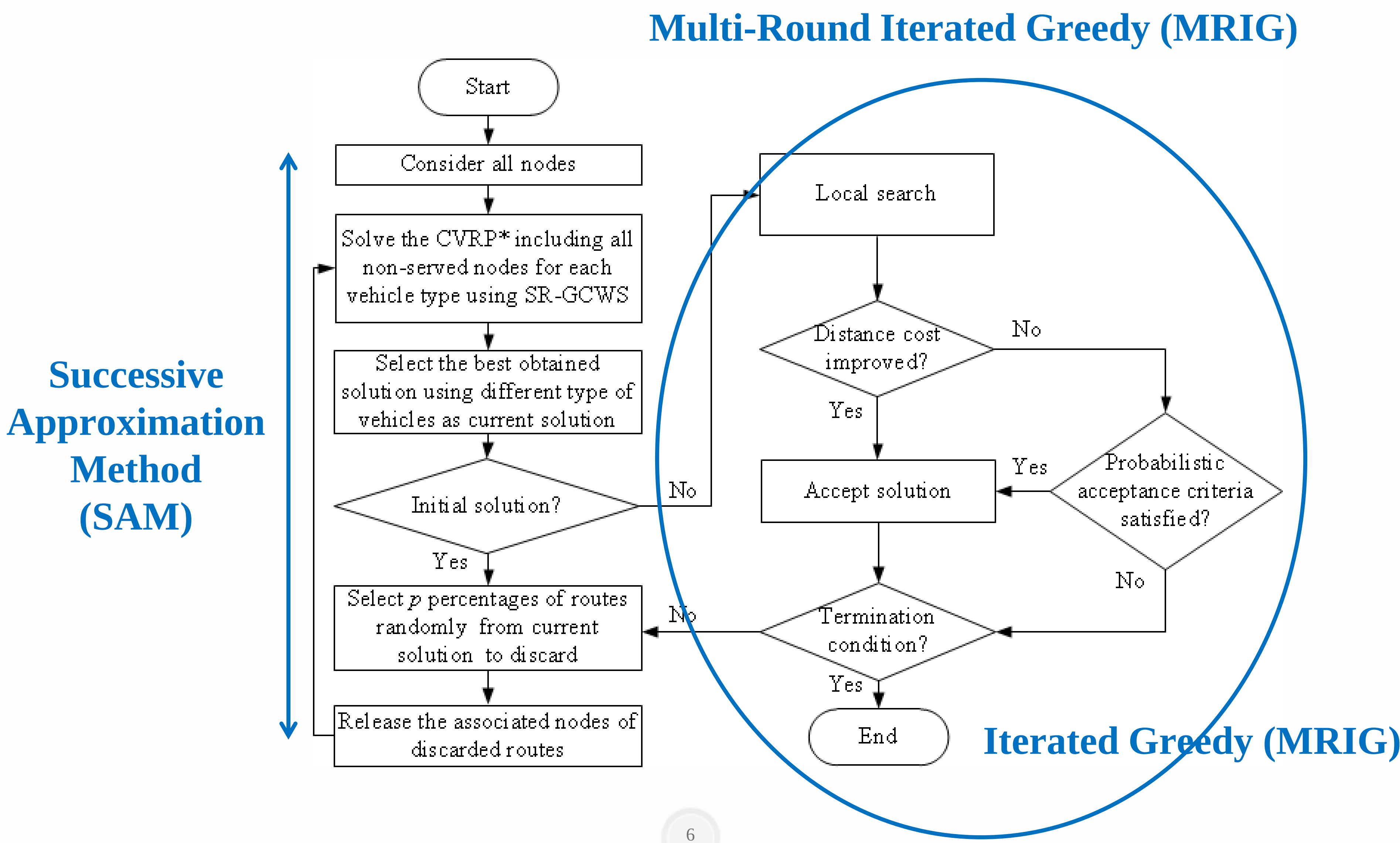
Vehicle Type	Vehicle capacity	Vehicle driving ranges (distance unit)	Symbol
ICEVs[1] and/or PHEVs[2]	$1.25Q_0$	No driving range limitation –Large	L
EVs	Q_0	200 – Medium	M
EVs	$0.8Q_0$	100 – Small	S

Develop an efficient solution method:

Multi-Round Iterated Greedy

[1]Internal Combustion Engine Vehicles
[2]Plug-in Hybrid Electric Vehicles

Proposed solving method



Analysis of the results

- ✓ 33 CVRP classical benchmark instances to solve both VRPMD and CVRPMD- are selected from a large number of instances
- ✓ using different criteria to select these benchmark instances
    - instances with an optimal or pseudo-optimal solution (instances from sets A, B, E, F, M and P)
    - instances with information on routes for the optimal or pseudo-optimal solution
    - mid-size instances including between 22 and 135 nodes.

Distance-based cost evaluation

Measure the performance of the results by Relative Percentage Difference (RPD)

$$\text{RPD}= \frac{Alg_{sol}-Best_{sol}}{Best_{sol}} \times 100$$

$Best_{sol}$: the best distance-based cost found through our results and the existing ones by Juan et al. (2014b), and the best known solutions (BKS) for any instance.

Alg_{sol} : the distance-based cost obtained by the proposed algorithm

Novel green indices for fleet configurations

$$GI_1 = \frac{S+\omega M}{S+M+L}$$

$\omega \in [0, 1]$.

The number of the used vehicle of types S, M and L are denoted by S, M and L, respectively.

The values of ω is set to 0.7.

Novel green indices for fleet configurations

$$GI_2 = \gamma S + \beta M + \alpha L$$

This index measures environmental unit cost for each fleet configuration.

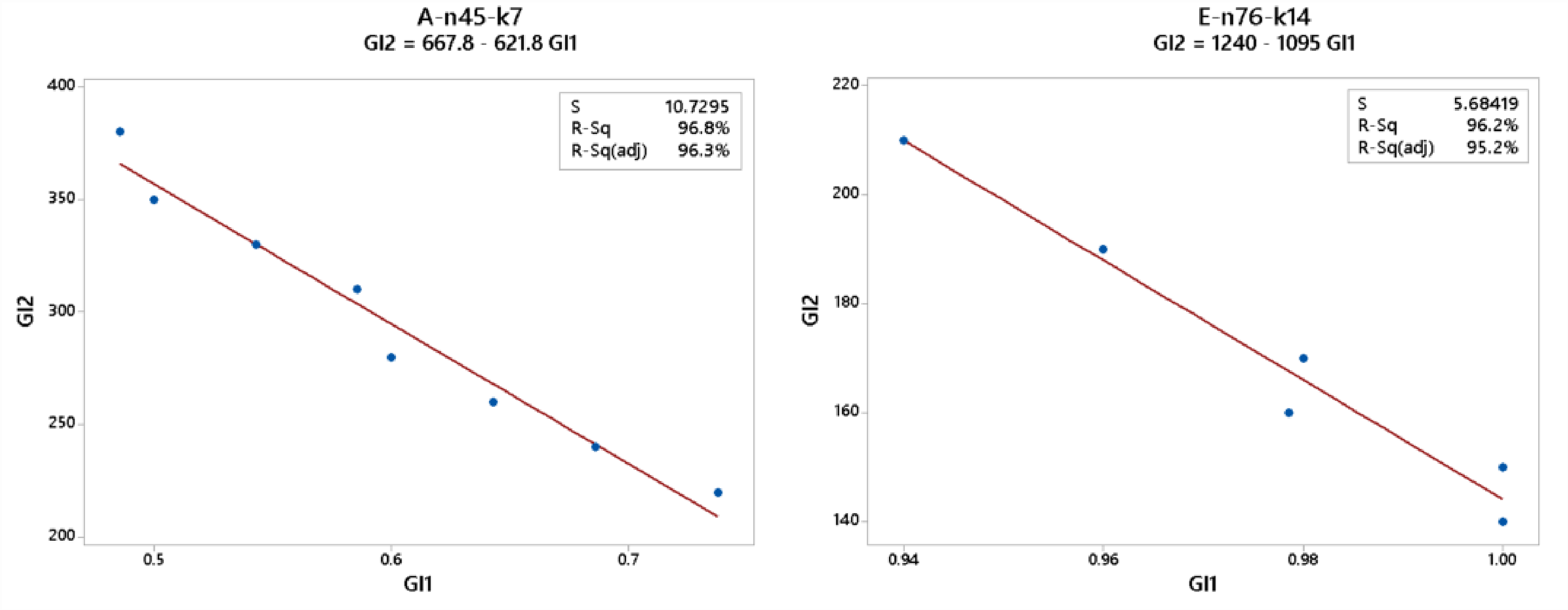
The values of α =100

β =30

and γ = 10.

Experimental results for VRPMD

Relation between Novel green indices



Experimental results for VRPMD

Instance name	Number of nodes	Capacity	*BKS*	*MRHA*		*MRIG*		*RPD*		Diversified Ratio
				Fleet *CFG*. *S/M/L*	*DBCost*	Fleet *CFG*. *S/M/L*	*DBCost*	*MRHA*	*MRIG*	
A-n80-k10	80	100	1766.50	2/5/3	**1776.19**	2/5/3	**1775.75**	**0.55**	**0.52**	2.5
				1/7/2	1785.05	1/7/2	1785.04	1.05	1.05	
						2/6/2	1794.42	-	-	
						0/9/1	1994.16	-	-	
						2/8/1	2016.21	-	-	
B-n57-k9	57	100	1603.63	0/4/5	**1602.29**	0/4/5	**1602.29**	**0.00**	**0.00**	1.6
				0/5/4	1603.37	0/5/4	1603.37	0.07	0.07	
				0/6/3	1631.66	0/6/3	1631.85	1.83	1.84	
				1/3/5	1642.53	1/3/5	1636.34	2.51	2.13	
				1/4/4	1646.65	1/4/4	1637.44	2.77	2.19	
						1/5/3	1650.87	-	-	
						2/2/6	1694.09	-	-	
						0/7/2	1707.81	-	-	
E-n30-k3	30	4500	535.80	1/3/0	**505.01**	1/3/0	**505.01**	**0.00**	**0.00**	4
						2/1/1	579.78	-	-	
						3/0/2	597.65	-	-	
						3/1/1	633.37	-	-	
F-n135-k7	135	2210	1170.65	3/1/3	**1175.73**	3/1/3	**1168.01**	**0.66**	**0.00**	2.5
				3/2/2	1190.07	3/2/2	1175.68	1.89	0.66	
						2/3/2	1171.18	-	-	
						1/5/1	1215.14	-	-	
						2/4/1	1241.70	-	-	
M-n121-k7	121	200	1045.16	2/3/2	**1047.96**	2/3/2	**1044.64**	**0.32**	**0.00**	2
				1/7/0	1274.60	1/7/0	1287.52	22.01	23.25	
						3/2/3	1050.66	-	-	
						1/5/1	1129.40	-	-	
P-n70-k10	70	135	830.02	8/2/0	**834.38**	8/2/0	843.63	**0.53**	1.64	2.5
				10/0/0	841.56	10/0/0	851.39	1.39	2.57	
						6/4/0	**841.42**	-	**1.37**	
						9/1/0	844.35	-	-	
						7/3/0	842.36	-	-	

Experimental results for 20 classical CVRP instances

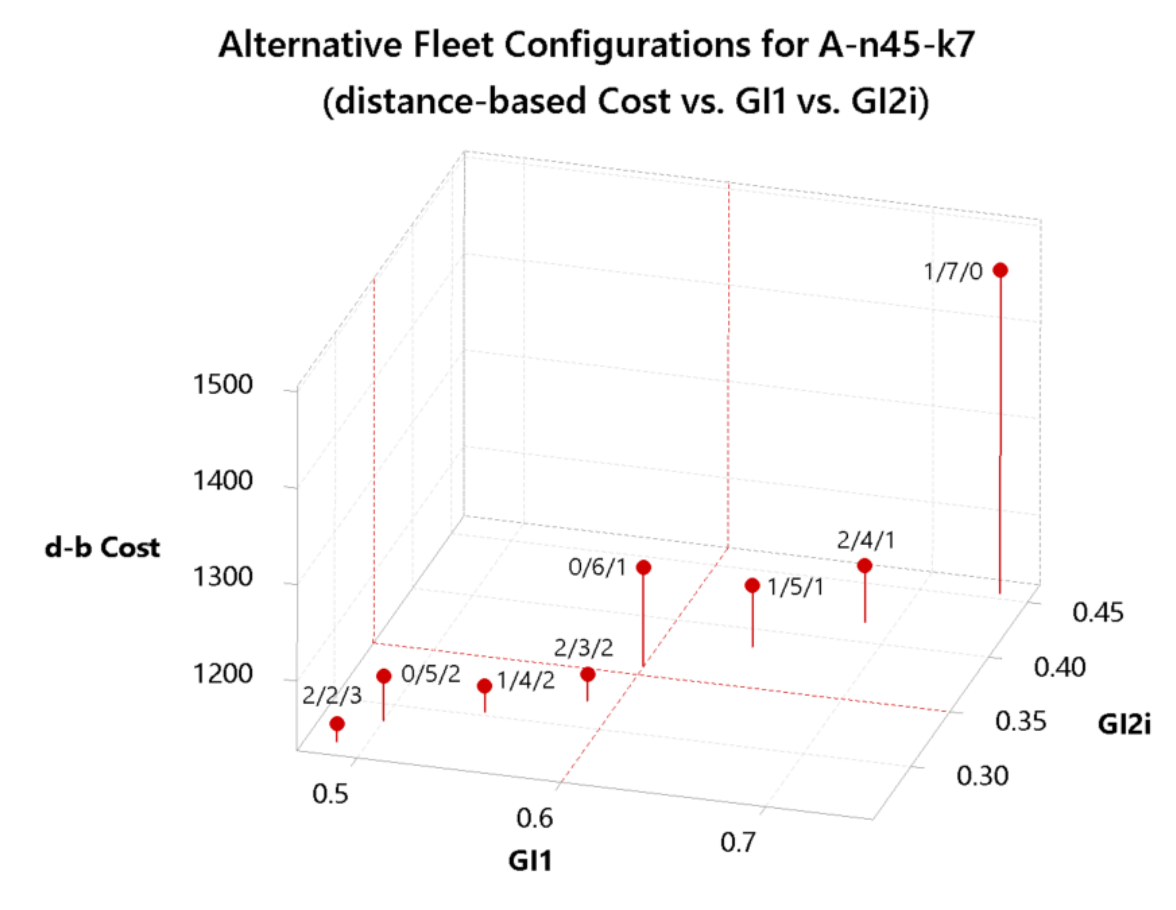
Experimental results for VRPMD

Instance name	Number of nodes	Capacity	BKS	$MRIG$		RPD
				Fleet $CFG.\ S/M/L$	Cost	
A-n45-k7	45	100	1147.28	2/2/3	1146.77	0.00
				1/4/2	1154.43	0.67
				2/3/2	1155.60	0.77
				1/5/1	1191.29	3.88
				0/5/2	1174.01	2.38
				0/6/1	1230.27	7.28
				1/7/0	1463.93	27.66
				2/4/1	1186.46	3.46
E-n76-k7	76	220	687.60	3/4/0	690.20	0.38
				4/3/0	695.26	1.11
				5/2/0	705.97	2.67
				6/1/0	733.74	6.71
F-n45-k4	45	2010	724.57	1/2/1	723.54	0.00
				2/0/2	792.37	9.51
P-n101-k4	101	400	692.28	0/3/1	691.29	0.00
				0/4/0	694.67	0.49
				1/1/2	703.91	1.83
				1/2/1	700.88	1.39
				2/3/0	729.90	5.59

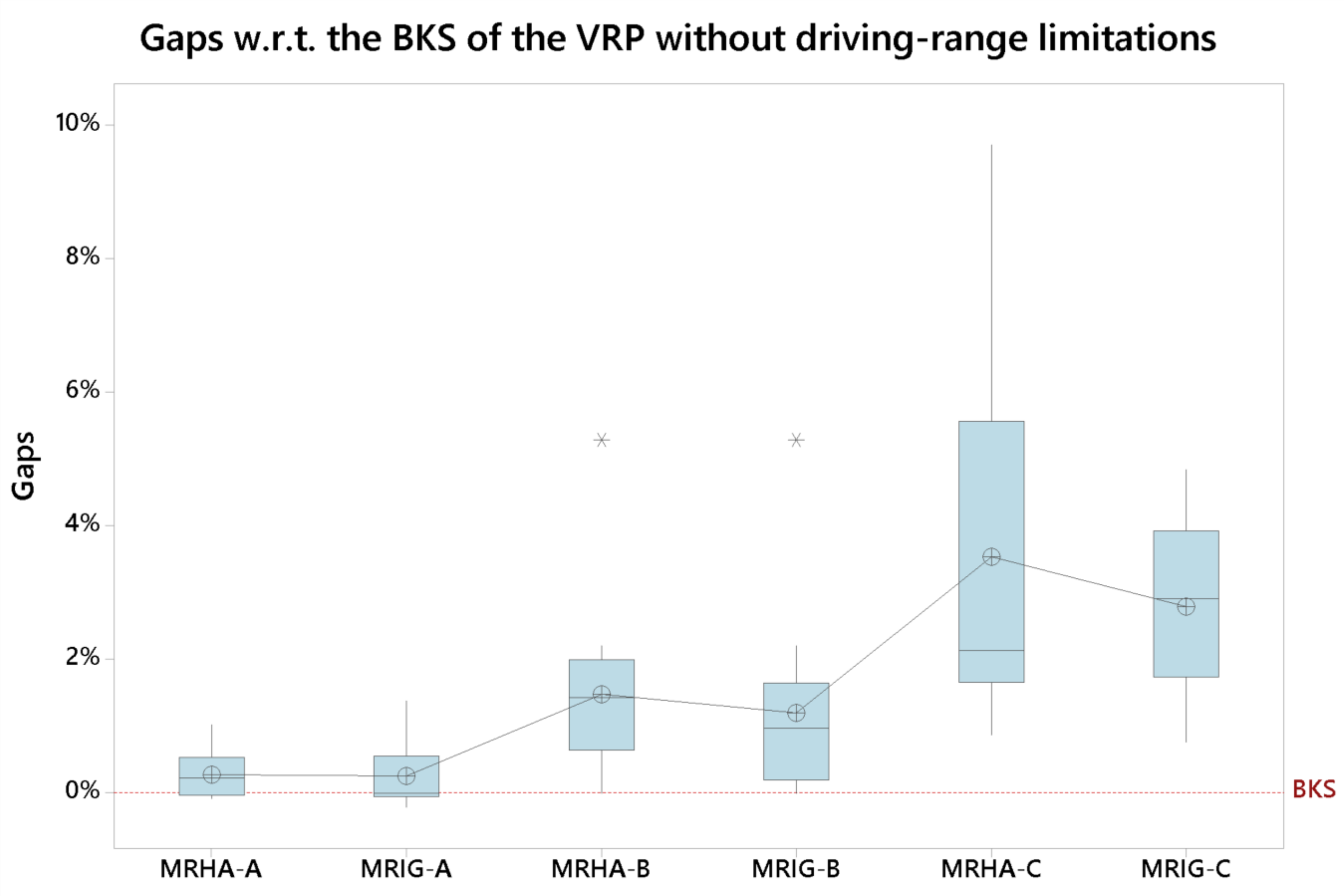
Experimental results for additional classical VRP instances

Experimental results for VRPMD

$$GI_2 i = 1/GI_2$$



Experimental results for VRPMD



Experimental results for CVRPMD

Instance name (Q_0)	BKS Cost	VS-VM-VL	$SetGI_1$					$SetGI_2$				
			Fleet CFG. S/M/L	$DBCost$	GI_1	GI_2	RPD	Fleet CFG. S/M/L	$DBCost$	GI_1	GI_2	RPD
P-n40-k5(140)	461.73	112-140-175	**0/1/3**	**431.67**	0.18	330	**0.00**					
			$0/0/4^{L_s}$	432.23	0.00	400	0.13	$2/0/4^{L_s}$	584.80	0.33	420	35.47
			$3/0/3^{L_m}$	457.78	0.50	330	6.05	$4/0/2^{L_m}$	463.83	0.67	240	7.45
			$6/0/0^{L_l}$	514.97	1.00	60	19.30	$6/0/0^{L_l}$	514.97	1.00	60	19.30
P-n50-k10(100)	699.56	80-100-125	$\mathbf{0/0/8}^{L_s}$	**607.39**	0.00	800	**0.00**	$0/1/8^{L_s}$	658.36	0.08	830	8.39
			$5/0/5^{L_m}$	669.00	0.50	550	10.14	$0/6/3^{L_m}$	657.15	0.47	480	8.19
			$13/0/0^{L_l}$	805.71	1.00	130	32.65	$13/0/0^{L_l}$	805.71	1.00	130	32.65
P-n55-k15(70)	991.48	56-70-87	$\mathbf{0/0/13}^{L_s}$	**824.21**	0.00	1300	**0.00**	$0/1/13^{L_s}$	883.51	0.05	1330	7.20
			$8/0/8^{L_m}$	915.58	0.50	880	11.09	$3/8/4^{L_m}$	919.94	0.57	670	11.62
			$20/0/0^{L_l}$	1126.70	1.00	200	36.70	$20/0/0^{L_l}$	1126.70	1.00	200	36.70
P-n65-k10(130)	796.67	104-130-162	$\mathbf{0/0/8}^{L_s}$	**726.51**	0.00	800	**0.00**	$3/0/8^{L_s}$	831.83	0.27	830	14.50
			$5/0/5^{L_m}$	779.95	0.50	550	7.36	$0/6/3^{L_m}$	766.30	0.47	480	5.48
			$13/0/0^{L_l}$	931.96	1.00	130	28.28	$13/0/0^{L_l}$	931.96	1.00	130	28.28
P-n70-k10(135)	830.02	108-135-196	$\mathbf{0/0/8}^{L_s}$	**760.93**	0.00	800	**0.00**	$1/1/8^{L_s}$	916.60	0.17	840	20.46
			$5/0/5^{L_m}$	821.68	0.50	550	7.98	$1/6/3^{L_m}$	812.82	0.52	490	6.82
			$13/0/0^{L_l}$	969.13	1.00	130	27.36	$13/0/0^{L_l}$	969.13	1.00	130	27.36
P-n76-k4(350)	598.22	280-350-437	**1/1/2**	**594.64**	0.43	240	**0.00**					
			$0/0/4^{L_s}$	695.78	0.00	400	17.01	$2/1/4^{L_s}$	935.17	0.39	450	57.27
			$2/0/2^{L_m}$	606.86	0.50	220	2.06	$0/2/2^{L_m}$	597.13	0.35	260	0.42
			$8/0/0^{L_l}$	744.71	1.00	80	25.24	$8/0/0^{L_l}$	744.71	1.00	80	25.24

Experimental results for CVRPMD with classical VRP instances

Conclusion and future work

- Extending the VRPMD:
  - Multiple capacities for each type of vehicles
  - developing an efficient method (MRIG)
- Developing reasonable solutions in terms of distance-based cost and more diverse solutions in terms of using greener fleet configurations.
- Help decision makers to decide the best routes for their managerial problems

Conclusion and future work

- Multi-objective optimization models
- integrating classical assumptions such as time windows and multi-depot
- Considering the impact of the carrying load of the vehicles on the resource consumption

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