

Appendix: Detailed Results on the Multi-Vehicle VMIRP

The notation used in tables (1)-(4) is the same as described in Section 5.1 about the MVPRP. Moreover, column “*id*” is used to denote the instance identifier. Concerning method EXM, a symbol “-” indicates that EXM runs out of memory or no feasible solution was found by EXM.

Table 1: Results on multi-vehicle VMIRP instances with three periods and low inventory costs

Adulyasak et al. (2014)															
n	l	m	id	Veh-Ind				Non-Veh-Ind				EXM			
				Best	ub	%lb	t	%lb	t	ub	lb	%lb	t	t _S	%rc
5	3	2	1	1396.33	100.0	0.1	100.0	0.1	1396.33	1396.33	100.0	0.7	0.0	93.2	
5	3	2	2	1437.90	100.0	0.0	100.0	0.0	1437.90	1437.90	100.0	0.7	0.0	93.8	
5	3	2	3	2468.94	100.0	0.1	100.0	0.3	2468.94	2468.94	100.0	0.8	0.0	94.4	
5	3	2	4	1717.43	100.0	0.0	100.0	0.1	1717.43	1717.43	100.0	0.7	0.0	96.2	
5	3	2	5	1224.63	100.0	0.0	100.0	0.0	1224.63	1224.63	100.0	0.7	0.0	89.1	
5	3	3	1	1540.57	100.0	0.1	100.0	0.1	1540.57	1540.57	100.0	0.6	0.0	93.9	
5	3	3	2	1720.83	100.0	0.1	100.0	0.1	1720.83	1720.83	100.0	0.5	0.0	94.8	
5	3	3	3	3503.33	100.0	0.0	100.0	0.1	3503.33	3503.33	100.0	0.7	0.0	96.0	
5	3	3	4	2552.79	100.0	0.0	100.0	0.1	2552.79	2552.79	100.0	0.5	0.0	97.5	
5	3	3	5	1682.44	100.0	0.0	100.0	0.1	1682.44	1682.44	100.0	0.6	0.0	92.0	
10	3	2	1	2468.22	100.0	1.8	100.0	1.7	2468.22	2468.22	100.0	4.6	1.5	87.6	
10	3	2	2	3166.19	100.0	2.9	100.0	3.5	3166.19	3166.19	100.0	6.4	2.9	91.8	
10	3	2	3	2449.10	100.0	1.2	100.0	1.6	2449.10	2449.10	100.0	3.4	0.5	90.1	
10	3	2	4	2859.45	100.0	2.7	100.0	5.4	2859.45	2859.45	100.0	5.8	3.0	91.4	
10	3	2	5	2486.41	100.0	1.6	100.0	2.6	2486.41	2486.41	100.0	5.3	2.2	87.2	
10	3	3	1	2914.09	100.0	4.1	100.0	5.2	2914.09	2914.09	100.0	2.6	0.6	89.5	
10	3	3	2	3641.19	100.0	7.1	100.0	3.3	3641.19	3641.19	100.0	2.4	0.5	92.9	
10	3	3	3	2734.10	100.0	2.4	100.0	1.3	2734.10	2734.10	100.0	2.0	0.2	91.1	
10	3	3	4	3318.99	100.0	7.2	100.0	10.8	3318.99	3318.99	100.0	4.2	2.2	92.6	
10	3	3	5	2704.71	100.0	3.3	100.0	1.5	2704.71	2704.71	100.0	3.0	0.6	88.3	
15	3	2	1	2631.53	100.0	7.3	100.0	8.5	2631.53	2631.53	100.0	19.8	2.4	85.5	
15	3	2	2	2907.34	100.0	5.2	100.0	36.5	2907.34	2907.34	100.0	27.5	5.9	87.4	
15	3	2	3	3081.56	100.0	4.9	100.0	5.3	3081.56	3081.56	100.0	18.0	1.4	86.1	
15	3	2	4	2745.98	100.0	3.6	100.0	24.3	2745.98	2746.98	100.0	23.1	6.1	88.6	
15	3	2	5	2862.50	100.0	6.1	100.0	58.9	2862.50	2862.50	100.0	24.5	6.4	89.2	
15	3	3	1	2928.16	100.0	12.5	100.0	109.3	2928.16	2928.16	100.0	9.7	1.6	87.1	
15	3	3	2	3217.61	100.0	17.3	100.0	88.2	3217.61	3217.61	100.0	19.0	6.3	88.5	
15	3	3	3	3401.56	100.0	20.3	100.0	36.3	3401.56	3401.56	100.0	10.7	1.9	87.4	
15	3	3	4	2961.29	100.0	10.6	100.0	12.2	2961.29	2961.29	100.0	12.2	3.2	89.5	
15	3	3	5	3302.02	100.0	35.0	100.0	170.4	3302.02	3302.02	100.0	17.7	6.3	90.6	
20	3	2	1	3398.29	100.0	128.1	100.0	278.4	3398.29	3398.29	100.0	364.0	123.5	85.2	
20	3	2	2	2925.55	100.0	18.9	100.0	21.9	2925.55	2925.55	100.0	105.6	29.0	82.4	
20	3	2	3	3401.56	100.0	50.1	100.0	128.0	3401.56	3401.56	100.0	117.6	28.7	84.1	
20	3	2	4	3837.54	100.0	64.7	99.2	7200.0	3837.54	3837.54	100.0	243.5	71.8	89.0	
20	3	2	5	3957.49	100.0	73.9	100.0	1331.3	3957.49	3957.49	100.0	1998.8	356.8	85.7	
20	3	3	1	3809.57	100.0	337.3	100.0	1552.4	3809.57	3809.57	100.0	976.4	94.5	86.7	
20	3	3	2	3063.77	100.0	67.4	100.0	95.0	3063.77	3063.77	100.0	49.0	12.6	83.2	
20	3	3	3	3805.55	100.0	359.3	100.0	5953.2	3805.55	3805.55	100.0	309.6	46.0	85.8	
20	3	3	4	4447.93	100.0	899.0	95.4	7200.0	4447.93	4447.93	100.0	1697.7	147.0	90.4	
20	3	3	5	4581.99	100.0	882.3	97.4	7200.0	4581.99	4581.99	100.0	5524.8	242.8	87.7	
25	3	2	1	3569.23	100.0	25.7	100.0	164.8	3569.23	3569.23	100.0	5061.4	4598.9	83.4	
25	3	2	2	3904.97	100.0	447.8	100.0	1798.3	3904.97	3904.97	100.0	2678.3	1253.8	83.7	
25	3	2	3	4006.11	100.0	93.3	100.0	434.5	4006.11	4006.11	100.0	1332.8	984.2	82.2	
25	3	2	4	3510.77	100.0	32.6	100.0	100.5	3510.77	3510.77	100.0	5254.6	5015.2	82.8	
25	3	2	5	3857.48	100.0	39.5	100.0	20.0	3857.48	3857.48	100.0	608.6	194.5	79.3	
25	3	3	1	3927.38	100.0	219.8	100.0	1521.0	3927.38	3927.38	100.0	3224.5	262.4	84.9	
25	3	3	2	4278.43	100.0	1609.5	97.0	7200.0	4278.43	4278.43	100.0	5016.6	524.7	85.1	
25	3	3	3	4658.61	100.0	1890.2	98.9	7200.0	4658.61	4613.86	99.0	7200.3	370.4	84.7	
25	3	3	4	3936.55	100.0	238.8	98.3	7200.0	3936.55	3936.55	100.0	697.4	171.0	84.7	
25	3	3	5	4550.44	100.0	1218.0	100.0	5702.7	4550.44	4392.76	96.5	7200.3	2061.4	82.5	
30	3	3	1	4697.49	100.0	2956.4	97.1	7200.0	-	4623.26	-	7201.7	7037.8	-	
30	3	3	2	4296.11	100.0	334.6	100.0	4168.2	4296.11	4187.66	97.5	7200.3	1420.9	80.3	
30	3	3	3	4272.41	100.0	2256.8	98.7	7200.0	4272.41	4272.41	100.0	2995.8	373.7	77.1	
30	3	3	4	4238.99	100.0	4683.7	95.7	7200.0	4238.99	4139.71	97.7	7200.3	2951.0	83.2	
30	3	3	5	3987.55	100.0	5038.9	93.8	7200.0	3987.55	3962.85	99.4	7200.3	794.2	80.7	
30	3	4	1	5297.66	89.1	7200.0	92.7	7200.0	5318.99	5136.46	96.6	7200.3	1976.9	81.9	
30	3	4	2	4634.58	100.0	4129.9	97.4	7200.0	4634.58	4614.99	99.6	7200.3	1575.1	81.8	
30	3	4	3	4569.05	92.3	7200.0	95.5	7200.0	4569.05	4575.04	99.5	7200.3	221.7	78.6	
30	3	4	4	4701.86	87.2	7200.0	93.8	7200.0	4915.80	4595.86	93.5	7201.0	4912.1	85.6	
30	3	4	5	4348.99	90.3	7200.0	92.8	7200.0	4348.99	4348.99	100.0	6138.5	334.7	82.3	
35	3	3	1	4473.28	100.0	2808.1	95.5	7200.0	4480.41	4385.81	97.9	7200.4	2684.0	79.7	
35	3	3	2	4438.80	100.0	1903.8	97.2	7200.0	4637.46	4334.65	93.5	7202.9	6501.0	83.4	
35	3	3	3	5249.48	98.8	7200.0	97.6	7200.0	-	5085.47	-	7200.38	7061.6	-	
35	3	3	4	4678.54	88.1	7200.0	92.8	7200.0	5689.84	4427.38	77.8	7206.84	7024.0	86.1	
35	3	3	5	4326.68	95.1	7200.0	97.5	7200.0	5766.29	4268.16	74.0	7205.17	7002.6	85.5	
35	3	4	1	4980.59	87.7	7200.0	92.4	7200.0	5026.70	4841.08	96.3	7200.22	3398.9	81.9	
35	3	4	2	4872.03	95.9	7200.0	94.5	7200.0	5291.20	4757.27	89.9	7210.38	7011.6	85.4	
35	3	4	3	6029.70	86.9	7200.0	89.4	7200.0	5939.48	5687.89	95.8	7200.26	6653.0	81.3	
35	3	4	4	5169.84	80.4	7200.0	90.4	7200.0	5102.75	4936.52	96.7	7200.25	4619.8	84.5	
35	3	4	5	4958.01	83.5	7200.0	91.1	7200.0	4873.60	4763.18	97.7	7203.13	7067.2	82.8	
40	3	3	1	5009.71	93.7	7200.0	92.7	7200.0	-	4974.97	-	7206.97	7010.0	-	
40	3	3	2	4742.39	100.0	6590.6	100.0	7200.0	6303.64	4574.25	72.6	7201.65	6590.4	86.7	
40	3	3	3	4747.71	96.4	7200.0	97.6	7200.0	6071.46	4642.03	76.5	7208.33	7003.0	82.1	
40	3	3	4	4580.04	96.2	7200.0	93.9	7200.0	4743.90	4423.22	93.2	7208.7	6722.4	81.6	
40	3	3	5	4612.63	99.1	7200.0	95.2	7200.0	5760.28	4558.94	79.1	7205.2	7007.2	81.7	
40	3	4	1	6025.70	74.8	7200.0	83.4	7200.0	5916.45	5504.21	93.0	7200.4	6890.5	81.9	
40	3	4	2	5622.76	81.4	7200.0	86.5	7200.0	7858.53	5156.13	65.6	7207.7	6974.5	89.3	
40	3	4	3	5136.06	90.0	7200.0	92.9	7200.0	6013.13	4984.39	82.9	7201.7	7002.6	81.8	
40	3	4	4	4855.93	85.9	7200.0	95.2	7200.0	5241.75	4787.40	96.9	7202.7	6664.8	82.3	
40	3	4	5	5213.30	87.3	7200.0	90.5	7200.0	5355.59	5051.54	94.3	7208.8	6940.8	80.3	
45	3	3	1	5039.51	n/a	n/a	n/a	n/a	-	4885.92	-	7204.8	7004.1	-	
45	3	3	2	5296.04	n/a	n/a	n/a	n/a	-	5155.97	-	7204.8	7004.1	-	
45	3	3	3	4754.62	n/a	n/a	n/a	n/a	5360.59	4622.71	86.2	7207.0	6913.1	77.3	
45	3	3	4	5458.59	n/a	n/a	n/a	n/a	7922.57	5229.54	66.0	7204.6	5352.3	86.4	
45	3	3	5	4374.87	n/a	n/a	n/a	n/a	7280.24	4305.89	5				

Table 2: Results on multi-vehicle VMIRP instances with three periods and high inventory costs

				Adulyasak et al. (2014)								EXM					
n	l	m	id	Veh-Ind				Non-Veh-Ind				ub	lb	%lb	t	t _S	%rc
				Best ub	%lb	t	%lb	t	%lb	t							
5	3	2	1	2266.61	100.0	0.1	100.0	0.1	2266.61	2266.61	100.0	0.8	0.0	57.4			
5	3	2	2	2229.38	100.0	0.0	100.0	0.0	2229.38	2229.38	100.0	0.7	0.0	60.5			
5	3	2	3	3698.48	100.0	0.1	100.0	0.2	3698.48	3698.48	100.0	0.9	0.0	63.0			
5	3	2	4	2302.44	100.0	0.1	100.0	0.0	2302.44	2302.44	100.0	0.8	0.0	71.8			
5	3	2	5	2413.72	100.0	0.0	100.0	0.0	2413.72	2413.72	100.0	0.8	0.0	45.2			
5	3	3	1	2414.03	100.0	0.1	100.0	0.1	2414.03	2414.03	100.0	0.6	0.0	59.9			
5	3	3	2	2511.05	100.0	0.1	100.0	0.1	2511.05	2511.05	100.0	0.6	0.0	65.0			
5	3	3	3	4753.03	100.0	0.0	100.0	0.1	4753.03	4753.03	100.0	0.8	0.0	70.8			
5	3	3	4	3132.21	100.0	0.0	100.0	0.1	3132.21	3132.21	100.0	0.7	0.0	79.5			
5	3	3	5	2875.58	100.0	0.0	100.0	0.1	2875.58	2875.58	100.0	0.7	0.0	53.8			
10	3	2	1	5263.22	100.0	1.4	100.0	0.9	5263.22	5263.22	100.0	6.1	2.9	41.1			
10	3	2	2	5464.48	100.0	2.9	100.0	3.2	5464.48	5464.48	100.0	9.2	5.2	53.2			
10	3	2	3	4630.08	100.0	1.1	100.0	1.2	4630.08	4630.08	100.0	4.7	1.3	47.6			
10	3	2	4	5031.00	100.0	3.2	100.0	7.2	5031.00	5031.00	100.0	5.6	2.2	52.3			
10	3	2	5	5318.75	100.0	1.7	100.0	2.5	5318.75	5318.75	100.0	6.1	2.6	41.0			
10	3	3	1	5714.31	100.0	3.7	100.0	5.7	5714.31	5714.31	100.0	2.6	0.3	45.6			
10	3	3	2	5938.08	100.0	7.3	100.0	3.4	5938.08	5938.08	100.0	3.2	0.8	57.0			
10	3	3	3	4919.04	100.0	1.8	100.0	1.3	4919.04	4919.04	100.0	2.5	0.3	50.6			
10	3	3	4	5482.86	100.0	9.3	100.0	15.5	5482.86	5482.86	100.0	4.1	1.7	56.1			
10	3	3	5	5539.77	100.0	2.6	100.0	2.8	5539.77	5539.77	100.0	2.9	0.7	43.1			
15	3	2	1	6108.84	100.0	7.4	100.0	38.9	6108.84	6108.84	100.0	21.3	2.8	36.8			
15	3	2	2	6211.69	100.0	4.6	100.0	51.4	6211.69	6211.69	100.0	28.3	6.2	40.9			
15	3	2	3	6946.05	100.0	10.9	100.0	8.7	6946.05	6946.05	100.0	21.1	2.2	38.2			
15	3	2	4	5551.36	100.0	4.2	100.0	44.0	5551.36	5551.36	100.0	22.8	5.4	44.0			
15	3	2	5	5623.74	100.0	4.6	100.0	44.7	5623.74	5623.74	100.0	29.3	7.8	45.4			
15	3	3	1	6375.95	100.0	11.6	100.0	45.2	6375.95	6375.95	100.0	12.9	3.8	40.0			
15	3	3	2	6533.72	100.0	17.5	100.0	23.5	6533.72	6533.72	100.0	26.9	11.7	43.6			
15	3	3	3	7265.38	100.0	14.0	100.0	32.7	7265.38	7265.38	100.0	12.7	3.1	40.9			
15	3	3	4	5776.88	100.0	6.7	100.0	6.9	5776.88	5776.88	100.0	14.7	3.4	45.9			
15	3	3	5	6068.46	100.0	32.7	100.0	87.3	6068.46	6068.46	100.0	22.7	9.1	49.3			
20	3	2	1	7958.82	100.0	130.1	100.0	407.3	7958.82	7958.82	100.0	307.7	90.9	36.4			
20	3	2	2	7502.09	100.0	19.5	100.0	21.5	7502.09	7502.09	100.0	73.5	13.9	32.2			
20	3	2	3	8228.35	100.0	46.0	100.0	504.1	8228.35	8228.35	100.0	120.1	32.3	34.8			
20	3	2	4	7650.75	100.0	60.2	100.0	6873.2	7650.75	7650.75	100.0	248.1	80.6	44.6			
20	3	2	5	9027.46	100.0	59.1	100.0	1024.2	9027.46	9027.46	100.0	1588.0	274.8	37.6			
20	3	3	1	8398.63	100.0	603.0	100.0	2058.1	8398.63	8398.63	100.0	1301.8	95.8	39.3			
20	3	3	2	7641.45	100.0	138.8	100.0	128.4	7641.45	7641.45	100.0	40.2	9.5	33.4			
20	3	3	3	8624.22	100.0	407.4	100.0	7200.0	8624.22	8624.22	100.0	331.4	65.0	37.9			
20	3	3	4	8270.08	100.0	811.2	100.0	7200.0	8270.08	8270.08	100.0	1508.7	179.3	48.6			
20	3	3	5	9656.83	100.0	892.3	100.0	3909.0	9656.83	9656.83	100.0	4731.1	240.4	41.6			
25	3	2	1	8923.37	100.0	55.3	100.0	80.5	8923.37	8923.37	100.0	1010.3	553.3	33.4			
25	3	2	2	9674.07	100.0	319.0	100.0	7152.1	9674.07	9674.07	100.0	2701.5	959.4	33.8			
25	3	2	3	10368.83	100.0	160.4	100.0	781.7	11104.06	10206.02	91.9	7200.8	7091.7	36.7			
25	3	2	4	8908.31	100.0	33.4	100.0	63.1	8908.31	8908.31	100.0	940.6	708.9	32.7			
25	3	2	5	11037.88	100.0	44.2	100.0	26.5	11037.88	11037.88	100.0	4371.6	3786.4	27.8			
25	3	3	1	9277.31	100.0	234.9	100.0	1954.7	9277.31	9277.31	100.0	3860.0	285.3	36.1			
25	3	3	2	10048.88	100.0	173.3	100.0	98.7	10048.88	10048.88	99.9	7200.2	542.8	36.4			
25	3	3	3	11022.72	100.0	185.7	99.1	7200.0	11022.72	10982.11	99.6	7200.2	385.4	35.8			
25	3	3	4	9334.96	100.0	233.0	99.1	7200.0	9334.96	9334.96	100.0	1149.9	319.5	35.7			
25	3	3	5	11715.70	100.0	1527.6	100.0	3195.1	11715.70	11549.05	98.6	7200.2	3420.8	32.1			
30	3	3	1	13390.84	100.0	2296.7	98.9	7200.0	14392.44	13320.81	92.6	7201.3	7050.4	33.2			
30	3	3	2	11911.63	100.0	435.5	100.0	5334.6	11911.63	11835.94	99.4	7200.2	806.3	29.0			
30	3	3	3	13003.14	100.0	1524.9	99.1	7200.0	13003.14	12995.29	99.9	7200.2	194.0	25.4			
30	3	3	4	10619.39	100.0	4296.7	98.0	7200.0	10619.39	10527.89	99.1	7200.2	1500.9	33.2			
30	3	3	5	10911.59	100.0	6708.9	97.6	7200.0	10911.59	10884.44	99.8	7200.2	796.1	29.5			
30	3	4	1	13976.21	94.8	7200.0	97.3	7200.0	13976.21	13830.47	99.0	7200.2	1396.7	31.0			
30	3	4	2	12525.36	100.0	2110.7	99.0	7200.0	12525.36	12294.56	99.8	7200.2	447.9	30.9			
30	3	4	3	13234.90	97.6	7200.0	98.8	7200.0	13234.90	13234.90	99.8	7200.2	3617.3	26.9			
30	3	4	4	11027.66	95.5	7200.0	97.4	7200.0	11049.15	10931.71	98.9	7200.2	3393.2	36.4			
30	3	4	5	11270.83	95.8	7200.0	97.1	7200.0	11270.83	11270.83	100.0	6844.6	283.1	31.9			
35	3	3	1	12764.43	99.7	7200.0	98.4	7200.0	13530.55	12694.97	93.8	7200.2	6962.7	32.1			
35	3	3	2	11352.68	100.0	817.2	98.8	7200.0	11449.35	11211.09	97.9	7203.2	6970.3	32.9			
35	3	3	3	15278.37	100.0	5074.4	99.4	7200.0	15566.09	15149.00	97.3	7200.3	6618.8	28.6			
35	3	3	4	11746.39	96.9	7200.0	97.1	7200.0	11873.09	11399.20	96.0	7205.1	7009.2	33.8			
35	3	3	5	11881.10	98.5	7200.0	99.3	7200.0	11946.74	11821.76	99.0	7200.3	2379.2	29.9			
35	3	4	1	13426.45	93.8	7200.0	96.0	7200.0	13296.40	13140.71	98.8	7200.2	1841.2	30.9			
35	3	4	2	11786.79	99.0	7200.0	97.8	7200.0	12352.07	11560.36	93.6	7204.9	7007.2	38.0			
35	3	4	3	16151.59	94.8	7200.0	95.7	7200.0	16699.15	15725.52	94.2	7227.3	7016.8	33.1			
35	3	4	4	12295.65	91.7	7200.0	95.5	7200.0	12160.17	11944.50	98.2	7200.2	2744.1	35.4			
35	3	4	5	12701.76	92.7	7200.0	94.9	7200.0	12448.27	12263.81	98.5	7203.0	7010.6	32.7			
40	3	3	1	14733.71	97.4	7200.0	97.9	7200.0	-	14707.52	-	7207.6	6560.4	-			
40	3	3	2	12267.02	100.0	6515.8	100.0	4039.2	13699.71	11987.27	87.5	7202.7	6724.4	39.0			
40	3	3	3	14525.45	99.5	7200.0	99.1	7200.0	15289.70	14235.11	93.1	7206.1	6897.4	29.0			
40	3	3	4	12401.25	99.3	7200.0	98.0	7200.0	12571.11	12178.95	96.9	7206.0	7044.1	31.1			
40	3	3	5	14143.72	100.0	5384.6	98.5	7200.0	16256.25	14121.72	86.9	7208.1	7002.3	35.1			
40	3	4	1	16057.77	89.7	7200.0	91.7	7200.0	15701.07	15232.85	97.0	7202.3	7017.6	31.2			
40	3	4	2	13022.49	93.0	7200.0	95.6	7200.0	12940.30	12568.74	97.1	7202.8	6929.8	35.4			
40	3	4	3	14898.49	96.3	7200.0	98.0	7200.0	15005.16	14677.13	97.8	7200.2	1786.5	27.7			
40	3	4	4	12725.05	93.8	7200.0	97.7	7200.0	12736.43	12571.78	98.7	7200.6	3602.3	32.1			
40	3	4	5	14763.54	95.6	7200.0	96.3	7200.0	14721.19	14504.47	98.5	7200.5	6002.3	28.1			
45	3	3	1	15327.90	n/a	n/a	n/a	n/a	17526.21	15259.30	87.1	7200.5	6909.8	34.9			
45	3	3	2	14818.70	n/a	n/a	n/a	n/a	-	14679.11	-	7202.3	6824.8	-			
45	3	3	3	15744.72	n/a	n/a	n/a	n/a	16425.69	15476.52	94.2	7205.7	6387.6	25.9			
45	3	3	4	15015.64	n/a												

Table 3: Results on multi-vehicle VMIRP instances with six periods and low inventory costs

n	l	m	id	Adulyasak et al. (2014)								EXM					
				Veh-Ind				Non-Veh-Ind				ub	lb	$\%lb$	t	t_S	$\%rc$
				Best	ub	$\%lb$	t	$\%lb$	t	$\%lb$	t						
5	6	2	1	4286.37	100.0	2.2	100.0	7.0	4286.37	4286.37	100.0	1.5	0.3	93.4			
5	6	2	2	3869.33	100.0	3.1	100.0	12.9	3869.33	3869.33	100.0	2.0	0.5	93.2			
5	6	2	3	5997.42	100.0	0.6	100.0	1.2	5997.42	5997.42	100.0	1.0	0.1	96.0			
5	6	2	4	3814.27	100.0	1.2	100.0	1.3	3814.27	3814.27	100.0	1.2	0.2	94.5			
5	6	2	5	3062.01	100.0	0.5	100.0	0.8	3062.01	3062.01	100.0	1.3	0.2	92.0			
5	6	3	1	5258.03	100.0	0.3	100.0	1.5	5258.03	5258.03	100.0	0.9	0.0	94.6			
5	6	3	2	4881.51	100.0	0.1	100.0	0.1	4881.51	4881.51	100.0	0.9	0.1	94.7			
5	6	3	3	10555.98	100.0	0.0	100.0	1.5	10555.98	10555.98	100.0	1.4	0.1	97.7			
5	6	3	4	5028.36	100.0	0.3	100.0	14.2	5028.36	5028.36	100.0	1.0	0.1	95.8			
5	6	3	5	4392.47	100.0	0.2	100.0	0.9	4392.47	4392.47	100.0	1.3	0.0	94.3			
10	6	2	1	5923.33	100.0	181.3	96.4	7200.0	5923.33	5923.33	100.0	177.7	11.4	91.9			
10	6	2	2	6927.65	100.0	621.0	100.0	598.2	6927.65	6927.65	100.0	2199.4	10.2	94.6			
10	6	2	3	5533.68	100.0	118.2	100.0	723.2	5533.68	5533.68	100.0	511.2	12.0	92.2			
10	6	2	4	6463.46	100.0	79.7	100.0	2585.2	6463.46	6463.46	100.0	293.4	16.2	93.5			
10	6	2	5	5441.76	100.0	97.8	100.0	371.9	5441.76	5441.76	100.0	1391.5	6.0	89.8			
10	6	3	1	7535.66	95.8	7200.0	91.5	7200.0	7535.66	7535.66	100.0	176.1	11.9	93.6			
10	6	3	2	8594.37	100.0	6709.7	100.0	7200.0	8594.37	8594.37	100.0	290.0	15.4	95.7			
10	6	3	3	6604.50	100.0	655.8	100.0	2816.0	6604.50	6604.50	100.0	829.1	9.4	93.5			
10	6	3	4	7891.84	100.0	2387.7	95.7	7200.0	7891.84	7891.84	100.0	1031.9	15.1	94.7			
10	6	3	5	6253.99	100.0	1571.1	100.0	2828.9	6253.99	6253.99	100.0	260.5	8.1	91.2			
15	6	2	1	6143.34	100.0	654.2	96.1	7200.0	6165.38	6001.02	97.3	7200.3	33.7	88.1			
15	6	2	2	6382.11	100.0	203.4	98.9	7200.0	6383.11	6222.30	97.5	7200.2	69.1	88.8			
15	6	2	3	7239.38	100.0	1062.1	95.2	7200.0	7239.38	7095.81	98.0	7200.4	48.4	88.6			
15	6	2	4	6465.37	100.0	720.6	97.0	7200.0	6494.35	6260.01	96.4	7200.2	92.3	91.2			
15	6	2	5	6669.99	100.0	1040.3	94.7	7200.0	6875.90	6413.55	93.3	7200.2	137.1	91.7			
15	6	3	1	7137.36	92.9	7200.0	91.9	7200.0	7304.36	6942.96	95.1	7200.2	99.8	90.0			
15	6	3	2	7559.90	95.7	7200.0	93.1	7200.0	7649.50	7292.03	95.3	7200.2	104.9	90.6			
15	6	3	3	8465.21	92.8	7200.0	91.4	7200.0	8539.91	8310.14	97.3	7200.2	104.4	90.3			
15	6	3	4	7604.86	94.0	7200.0	92.8	7200.0	7618.82	7352.53	96.5	7200.2	84.6	92.5			
15	6	3	5	8046.60	91.9	7200.0	92.4	7200.0	8224.07	7681.01	93.4	7200.2	218.1	93.1			
20	6	2	1	7704.14	n/a	n/a	n/a	n/a	8086.34	7330.65	90.7	7200.2	2426.7	88.8			
20	6	2	2	6569.33	n/a	n/a	n/a	n/a	6675.70	6379.43	95.6	7200.3	452.5	85.6			
20	6	2	3	7781.52	n/a	n/a	n/a	n/a	8013.64	7532.06	94.0	7200.2	401.2	89.4			
20	6	2	4	8746.71	n/a	n/a	n/a	n/a	9128.25	8294.62	90.9	7200.3	1596.3	91.4			
20	6	2	5	8968.73	n/a	n/a	n/a	n/a	9377.61	8479.43	90.4	7204.4	1681.6	89.7			
20	6	3	1	9690.78	n/a	n/a	n/a	n/a	9860.50	8842.56	89.7	7200.2	1181.9	90.8			
20	6	3	2	7477.33	n/a	n/a	n/a	n/a	7527.54	7040.63	93.5	7200.2	236.8	87.2			
20	6	3	3	9335.74	n/a	n/a	n/a	n/a	9080.12	8574.27	94.4	7200.2	181.9	90.6			
20	6	3	4	10989.06	n/a	n/a	n/a	n/a	10846.92	10028.15	92.5	7200.2	433.2	92.7			
20	6	3	5	11826.34	n/a	n/a	n/a	n/a	11357.43	10557.12	93.0	7200.2	4056.8	91.5			
25	6	2	1	7892.30	n/a	n/a	n/a	n/a	8657.11	7573.02	87.5	7200.2	6616.6	89.2			
25	6	2	2	8667.63	n/a	n/a	n/a	n/a	9780.01	8260.99	84.5	7202.8	6873.2	89.5			
25	6	2	3	8950.41	n/a	n/a	n/a	n/a	9754.76	8739.19	89.6	7200.2	6788.5	88.1			
25	6	2	4	7954.64	n/a	n/a	n/a	n/a	8549.26	7814.72	91.4	7202.0	6990.8	88.5			
25	6	2	5	9049.47	n/a	n/a	n/a	n/a	9374.68	8587.22	91.6	7202.8	6451.6	86.3			
25	6	3	1	9024.73	n/a	n/a	n/a	n/a	9375.30	8420.46	89.8	7200.2	1541.7	90.0			
25	6	3	2	11136.70	n/a	n/a	n/a	n/a	10430.03	9662.85	92.6	7200.3	3034.9	90.1			
25	6	3	3	11320.78	n/a	n/a	n/a	n/a	14146.16	10398.27	73.5	7200.3	7000.5	91.8			
25	6	3	4	9233.14	n/a	n/a	n/a	n/a	9338.73	8760.84	93.8	7200.3	1917.9	89.5			
25	6	3	5	11760.03	n/a	n/a	n/a	n/a	11037.56	10346.64	93.7	7200.3	1671.5	88.4			
30	6	3	1	n/a	n/a	n/a	n/a	n/a	14115.87	10493.40	74.3	7202.1	6910.6	88.4			
30	6	3	2	n/a	n/a	n/a	n/a	n/a	10323.19	9334.39	90.4	7202.3	6924.4	86.7			
30	6	3	3	n/a	n/a	n/a	n/a	n/a	10449.54	9428.62	90.2	7208.8	5297.7	83.8			
30	6	3	4	n/a	n/a	n/a	n/a	n/a	10719.44	9183.27	85.7	7200.2	6954.6	89.5			
30	6	3	5	n/a	n/a	n/a	n/a	n/a	10071.78	9058.20	89.9	7203.5	6262.8	87.1			
30	6	4	1	n/a	n/a	n/a	n/a	n/a	13066.99	12092.09	92.5	7200.3	3482.9	87.4			
30	6	4	2	n/a	n/a	n/a	n/a	n/a	11914.42	10647.63	89.4	7200.3	2290.7	88.5			
30	6	4	3	n/a	n/a	n/a	n/a	n/a	11269.56	10341.72	91.8	7200.2	1508.8	85.0			
30	6	4	4	n/a	n/a	n/a	n/a	n/a	11881.20	10446.30	87.9	7200.7	6699.0	90.5			
30	6	4	5	n/a	n/a	n/a	n/a	n/a	11407.76	10232.09	89.7	7200.2	2292.0	88.6			

Table 4: Results on multi-vehicle VMIRP instances with six periods and high inventory costs

n	l	m	id	Adulyasak et al. (2014)								EXM				
				Best ub	Veh-Ind		Non-Veh-Ind		ub	lb	$\%lb$	t	t_S	$\%rc$		
					$\%lb$	t	$\%lb$	t								
5	6	2	1	6888.73	100.0	2.0	100.0	3.5	6888.73	6888.73	100.0	1.7	0.3	58.1		
5	6	2	2	6202.65	100.0	2.4	100.0	15.5	6202.65	6202.65	100.0	2.3	0.5	58.3		
5	6	2	3	8183.76	100.0	1.0	100.0	1.2	8183.76	8183.76	100.0	1.0	0.1	70.3		
5	6	2	4	5726.62	100.0	1.1	100.0	1.3	5726.62	5726.62	100.0	1.1	0.1	62.9		
5	6	2	5	5234.05	100.0	0.5	100.0	0.6	5234.05	5234.05	100.0	1.1	0.1	53.8		
5	6	3	1	7864.79	100.0	0.2	100.0	0.8	7864.79	7864.79	100.0	0.8	0.0	63.2		
5	6	3	2	7174.59	100.0	0.1	100.0	0.1	7174.59	7174.59	100.0	0.8	0.1	64.4		
5	6	3	3	12780.57	100.0	0.0	100.0	0.3	12780.57	12780.57	100.0	0.8	0.1	80.7		
5	6	3	4	6933.86	100.0	0.3	100.0	18.0	6933.86	6933.86	100.0	0.9	0.1	69.5		
5	6	3	5	6593.51	100.0	0.2	100.0	0.9	6593.51	6593.51	100.0	0.7	0.0	62.8		
10	6	2	1	10294.48	100.0	240.2	99.2	7200.0	10294.48	10294.48	100.0	177.2	6.2	52.9		
10	6	2	2	10265.25	100.0	785.2	100.0	1944.9	10265.25	10265.25	100.0	2182.1	27.5	63.9		
10	6	2	3	9400.47	100.0	102.9	100.0	669.0	9400.47	9400.47	100.0	420.6	9.8	54.3		
10	6	2	4	10161.40	100.0	150.7	100.0	1986.1	10161.40	10161.40	100.0	302.2	10.8	59.5		
10	6	2	5	10391.07	100.0	82.9	100.0	341.9	10391.07	10391.07	100.0	316.4	6.5	47.1		
10	6	3	1	11900.94	96.4	7200.0	94.4	7200.0	11900.94	11900.94	100.0	111.8	9.5	59.3		
10	6	3	2	11929.85	100.0	5313.3	99.4	7200.0	11929.85	11929.85	100.0	133.6	11.3	68.9		
10	6	3	3	10456.78	100.0	871.2	100.0	2929.3	10456.78	10456.78	100.0	1258.2	10.2	59.0		
10	6	3	4	11598.75	100.0	2521.3	95.6	7200.0	11598.75	11598.75	100.0	1354.5	12.9	64.4		
10	6	3	5	11192.68	100.0	1903.0	100.0	1962.0	11192.68	11192.68	100.0	268.6	7.2	51.0		
15	6	2	1	12825.51	100.0	246.4	97.7	7200.0	12830.99	12648.57	98.6	7200.2	41.0	42.4		
15	6	2	2	12821.22	100.0	263.1	99.4	7200.0	12826.37	12623.23	98.4	7200.3	58.3	44.3		
15	6	2	3	14733.15	100.0	1251.9	97.6	7200.0	14796.15	14582.63	98.6	7200.3	44.7	43.8		
15	6	2	4	11592.15	100.0	555.8	98.1	7200.0	11605.05	11442.76	98.6	7200.2	92.4	50.9		
15	6	2	5	11748.70	100.0	1498.5	97.8	7200.0	11748.70	11504.56	97.9	7200.2	118.3	51.9		
15	6	3	1	13785.72	96.5	7200.0	95.6	7200.0	13785.72	13624.12	98.8	7200.2	82.5	46.5		
15	6	3	2	14009.39	97.0	7200.0	96.3	7200.0	14095.52	13693.86	97.2	7200.2	113.0	49.2		
15	6	3	3	15974.42	95.5	7200.0	95.2	7200.0	16012.42	15791.81	98.6	7200.2	72.9	47.9		
15	6	3	4	12734.73	97.4	7200.0	96.1	7200.0	12887.45	12449.05	96.6	7200.3	141.1	55.8		
15	6	3	5	13134.22	95.5	7200.0	94.9	7200.0	13232.49	12715.72	96.1	7200.3	155.7	57.5		
20	6	2	1	15946.57	n/a	n/a	n/a	n/a	16098.83	15393.92	95.6	7200.3	2600.4	43.3		
20	6	2	2	15144.35	n/a	n/a	n/a	n/a	15191.83	14882.20	98.0	7200.3	260.8	37.4		
20	6	2	3	15366.82	n/a	n/a	n/a	n/a	15503.94	14968.21	96.5	7200.3	442.9	45.6		
20	6	2	4	15850.97	n/a	n/a	n/a	n/a	16274.16	15242.53	93.7	7200.3	1118.5	51.5		
20	6	2	5	17654.71	n/a	n/a	n/a	n/a	17909.43	16972.18	94.8	7200.3	1527.5	46.1		
20	6	3	1	17853.11	n/a	n/a	n/a	n/a	17932.95	16974.28	94.7	7200.2	821.3	48.9		
20	6	3	2	15939.81	n/a	n/a	n/a	n/a	15982.33	15498.24	97.0	7200.3	232.5	40.4		
20	6	3	3	16871.90	n/a	n/a	n/a	n/a	16825.56	16027.68	95.3	7200.3	248.2	49.9		
20	6	3	4	18130.74	n/a	n/a	n/a	n/a	17834.74	16987.27	95.2	7200.2	581.4	55.7		
20	6	3	5	20298.58	n/a	n/a	n/a	n/a	20429.06	19003.73	93.0	7200.3	835.4	52.8		
25	6	2	1	16383.06	n/a	n/a	n/a	n/a	16915.50	15868.56	93.8	7200.7	6402.9	44.4		
25	6	2	2	18060.15	n/a	n/a	n/a	n/a	20127.08	17275.64	85.8	7205.1	7026.8	48.6		
25	6	2	3	19352.31	n/a	n/a	n/a	n/a	20406.40	18873.77	92.5	7201.1	7097.1	43.5		
25	6	2	4	16781.57	n/a	n/a	n/a	n/a	17181.65	16388.07	95.4	7205.9	6825.6	43.1		
25	6	2	5	20682.66	n/a	n/a	n/a	n/a	22370.02	19923.07	89.1	7205.5	6941.5	42.5		
25	6	3	1	17426.30	n/a	n/a	n/a	n/a	17832.54	16705.73	93.7	7200.3	1290.5	47.1		
25	6	3	2	20477.42	n/a	n/a	n/a	n/a	19624.32	18790.26	95.7	7200.3	2616.6	47.2		
25	6	3	3	21748.29	n/a	n/a	n/a	n/a	21910.48	20570.19	93.9	7200.3	1630.2	47.4		
25	6	3	4	18001.88	n/a	n/a	n/a	n/a	18240.43	17357.35	95.2	7200.3	2856.9	46.3		
25	6	3	5	23562.27	n/a	n/a	n/a	n/a	-	21688.16	-	7203.9	7115.1	-		
30	6	3	1	n/a	n/a	n/a	n/a	n/a	27412.68	25034.46	91.3	7204.6	6913.0	39.9		
30	6	3	2	n/a	n/a	n/a	n/a	n/a	22580.76	21445.55	95.0	7208.8	3137.7	39.4		
30	6	3	3	n/a	n/a	n/a	n/a	n/a	25523.43	24282.77	95.1	7200.3	1979.3	34.1		
30	6	3	4	n/a	n/a	n/a	n/a	n/a	20686.07	18930.76	91.5	7205.4	6402.6	45.9		
30	6	3	5	n/a	n/a	n/a	n/a	n/a	21665.65	20412.67	94.2	7206.8	4814.3	40.4		
30	6	4	1	n/a	n/a	n/a	n/a	n/a	28197.79	26702.31	94.7	7200.2	1828.9	41.5		
30	6	4	2	n/a	n/a	n/a	n/a	n/a	24124.71	22720.94	94.2	7200.3	4235.9	43.2		
30	6	4	3	n/a	n/a	n/a	n/a	n/a	26545.07	25212.25	95.0	7200.3	1282.1	36.7		
30	6	4	4	n/a	n/a	n/a	n/a	n/a	21976.70	20205.37	91.9	7200.2	4461.9	49.1		
30	6	4	5	n/a	n/a	n/a	n/a	n/a	22854.80	21564.19	94.4	7200.2	1673.7	43.6		