

Appendix A: Instance generator

A custom instance generator was developed to create realistic and diverse test cases. The generator samples vessels from three predefined ship types (A, B, and C), each with different characteristics, presented in Table 1. Vessel arrival times were uniformly distributed over a planning horizon of 168 hours, with scenario-based disruptions affecting arrival times (Uniform[-2,2] hours) QC-hour demand (Uniform[-5,5] hours), with all scenarios assumed equally likely. The cost structure was chosen in order to penalize vessel waiting time, tardiness, quay crane usage, and buffer crane activation through predefined coefficients (e.g., c_i , c^2 , c^3 , α , β). A total of nine instances were generated with vessel counts ranging from 5 to 20, scenarios from 2 to 10, and quay cranes from 5 to 10. Detailed information can be found in Appendix B.

Table 1: Vessel type characteristics distribution

Vessel type	Vessel length (l_i)	Crane number $\{r_i^{max}, r_i^{max}\}$	QC-hour demand (m_i)
Type A	Uniform[70,200]	$\{1,2\}$	Uniform[5,15]
Type B	Uniform[201,300]	$\{2,4\}$	Uniform[15,45]
Type C	Uniform[301,400]	$\{4,6\}$	Uniform[30,60]

Appendix B: Instances

Table 2: Instance 5V_2S_5Q_800L vessel related parameters

Vessel	Type	l_i	b_i^0	m_i	r_i^{min}	r_i^{max}	a_i	EFT_i	c_i
1	C	396	261	49	4	6	6	26	3
2	A	124	173	13	1	2	119	137	1
3	A	130	327	9	1	2	42	64	1
4	B	233	724	26	2	4	13	31	2
5	A	162	390	15	1	2	67	89	1

Table 3: Instance 5V_2S_5Q_800L general parameters

α	β	c^2	c^3	M	Q	H	L
0.9	0.01	0.1	0.06	10000	5	168	800

Table 4: Instance 5V_2S_5Q_800L scenario parameters

Scenario	Probability	Vessel	a_i^ξ	m_i^ξ
0	0.5	1	6	49
0	0.5	2	120	12
0	0.5	3	43	5
0	0.5	4	13	25
0	0.5	5	66	19
1	0.5	1	4	49
1	0.5	2	117	13
1	0.5	3	43	7
1	0.5	4	15	22
1	0.5	5	66	18

Table 5: Instance 5V_5S_5Q_800L vessel related parameters

Vessel	Type	l_i	b_i^0	m_i	r_i^{min}	r_i^{max}	a_i	EFT_i	c_i
1	A	75	350	8	1	2	138	158	1
2	C	339	435	39	4	6	59	82	3
3	B	236	43	45	2	4	61	85	2
4	A	99	138	7	1	2	92	109	1
5	B	241	733	32	2	4	106	129	2

Table 6: Instance 5V_5S_5Q_800L general parameters

α	β	c^2	c^3	M	Q	H	L
0.9	0.01	0.1	0.06	10000	5	168	800

Table 7: Instance 5V_5S_5Q_800L scenario parameters

Scenario	Probability	Vessel	a_i^ξ	m_i^ξ
0	0.2	1	138	13
0	0.2	2	59	36
0	0.2	3	62	46
0	0.2	4	91	7
0	0.2	5	105	32
1	0.2	1	138	7
1	0.2	2	59	39
1	0.2	3	63	48
1	0.2	4	93	8
1	0.2	5	105	30
2	0.2	1	138	6
2	0.2	2	57	41
2	0.2	3	62	46
2	0.2	4	93	4
2	0.2	5	105	27
3	0.2	1	140	12
3	0.2	2	57	44
3	0.2	3	61	49
3	0.2	4	92	3
3	0.2	5	105	28
4	0.2	1	139	13
4	0.2	2	59	39
4	0.2	3	63	45
4	0.2	4	92	8
4	0.2	5	105	35

Table 8: Instance 10V_3S_6Q_1000L vessel related parameters

Vessel	Type	l_i	b_i^0	m_i	r_i^{min}	r_i^{max}	a_i	EFT_i	c_i
1	B	268	721	27	2	4	134	156	2
2	A	107	365	12	1	2	145	159	1
3	A	124	295	13	1	2	41	60	1
4	C	309	239	52	4	6	69	88	3
5	B	207	756	18	2	4	58	77	2
6	B	216	565	16	2	4	43	65	2
7	C	377	598	47	4	6	3	26	3
8	C	369	556	50	4	6	39	58	3
9	A	139	513	6	1	2	119	138	1
10	A	75	635	13	1	2	12	28	1

Table 9: Instance 10V_3S_6Q_1000L general parameters

α	β	c^2	c^3	M	Q	H	L
0.9	0.01	0.1	0.06	10000	6	168	1000

Table 10: Instance 10V_3S_6Q_1000L scenario parameters

Scenario	Probability	Vessel	a_i^ξ	m_i^ξ
0	0.33	1	135	23
0	0.33	2	146	9
0	0.33	3	41	9
0	0.33	4	70	47
0	0.33	5	57	22
0	0.33	6	42	13
0	0.33	7	1	42
0	0.33	8	40	55
0	0.33	9	118	10
0	0.33	10	10	11
1	0.33	1	135	28
1	0.33	2	146	13
1	0.33	3	43	13
1	0.33	4	71	52
1	0.33	5	57	22
1	0.33	6	42	11
1	0.33	7	4	47
1	0.33	8	38	51
1	0.33	9	118	2
1	0.33	10	14	11
2	0.33	1	136	32
2	0.33	2	146	9
2	0.33	3	39	16
2	0.33	4	69	48
2	0.33	5	60	18
2	0.33	6	45	13
2	0.33	7	3	44
2	0.33	8	38	54
2	0.33	9	121	9
2	0.33	10	12	11

Table 11: Instance 10V_5S_6Q_1000L vessel related parameters

Vessel	Type	l_i	b_i^0	m_i	r_i^{min}	r_i^{max}	a_i	EFT_i	c_i
1	A	114	54	11	1	2	39	57	1
2	A	152	628	13	1	2	106	130	1
3	C	375	524	36	4	6	75	91	3
4	A	101	838	14	1	2	84	97	1
5	B	289	318	28	2	4	128	147	2
6	A	157	107	13	1	2	121	143	1
7	A	167	245	14	1	2	73	92	1
8	A	144	142	7	1	2	15	32	1
9	B	217	639	36	2	4	70	83	2
10	C	377	369	43	4	6	78	94	3

Table 12: Instance 10V_5S_6Q_1000L general parameters

α	β	c^2	c^3	M	Q	H	L
0.9	0.01	0.1	0.06	10000	6	168	1000

Table 13: Instance 10V_5S_6Q_1000L scenario parameters

Scenario	Probability	Vessel	a_i^ξ	m_i^ξ
0	0.2	1	38	7
0	0.2	2	107	13
0	0.2	3	76	34
0	0.2	4	84	19
0	0.2	5	129	28
0	0.2	6	121	8
0	0.2	7	74	10
0	0.2	8	13	4
0	0.2	9	69	32
0	0.2	10	78	41
1	0.2	1	41	10
1	0.2	2	106	11
1	0.2	3	75	36
1	0.2	4	84	19
1	0.2	5	128	26
1	0.2	6	121	13
1	0.2	7	72	14
1	0.2	8	15	4
1	0.2	9	72	36
1	0.2	10	79	43
2	0.2	1	38	7
2	0.2	2	107	14
2	0.2	3	75	37
2	0.2	4	85	11
2	0.2	5	126	32
2	0.2	6	123	13
2	0.2	7	71	13
2	0.2	8	14	10
2	0.2	9	69	34
2	0.2	10	80	42
3	0.2	1	38	8
3	0.2	2	105	15
3	0.2	3	75	40
3	0.2	4	84	14
3	0.2	5	127	25
3	0.2	6	120	10
3	0.2	7	72	18
3	0.2	8	15	10
3	0.2	9	70	36
3	0.2	10	80	44
4	0.2	1	40	9
4	0.2	2	107	15

Scenario	Probability	Vessel	a_i^ξ	m_i^ξ
4	0.2	3	75	32
4	0.2	4	83	14
4	0.2	5	127	28
4	0.2	6	122	10
4	0.2	7	72	16
4	0.2	8	15	11
4	0.2	9	71	36
4	0.2	10	77	46

Table 14: Instance 10V_10S_6Q_1000L vessel related parameters

Vessel	Type	l_i	b_i^0	m_i	r_i^{min}	r_i^{max}	a_i	EFT_i	c_i
1	A	88	681	9	1	2	46	63	1
2	B	256	465	30	2	4	3	20	2
3	A	148	51	8	1	2	123	139	1
4	B	259	453	44	2	4	114	132	2
5	B	254	304	22	2	4	111	132	2
6	B	214	716	40	2	4	25	44	2
7	C	340	269	36	4	6	33	50	3
8	B	291	332	34	2	4	103	124	2
9	B	295	547	20	2	4	117	140	2
10	A	182	501	14	1	2	152	171	1

Table 15: Instance 10V_10S_6Q_1000L general parameters

α	β	c^2	c^3	M	Q	H	L
0.9	0.01	0.1	0.06	10000	6	168	1000

Table 16: Instance 10V_10S_6Q_1000L scenario parameters

Scenario	Probability	Vessel	a_i^ξ	m_i^ξ
0	0.1	1	45	14
0	0.1	2	3	27
0	0.1	3	122	13
0	0.1	4	116	47
0	0.1	5	110	25
0	0.1	6	24	39
0	0.1	7	32	31
0	0.1	8	102	33
0	0.1	9	116	16
0	0.1	10	152	17
1	0.1	1	45	7
1	0.1	2	4	32
1	0.1	3	124	6
1	0.1	4	114	44
1	0.1	5	112	18

Scenario	Probability	Vessel	a_i^ξ	m_i^ξ
1	0.1	6	23	40
1	0.1	7	35	34
1	0.1	8	105	34
1	0.1	9	118	25
1	0.1	10	154	10
2	0.1	1	47	11
2	0.1	2	3	28
2	0.1	3	125	6
2	0.1	4	115	47
2	0.1	5	111	22
2	0.1	6	25	42
2	0.1	7	32	35
2	0.1	8	105	35
2	0.1	9	115	18
2	0.1	10	153	16
3	0.1	1	44	11
3	0.1	2	2	26
3	0.1	3	122	13
3	0.1	4	115	43
3	0.1	5	109	20
3	0.1	6	25	44
3	0.1	7	32	35
3	0.1	8	103	32
3	0.1	9	115	16
3	0.1	10	152	13
4	0.1	1	45	11
4	0.1	2	2	31
4	0.1	3	123	11
4	0.1	4	116	44
4	0.1	5	111	24
4	0.1	6	25	38
4	0.1	7	35	31
4	0.1	8	103	33
4	0.1	9	118	15
4	0.1	10	152	12
5	0.1	1	47	8
5	0.1	2	1	29
5	0.1	3	121	10
5	0.1	4	114	39
5	0.1	5	112	26
5	0.1	6	26	37
5	0.1	7	34	32
5	0.1	8	103	36
5	0.1	9	117	22
5	0.1	10	152	10
6	0.1	1	48	13
6	0.1	2	3	34
6	0.1	3	122	4
6	0.1	4	115	40

Scenario	Probability	Vessel	a_i^ξ	m_i^ξ
6	0.1	5	110	19
6	0.1	6	26	41
6	0.1	7	34	39
6	0.1	8	104	31
6	0.1	9	116	21
6	0.1	10	153	19
7	0.1	1	46	4
7	0.1	2	3	32
7	0.1	3	122	12
7	0.1	4	114	49
7	0.1	5	111	25
7	0.1	6	24	38
7	0.1	7	31	40
7	0.1	8	101	35
7	0.1	9	116	18
7	0.1	10	152	14
8	0.1	1	47	13
8	0.1	2	2	34
8	0.1	3	124	11
8	0.1	4	114	41
8	0.1	5	113	21
8	0.1	6	24	41
8	0.1	7	33	33
8	0.1	8	102	30
8	0.1	9	117	16
8	0.1	10	152	12
9	0.1	1	47	11
9	0.1	2	1	32
9	0.1	3	123	7
9	0.1	4	115	46
9	0.1	5	112	21
9	0.1	6	23	39
9	0.1	7	33	32
9	0.1	8	104	30
9	0.1	9	116	20
9	0.1	10	153	15

Table 17: Instance 15V_3S_8Q_1200L vessel related parameters

Vessel	Type	l_i	b_i^0	m_i	r_i^{min}	r_i^{max}	a_i	EFT_i	c_i
1	A	91	671	11	1	2	30	45	1
2	B	204	789	24	2	4	121	142	2
3	B	208	87	31	2	4	66	78	2
4	A	70	650	13	1	2	112	126	1
5	B	250	715	21	2	4	136	158	2
6	C	327	50	34	4	6	79	92	3
7	A	114	721	10	1	2	75	99	1
8	B	293	258	26	2	4	35	55	2
9	B	234	26	22	2	4	3	25	2
10	A	178	693	14	1	2	149	170	1
11	B	242	2	39	2	4	55	75	2
12	B	231	214	16	2	4	71	88	2
13	B	295	604	44	2	4	60	77	2
14	B	221	474	29	2	4	113	131	2
15	B	281	525	26	2	4	41	54	2

Table 18: Instance 15V_3S_8Q_1200L general parameters

α	β	c^2	c^3	M	Q	H	L
0.9	0.01	0.1	0.06	10000	8	168	1200

Table 19: Instance 15V_3S_8Q_1200L scenario parameters

Scenario	Probability	Vessel	a_i^ξ	m_i^ξ
0	0.33	1	31	15
0	0.33	2	120	26
0	0.33	3	66	27
0	0.33	4	113	10
0	0.33	5	134	19
0	0.33	6	77	32
0	0.33	7	76	14
0	0.33	8	33	29
0	0.33	9	4	25
0	0.33	10	149	18
0	0.33	11	53	40
0	0.33	12	69	12
0	0.33	13	58	49
0	0.33	14	112	33
0	0.33	15	40	29
1	0.33	1	30	7
1	0.33	2	120	20
1	0.33	3	66	30
1	0.33	4	113	15
1	0.33	5	134	17
1	0.33	6	78	31

Scenario	Probability	Vessel	a_i^ξ	m_i^ξ
1	0.33	7	75	12
1	0.33	8	33	29
1	0.33	9	4	24
1	0.33	10	150	12
1	0.33	11	53	43
1	0.33	12	71	18
1	0.33	13	61	40
1	0.33	14	111	31
1	0.33	15	43	24
2	0.33	1	28	12
2	0.33	2	121	21
2	0.33	3	64	27
2	0.33	4	114	15
2	0.33	5	135	23
2	0.33	6	80	30
2	0.33	7	74	9
2	0.33	8	34	29
2	0.33	9	4	25
2	0.33	10	150	10
2	0.33	11	54	43
2	0.33	12	69	15
2	0.33	13	59	39
2	0.33	14	111	24
2	0.33	15	40	24

Table 20: Instance 15V_3S_8Q_1200L vessel related parameters

Vessel	Type	l_i	b_i^0	m_i	r_i^{min}	r_i^{max}	a_i	EFT_i	c_i
1	B	273	359	39	2	4	51	70	2
2	C	329	628	48	4	6	91	107	3
3	A	152	421	5	1	2	60	80	1
4	B	257	451	31	2	4	44	57	2
5	A	97	466	7	1	2	16	29	1
6	A	158	462	10	1	2	17	33	1
7	A	110	19	12	1	2	116	136	1
8	B	248	66	17	2	4	36	58	2
9	A	109	678	10	1	2	132	151	1
10	C	362	364	30	4	6	85	100	3
11	B	243	580	33	2	4	48	67	2
12	B	201	576	43	2	4	94	108	2
13	B	298	516	22	2	4	89	108	2
14	C	385	26	58	4	6	86	102	3
15	B	275	477	42	2	4	53	69	2

Table 21: Instance 15V_3S_8Q_1200L general parameters

α	β	c^2	c^3	M	Q	H	L
0.9	0.01	0.1	0.06	10000	8	168	1200

Table 22: Instance 15V_3S_8Q_1200L scenario parameters

Scenario	Probability	Vessel	a_i^ξ	m_i^ξ
0	0.2	1	51	40
0	0.2	2	90	51
0	0.2	3	62	1
0	0.2	4	42	31
0	0.2	5	17	11
0	0.2	6	17	6
0	0.2	7	115	15
0	0.2	8	37	14
0	0.2	9	133	5
0	0.2	10	85	30
0	0.2	11	47	35
0	0.2	12	95	45
0	0.2	13	90	20
0	0.2	14	86	56
0	0.2	15	53	42
1	0.2	1	50	38
1	0.2	2	92	52
1	0.2	3	61	8
1	0.2	4	43	34
1	0.2	5	15	10
1	0.2	6	18	14
1	0.2	7	114	16
1	0.2	8	36	16
1	0.2	9	134	7
1	0.2	10	83	28
1	0.2	11	49	30
1	0.2	12	93	40
1	0.2	13	88	25
1	0.2	14	84	62
1	0.2	15	51	37
2	0.2	1	52	44
2	0.2	2	91	46
2	0.2	3	61	3
2	0.2	4	42	34
2	0.2	5	16	12
2	0.2	6	17	14
2	0.2	7	116	16
2	0.2	8	34	17
2	0.2	9	132	6
2	0.2	10	84	35
2	0.2	11	50	28
2	0.2	12	95	45

Scenario	Probability	Vessel	a_i^ξ	m_i^ξ
2	0.2	13	90	23
2	0.2	14	85	55
2	0.2	15	55	45
3	0.2	1	51	35
3	0.2	2	90	49
3	0.2	3	59	3
3	0.2	4	43	33
3	0.2	5	15	7
3	0.2	6	19	12
3	0.2	7	114	17
3	0.2	8	35	18
3	0.2	9	133	12
3	0.2	10	85	27
3	0.2	11	47	32
3	0.2	12	96	47
3	0.2	13	89	24
3	0.2	14	85	61
3	0.2	15	52	40
4	0.2	1	50	38
4	0.2	2	91	46
4	0.2	3	60	8
4	0.2	4	45	27
4	0.2	5	15	2
4	0.2	6	16	7
4	0.2	7	117	14
4	0.2	8	36	13
4	0.2	9	133	7
4	0.2	10	86	33
4	0.2	11	50	34
4	0.2	12	94	41
4	0.2	13	89	27
4	0.2	14	87	54
4	0.2	15	51	46

Table 23: Instance 20V_5S_10Q_1400L vessel related parameters

Vessel	Type	l_i	b_i^0	m_i	r_i^{min}	r_i^{max}	a_i	EFT_i	c_i
1	C	375	517	55	4	6	56	76	3
2	B	262	671	42	2	4	103	116	2
3	C	343	82	35	4	6	50	65	3
4	C	329	133	55	4	6	62	86	3
5	C	365	24	51	4	6	17	41	3
6	B	232	116	33	2	4	25	43	2
7	A	124	78	14	1	2	51	65	1
8	B	289	702	19	2	4	31	43	2
9	C	397	432	50	4	6	30	48	3
10	A	197	434	13	1	2	149	162	1
11	B	250	706	17	2	4	92	116	2
12	B	298	695	24	2	4	102	123	2
13	A	91	218	15	1	2	129	150	1
14	B	282	434	39	2	4	16	38	2
15	A	172	303	9	1	2	11	33	1
16	A	131	688	11	1	2	20	37	1
17	A	92	845	10	1	2	60	82	1
18	B	298	28	25	2	4	35	49	2
19	A	139	494	12	1	2	115	139	1
20	A	195	62	7	1	2	146	163	1

Table 24: Instance 20V_5S_10Q_1400L general parameters

α	β	c^2	c^3	M	Q	H	L
0.9	0.01	0.1	0.06	10000	10	168	1400

Table 25: Instance 20V_5S_10Q_1400L scenario parameters

Scenario	Probability	Vessel	a_i^ξ	m_i^ξ
0	0.2	1	54	52
0	0.2	2	103	40
0	0.2	3	49	35
0	0.2	4	63	54
0	0.2	5	15	54
0	0.2	6	25	36
0	0.2	7	52	16
0	0.2	8	30	17
0	0.2	9	31	45
0	0.2	10	149	12
0	0.2	11	92	13
0	0.2	12	104	26
0	0.2	13	127	11
0	0.2	14	18	34
0	0.2	15	12	13
0	0.2	16	20	15

Scenario	Probability	Vessel	a_i^ξ	m_i^ξ
0	0.2	17	60	14
0	0.2	18	33	26
0	0.2	19	113	16
0	0.2	20	144	6
1	0.2	1	56	54
1	0.2	2	102	47
1	0.2	3	51	38
1	0.2	4	63	51
1	0.2	5	17	49
1	0.2	6	26	37
1	0.2	7	51	13
1	0.2	8	31	19
1	0.2	9	29	49
1	0.2	10	149	11
1	0.2	11	93	13
1	0.2	12	104	26
1	0.2	13	127	10
1	0.2	14	15	35
1	0.2	15	11	12
1	0.2	16	19	16
1	0.2	17	59	7
1	0.2	18	36	26
1	0.2	19	115	8
1	0.2	20	145	4
2	0.2	1	55	50
2	0.2	2	104	39
2	0.2	3	49	31
2	0.2	4	64	58
2	0.2	5	18	54
2	0.2	6	26	30
2	0.2	7	49	17
2	0.2	8	30	17
2	0.2	9	31	48
2	0.2	10	151	12
2	0.2	11	93	14
2	0.2	12	101	23
2	0.2	13	130	13
2	0.2	14	15	37
2	0.2	15	12	6
2	0.2	16	18	16
2	0.2	17	62	7
2	0.2	18	37	23
2	0.2	19	116	17
2	0.2	20	146	10
3	0.2	1	57	51
3	0.2	2	101	46
3	0.2	3	49	35
3	0.2	4	63	55
3	0.2	5	18	51

Scenario	Probability	Vessel	a_i^ξ	m_i^ξ
3	0.2	6	26	34
3	0.2	7	53	19
3	0.2	8	31	23
3	0.2	9	29	52
3	0.2	10	151	12
3	0.2	11	93	19
3	0.2	12	104	24
3	0.2	13	129	18
3	0.2	14	15	35
3	0.2	15	10	7
3	0.2	16	21	13
3	0.2	17	60	7
3	0.2	18	34	21
3	0.2	19	116	14
3	0.2	20	146	6
4	0.2	1	56	54
4	0.2	2	104	40
4	0.2	3	51	31
4	0.2	4	60	58
4	0.2	5	18	49
4	0.2	6	23	29
4	0.2	7	51	10
4	0.2	8	30	19
4	0.2	9	31	50
4	0.2	10	151	11
4	0.2	11	91	13
4	0.2	12	103	28
4	0.2	13	130	18
4	0.2	14	17	35
4	0.2	15	12	5
4	0.2	16	21	8
4	0.2	17	58	8
4	0.2	18	35	22
4	0.2	19	116	15
4	0.2	20	146	7

Table 26: Instance 20V_10S_10Q_1400L vessel related parameters

Vessel	Type	l_i	b_i^0	m_i	r_i^{min}	r_i^{max}	a_i	EFT_i	c_i
1	A	173	764	13	1	2	7	23	1
2	A	148	688	9	1	2	52	70	1
3	B	242	39	27	2	4	57	71	2
4	B	260	180	37	2	4	12	29	2
5	A	197	186	5	1	2	160	175	1
6	A	117	805	12	1	2	76	98	1
7	C	372	208	50	4	6	34	51	3
8	C	341	311	41	4	6	58	71	3
9	A	155	699	6	1	2	113	129	1
10	B	290	551	29	2	4	66	81	2
11	A	87	548	11	1	2	91	106	1
12	C	340	391	49	4	6	1	17	3
13	A	126	314	14	1	2	85	109	1
14	C	329	445	31	4	6	70	91	3
15	B	281	506	30	2	4	15	36	2
16	C	351	198	55	4	6	21	35	3
17	C	370	321	44	4	6	38	57	3
18	A	76	415	11	1	2	27	48	1
19	A	104	626	7	1	2	156	176	1
20	A	102	275	6	1	2	65	83	1

Table 27: Instance 20V_10S_10Q_1400L general parameters

α	β	c^2	c^3	M	Q	H	L
0.9	0.01	0.1	0.06	10000	10	168	1400

Table 28: Instance 20V_10S_10Q_1400L scenario parameters

Scenario	Probability	Vessel	a_i^ξ	m_i^ξ
0	0.1	1	5	16
0	0.1	2	53	10
0	0.1	3	58	29
0	0.1	4	10	42
0	0.1	5	160	1
0	0.1	6	76	15
0	0.1	7	33	51
0	0.1	8	56	44
0	0.1	9	113	6
0	0.1	10	65	34
0	0.1	11	93	12
0	0.1	12	0	50
0	0.1	13	84	13
0	0.1	14	69	33
0	0.1	15	16	27
0	0.1	16	21	52

Scenario	Probability	Vessel	a_i^ξ	m_i^ξ
0	0.1	17	40	43
0	0.1	18	28	7
0	0.1	19	155	5
0	0.1	20	66	8
1	0.1	1	9	8
1	0.1	2	50	7
1	0.1	3	58	30
1	0.1	4	12	34
1	0.1	5	159	6
1	0.1	6	76	12
1	0.1	7	36	51
1	0.1	8	60	42
1	0.1	9	115	5
1	0.1	10	66	28
1	0.1	11	93	14
1	0.1	12	0	49
1	0.1	13	84	16
1	0.1	14	71	27
1	0.1	15	17	26
1	0.1	16	22	54
1	0.1	17	37	46
1	0.1	18	29	15
1	0.1	19	157	3
1	0.1	20	63	10
2	0.1	1	5	11
2	0.1	2	51	11
2	0.1	3	56	27
2	0.1	4	13	41
2	0.1	5	161	1
2	0.1	6	77	16
2	0.1	7	35	49
2	0.1	8	58	38
2	0.1	9	112	1
2	0.1	10	65	32
2	0.1	11	93	6
2	0.1	12	0	47
2	0.1	13	85	13
2	0.1	14	69	32
2	0.1	15	16	33
2	0.1	16	19	57
2	0.1	17	38	40
2	0.1	18	27	7
2	0.1	19	156	9
2	0.1	20	64	3
3	0.1	1	6	15
3	0.1	2	51	7
3	0.1	3	58	29
3	0.1	4	11	35
3	0.1	5	160	7

Scenario	Probability	Vessel	a_i^ξ	m_i^ξ
3	0.1	6	77	13
3	0.1	7	35	45
3	0.1	8	59	39
3	0.1	9	111	9
3	0.1	10	68	34
3	0.1	11	92	10
3	0.1	12	3	48
3	0.1	13	86	17
3	0.1	14	68	28
3	0.1	15	15	25
3	0.1	16	19	59
3	0.1	17	37	42
3	0.1	18	28	15
3	0.1	19	158	8
3	0.1	20	66	11
4	0.1	1	6	15
4	0.1	2	53	8
4	0.1	3	56	23
4	0.1	4	12	36
4	0.1	5	159	5
4	0.1	6	77	10
4	0.1	7	33	47
4	0.1	8	58	42
4	0.1	9	115	3
4	0.1	10	66	31
4	0.1	11	92	6
4	0.1	12	0	49
4	0.1	13	83	18
4	0.1	14	69	35
4	0.1	15	13	30
4	0.1	16	19	55
4	0.1	17	39	41
4	0.1	18	28	9
4	0.1	19	156	11
4	0.1	20	65	7
5	0.1	1	5	13
5	0.1	2	51	11
5	0.1	3	59	24
5	0.1	4	12	33
5	0.1	5	161	1
5	0.1	6	74	11
5	0.1	7	35	45
5	0.1	8	59	43
5	0.1	9	114	3
5	0.1	10	66	30
5	0.1	11	93	10
5	0.1	12	1	51
5	0.1	13	86	17
5	0.1	14	68	30

Scenario	Probability	Vessel	a_i^ξ	m_i^ξ
5	0.1	15	16	26
5	0.1	16	22	59
5	0.1	17	39	45
5	0.1	18	29	13
5	0.1	19	155	10
5	0.1	20	65	4
6	0.1	1	7	15
6	0.1	2	54	4
6	0.1	3	58	29
6	0.1	4	14	36
6	0.1	5	161	7
6	0.1	6	77	12
6	0.1	7	34	50
6	0.1	8	58	41
6	0.1	9	114	1
6	0.1	10	66	33
6	0.1	11	91	15
6	0.1	12	0	47
6	0.1	13	86	14
6	0.1	14	70	34
6	0.1	15	14	31
6	0.1	16	23	59
6	0.1	17	40	47
6	0.1	18	28	13
6	0.1	19	155	6
6	0.1	20	65	6
7	0.1	1	6	10
7	0.1	2	52	9
7	0.1	3	58	26
7	0.1	4	13	37
7	0.1	5	161	6
7	0.1	6	78	11
7	0.1	7	32	50
7	0.1	8	58	42
7	0.1	9	112	7
7	0.1	10	65	25
7	0.1	11	89	15
7	0.1	12	1	45
7	0.1	13	87	18
7	0.1	14	69	29
7	0.1	15	16	26
7	0.1	16	22	57
7	0.1	17	38	45
7	0.1	18	26	10
7	0.1	19	156	6
7	0.1	20	67	5
8	0.1	1	6	15
8	0.1	2	53	9
8	0.1	3	57	27

Scenario	Probability	Vessel	a_i^ξ	m_i^ξ
8	0.1	4	13	33
8	0.1	5	158	9
8	0.1	6	77	11
8	0.1	7	32	47
8	0.1	8	56	42
8	0.1	9	114	3
8	0.1	10	67	27
8	0.1	11	91	7
8	0.1	12	2	46
8	0.1	13	83	15
8	0.1	14	69	35
8	0.1	15	15	34
8	0.1	16	22	60
8	0.1	17	38	46
8	0.1	18	25	11
8	0.1	19	154	3
8	0.1	20	65	4
9	0.1	1	8	11
9	0.1	2	54	6
9	0.1	3	56	30
9	0.1	4	13	35
9	0.1	5	159	1
9	0.1	6	74	15
9	0.1	7	33	46
9	0.1	8	58	41
9	0.1	9	112	4
9	0.1	10	67	32
9	0.1	11	91	13
9	0.1	12	3	53
9	0.1	13	86	14
9	0.1	14	71	31
9	0.1	15	15	29
9	0.1	16	20	60
9	0.1	17	38	42
9	0.1	18	28	9
9	0.1	19	157	12
9	0.1	20	65	9

Appendix C: Monolithic results

Table 29: Monolithic model metrics: instance characteristics.

Instance	Number of vessels	Length of wharf	Number of scenarios	Number of periods
5V_2S_5Q_800L	5	800	2	168
5V_5S_5Q_800L	5	800	5	168
10V_3S_6Q_1000L	10	1000	3	168
10V_5S_6Q_1000L	10	1000	5	168
10V_10S_6Q_1000L	10	1000	10	168
15V_3S_8Q_1200L	15	1200	3	168
15V_5S_8Q_1200L	15	1200	5	168
20V_5S_10Q_1400L	20	1400	5	168
20V_10S_10Q_1400L	20	1400	10	168

Table 30: Monolithic model metrics: solution statistics.

Instance	Total cost	Solve time	Number of variables	Number of constraints	Gap
5V_2S_5Q_800L	72.26	13.02	15019	18238	0.000%
5V_5S_5Q_800L	80.87	94.48	27523	32195	0.000%
10V_3S_6Q_1000L	90.55	6000.47	39670	45768	0.072%
10V_5S_6Q_1000L	290.33	6000.35	53294	64036	38.126%
10V_10S_6Q_1000L	133.24	6000.37	97602	109152	20.530%
15V_3S_8Q_1200L	94.43	2280.87	61785	69519	0.000%
20V_5S_10Q_1400L					No solution found
20V_5S_10Q_1400L					No solution found
20V_5S_10Q_1400L					No solution found

Table 31: Baseline and expected-relative-lateness results (monolithic).

Instance	Baseline waiting	Baseline tardiness	Baseline QC cost	Expected relative lateness
5V_2S_5Q_800L	5	7	0	0
5V_5S_5Q_800L	8	3	0	0.6
10V_3S_6Q_1000L	5	1	0	0.7
10V_5S_6Q_1000L	35	27	0	4
10V_10S_6Q_1000L	8	4	0	3.9
15V_3S_8Q_1200L	1	0	0	0.7
15V_5S_8Q_1200L				No solution found
20V_5S_10Q_1400L				No solution found
20V_10S_10Q_1400L				No solution found

Table 32: Expected scenario statistics (monolithic).

Instance	Expected buffer overrun	Expected scenario waiting	Expected scenario tardiness
5V_2S_5Q_800L	0	3	4
5V_5S_5Q_800L	0	6	1.2
10V_3S_6Q_1000L	0.7	5.3	0
10V_5S_6Q_1000L	4	22.4	14.4
10V_10S_6Q_1000L	2.9	10.5	4.9
15V_3S_8Q_1200L	0	1	0
15V_5S_8Q_1200L			No solution found
20V_5S_10Q_1400L			No solution found
20V_10S_10Q_1400L			No solution found

Appendix D: Benders results

Table 33: Benders model metrics: instance characteristics.

Instance	Number of vessels	Length of wharf	Number of scenarios	Number of periods
5V_2S_5Q_800L	5	800	2	168
5V_5S_5Q_800L	5	800	5	168
10V_3S_6Q_1000L	10	1000	3	168
10V_5S_6Q_1000L	10	1000	5	168
10V_10S_6Q_1000L	10	1000	10	168
15V_3S_8Q_1200L	15	1200	3	168
15V_5S_8Q_1200L	15	1200	5	168
20V_5S_10Q_1400L	20	1400	5	168
20V_10S_10Q_1400L	20	1400	10	168

Table 34: Benders model metrics: solution statistics.

Instance	Total cost	Solve time	Number of variables	Number of constraints	Gap
5V_2S_5Q_800L	45.7	8.19	7469	9190	0.000%
5V_5S_5Q_800L	43.3	3.8	7808	9606	0.000%
10V_3S_6Q_1000L	45.9	6000	15709	18695	0.027%
10V_5S_6Q_1000L	101.29	315.55	15039	18952	0.000%
10V_10S_6Q_1000L	56.7	78.54	16052	19023	0.000%
15V_3S_8Q_1200L	46.1	20.72	24384	28486	0.000%
15V_5S_8Q_1200L	256.77	6000	24050	28230	0.069%
20V_5S_10Q_1400L	99.68	714.97	31817	37773	0.000%
20V_10S_10Q_1400L	98.32	6000	31150	37578	0.178%

Table 35: Baseline and expected-relative-lateness results (Benders).

Instance	Baseline waiting	Baseline tardiness	Baseline QC cost	Expected relative lateness
5V_2S_5Q_800L	5	7	18.1	0
5V_5S_5Q_800L	8	3	21.3	0
10V_3S_6Q_1000L	9	0	28.9	0.3
10V_5S_6Q_1000L	22	6	24.3	0
10V_10S_6Q_1000L	8	4	32.7	0
15V_3S_8Q_1200L	1	0	44.1	0
15V_5S_8Q_1200L	52	37	50.5	0.6
20V_5S_10Q_1400L	6	6	75.5	0
20V_10S_10Q_1400L	11	0	70.5	0.5

Table 36: Expected scenario statistics (Benders).

Instance	Expected buffer overrun	Expected scenario waiting	Expected scenario tardiness
5V_2S_5Q_800L	0	0	0
5V_5S_5Q_800L	0	0	0
10V_3S_6Q_1000L	0.7	3	0
10V_5S_6Q_1000L	0	0	0
10V_10S_6Q_1000L	0	0	0
15V_3S_8Q_1200L	0	0	0
15V_5S_8Q_1200L	0.6	4.2	3.2
20V_5S_10Q_1400L	0	0	0
20V_10S_10Q_1400L	0.2	0	0