A

Optimal Communication Spanning Tree Test Instances

Searching the literature for standard test problems for the optimal communication spanning tree (OCST) problem reveals that many researchers use their private test problems which are mostly not published. As a result, the comparison of different search algorithms or representations is a difficult and time consuming task. It is not possible to quickly check if a new search method is better than the existing ones. Furthermore, applicants hesitate to use new and efficient search methods or representations if they can not be tested on a variety of different test problems and solve these problems well and reliably. Therefore, the building up of a collection of test instances for the OCST problem is necessary.

The purpose of this appendix is to go one step in this direction and to present a collection of different test instances for the OCST problem. It gives exact details concerning the properties of the problems we used in Sect. 8.2 for the comparison of different types of representations. Based on the presented test instances, a fair and standardized comparison of new search techniques or representations becomes possible.

For each test problem we present the best known solution, the demands, and the distance weights. The upper right corner of the presented matrices specifies the demands and distance weights. Sect. A.1 summarizes the properties of the test instances from Palmer (1994). We are not able to present data for the 47 and 98 node problems because these are no longer available. Sect. A.2 presents the details for the 10, 20, and 50 node OCST problem from Raidl (2001), Sect. A.3 specifies the berry6, berry35, and berry35u problems presented by Berry et al. (1995), and Sect. A.4 summarizes the specifications of four real-world test problems from Rothlauf et al. (2002).

A.1 Palmer's Test Instances

We present the details for palmer6, palmer12, and palmer24 test instances presented by Palmer (1994).

Table A.1 gives an overview of the best known solutions for the three test problems. The cost of a link is calculated as the traffic over a link multiplied by the distance weight of this link (compare (8.4)). Table A.2 lists the demands and distance weights for the palmer6 problem. The properties of the palmer12 problem are specified in Table A.3 (demands) and Table A.4 (distance weights). Finally, the properties of the palmer24 problem are listed in Table A.5 (demands) and Table A.6 (distance weights).

	$c(T_{opt})$	used links
palmer6	693,180	DET-CHI, PHIL-DET, PHIL-NY, HOU-LA, HOU-DET
palmer12	3,428,509	SD-PHNX, SD-LA, SF-SD, DET-CHI, PHIL-BALT, PHIL-DET, PHIL-NY, DAL-SD, DAL-DET, HOU-DAL, SANAN-DAL
palmer24	1,086,656	LA-PHNX, SD-LA, SF-LA, SJ-LA, CHI-LA, CHI-DEN, DET-CHI, DET-IND, NY-BOS, CLEVE-DET, COL-DET, PHIL-WDC, PHIL-JACK, PHIL-BALT, PHIL-DET, PHIL-NY, HOU-NO, HOU-DET, HOU-MEMP, HOU-DAL, HOU-ELPAS, SANAN-HOU, MILW-CHI

Table A.1. Cost and structure of the best solutions to the test instances from Palmer (1994)

(a) Demand matrix

	LA	CHI	DET	NY	PHIL	HOU
LA	0	1	1	1	1	2
CHI	-	0	10	3	4	3
DET	-	-	0	5	6	2
NY	-	-	-	0	31	2
PHIL	-	-	-	-	0	2
HOU	-	-	-	-	-	0

(b) Distance matrix

	LA	CHI	DET	NY	PHIL	HOU
LA	0	16,661	18,083	21,561	21,099	13,461
CHI	-	0	5,658	9,194	8,797	10,440
DET	-	-	0	7,230	6,899	11,340
NY	-	-	-	0	4,300	13,730
PHIL	-	-	-	-	0	13,130
HOU	-	-	-	-	-	0

Table A.2. Demand and distance matrix for palmer6

Table A.3. Demand matrix for palmer12

	PHNX	LA	SD	SF	CHI	BALT	DET	NY	PHIL	DAL	HOU	SANAN
PHNX	0	7	8	4	2	1	2	1	1	3	3	3
LA	-	0	25	7	1	1	1	1	1	2	2	2
SD	-	-	0	6	1	1	1	1	1	2	2	2
SF	-	-	-	0	1	1	1	1	1	2	2	2
CHI	-	-	-	-	0	4	11	4	4	3	3	2
BALT	-	-	-	-	-	0	6	15	29	2	2	2
DET	-	-	-	-	-	-	0	5	6	3	2	2
NY	-	-	-	-	-	-	-	0	33	2	2	2
PHIL	-	-	-	-	-	-	-	-	0	2	2	2
DAL	-	-	-	-	-	-	-	-	-	0	11	10
HOU	-	-	-	-	-	-	-	-	-	-	0	14
SANAN	-	-	-	-	-	-	-	-	-	-	-	0

Table A.4. Distance matrix for palmer12

	PHNX	LA	SD	SF	CHI	BALT	DET	NY	PHIL	DAL	HOU	SANAN
PHNX	0	6,490	5,903	8,484	14,561	18,359	15,976	19,360	18,867	10,090	10,883	9,665
LA	-	0	4,523	6,256	16,661	20,618	18,083	21,561	21,099	12,639	13,461	12,236
SD	-	-	0	6,908	16,414	20,292	17,829	21,263	20,787	12,073	12,802	11,540
SF	-	-	-	0	17,328	21,452	18,714	22,286	21,874	14,234	15,259	14,136
CHI	-	-	-	-	0	8,425	5,658	9,194	8,797	9,603	10,440	11,237
BALT	-	-	-	-	-	0	6,621	5,067	4,439	12,385	12,526	13,722
DET	-	-	-	-	-	-	0	7,230	6,899	10720	11,340	12,297
NY	-	-	-	-	-	-	-	0	4,300	13,531	13,730	14,912
PHIL	-	-	-	-	-	-	-	-	0	12,967	13,130	14,319
DAL	-	-	-	-	-	-	-	-	-	0	4,888	5,076
HOU	-	-	-	-	-	-	-	-	-	-	0	4,478
SANAN	-	-	-	-	-	-	-	-	-	-	-	0

Table A.5. Demand matrix for palmer24

	PHNX	LA	SD	SF	SJ	DEN	WDC	JACK	CHI	IND	NO	BOS	BALT	DET	NY	CLEVE	COL	PHIL	MEMP	DAL	ELPAS	HOU	SANAN	MILW
PHNX	0	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LA	-	0	100	100	100	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SD	-	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SF	-	-	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SJ	-	-	-	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DEN	-	-	-	-	-	0	0	0	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
WDC	-	-	-	-	-	-	0	0	0	0	0	0	0	0	0	0	0	100	0	0	0	0	0	0
JACK	-	-	-	-	-	-	-	0	0	0	0	0	0	0	0	0	0	100	0	0	0	0	0	0
CHI	-	-	-	-	-	-	-	-	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	100
IND	-	-	-	-	-	-	-	-	-	0	0	0	0	100	0	0	0	0	0	0	0	0	0	0
NO	-	-	-	-	-	-	-	-	-	-	0	0	0	0	0	0	0	0	0	0	0	100	0	0
BOS	-	-	-	-	-	-	-	-	-	-	-	0	0	0	100	0	0	0	0	0	0	0	0	0
BALT	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0	0	0	100	0	0	0	0	0	0
DET	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	100	100	2	0	0	0	2	0	0
NY	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0	2	0	0	0	0	0	0
CLEVE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0	0	0	0	0	0	0
COL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0	0	0	0	0	0
PHIL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0	0	0	0	0
MEMP	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0	100	0	0
DAL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	100	0	0
ELPAS	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	100	0	0
HOU	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	100	0
SANAN	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0
MILW	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0

Table A.6. Distance matrix for palmer24

	PHNX	LA	SD	SF	SJ	DEN	WDC	JACK	CHI	IND	NO	BOS	BALT	DET	NY	CLEVE	COL	PHIL	MEMP	DAL	ELPAS	HOU	SANAN	MILW
PHNX	0	649	590	848	824	808	1,810	1,700	1,456	1,489	1,336	2,059	1,835	1,597	1,936	1,674	1,588	1,886	1,289	1,009	602	1,088	966	1,461
LA	-	0	453	626	599	980	2,034	1,955	1,661	1,717	1,595	2,275	2,068	1,803	2,151	1,890	1,813	2,109	1,537	1,269	852	1,341	1,226	1,664
SD	-	-	0	698	664	967	2,003	1,897	1,644	1,688	1,539	2,241	2,022	1,789	2,123	1,864	1,784	2,077	1,483	1,203	791	1,282	1,150	1,644
SF	-	-	-	0	282	1,056	2,126	2,106	1,738	1,795	1,758	2,339	2,142	1,874	2,226	1,963	1,892	2,184	1,663	1,424	1,051	1,529	1,416	1,715
SJ	-	-	-	-	0	1,046	2,114	2,088	1,720	1,782	1,742	2,323	2,136	1,860	2,228	1,955	1,887	2,176	1,643	1,404	1,031	1,508	1,390	1,719
DEN	-	-	-	-	-	0	1,451	1,456	1,068	1,129	1,154	1,674	1,471	1,203	1,561	1,295	1,223	1,515	1,005	833	741	975	920	1,065
WDC	-	-	-	-	-	-	0	855	829	754	1,064	675	387	657	524	615	605	463	914	1,206	1,582	1,225	1,348	853
JACK	-	-	-	-	-	-	-	0	1,036	929	752	1,144	888	983	1,005	979	870	942	817	1,037	1,424	954	1,092	1,097
CHI	-	-	-	-	-	-	-	-	0	549	995	1,030	845	568	914	651	600	877	736	963	1,264	1,040	1,127	475
IND	-	-	-	-	-	-	-	-	-	0	919	993	771	567	875	618	528	821	667	932	1,280	995	1,089	592
NO	-	-	-	-	-	-	-	-	-	-	0	1,373	1,100	1,047	1,226	1,074	958	1,161	621	675	1,058	577	714	1,056
BOS	-	-	-	-	-	-	-	-	-	-	-	0	655	823	530	813	8,571	585	1,203	1,494	1,851	1,511	1,631	1,038
BALT	-	-	-	-	-	-	-	-	-	-	-	-	0	661	507	633	627	449	940	1,235	1,617	1,256	1,372	862
DET	-	-	-	-	-	-	-	-	-	-	-	-	-	0	720	463	491	689	812	1,070	1,404	1,130	1,227	576
NY	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	702	722	430	1,068	1,351	1,727	1,370	1,492	934
CLEVE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	493	660	858	1,123	1,472	1,170	1,279	663
COL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	671	739	1,019	1,377	1,060	1,162	635
PHIL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	1,000	1,297	1,663	1,310	1,439	896
MEMP	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	652	1,044	680	795	792
DAL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	744	488	506	990
ELPAS	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	809	674	1,280
HOU	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	448	1,084
SANAN	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	1,166
MILW	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0

A.2 Raidl's Test Instances

This section presents the details for the raidl10, raidl20, and raidl50 test problem proposed by Raidl (2001). We do not list the 75 and 100 nodes test problems herein because they are too extensive to be published. However, the details of the test instances are available and can be directly obtained from the author[1]. All demands and distance weights between the nodes were generated randomly and are uniformly distributed. The cost of a link is calculated as the amount of traffic over a link multiplied by its distance weight (compare (8.2)). The nodes are labeled with numbers between zero and $n-1$.

Table A.7 presents the properties of the best known solutions for the raidl10 and raidl20 problems. The demands and distance weights of the raidl10 test problem are specified in Table A.8. The demands for the raidl20 and raidl50 test problem are shown in Tables A.9 and A.11. The corresponding distance weights can be found in Tables A.10 and A.12.

	$c(T_{opt})$	used links
raidl10	53,674	1-0, 2-0, 3-0, 4-1, 5-0, 6-0, 7-3, 8-1, 9-1
raidl20	157,570	2-0, 7-5, 9-6, 9-7, 10-0, 11-0, 12-4, 13-0, 13-1, 13-3, 13-4, 14-10, 16-2, 17-0, 17-15, 18-8, 18-9, 18-10, 19-10

Table A.7. Cost and structure of the best solutions for raidl10 and raidl20

Table A.8. Demand and distance matrix for raidl10

(a) Demand matrix

	0	1	2	3	4	5	6	7	8	9
0	0	34	97	50	93	100	89	24	89	3
1	-	0	79	65	78	81	82	66	98	72
2	-	-	0	11	36	87	23	78	97	81
3	-	-	-	0	23	88	40	91	83	84
4	-	-	-	-	0	80	16	47	96	9
5	-	-	-	-	-	0	46	84	100	0
6	-	-	-	-	-	-	0	53	78	66
7	-	-	-	-	-	-	-	0	98	58
8	-	-	-	-	-	-	-	-	0	13
9	-	-	-	-	-	-	-	-	-	0

(b) Distance matrix

	0	1	2	3	4	5	6	7	8	9
0	0	8	17	1	41	12	7	16	90	47
1	-	0	47	31	17	87	59	14	5	9
2	-	-	0	53	36	29	47	14	18	84
3	-	-	-	0	53	83	72	6	79	36
4	-	-	-	-	0	64	39	52	16	31
5	-	-	-	-	-	0	63	75	47	5
6	-	-	-	-	-	-	0	21	45	87
7	-	-	-	-	-	-	-	0	89	31
8	-	-	-	-	-	-	-	-	0	45
9	-	-	-	-	-	-	-	-	-	0

[1]Address: Günther Raidl, Institute of Computer Graphics, Vienna University of Technology, Favoritenstraße 9-11/1861, 1040 Vienna, Austria. E-Mail: raidl@apm.tuwien.ac.at

Table A.9. Demand matrix for raidl20

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
0	0	19	7	97	99	22	65	82	53	76	2	44	7	40	67	100	7	40	94	90
1	-	0	37	18	98	75	99	90	42	51	4	91	76	91	10	49	53	75	72	17
2	-	-	0	56	91	59	24	34	33	30	0	32	38	6	25	94	43	9	57	18
3	-	-	-	0	8	13	26	25	17	16	67	74	93	16	26	33	54	10	90	44
4	-	-	-	-	0	69	80	44	1	10	10	100	14	16	92	7	26	0	30	44
5	-	-	-	-	-	0	75	43	36	66	26	18	33	100	11	15	26	44	69	2
6	-	-	-	-	-	-	0	100	79	37	80	22	39	56	32	4	70	48	96	77
7	-	-	-	-	-	-	-	0	74	63	73	84	3	16	86	70	8	4	2	8
8	-	-	-	-	-	-	-	-	0	82	84	0	92	52	2	58	30	39	3	18
9	-	-	-	-	-	-	-	-	-	0	44	59	50	15	28	64	77	71	4	5
10	-	-	-	-	-	-	-	-	-	-	0	43	88	9	25	40	79	34	44	47
11	-	-	-	-	-	-	-	-	-	-	-	0	8	92	30	8	83	82	77	40
12	-	-	-	-	-	-	-	-	-	-	-	-	0	78	82	43	96	93	68	11
13	-	-	-	-	-	-	-	-	-	-	-	-	-	0	7	96	75	84	66	79
14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	90	76	33	99	0
15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	73	43	0	83
16	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	90	8	74
17	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	86	83
18	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	22
19	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0

Table A.10. Distance matrix for raidl20

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
0	0	30	6	15	67	100	99	34	85	56	3	13	23	2	72	24	53	12	94	57
1	-	0	98	30	53	35	38	59	85	82	85	78	16	3	59	73	17	77	73	15
2	-	-	0	62	9	70	65	21	44	18	44	68	71	56	13	79	5	43	83	39
3	-	-	-	0	80	93	23	61	78	52	28	80	62	1	48	38	25	62	100	33
4	-	-	-	-	0	84	16	6	27	85	49	46	7	4	59	37	8	53	19	98
5	-	-	-	-	-	0	32	12	20	92	41	71	20	72	32	72	19	22	96	80
6	-	-	-	-	-	-	0	73	80	15	88	85	94	72	34	39	79	89	49	15
7	-	-	-	-	-	-	-	0	49	1	86	46	32	97	66	76	37	88	47	8
8	-	-	-	-	-	-	-	-	0	72	18	78	93	65	57	65	44	24	4	29
9	-	-	-	-	-	-	-	-	-	0	17	75	14	55	5	54	56	72	2	56
10	-	-	-	-	-	-	-	-	-	-	0	57	100	40	5	17	67	93	4	13
11	-	-	-	-	-	-	-	-	-	-	-	0	52	75	82	29	19	46	37	83
12	-	-	-	-	-	-	-	-	-	-	-	-	0	41	60	38	21	76	13	86
13	-	-	-	-	-	-	-	-	-	-	-	-	-	0	83	69	40	90	40	93
14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	97	48	92	36	52
15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	8	2	44	12
16	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	66	95	38
17	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	99	23
18	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	57
19	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0

Table A.11. Demand matrix for raidl50

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49
0	0	62	56	24	24	29	17	9	97	47	42	5	25	22	11	59	16	97	87	26	65	7	38	9	66	74	94	2	23	14	65	42	42	87	32	66	16	49	75	79	97	83	50	21	71	62	47	87	24	100
1	-	0	79	55	6	16	64	73	57	23	41	80	37	72	88	45	58	19	78	40	69	18	86	31	1	35	18	38	63	65	25	54	64	70	8	37	87	39	9	43	62	50	22	66	21	10	10	45	96	88
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49	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0

Table A.12. Distance matrix for raidl50

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26	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	78	59	91	32	74	9	42	20	91	96	28	90	100	69	3	27	74	2	88	46	14	94	26
27	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	27	76	95	14	99	77	84	62	6	42	4	37	67	12	31	86	2	26	66	91	78	34
28	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	45	4	59	98	43	5	12	88	82	90	64	28	55	14	4	39	27	61	32	30	50
29	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	51	42	80	88	43	57	53	86	86	39	82	89	49	80	83	53	43	71	87	84
30	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	86	14	38	99	70	28	25	30	12	6	79	62	47	10	1	42	67	54	27
31	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	52	44	60	93	92	91	75	97	85	97	83	68	82	96	58	80	65	37
32	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	56	47	100	62	77	13	60	87	14	1	5	67	79	56	10	39	100
33	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	1	81	27	49	66	23	31	33	5	79	42	36	95	79	44	41
34	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	78	57	18	91	16	56	56	69	60	22	47	67	83	37	67
35	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	35	70	45	84	35	67	66	67	23	44	61	11	91	39
36	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	54	31	68	62	100	10	77	55	65	97	66	38	96
37	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	33	20	84	51	7	53	95	90	87	13	7	6
38	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	36	51	66	98	93	56	3	23	23	64	75
39	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	33	92	81	49	89	47	87	84	31	58
40	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	67	81	64	20	27	5	58	39	12
41	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	63	26	14	80	75	6	35	77
42	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	80	58	40	54	42	32	87
43	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	90	20	85	76	55	67
44	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	86	21	99	49	92
45	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	25	54	50	15
46	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	65	64	93
47	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	30	44
48	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	67
49	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0

A.3 Berry's Test Instances

This section presents the details for the berry6, berry35, and berry35u problem instances proposed by Berry et al. (1995). Table A.13 presents the properties of the best known solutions to the different problem instances. The demands for the test problems are presented in Tables A.14(a) (berry6) and A.15(a) (berry35 and berry35u). The distance weights are shown in Tables A.14(b) (berry6) and A.15(b) (berry35). For berry35u, the distance weights $d_{ij} = 1$, for $i, j \in \{0, \dots, 34\}$. The demands are the same for berry35 and berry35u.

	$c(T_{opt})$	used links
berry6	534	1-0, 3-1, 5-2, 5-3, 5-4
berry35u	16,273	1-0, 8-2, 11-4, 12-9, 12-10, 13-8, 15-9, 16-2, 17-3, 18-6, 19-15, 20-9, 21-8, 25-1, 25-3, 25-19, 25-24, 26-22, 27-15, 28-9, 29-8, 29-11, 29-25, 30-5, 30-14, 30-21, 30-22, 31-7, 31-12, 31-23, 32-18, 32-25, 33-25, 34-29
berry35	16,915	1-0, 8-2, 11-4, 12-9, 12-10, 13-8, 16-2, 17-3, 18-6, 19-15, 20-9, 20-15, 21-8, 24-1, 24-17, 24-18, 25-3, 25-8, 25-19, 26-22, 27-15, 28-9, 29-11, 29-25, 30-5, 30-14, 30-21, 30-22, 31-7, 31-12, 31-23, 32-18, 33-24, 34-29

Table A.13. Cost and structure of the best solutions for berry6, berry35u, and berry35

Table A.14. Demand and distance matrix for berry6

(a) Demand matrix

	0	1	2	3	4	5
0	0	5	13	12	8	9
1	-	0	7	4	2	6
2	-	-	0	3	10	15
3	-	-	-	0	11	7
4	-	-	-	-	0	12
5	-	-	-	-	-	0

(b) Distance matrix

	0	1	2	3	4	5
0	0	3	6	5	9	7
1	-	0	3	2	4	8
2	-	-	0	3	7	2
3	-	-	-	0	9	2
4	-	-	-	-	0	1
5	-	-	-	-	-	0

Table A.15. Demand and distance matrix for berry35 and berry35u

(a) Demand matrix for berry35 and berry35u

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34
0	0	639	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	93	0	0	0	0	0	0	0	129	0
1	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	147	0	0	0	0	0	0	0	83	0	0
2	-	-	0	0	0	0	0	0	189	0	0	0	0	0	0	0	99	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	43	0	0
3	-	-	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	531	0	0	0	0	0	0	0	623	0	0	0	0	0	0	0	0	0
4	-	-	-	-	0	0	0	0	0	0	0	53	0	0	0	0	0	0	0	39	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	-	-	-	-	-	0	43	0	0	0	0	0	0	0	119	0	0	0	0	0	0	0	329	0	0	0	0	0	0	0	651	0	0	0	0
6	-	-	-	-	-	-	0	0	0	0	0	0	0	0	0	0	0	0	371	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	-	-	-	-	-	-	-	0	0	0	0	0	0	0	0	23	0	0	0	0	0	0	0	9	0	0	0	0	0	0	0	171	0	0	0
8	-	-	-	-	-	-	-	-	0	0	0	0	0	41	0	0	0	0	0	0	0	189	0	0	0	0	0	0	0	123	0	0	0	0	0
9	-	-	-	-	-	-	-	-	-	0	0	0	351	0	0	0	0	0	0	0	61	0	0	0	0	0	0	0	217	0	0	0	0	0	0
10	-	-	-	-	-	-	-	-	-	-	0	0	81	0	0	0	0	0	0	0	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	-	-	-	-	-	-	-	-	-	-	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	133	0	0	0	0	0
12	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0	27	0	0	0	0	0	0	0	161	0	0	0	0	0	0	0	261	0	0	0
13	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0	0	0	0	0	0	261	0	0	0	0	0	0	0	639	0	0	0	0
15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0	0	147	0	0	0	0	0	0	0	423	0	0	0	0	0	0	0
16	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0	0	0	0	0	0	0	69	0	0	0	0	0	0	0	0	0
17	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0	0	0	0	0	351	0	0	0	0	0	0	0	117	0	0
18	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0	0	0	0	243	0	0	0	0	0	0	0	873	0	0
19	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0	0	0	0	639	0	0	0	0	0	0	0	119	0
20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0	0	0	0	0	57	0	0	0	0	0	0	0
21	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	91	0	0	0	0	0	0	0	387	0	0	0	0
22	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0	0	89	0	0	0	0	0	0	0	0
23	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0	0	0	0	0	0	651	0	0	0
24	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0	0	0	133	0	0	0	0	0
25	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0	21	0	0	0	0	0	0
26	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0	0	0	0	0	0	0
27	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	111	0	0	0	0	0
28	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0	0	0	0	0
29	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0	0	0	63
30	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0	0	0
31	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0	0
32	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	71	0
33	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0
34	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0

(b) Distance matrix for berry35

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34
0	0	1	7	4	8	9	4	12	6	9	11	7	10	7	9	7	8	3	3	6	8	7	10	12	2	5	9	8	10	6	8	11	4	3	7
1	-	0	6	3	7	8	3	11	5	8	10	6	9	6	8	6	7	2	2	5	7	6	9	11	1	4	8	7	9	5	7	10	3	2	6
2	-	-	0	3	5	4	7	9	1	6	8	4	7	2	4	4	1	4	6	3	5	2	5	9	5	2	4	5	7	3	3	8	7	6	4
3	-	-	-	0	4	5	4	8	2	5	7	3	6	3	5	3	4	1	3	2	4	3	6	8	2	1	5	4	6	2	4	7	4	3	3
4	-	-	-	-	0	7	8	10	4	7	9	1	8	5	7	5	6	5	7	4	6	5	8	10	6	3	7	6	8	2	6	9	8	7	3
5	-	-	-	-	-	0	9	11	3	8	10	6	9	4	2	6	5	6	8	5	7	2	3	11	7	4	2	7	9	5	1	10	9	8	6
6	-	-	-	-	-	-	0	12	6	9	11	7	10	7	9	7	8	3	1	6	8	7	10	12	2	5	9	8	10	6	8	11	2	3	7
7	-	-	-	-	-	-	-	0	8	3	3	9	2	9	11	5	10	9	11	6	4	9	12	2	10	7	11	6	4	8	10	1	12	11	9
8	-	-	-	-	-	-	-	-	0	5	7	3	6	1	3	3	2	3	5	2	4	1	4	8	4	1	3	4	6	2	2	7	6	5	3
9	-	-	-	-	-	-	-	-	-	0	2	6	1	6	8	2	7	6	8	3	1	6	9	3	7	4	8	3	1	5	7	2	9	8	6
10	-	-	-	-	-	-	-	-	-	-	0	8	1	8	10	4	9	8	10	5	3	8	11	3	9	6	10	5	3	7	9	2	11	10	8
11	-	-	-	-	-	-	-	-	-	-	-	0	7	4	6	4	5	4	6	3	5	4	7	9	5	2	6	5	7	1	5	8	7	6	2
12	-	-	-	-	-	-	-	-	-	-	-	-	0	7	9	3	8	7	9	4	2	7	10	2	8	5	9	4	2	6	8	1	10	9	7
13	-	-	-	-	-	-	-	-	-	-	-	-	-	0	4	4	3	4	6	3	5	2	5	9	5	2	4	5	7	3	3	8	7	6	4
14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	6	5	6	8	5	7	2	3	11	7	4	2	7	9	5	1	10	9	8	6
15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	5	4	6	1	1	4	7	5	5	2	6	1	3	3	5	4	7	6	4
16	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	5	7	4	6	3	6	10	6	3	5	6	8	4	4	9	8	7	5
17	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	2	3	5	4	7	9	1	2	6	5	7	3	5	8	3	2	4
18	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	5	7	6	9	11	1	4	8	7	9	5	7	10	1	2	6
19	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	2	3	6	6	4	1	5	2	4	2	4	5	6	5	3
20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	5	8	4	6	3	7	2	2	4	6	3	8	7	5
21	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	3	9	5	2	2	5	7	3	1	8	7	6	4
22	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	12	8	5	1	8	10	6	2	11	10	9	7
23	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	10	7	11	6	4	8	10	1	12	11	9
24	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	3	7	6	8	4	6	9	2	1	5
25	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	4	3	5	1	3	6	5	4	2
26	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	7	9	5	1	10	9	8	6
27	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	4	4	6	5	8	7	5
28	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	6	8	3	10	9	7
29	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	4	7	6	5	1
30	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	9	8	7	5
31	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	11	10	8
32	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	3	7
33	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	6
34	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0

A.4 Real World Problems

This section presents the properties of four real-world problems. The presented problems are no classical OCST problems as the cost of a link depends non-linearly on its distance weights d_{ij} and the traffic b_{ij} running over the link.

For fulfilling the demands between the nodes, different line types with only discrete capacities are available. The cost of installing a link consists of a fixed and length dependent share. Both depend on the capacity of the link. The costs are based on the tariffs of the German Telekom from 1996 and represent the amount of money (in German Marks) a company has to pay for a telecommunication line of a specific length and capacity per month. For a detailed description of the four different problems the reader is referred to Sect. 8.2.3. In particular, the overall cost of a communication network is calculated as

$$c(T) = \sum_{i,j \in F} f(d_{ij}, cap_{ij}),$$

where F denotes the set of used links, d_{ij} are the distance weights of the links between node i to node j, and cap_{ij} is the capacity of the links. The distance weight d_{ij} corresponds to the Euclidean distance between the nodes i and j. The capacity cap_{ij} of a link must be higher than the overall traffic b_{ij} running over a link. Therefore,

$$cap_{ij} \geq b_{ij},$$

where b_{ij} denotes the overall traffic over the link between the nodes i and j. This means that to every link between i and j a line is assigned with the next higher available capacity cap_{ij}.

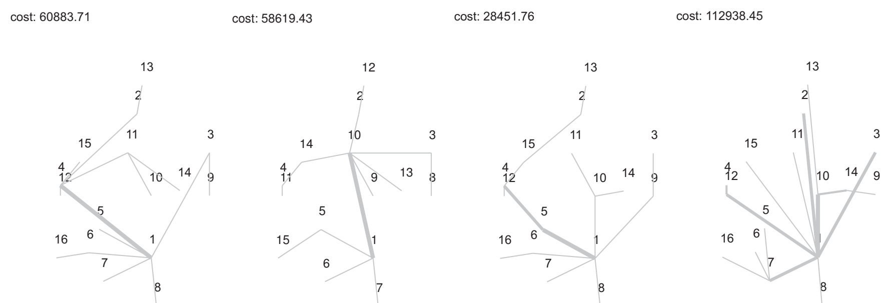
We illustrate this with a brief example. If there are three line types available with capacity 64 kBit/s, 512 kBit/s, and 2048 kBit/s, a line with capacity $cap = 64$ kBit/s is assigned to all links with less than $b = 64$ kBit/s of traffic. If the traffic over a link is between 64 kBit/s and 512 kBit/s the 512 kBit/s line is chosen. If the traffic over a link exceeds 512 kBit/s the 2048 kBit/s line must be chosen.

Table A.16 and Fig. A.1 present the properties of the best known solutions to the four test problems. Table A.17(a) (rothlauf1 and rothlauf2), Table A.17(b) (rothlauf3), and Table A.18 (rothlauf4) illustrate how the cost of a link depends on the overall traffic b_{ij} and the distance weight d_{ij} of the used line. The largest available line type has capacity $cap = 2,048$ kBit/s (rothlauf1-3) or $cap = 4,096$ kBit/s (rothlauf4). If the traffic b over a link exceeds this value a large penalty is used.

In Table A.19 (rothlauf1 and rothlauf3), Table A.20 (rothlauf2), and Table A.21 (rothlauf4) we present the demands for the different test problems. Table A.22 lists the coordinates of the nodes. The distance weights $d_{i,j}$ are calculated as $d_{ij} = \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2}$, where x and y denote the coordinates of the nodes. To get the distances and coordinates in kilometer, the distance weights must be multiplied by 14.87. The factor 14.87 results from the used "Gebührenfeldverfahren" of the German Telekom.

	$c(T_{opt})$	used links
rothlauf1	60,883	3-1, 4-1, 4-2, 5-1, 6-1, 7-1, 8-1, 9-3, 11-4, 11-10, 12-4, 13-2, 14-11, 15-4, 16-6
rothlauf2	58,619	5-1, 6-1, 7-1, 8-3, 10-1, 10-2, 10-3, 10-9, 11-4, 12-2, 13-10, 14-4, 14-10, 15-5
rothlauf3	28,451	5-1, 5-4, 6-1, 7-1, 8-1, 9-1, 9-3, 10-1, 11-10, 12-4, 13-2, 14-10, 15-2, 15-4, 16-6
rothlauf4	112,938	2-1, 3-1, 7-1, 7-5, 7-6, 8-1, 10-1, 11-1, 12-1, 12-4, 13-10, 14-9, 14-10, 15-1, 16-7

Table A.16. Cost and structure of the best solutions for selected real-world test instances



(a) rothlauf1 (b) rothlauf2 (c) rothlauf3 (d) rothlauf4

Figure A.1. Best known solutions T_{opt} for the four real-world problem instances

Table A.17. Cost of a link for rothlauf1, rothlauf2, and rothlauf3

(a) rothlauf1 and rothlauf2

b_{ij}	d_{ij}	cost
<64 kBit/s	$[0;1]$	$334.58d + 385$
	$]1;3]$	$148.70d + 572$
	$]3;10]$	$29.74d + 972.50$
	$]10;\infty]$	$22.31d + 1,047$
<512 kBit/s	$[0;1]$	$1,107d + 975$
	$]1;3]$	$520d + 1,567$
	$]3;10]$	$178d + 2,717$
	$]10;\infty]$	$111.53d + 3,392$
<2,048 kBit/s	$[0;1]$	$2,215d + 1,950$
	$]1;3]$	$1,040.9d + 3,135$
	$]3;10]$	$356.88d + 5,435$
	$]10;\infty]$	$223.05d + 6,785$
>2,048 kBit/s	$[0;\infty]$	$500,000d + 50,000$

(b) rothlauf3

b_{ij}	d_{ij}	cost
<64 kBit/s	$[0;1]$	$334.58d + 38,5$
	$]1;3]$	$148.7d + 57,2$
	$]3;10]$	$29.74d + 97,25$
	$]10;\infty]$	$22.31d + 104.7$
<512 kBit/s	$[0;1]$	$1,107d + 97.5$
	$]1;3]$	$520d + 156.7$
	$]3;10]$	$178d + 271.7$
	$]10;\infty]$	$111.53d + 339.2$
<2,048 kBit/s	$[0;1]$	$2,215d + 195$
	$]1;3]$	$1,040.9d + 313.5$
	$]3;10]$	$356.88d + 543.5$
	$]10;\infty]$	$223.05d + 678.5$
>2,048 kBit/s	$[0;\infty]$	$500,000d + 50,000$

b_{ij}	d_{ij}	cost
<64 kBit/s	$[0;1]$	$334.58d + 385$
	$]1;3]$	$148.70d + 572$
	$]3;10]$	$29.74d + 972.50$
	$]10;\infty]$	$22.31d + 1,047$
<128 kBit/s	$[0;1]$	$669.16d + 770$
	$]1;3]$	$297.40d + 1,144$
	$]3;10]$	$59.48d + 1,945$
	$]10;\infty]$	$44.62d + 2,094$
<512 kBit/s	$[0;1]$	$1,107d + 975$
	$]1;3]$	$520d + 1,567$
	$]3;10]$	$178d + 2,717$
	$]10;\infty]$	$111.53d + 3,392$
<2,048 kBit/s	$[0;1]$	$2,215d + 1,950$
	$]1;3]$	$1,040.90d + 3,135$
	$]3;10]$	$356.88d + 5,435$
	$]10;\infty]$	$223.05d + 6,785$
<4,096 kBit/s	$[0;1]$	$4,430d + 3,900$
	$]1;3]$	$2,081.80d + 6,270$
	$]3;10]$	$713.76d + 10,870$
	$]10;\infty]$	$446.10d + 13,570$
>4,096 kBit/s	$[0;\infty]$	$500{,}000d + 50{,}000$

Table A.18. Cost of a link for rothlauf4

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
1	0	424	458	727	468	414	440	521	50	48	381	34	28	48	34	28
2	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	-	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	-	-	-	0	0	0	0	0	0	0	0	0	0	0	0	0
5	-	-	-	-	0	0	0	0	0	0	0	0	0	0	0	0
6	-	-	-	-	-	0	0	0	0	0	0	0	0	0	0	0
7	-	-	-	-	-	-	0	0	0	0	0	0	0	0	0	0
8	-	-	-	-	-	-	-	0	0	0	0	0	0	0	0	0
9	-	-	-	-	-	-	-	-	0	0	0	0	0	0	0	0
10	-	-	-	-	-	-	-	-	-	0	0	0	0	0	0	0
11	-	-	-	-	-	-	-	-	-	-	0	0	0	0	0	0
12	-	-	-	-	-	-	-	-	-	-	-	0	0	0	0	0
13	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0	0
14	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0
15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0
16	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0

Table A.19. Demand matrix for rothlauf1 and rothlauf3

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	0	424	458	200	468	440	521	50	48	600	34	28	48	34	28
2	-	0	0	0	0	0	0	0	0	0	0	0	0	40	0
3	-	-	0	0	0	0	0	0	0	0	0	0	0	0	0
4	-	-	-	0	0	0	0	0	0	0	0	0	0	0	0
5	-	-	-	-	0	0	0	0	0	0	0	0	0	0	100
6	-	-	-	-	-	0	0	0	0	0	0	0	0	0	0
7	-	-	-	-	-	-	0	0	0	0	0	0	0	0	0
8	-	-	-	-	-	-	-	0	0	0	0	0	0	0	0
9	-	-	-	-	-	-	-	-	0	0	0	0	0	0	0
10	-	-	-	-	-	-	-	-	-	0	0	0	0	0	0
11	-	-	-	-	-	-	-	-	-	-	0	0	0	0	0
12	-	-	-	-	-	-	-	-	-	-	-	0	0	0	0
13	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0
14	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0
15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0

Table A.20. Demand matrix for rothlauf2

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	0	308	491	364	36	51	195	72	114	111	14	150	78	136	33	44
2	-	0	503	323	27	38	146	54	86	83	11	112	59	102	24	33
3	-	-	0	272	18	25	97	36	57	55	7	75	39	68	16	22
4	-	-	-	0	9	12	48	18	28	27	3	37	19	34	8	11
5	-	-	-	-	0	51	17	1	34	40	54	36	47	45	25	11
6	-	-	-	-	-	0	15	63	22	16	31	42	28	54	33	7
7	-	-	-	-	-	-	0	5	26	62	54	45	39	12	16	18
8	-	-	-	-	-	-	-	0	32	13	40	22	20	34	61	38
9	-	-	-	-	-	-	-	-	0	35	16	54	13	38	49	17
10	-	-	-	-	-	-	-	-	-	0	10	12	47	4	5	49
11	-	-	-	-	-	-	-	-	-	-	0	49	10	55	28	39
12	-	-	-	-	-	-	-	-	-	-	-	0	10	4	48	37
13	-	-	-	-	-	-	-	-	-	-	-	-	0	19	41	38
14	-	-	-	-	-	-	-	-	-	-	-	-	-	0	17	34
15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	36
16	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0

Table A.21. Demand matrix for rothlauf4

problem	node	x;y	node	x;y	node	x;y
rothlauf1, rothlauf3, rothlauf4	1	29;12	2	26;42	3	41;34
	4	10;27	5	18;18	6	16;13
	7	19;7	8	30;2	9	41;25
	10	29;25	11	24;34	12	10;25
	13	27;48	14	35;26	15	14;32
	16	9;12				
rothlauf2	1	29;12	2	26;42	3	41;34
	4	10;27	5	18;18	6	19;7
	7	30;2	8	41;25	9	29;25
	10	24;34	11	10;25	12	27;48
	13	35;26	14	14;32	15	9;12

Table A.22. Position of the nodes for the four selected real-world problems