Appendix

A.1 Notation

γ : Return ratio.

γ_o: The optimal return ratio.

ω : Waste ratio.

ω_y: Waste ratio in y^{th} year.

w_1: The weight for net profit in the BLS.

w_2: The weight for net profit in the RLS.

$\tau_{a/b}$: The transition ratio between a products and b products.

$\tau_{vm/rm}$: The transition ratio between virgin materials and raw materials.

$\tau_{rm/p}$: The transition ratio between raw materials and demanded products.

$\tau_{rbm/up}$: The transition ratio between reusable materials and useless products.

$\tau_{dw/up}$: The transition ratio between derivative waste and useless products.

$\tau_{rbm/rrm}$: The transition ratio between reusable materials and reused raw materials.

λ_D: The average quantity of demands in a time interval.

λ_R: The average quantity of returns in a time interval.

λ_{EW}: The average quantity of estimated waste in a time interval.

$D^j(k)$: The quantity of demands in k^{th} time interval in j^{th} end-customer.

$R^j(k)$: The quantity of returns in k^{th} time interval in j^{th} end-customer.

$t^i_{products\text{-}members}$: The lead-times of procuring products from layer i in members or transporting products to members in layer i.

$t^4_{rm\text{-}m}$: The lead-times of procuring raw materials from layer 4 in manufacturers.

$t^3_{p\text{-}members}$: The lead-times of procuring demanded products from layer 3 in members.

$t^3_{p\text{-}ws}$: The lead-times of procuring demanded products from layer 3 in wholesalers.

$t^3_{p\text{-}r}$: The lead-times of procuring demanded products from layer 3 in retailers.

$t^3_{p\text{-}ec}$: The lead-times of procuring demanded products from layer 3 in end-customers.

$t^{2}_{p\text{- members}}$: The lead-times of procuring demanded products from layer 2 in members.

$t^{2}_{p\text{-r}}$: The lead-times of procuring demanded products from layer 2 in retailers.

$t^{2}_{p\text{-ec}}$: The lead-times of procuring demanded products from layer 2 in end-customers.

$t^{1}_{p\text{-ec}}$: The lead-times of procuring demanded products from layer 1 in end-customers.

$t^{0}_{up\text{-cp}}$: The lead-times of transporting useless products to collecting points in layer 0.

$t^{0}_{up\text{-rp}}$: The lead-times of transporting useless products to recycle plants in layer 0.

$t^{0}_{up\text{-dp}}$: The lead-times of transporting useless products to disassembly plants in layer 0.

$t^{-1}_{up\text{- members}}$: The lead-times of transporting useless products to members in layer -1.

$t^{-1}_{up\text{-rp}}$: The lead-times of transporting useless products to recycle plants in layer -1.

$t^{-1}_{up\text{-dp}}$: The lead-times of transporting useless products to disassembly plants in layer -1.

$t^{-2}_{up\text{-dp}}$: The lead-times of transporting useless products to disassembly plants in layer -2.

$t^{-3}_{rbm\text{-}smm}$: The lead-times of transporting reusable materials to secondary material market in layer -3.

$t^{-3}_{dw\text{-}li}$: The lead-times of transporting derivative waste to landfills/ incinerators in layer -3.

$t^{-4}_{rrm\text{-}m}$: The lead-times of transporting reusable materials to manufacturers in layer -4.

$P_{p\text{-}m1}$: The unit cost of procuring demand products from manufacturer 1.

$P_{p\text{-}ws1}$: The unit cost of procuring demand products from wholesaler 1.

$P_{p\text{-}ws2}$: The unit cost of procuring demand products from wholesaler 2.

$P_{p\text{-}r1}$: The unit cost of procuring demand products from retailer 1.

$P_{p\text{-}r2}$: The unit cost of procuring demand products from retailer 2.

$P_{p\text{-}r3}$: The unit cost of procuring demand products from retailer 3.

$P_{up\text{-}ec1}$: The unit cost of procuring useless products from end-customer 1.

$P_{up\text{-}ec2}$: The unit cost of procuring useless products from end-customer 2.

$P_{up\text{-}ec3}$: The unit cost of procuring useless products from end-customer 3.

$P_{up\text{-}ec4}$: The unit cost of procuring useless products from end-customer 4.

$P_{up\text{-}ec5}$: The unit cost of procuring useless products from end-customer 5.

$P_{up\text{-}cp1}$: The unit cost of procuring useless products from collecting point 1.

$P_{up\text{-}cp2}$: The unit cost of procuring useless products from collecting point 2.

$P_{up\text{-}cp3}$: The unit cost of procuring useless products from collecting point 3.

$P_{up\text{-}rp1}$: The unit cost of procuring useless products from recycle plant 1.

$P_{up\text{-}rp2}$: The unit cost of procuring useless products from recycle plant 2.

$T_{p\text{-}ws1}$: The unit cost of transporting demanded products to wholesaler 1.

$T_{p\text{-}ws2}$: The unit cost of transporting demanded products to wholesaler 2.

$T_{p\text{-}r1}$: The unit cost of transporting demanded products to retailer 1.

$T_{p\text{-}r2}$: The unit cost of transporting demanded products to retailer 2.

$T_{p\text{-}r3}$: The unit cost of transporting demanded products to retailer 3.

$T_{p\text{-}ec1}$: The unit cost of transporting demanded products to end-customer 1.

$T_{p\text{-}ec2}$: The unit cost of transporting demanded products to end-customer 2.

$T_{p\text{-}ec3}$: The unit cost of transporting demanded products to end-customer 3.

$T_{p\text{-}ec4}$: The unit cost of transporting demanded products to end-customer 4.

$T_{p\text{-}ec5}$: The unit cost of transporting demanded products to end-customer 5.

$T_{up\text{-}cp1}$: The unit cost of transporting useless products to collecting point 1.

$T_{up\text{-}cp2}$: The unit cost of transporting useless products to collecting point 2.

$T_{up\text{-}cp3}$: The unit cost of transporting useless products to collecting point 3.

$T_{up\text{-}rp1}$: The unit cost of transporting useless products to recycle plant 1.

$T_{up\text{-}rp2}$: The unit cost of transporting useless products to recycle plant 2.

A.2 Cost Parameters of Case Study

Table A.2-1 Cost Parameters in the Raw Material Supplier 1

i=4	j=1				
k	M_{rm}	P_{vm}	I_{vm}	I_{rm}	$T_{rm\text{-}m}$
1	2294	26982	46838	36999	6
2	2857	20717	52809	58037	9
3	3315	15513	36026	47493	6
4	3960	16394	36854	53914	9
5	2581	18721	25284	62185	9
6	1877	23726	43853	73988	6
7	3066	27580	52946	42914	8
8	2837	23749	29265	79492	6
9	2374	14204	46470	55080	8
10	2397	17783	26341	52450	7
11	1765	24007	31134	78219	9
12	3264	20481	48810	53278	9

Table A.2-2 Cost Parameters in the Manufacturer 1

i=3	j=1				
k	M_p	P_{rm}	P_{rrm}	I_{rm}	I_p
1	3889	18645	32980	51141	67482
2	4292	32791	36460	61178	85293
3	2614	21227	20722	75458	64148
4	4934	21642	31095	69724	104156
5	3735	27772	34483	51916	57373
6	4973	34740	28169	51774	76385
7	4743	24780	37762	72547	101644
8	3853	28837	28855	40511	68685
9	3047	21784	31510	71453	81178
10	2598	21383	34955	71832	83100
11	3113	24872	23587	48023	91579
12	3197	30911	30577	72759	51101

k	$T_{p\text{-}ws1}$	$T_{p\text{-}ws2}$	$T_{p\text{-}r1}$	$T_{p\text{-}r2}$	$T_{p\text{-}r3}$
1	7	10	10	9	9
2	9	9	6	10	10
3	7	8	5	5	8
4	5	6	7	6	7
5	7	9	5	8	8
6	8	10	5	6	9
7	6	5	10	9	6
8	7	7	9	8	7
9	6	7	8	10	8
10	8	7	8	6	8
11	8	7	7	7	6
12	10	5	10	6	8

k	$T_{p\text{-}ec1}$	$T_{p\text{-}ec2}$	$T_{p\text{-}ec3}$	$T_{p\text{-}ec4}$	$T_{p\text{-}ec5}$
1	6	10	8	5	5
2	9	6	6	9	9
3	9	6	6	6	5
4	9	6	9	9	8
5	10	10	6	10	6
6	10	7	7	9	9
7	5	9	7	9	5
8	7	10	9	10	9
9	8	6	8	6	9
10	8	5	10	9	6
11	6	8	9	7	9
12	6	10	7	8	10

Table A.2-3 Cost Parameters in the Wholesaler 1

i=2	j=1									
k	$P_{p\text{-}m1}$	I_p	$T_{p\text{-}r1}$	$T_{p\text{-}r2}$	$T_{p\text{-}r3}$	$T_{p\text{-}ec1}$	$T_{p\text{-}ec2}$	$T_{p\text{-}ec3}$	$T_{p\text{-}ec4}$	$T_{p\text{-}ec5}$
1	31224	101227	8	9	5	7	6	9	7	8
2	50049	132014	10	8	8	6	6	8	7	7
3	27192	141366	6	6	9	5	5	5	8	8
4	32893	123585	5	7	8	6	9	8	6	10
5	29581	80230	8	10	8	6	9	8	8	10
6	48359	117270	6	9	5	9	7	10	8	8
7	47132	127860	10	6	10	10	6	9	8	8
8	32517	126713	5	6	7	7	9	8	10	9
9	55283	87949	8	8	9	8	9	9	9	8
10	49328	89379	7	5	8	6	7	9	8	9
11	31002	150684	6	7	9	7	7	8	7	7
12	35651	154848	8	7	10	8	9	6	8	8

Table A.2-4 Cost Parameters in the Wholesaler 2

i=2	j=2									
k	$P_{p\text{-}m1}$	I_p	$T_{p\text{-}r1}$	$T_{p\text{-}r2}$	$T_{p\text{-}r3}$	$T_{p\text{-}ec1}$	$T_{p\text{-}ec2}$	$T_{p\text{-}ec3}$	$T_{p\text{-}ec4}$	$T_{p\text{-}ec5}$
1	55220	117661	9	8	5	10	6	6	6	7
2	37837	82695	8	9	8	8	5	7	9	6
3	44891	92917	5	6	8	10	9	8	5	9
4	49704	140839	6	5	7	5	6	5	6	6
5	45282	102771	7	7	5	10	7	9	9	6
6	31725	83012	5	8	7	7	9	8	9	5
7	52995	111342	10	7	9	6	9	10	8	7
8	51190	155464	9	9	6	9	9	7	9	8
9	31639	99869	7	8	7	9	7	7	9	5
10	30495	98287	8	9	5	5	7	6	8	5
11	28371	95714	7	8	7	9	7	6	10	8
12	30837	114953	8	5	5	6	10	8	6	5

Table A.2-5 Cost Parameters in the Retailer 1

i=1	j=1				
k	$P_{p\text{-}m1}$	$P_{p\text{-}ws1}$	$P_{p\text{-}ws2}$	I_p	——
1	36527	58844	63710	72233	——
2	28293	74293	66675	123711	——
3	25384	67345	71904	161133	——
4	45677	73530	45660	127864	——
5	47137	69123	55983	144030	——
6	27642	76293	76777	99445	——
7	44872	45181	45675	134163	——
8	35204	65173	50633	100809	——
9	36184	42550	62271	118656	——
10	34784	49901	49396	111413	——
11	32597	57012	77575	91191	——
12	26161	76375	60556	124356	——
k	$T_{p\text{-}ec1}$	$T_{p\text{-}ec2}$	$T_{p\text{-}ec3}$	$T_{p\text{-}ec4}$	$T_{p\text{-}ec5}$
1	10	6	8	9	6
2	9	7	8	6	9
3	6	7	9	7	8
4	6	5	7	8	6
5	10	8	7	7	8
6	8	8	10	6	6
7	7	9	9	9	9
8	6	9	7	9	7
9	8	9	5	8	9
10	6	6	9	6	8
11	5	5	8	6	5
12	9	6	9	8	7

Table A.2-6 Cost Parameters in the Retailer 2

i=1	j=2				
k	$P_{p\text{-}m1}$	$P_{p\text{-}ws1}$	$P_{p\text{-}ws2}$	I_p	——
1	43180	77788	76238	129479	——
2	56034	42772	64319	126852	——
3	53274	56226	56614	96885	——
4	45583	57851	68255	152147	——
5	34463	48267	45238	138498	——
6	27525	69286	62032	81030	——
7	27446	44805	62155	149055	——
8	34868	57471	73088	98539	——
9	50415	55593	68763	91663	——
10	40154	63050	58814	97324	——
11	43255	57187	57765	108513	——
12	42538	54352	74288	105302	——
k	$T_{p\text{-}ec1}$	$T_{p\text{-}ec2}$	$T_{p\text{-}ec3}$	$T_{p\text{-}ec4}$	$T_{p\text{-}ec5}$
1	7	8	7	8	5
2	8	6	8	5	10
3	10	6	6	5	10
4	6	7	7	9	6
5	10	6	8	9	5
6	8	9	6	9	8
7	6	9	5	7	10
8	8	5	7	5	6
9	8	9	7	10	6
10	6	10	9	10	9
11	6	9	9	7	9
12	8	9	7	9	7

Table A.2-7 Cost Parameters in the Retailer 3

i=1	j=3				
k	$P_{p\text{-}m1}$	$P_{p\text{-}ws1}$	$P_{p\text{-}ws2}$	I_p	——
1	40229	42431	69152	103196	——
2	32167	52351	54400	146366	——
3	46601	60608	47097	114414	——
4	27537	59283	57797	149112	——
5	41883	43932	60461	141200	——
6	27971	45486	56479	117455	——
7	36867	52286	61282	130642	——
8	43757	71534	66430	137096	——
9	48236	42395	62547	129502	——
10	37422	67507	45699	130024	——
11	56364	57725	75897	95206	——
12	36137	60301	75071	107545	——
k	$T_{p\text{-}ec1}$	$T_{p\text{-}ec2}$	$T_{p\text{-}ec3}$	$T_{p\text{-}ec4}$	$T_{p\text{-}ec5}$
1	8	8	10	10	7
2	6	8	7	7	9
3	7	8	7	6	6
4	6	10	6	9	8
5	8	10	8	6	7
6	6	6	7	8	9
7	7	6	8	7	8
8	6	7	5	7	6
9	9	9	6	9	9
10	6	9	5	9	10
11	7	8	7	8	6
12	7	7	7	6	8

Table A.2-8 Cost Parameters of Procurement in the End-Customer 1

i=0	j=1					
k	$P_{p\text{-}m1}$	$P_{p\text{-}ws1}$	$P_{p\text{-}ws2}$	$P_{p\text{-}r1}$	$P_{p\text{-}r2}$	$P_{p\text{-}r3}$
1	43598	41740	66653	50012	55615	64662
2	44210	60633	57013	47762	68826	42799
3	27186	70860	59202	69103	49971	43976
4	34635	54806	66390	69710	50963	42703
5	53486	74070	54469	53083	72520	67668
6	55716	61490	47904	67020	61892	62835
7	29942	38929	40446	72299	68564	48853
8	44411	46378	42171	46851	72348	38411
9	34087	48232	39218	70456	68907	57916
10	28996	41060	56426	69329	51110	54114
11	33511	52422	65940	62976	43920	47346
12	52248	60008	63855	78299	49575	53023

Table A.2-9 Cost Parameters of Procurement in the End-Customer 2

i=0	j=2					
k	$P_{p\text{-}m1}$	$P_{p\text{-}ws1}$	$P_{p\text{-}ws2}$	$P_{p\text{-}r1}$	$P_{p\text{-}r2}$	$P_{p\text{-}r3}$
1	51976	58667	46625	74544	72718	44833
2	54170	73961	74175	63346	75029	46110
3	40381	59543	61762	39448	45070	58449
4	54401	66694	65067	51944	73831	77954
5	29278	71164	76508	44023	61981	51055
6	26301	75825	65271	61190	43848	42913
7	52140	63134	71250	54534	36226	46840
8	29651	54340	47290	45107	42605	53587
9	48962	55139	57922	39890	56445	54663
10	37263	50303	67071	45834	57156	47776
11	31919	55917	58432	71317	53613	70062
12	46679	71082	65217	42311	38527	45626

Table A.2-10 Cost Parameters of Procurement in the End-Customer 3

i=0	j=3					
k	$P_{p\text{-}m1}$	$P_{p\text{-}ws1}$	$P_{p\text{-}ws2}$	$P_{p\text{-}r1}$	$P_{p\text{-}r2}$	$P_{p\text{-}r3}$
1	33958	71884	47536	66488	55378	78166
2	55737	39077	52193	67030	48598	40077
3	36177	65793	45755	40209	70323	71102
4	32442	54261	56032	60010	70248	43831
5	56269	40805	75782	64933	60749	66699
6	44453	72189	43133	68730	70899	58549
7	28894	40383	71531	64145	60502	69724
8	45609	59296	48851	44553	63208	72213
9	51442	71201	55253	66720	66391	63770
10	52416	72670	51698	43283	50920	38562
11	51402	66180	71620	42067	59310	59252
12	26518	56197	62338	67184	63663	36552

Table A.2-11 Cost Parameters of Procurement in the End-Customer 4

i=0	j=4					
k	$P_{p\text{-}m1}$	$P_{p\text{-}ws1}$	$P_{p\text{-}ws2}$	$P_{p\text{-}r1}$	$P_{p\text{-}r2}$	$P_{p\text{-}r3}$
1	31478	43373	58977	41225	52145	54780
2	38410	44716	75771	61429	77273	64409
3	41583	76706	41516	77875	55230	77593
4	37161	62004	54054	68475	59814	36647
5	40900	41705	76840	39457	80216	71825
6	45935	51719	51440	39033	51132	73912
7	56377	72661	57376	71350	49270	76706
8	47357	59372	50525	74017	41281	71070
9	32566	58419	52821	49657	70503	46477
10	56416	48920	42012	36595	44616	39545
11	32970	77761	72324	71657	48678	60861
12	38091	43973	64120	41863	42311	58835

Table A.2-12 Cost Parameters of Procurement in the End-Customer 5

i=0	j=5					
k	$P_{p\text{-}m1}$	$P_{p\text{-}ws1}$	$P_{p\text{-}ws2}$	$P_{p\text{-}r1}$	$P_{p\text{-}r2}$	$P_{p\text{-}r3}$
1	47306	45737	64915	41346	74871	72892
2	30237	62916	75170	81214	38253	59307
3	33815	76703	40563	74349	59831	77847
4	32284	40704	42478	51267	38269	40784
5	51094	67051	60079	59446	69529	57351
6	35614	61757	45618	53549	51713	75113
7	26325	47742	74238	53964	66711	78014
8	30278	62793	66074	74358	76181	56463
9	40661	63352	76902	77602	48946	80718
10	41349	61563	43915	68621	61593	68608
11	38569	53662	45381	80844	37937	47512
12	50345	73283	54032	58086	68202	80896

Table A.2-13 Cost Parameters of Transportation in the End-Customer 1

i=0	j=1					
k	$T_{up\text{-}cp1}$	$T_{up\text{-}cp2}$	$T_{up\text{-}cp3}$	$T_{up\text{-}rp1}$	$T_{up\text{-}rp2}$	$T_{up\text{-}dp}$
1	6	6	6	8	7	10
2	9	8	7	8	6	8
3	9	8	6	10	7	6
4	8	6	6	6	9	6
5	9	6	9	8	9	5
6	7	6	5	10	8	6
7	6	7	10	9	6	9
8	5	8	8	9	7	9
9	7	6	9	7	8	9
10	6	9	9	9	8	10
11	6	10	9	7	8	9
12	10	7	10	7	5	7

Table A.2-14 Cost Parameters of Transportation in the End-Customer 2

i=0	j=2					
k	$T_{up\text{-}cp1}$	$T_{up\text{-}cp2}$	$T_{up\text{-}cp3}$	$T_{up\text{-}rp1}$	$T_{up\text{-}rp2}$	$T_{up\text{-}dp}$
1	9	9	6	8	10	5
2	6	10	9	5	5	7
3	9	7	9	8	9	6
4	5	6	8	7	6	8
5	6	6	6	6	9	8
6	7	8	9	8	6	10
7	8	9	7	6	8	8
8	7	6	9	8	7	5
9	6	8	6	7	7	7
10	6	5	5	7	5	9
11	10	9	5	8	6	7
12	8	8	7	10	6	7

Table A.2-15 Cost Parameters of Transportation in the End-Customer 3

i=0	j=3					
k	$T_{up\text{-}cp1}$	$T_{up\text{-}cp2}$	$T_{up\text{-}cp3}$	$T_{up\text{-}rp1}$	$T_{up\text{-}rp2}$	$T_{up\text{-}dp}$
1	7	7	9	10	9	6
2	7	8	8	7	7	9
3	6	6	10	9	6	5
4	7	9	9	6	9	6
5	6	5	9	8	9	10
6	9	7	9	9	9	6
7	9	10	6	6	5	6
8	9	6	7	5	9	6
9	5	5	7	5	6	5
10	7	7	7	9	5	5
11	7	9	6	7	8	7
12	9	6	7	5	8	6

Table A.2-16 Cost Parameters of Transportation in the End-Customer 4

i=0	j=4					
k	$T_{up\text{-}cp1}$	$T_{up\text{-}cp2}$	$T_{up\text{-}cp3}$	$T_{up\text{-}rp1}$	$T_{up\text{-}rp2}$	$T_{up\text{-}dp}$
1	9	9	10	6	6	8
2	6	6	6	6	6	8
3	6	5	6	6	5	6
4	6	6	9	6	6	7
5	5	8	5	7	6	7
6	5	5	7	7	5	8
7	6	10	7	6	7	5
8	8	9	8	5	6	8
9	8	7	7	7	10	9
10	10	7	7	5	10	6
11	8	8	8	9	9	5
12	8	5	8	6	7	7

Table A.2-17 Cost Parameters of Transportation in the End-Customer 5

i=0	j=5					
k	$T_{up\text{-}cp1}$	$T_{up\text{-}cp2}$	$T_{up\text{-}cp3}$	$T_{up\text{-}rp1}$	$T_{up\text{-}rp2}$	$T_{up\text{-}dp}$
1	10	7	10	9	10	8
2	6	7	8	9	5	7
3	9	9	9	9	7	5
4	6	8	7	6	9	9
5	10	10	5	8	8	6
6	7	9	7	7	6	8
7	6	8	6	7	7	10
8	10	7	7	6	10	8
9	8	9	10	6	9	10
10	10	7	9	9	9	9
11	9	6	8	8	5	5
12	8	9	6	9	8	6

Table A.2-18 Cost Parameters in the Collecting Point 1

i=-1	j=1								
k	$P_{up\text{-}ec1}$	$P_{up\text{-}ec2}$	$P_{up\text{-}ec3}$	$P_{up\text{-}ec4}$	$P_{up\text{-}ec5}$	I_{up}	$T_{up\text{-}rp1}$	$T_{up\text{-}rp2}$	$T_{up\text{-}dp}$
1	100	100	100	100	100	350	7	9	10
2	100	100	100	100	100	350	10	10	6
3	100	100	100	100	100	350	6	6	7
4	100	100	100	100	100	350	6	9	8
5	100	100	100	100	100	350	9	5	7
6	100	100	100	100	100	350	5	9	8
7	100	100	100	100	100	350	7	8	7
8	100	100	100	100	100	350	5	9	8
9	100	100	100	100	100	350	8	7	7
10	100	100	100	100	100	350	5	5	8
11	100	100	100	100	100	350	6	7	6
12	100	100	100	100	100	350	6	7	10

Table A.2-19 Cost Parameters in the Collecting Point 2

i=-1	j=2								
k	$P_{up\text{-}ec1}$	$P_{up\text{-}ec2}$	$P_{up\text{-}ec3}$	$P_{up\text{-}ec4}$	$P_{up\text{-}ec5}$	I_{up}	$T_{up\text{-}rp1}$	$T_{up\text{-}rp2}$	$T_{up\text{-}dp}$
1	100	100	100	100	100	350	8	8	5
2	100	100	100	100	100	350	6	10	9
3	100	100	100	100	100	350	9	8	10
4	100	100	100	100	100	350	8	9	7
5	100	100	100	100	100	350	10	6	7
6	100	100	100	100	100	350	10	5	7
7	100	100	100	100	100	350	6	10	5
8	100	100	100	100	100	350	7	8	9
9	100	100	100	100	100	350	7	8	10
10	100	100	100	100	100	350	9	8	8
11	100	100	100	100	100	350	9	5	10
12	100	100	100	100	100	350	9	5	5

Table A.2-20 Cost Parameters in the Collecting Point 3

i=-1	j=3								
k	$P_{up\text{-}ec1}$	$P_{up\text{-}ec2}$	$P_{up\text{-}ec3}$	$P_{up\text{-}ec4}$	$P_{up\text{-}ec5}$	I_{up}	$T_{up\text{-}rp1}$	$T_{up\text{-}rp2}$	$T_{up\text{-}dp}$
1	100	100	100	100	100	350	6	9	7
2	100	100	100	100	100	350	6	10	9
3	100	100	100	100	100	350	5	5	9
4	100	100	100	100	100	350	6	7	8
5	100	100	100	100	100	350	6	9	5
6	100	100	100	100	100	350	7	7	9
7	100	100	100	100	100	350	6	7	7
8	100	100	100	100	100	350	9	9	10
9	100	100	100	100	100	350	6	8	7
10	100	100	100	100	100	350	6	9	10
11	100	100	100	100	100	350	9	9	7
12	100	100	100	100	100	350	8	6	6

Table A.2-21 Cost Parameters in the Recycle Plant 1

i=-2	j=1									
k	$P_{up\text{-}cp1}$	$P_{up\text{-}cp2}$	$P_{up\text{-}cp3}$	$P_{up\text{-}ec1}$	$P_{up\text{-}ec2}$	$P_{up\text{-}ec3}$	$P_{up\text{-}ec4}$	$P_{up\text{-}ec5}$	I_{up}	$T_{up\text{-}dp}$
1	150	150	150	150	150	150	150	150	400	10
2	150	150	150	150	150	150	150	150	400	8
3	150	150	150	150	150	150	150	150	400	7
4	150	150	150	150	150	150	150	150	400	9
5	150	150	150	150	150	150	150	150	400	8
6	150	150	150	150	150	150	150	150	400	9
7	150	150	150	150	150	150	150	150	400	7
8	150	150	150	150	150	150	150	150	400	6
9	150	150	150	150	150	150	150	150	400	5
10	150	150	150	150	150	150	150	150	400	9
11	150	150	150	150	150	150	150	150	400	10
12	150	150	150	150	150	150	150	150	400	6

Table A.2-22 Cost Parameters in the Recycle Plant 2

i=-2	j=2									
k	$P_{up\text{-}cp1}$	$P_{up\text{-}cp2}$	$P_{up\text{-}cp3}$	$P_{up\text{-}ec1}$	$P_{up\text{-}ec2}$	$P_{up\text{-}ec3}$	$P_{up\text{-}ec4}$	$P_{up\text{-}ec5}$	I_{up}	$T_{up\text{-}dp}$
1	150	150	150	150	150	150	150	150	400	9
2	150	150	150	150	150	150	150	150	400	8
3	150	150	150	150	150	150	150	150	400	9
4	150	150	150	150	150	150	150	150	400	9
5	150	150	150	150	150	150	150	150	400	6
6	150	150	150	150	150	150	150	150	400	9
7	150	150	150	150	150	150	150	150	400	9
8	150	150	150	150	150	150	150	150	400	10
9	150	150	150	150	150	150	150	150	400	7
10	150	150	150	150	150	150	150	150	400	6
11	150	150	150	150	150	150	150	150	400	7
12	150	150	150	150	150	150	150	150	400	8

Table A.2-23 Cost Parameters in the Disassembly Plant 1

i=-3	j=1							
k	$P_{up\text{-}rp1}$	$P_{up\text{-}rp2}$	$P_{up\text{-}cp1}$	$P_{up\text{-}cp2}$	$P_{up\text{-}cp3}$	$P_{up\text{-}ec1}$	$P_{up\text{-}ec2}$	$P_{up\text{-}ec3}$
1	200	200	200	200	200	200	200	200
2	200	200	200	200	200	200	200	200
3	200	200	200	200	200	200	200	200
4	200	200	200	200	200	200	200	200
5	200	200	200	200	200	200	200	200
6	200	200	200	200	200	200	200	200
7	200	200	200	200	200	200	200	200
8	200	200	200	200	200	200	200	200
9	200	200	200	200	200	200	200	200
10	200	200	200	200	200	200	200	200
11	200	200	200	200	200	200	200	200
12	200	200	200	200	200	200	200	200

k	$P_{up\text{-}ec4}$	$P_{up\text{-}ec5}$	I_{up}	I_{rbm}	I_{dw}	$T_{rbm\text{-}smm}$	$T_{dw\text{-}li}$	TR_{up}
1	200	200	606	72	6	7	3	123
2	200	200	606	72	6	8	3	123
3	200	200	606	72	10	9	5	119
4	200	200	606	72	6	10	3	118
5	200	200	606	72	10	9	4	119
6	200	200	606	72	8	7	2	115
7	200	200	606	72	11	7	3	117
8	200	200	606	72	7	6	2	115
9	200	200	606	72	10	6	2	117
10	200	200	606	72	6	10	3	118
11	200	200	606	72	9	9	4	124
12	200	200	606	72	10	8	5	119

Table A.2-24 Cost Parameters in the Secondary Material Market 1 and Landfill/ Incinerator 1

i=-4	j=1					i=-5	j=1	
k	M_{rrm}	P_{rbm}	I_{rbm}	I_{rrm}	$T_{rrm\text{-}m}$	k	I_{dw}	TR_{dw}
1	3155	36	54466	61260	5	1	3	5
2	3737	36	46558	77015	8	2	3	4
3	4029	36	38943	79786	7	3	5	4
4	2407	36	31798	45291	10	4	4	6
5	3075	36	47248	37557	6	5	5	5
6	4000	36	46687	54411	7	6	6	5
7	3259	36	40416	58989	9	7	5	3
8	4112	36	44793	65677	7	8	5	4
9	1922	36	46869	65798	6	9	3	5
10	3819	36	47612	41374	8	10	5	3
11	2238	36	44074	53856	6	11	3	6
12	3806	36	46577	45478	6	12	5	6

A.3 Results of Planning

Table A.3-1 Output of the Raw Material Supplier ($\gamma = 0.71$)

i=4	j=1				
k	$Q_{rm\text{-}M}$	$Q_{vm\text{-}P}$	$Q_{vm\text{-}I}$	$Q_{rm\text{-}I}$	$Q_{rm\text{-}m}$
0			250	700	
1	1703	1453	0	2131	272
2	3357	3357	0	1654	3834
3	4408	4408	0	1051	5011
4	5097	5097	0	688	5459
5	5516	5516	0	419	5785
6	5778	5778	0	263	5935
7	5937	5937	0	158	6041
8	6016	6016	0	79	6095
9	6078	6078	0	63	6095
10	6109	6109	0	31	6141
11	6109	6109	0	0	6141
12	6093	6093	0	0	6093

Table A.3-2 Output of the Manufacturer ($\gamma = 0.71$)

i=3	j=1							
k	$Q_{p\text{-}M}$	$Q_{rm\text{-}P}$	$Q_{rrm\text{-}P}$	$Q_{rm\text{-}I}$	$Q_{p\text{-}I}$	$Q_{p\text{-}ws}$	$Q_{p\text{-}r}$	$Q_{p\text{-}ec}$
0				2000	4700			
1	2292	272	20	0	2922	1800	1110	1160
2	3837	3834	3	0	1545	2700	1113	1400
3	5017	5011	6	0	1181	2933	1200	1249
4	5463	5459	4	0	446	3248	1200	1750
5	5787	5785	2	0	325	3308	1200	1400
6	5937	5935	2	0	150	3374	1200	1538
7	6043	6041	2	0	106	3374	1200	1514
8	6097	6095	2	0	54	3374	1200	1575
9	6097	6095	2	0	0	3374	1200	1577
10	6143	6141	2	0	46	3416	1200	1481
11	6143	6141	2	0	0	3416	1200	1573
12	6095	6093	2	0	0	3416	1200	1479

Table A.3-3 Output of the Wholesalers ($\gamma = 0.71$)

i=2	j=1				j=2			
k	$Q_{p\text{-}P}$	$Q_{p\text{-}I}$	$Q_{p\text{-}r}$	$Q_{p\text{-}ec}$	$Q_{p\text{-}P}$	$Q_{p\text{-}I}$	$Q_{p\text{-}r}$	$Q_{p\text{-}ec}$
0		1700				1600		
1	900	900	950	750	900	900	850	750
2	1350	450	1050	750	1350	450	1050	750
3	1358	8	1050	750	1575	225	1050	750
4	1579	221	765	600	1669	94	1050	750
5	1639	61	1050	750	1669	0	1013	750
6	1639	0	950	750	1735	66	950	719
7	1639	0	950	689	1735	0	1050	750
8	1639	0	889	750	1735	0	985	750
9	1639	0	950	689	1735	0	1050	685
10	1681	42	950	689	1735	0	985	750
11	1681	0	974	750	1735	0	985	750
12	1681	0	931	750	1735	0	985	750

Table A.3-4 Output of the Retailers ($\gamma = 0.71$)

i=1	j=1			j=2			j=3		
k	$Q_{p\text{-}P}$	$Q_{p\text{-}I}$	$Q_{p\text{-}ec}$	$Q_{p\text{-}P}$	$Q_{p\text{-}I}$	$Q_{p\text{-}ec}$	$Q_{p\text{-}P}$	$Q_{p\text{-}I}$	$Q_{p\text{-}ec}$
0		490			230			150	
1	910	150	1250	1020	0	1250	980	0	1130
2	1100	0	1250	1013	0	1013	1100	0	1100
3	1100	0	1100	1100	0	1100	1100	0	1100
4	1100	0	1100	815	0	815	1100	0	1100
5	1100	0	1100	1100	0	1100	1063	0	1063
6	1000	0	1000	1100	0	1100	1000	0	1000
7	1100	0	1100	1000	0	1000	1100	0	1100
8	1100	0	1100	939	0	939	1035	0	1035
9	1000	0	1000	1100	0	1100	1100	0	1100
10	1000	0	1000	1100	0	1100	1035	0	1035
11	1058	0	1058	1000	0	1000	1100	0	1100
12	1081	0	1081	1000	0	1000	1035	0	1035

Table A.3-5 Output of the Returns ($\gamma = 0.71$)

i=0	j=1	j=2	j=3	j=4	j=5	j=1~5
k	Q_{up}	Q_{up}	Q_{up}	Q_{up}	Q_{up}	Total
1	256	227	231	218	234	1167
2	197	242	228	207	229	1103
3	222	204	226	231	221	1104
4	235	227	233	212	205	1113
5	230	219	217	230	227	1124
6	220	237	230	234	231	1153
7	209	219	213	226	196	1063
8	218	218	210	193	229	1068
9	219	213	236	212	253	1133
10	217	236	206	222	222	1102
11	201	205	235	213	217	1071
12	179	229	230	211	221	1069
Total	2603	2677	2696	2609	2684	13268

Table A.3-6 Output of the End-Customers ($\gamma = 0.71$)

i=0	j=1			j=2			j=3		
k	$Q_{up\text{-}cp}$	$Q_{up\text{-}rp}$	$Q_{up\text{-}dp}$	$Q_{up\text{-}cp}$	$Q_{up\text{-}rp}$	$Q_{up\text{-}dp}$	$Q_{up\text{-}cp}$	$Q_{up\text{-}rp}$	$Q_{up\text{-}dp}$
1	36	200	0	36	200	0	36	200	0
2	19	200	0	12	200	0	12	200	0
3	24	200	0	20	200	0	24	200	0
4	29	200	0	24	200	0	12	200	0
5	16	200	0	36	200	0	24	200	0
6	36	200	0	36	200	0	21	200	0
7	12	200	0	0	200	0	12	200	0
8	12	200	0	24	200	0	24	200	0
9	24	200	0	36	200	0	36	200	0
10	12	200	0	36	200	0	18	200	0
11	12	200	0	12	200	0	24	200	0
12	12	200	0	36	160	0	36	200	0

i=0	j=4			j=5			——		
k	$Q_{up\text{-}cp}$	$Q_{up\text{-}rp}$	$Q_{up\text{-}dp}$	$Q_{up\text{-}cp}$	$Q_{up\text{-}rp}$	$Q_{up\text{-}dp}$	——	——	——
1	36	200	0	23	200	0	——	——	——
2	36	200	0	24	200	0	——	——	——
3	36	200	0	0	200	0	——	——	——
4	24	200	0	24	200	0	——	——	——
5	36	200	0	12	200	0	——	——	——
6	36	200	0	24	200	0	——	——	——
7	15	200	0	24	200	0	——	——	——
8	0	200	0	8	200	0	——	——	——
9	25	200	0	12	200	0	——	——	——
10	24	200	0	12	200	0	——	——	——
11	11	200	0	12	200	0	——	——	——
12	36	200	0	29	160	0	——	——	——

Table A.3-7 Output of the Collecting Points ($\gamma = 0.71$)

i=-1	j=1				j=2				j=3			
k	$Q_{up\text{-}P}$	$Q_{up\text{-}I}$	$Q_{up\text{-}rp}$	$Q_{up\text{-}dp}$	$Q_{up\text{-}P}$	$Q_{up\text{-}I}$	$Q_{up\text{-}rp}$	$Q_{up\text{-}dp}$	$Q_{up\text{-}P}$	$Q_{up\text{-}I}$	$Q_{up\text{-}rp}$	$Q_{up\text{-}dp}$
0		350				260				285		
1	60	360	40	10	60	270	40	10	47	282	40	10
2	24	334	40	10	31	251	40	10	48	280	40	10
3	36	320	40	10	44	245	40	10	24	254	40	10
4	48	318	40	10	29	223	40	10	36	240	40	10
5	40	308	40	10	48	221	40	10	36	226	40	10
6	60	318	40	10	45	216	40	10	48	224	40	10
7	12	280	40	10	27	193	40	10	24	198	40	10
8	36	266	40	10	24	167	40	10	8	155	40	10
9	48	264	40	10	60	177	40	10	25	131	40	10
10	36	250	40	10	30	157	40	10	36	117	40	10
11	12	212	40	10	47	154	40	10	12	79	40	10
12	36	198	40	10	60	164	40	10	53	82	40	10

Table A.3-8 Output of the Recycle Plants ($\gamma = 0.71$)

i=-2	j=1			j=2		
k	$Q_{up\text{-}P}$	$Q_{up\text{-}I}$	$Q_{up\text{-}dp}$	$Q_{up\text{-}P}$	$Q_{up\text{-}I}$	$Q_{up\text{-}dp}$
0		150			230	
1	560	560	150	560	560	230
2	560	320	800	560	320	800
3	560	80	800	560	80	800
4	560	40	600	560	40	600
5	560	40	560	560	40	560
6	560	40	560	560	40	560
7	560	40	560	560	40	560
8	560	40	560	560	40	560
9	560	40	560	560	40	560
10	560	40	560	560	40	560
11	560	40	560	560	40	560
12	520	0	560	520	0	560

Table A.3-9 Output of the Disassembly Plant ($\gamma = 0.71$)

i=-3	j=1						
k	$Q_{up\text{-}P}$	$Q_{up\text{-}I}$	$Q_{rbm\text{-}I}$	$Q_{dw\text{-}I}$	$Q_{rbm\text{-}smm}$	$Q_{dw\text{-}li}$	$Q_{up\text{-}TR}$
0		470	450	380			
1	410	0	882	880	448	380	880
2	1630	0	750	750	1762	1760	1630
3	1630	0	575	0	1805	2380	1630
4	1230	0	0	0	1805	1230	1230
5	1150	0	0	0	1150	1150	1150
6	1150	0	0	0	1150	1150	1150
7	1150	0	0	0	1150	1150	1150
8	1150	0	0	0	1150	1150	1150
9	1150	0	0	0	1150	1150	1150
10	1150	0	0	0	1150	1150	1150
11	1150	0	0	0	1150	1150	1150
12	1150	0	0	1150	1150	0	1150

Table A.3-10 Output of the Secondary Material Market and Landfill/ Incinerator ($\gamma = 0.71$)

i=-4	j=1					i=-5	j=1	
k	Q_{rrm-M}	Q_{rbm-P}	Q_{rbm-I}	Q_{rrm-I}	Q_{rrm-m}	k	Q_{dw-I}	Q_{dw-TR}
0			200	20		0		200
1	1	448	0	1	20	1	580	0
2	4	1762	0	2	3	2	1760	0
3	4	1805	0	0	6	3	2380	0
4	4	1805	0	0	4	4	1230	0
5	2	1150	0	0	2	5	1150	0
6	2	1150	0	0	2	6	1150	0
7	2	1150	0	0	2	7	1150	0
8	2	1150	0	0	2	8	1150	0
9	2	1150	0	0	2	9	1150	0
10	2	1150	0	0	2	10	1150	0
11	2	1150	0	0	2	11	1150	0
12	2	1150	0	0	2	12	0	0

Table A.3-11 Output of the Raw Material Supplier (γ＝0. 6157635)

i=4	j=1				
k	Q_{rm-M}	Q_{vm-P}	Q_{vm-I}	Q_{rm-I}	Q_{rm-m}
0			250	700	
1	1703	1453	0	2131	272
2	3357	3357	0	1654	3834
3	4408	4408	0	1051	5011
4	5097	5097	0	688	5459
5	5516	5516	0	419	5785
6	5779	5779	0	263	5935
7	5937	5937	0	158	6041
8	6016	6016	0	79	6095
9	6079	6079	0	63	6095
10	6110	6110	0	31	6141
11	6110	6110	0	0	6141
12	6093	6093	0	0	6093

Table A.3-12 Output of the Manufacturer (γ＝0. 6157635)

i=3	j=1							
k	Q_{p-M}	Q_{rm-P}	Q_{rrm-P}	Q_{rm-I}	Q_{p-I}	Q_{p-ws}	Q_{p-r}	Q_{p-ec}
0				2000	4700			
1	2292	272	20	0	2922	1800	1110	1160
2	3837	3834	3	0	1545	2700	1113	1400
3	5017	5011	6	0	1181	2933	1200	1249
4	5463	5459	3	0	446	3248	1200	1750
5	5787	5785	2	0	325	3308	1200	1400
6	5937	5935	2	0	150	3374	1200	1538
7	6043	6041	2	0	106	3374	1200	1514
8	6097	6095	2	0	54	3374	1200	1575
9	6097	6095	2	0	0	3374	1200	1577
10	6143	6141	2	0	46	3416	1200	1481
11	6143	6141	2	0	0	3416	1200	1573
12	6095	6093	2	0	0	3416	1200	1479

Table A.3-13 Output of the Wholesalers (γ＝0. 6157635)

i=2	j=1				j=2			
k	$Q_{p\text{-}P}$	$Q_{p\text{-}I}$	$Q_{p\text{-}r}$	$Q_{p\text{-}ec}$	$Q_{p\text{-}P}$	$Q_{p\text{-}I}$	$Q_{p\text{-}r}$	$Q_{p\text{-}ec}$
0		1700				1600		
1	900	900	950	750	900	900	850	750
2	1350	450	1050	750	1350	450	1050	750
3	1358	8	1050	750	1575	225	1050	750
4	1579	221	765	600	1669	94	1050	750
5	1639	61	1050	750	1669	0	1013	750
6	1639	0	950	750	1735	66	950	719
7	1639	0	950	689	1735	0	1050	750
8	1639	0	889	750	1735	0	985	750
9	1639	0	950	689	1735	0	1050	685
10	1681	42	950	689	1735	0	985	750
11	1681	0	974	750	1735	0	985	750
12	1681	0	931	750	1735	0	985	750

Table A.3-14 Output of the Retailers (γ＝0. 6157635)

i=1	j=1			j=2			j=3		
k	$Q_{p\text{-}P}$	$Q_{p\text{-}I}$	$Q_{p\text{-}ec}$	$Q_{p\text{-}P}$	$Q_{p\text{-}I}$	$Q_{p\text{-}ec}$	$Q_{p\text{-}P}$	$Q_{p\text{-}I}$	$Q_{p\text{-}ec}$
0		490			230			150	
1	910	150	1250	1020	0	1250	980	0	1130
2	1100	0	1250	1013	0	1013	1100	0	1100
3	1100	0	1100	1100	0	1100	1100	0	1100
4	1100	0	1100	815	0	815	1100	0	1100
5	1100	0	1100	1100	0	1100	1063	0	1063
6	1000	0	1000	1100	0	1100	1000	0	1000
7	1100	0	1100	1000	0	1000	1100	0	1100
8	1100	0	1100	939	0	939	1035	0	1035
9	1000	0	1000	1100	0	1100	1100	0	1100
10	1000	0	1000	1100	0	1100	1035	0	1035
11	1058	0	1058	1000	0	1000	1100	0	1100
12	1081	0	1081	1000	0	1000	1035	0	1035

Table A.3-15 Output of the Returns (γ＝0. 6157635)

i=0	j=1	j=2	j=3	j=4	j=5	j=1~5
k	Q_{up}	Q_{up}	Q_{up}	Q_{up}	Q_{up}	Total
1	222	197	201	189	203	1012
2	171	210	198	179	198	956
3	192	177	196	200	192	958
4	204	197	202	184	178	965
5	200	190	188	200	197	975
6	191	206	200	203	201	1000
7	182	190	185	196	170	922
8	189	189	182	167	198	926
9	190	185	204	184	219	983
10	188	205	179	192	192	956
11	174	178	204	185	188	929
12	155	198	200	183	192	927
Total	2257	2322	2338	2262	2328	11507

Table A.3-16 Output of the End-Customers (γ＝0. 6157635)

i=0	j=1			j=2			j=3		
k	$Q_{up\text{-}cp}$	$Q_{up\text{-}rp}$	$Q_{up\text{-}dp}$	$Q_{up\text{-}cp}$	$Q_{up\text{-}rp}$	$Q_{up\text{-}dp}$	$Q_{up\text{-}cp}$	$Q_{up\text{-}rp}$	$Q_{up\text{-}dp}$
1	36	200	0	36	200	0	36	200	0
2	19	200	0	12	200	0	12	200	0
3	24	200	0	20	200	0	24	200	0
4	29	200	0	24	200	0	12	200	0
5	16	200	0	36	200	0	24	200	0
6	36	200	0	36	200	0	21	200	0
7	12	200	0	0	200	0	12	200	0
8	12	200	0	24	200	0	24	200	0
9	24	200	0	36	200	0	36	200	0
10	12	200	0	36	200	0	18	200	0
11	12	200	0	12	200	0	24	200	0
12	12	200	0	36	160	0	36	200	0

i=0	j=4			j=5			——		
k	$Q_{up\text{-}cp}$	$Q_{up\text{-}rp}$	$Q_{up\text{-}dp}$	$Q_{up\text{-}cp}$	$Q_{up\text{-}rp}$	$Q_{up\text{-}dp}$	——	——	——
1	36	200	0	23	200	0	——	——	——
2	36	200	0	24	200	0	——	——	——
3	36	200	0	0	200	0	——	——	——
4	24	200	0	24	200	0	——	——	——
5	36	200	0	12	200	0	——	——	——
6	36	200	0	24	200	0	——	——	——
7	15	200	0	24	200	0	——	——	——
8	0	200	0	8	200	0	——	——	——
9	25	200	0	12	200	0	——	——	——
10	24	200	0	12	200	0	——	——	——
11	11	200	0	12	200	0	——	——	——
12	36	200	0	29	160	0	——	——	——

Table A.3-17 Output of the Collecting Points (γ＝0. 6157635)

i=-1	j=1				j=2				j=3			
k	$Q_{up\text{-}P}$	$Q_{up\text{-}I}$	$Q_{up\text{-}rp}$	$Q_{up\text{-}dp}$	$Q_{up\text{-}P}$	$Q_{up\text{-}I}$	$Q_{up\text{-}rp}$	$Q_{up\text{-}dp}$	$Q_{up\text{-}P}$	$Q_{up\text{-}I}$	$Q_{up\text{-}rp}$	$Q_{up\text{-}dp}$
0		350				260				285		
1	0	300	40	10	12	222	40	10	0	235	40	10
2	0	250	40	10	0	172	40	10	0	185	40	10
3	0	200	40	10	0	122	40	10	0	135	40	10
4	0	150	40	10	0	72	40	10	0	85	40	10
5	0	100	40	10	0	22	40	10	0	35	40	10
6	0	50	40	10	18	18	12	10	40	40	25	10
7	18	18	40	10	10	0	18	10	10	0	40	10
8	18	0	36	0	10	0	0	10	10	0	0	10
9	30	12	8	10	11	1	0	10	10	0	0	10
10	30	0	32	10	11	0	2	10	10	0	0	10
11	30	0	20	10	11	0	1	10	10	0	0	10
12	30	0	20	10	11	0	1	10	10	0	0	10

Table A.3-18 Output of the Recycle Plants (γ＝0. 6157635)

i=-2	j=1			j=2		
k	Q_{up-P}	Q_{up-I}	Q_{up-dp}	Q_{up-P}	Q_{up-I}	Q_{up-dp}
0		150			230	
1	560	560	150	560	560	230
2	540	300	800	536	296	800
3	560	60	800	518	21	793
4	525	5	580	560	82	499
5	560	75	490	535	15	602
6	524	4	595	495	0	510
7	504	0	508	478	0	478
8	484	0	484	440	0	440
9	468	0	468	471	15	456
10	460	0	460	479	0	494
11	420	0	420	479	0	479
12	420	0	420	477	0	477

Table A.3-19 Output of the Disassembly Plant (γ＝0. 6157635)

i=-3	j=1						
k	Q_{up-P}	Q_{up-I}	Q_{rbm-I}	Q_{dw-I}	$Q_{rbm-smm}$	Q_{dw-li}	Q_{up-TR}
0		470	450	380			
1	410	0	880	880	450	380	880
2	1630	0	750	750	1760	1760	1630
3	1623	0	613	0	1760	2373	1623
4	1109	0	0	0	1721	1109	1109
5	1122	0	14	14	1109	1109	1122
6	1135	0	39	12	1109	1136	1135
7	1016	0	0	0	1055	1028	1016
8	944	0	0	0	944	944	944
9	954	0	10	10	944	944	954
10	984	0	33	30	961	964	984
11	929	0	0	0	961	959	929
12	927	0	0	927	927	0	927

Table A.3-20 Output of the Secondary Material Market

and Landfill/ Incinerator (γ＝0. 6157635)

i=-4	j=1					i=-5	j=1	
k	Q_{rrm-M}	Q_{rbm-P}	Q_{rbm-I}	Q_{rrm-I}	Q_{rrm-m}	k	Q_{dw-I}	Q_{dw-TR}
0			200	20		0		200
1	1	450	0	1	20	1	580	0
2	4	1760	0	2	3	2	1760	0
3	4	1760	0	0	6	3	2373	0
4	3	1721	0	0	3	4	1109	0
5	2	1109	0	0	2	5	1109	0
6	2	1109	0	0	2	6	1136	0
7	2	1055	0	0	2	7	1028	0
8	2	944	0	0	2	8	944	0
9	2	944	0	0	2	9	944	0
10	2	961	0	0	2	10	964	0
11	2	961	0	0	2	11	959	0
12	2	927	0	0	2	12	0	0

A.4 Program of Case Study

Model:

```
 Sets:

    !Set members in each layer;
     rms      / 1..1 /;
     m        / 1..1 /;
     ws       / 1..2 /;
     r        / 1..3 /;
     ec       / 1..5 /;
     cp       / 1..3 /;
     rp       / 1..2 /;
     dp       / 1..1 /;
     smm      / 1..1 /;
     li       / 1..1 /;

     ws_r     / 1..6    /;    ! ws * r    ;
     ws_ec    / 1..10 /;    ! ws * ec ;
     r_ec     / 1..15 /;    ! ws * ec ;

     ec_cp    / 1..15    /;    ! ec * cp    ;
     ec_rp    / 1..10    /;    ! ec * rp ;
     cp_rp    / 1..6     /;    ! cp * rp ;

    !Set time intervals;
     k      / 1..12 /;

    !Set manufacture cost        variables
          manufacture quantity variables ;
     M_rm      ( k, rms ) :      MC1,    QM1;
     M_p       ( k, m    ) :     MC2,    QM2;
     M_rrm     ( k, smm ) :    MC3,    QM3;

   !Set manufacture quantity variables of each time interval;
     M_rm_p      ( k ) :    QMP1;      ! QM1 ;
     M_p_p       ( k ) :    QMP2;      ! QM2 ;
     M_rrm_p     ( k ) :    QMP3;      ! QM3 ;
```

```
!Set treat    cost           variables
       treat    quantity    variables ;
  TR_up_dp      ( k, dp    ) :    TRC2, QTR2;
  TR_dw_li       ( k, li    ) :    TRC3, QTR3;

!Set treat quantity variables of time interval;
  TR_up_dp_p      ( k ) :    QTRP2 ;      ! QTR2 ;
  TR_dw_li_p      ( k ) :      QTRP3 ;    ! QTR3 ;

 !Set procurement      cost          variables
       transportation    cost          variables
       transportation    quantity    variables ;
  vm_rms        ( k, rms      ) :    PC0,                QT0;
  rm_m          ( k, rms      ) :    PC1,        TC1,    QT1;
  rrm_m         ( k, smm      ) :    PC2,        TC2,    QT2;
  p_m_ws        ( k, ws       ) :    PC3,        TC3,    QT3;
  p_m_r         ( k, r        ) :    PC4,        TC4,    QT4;
  p_ws_r        ( k, ws_r     ) :    PC5,        TC5,    QT5;
  p_m_ec        ( k, ec       ) :    PC6,        TC6,    QT6;
  p_ws_ec       ( k, ws_ec ) :    PC7,        TC7,    QT7;
  p_r_ec        ( k, r_ec     ) :    PC8,        TC8,    QT8;
  up_ec_cp      ( k, ec_cp ) :    PC9,        TC9,    QT9;
  up_ec_rp      ( k, ec_rp ) :    PC10,       TC10,   QT10;
  up_ec_dp      ( k, ec       ) : PC11,       TC11,   QT11;
  up_cp_rp      ( k, cp_rp ) :    PC12,       TC12,   QT12;
  up_cp_dp      ( k, cp       ) : PC13,       TC13,   QT13;
  up_rp_dp      ( k, rp       ) :    PC14,    TC14,   QT14;
  rbm_smm       ( k, smm      ) : PC15,    TC15,   QT15;
  dw_dp_li      ( k, dp       ) : PC17,    TC17,   QT17;

!Set transportation quantity variables of each time interval;
  vm_rms_p      ( k ) :    QTP0;        ! QT0;
  rm_m_p        ( k ) :    QTP1;        ! QT1;
  rrm_m_p       ( k ) :    QTP2;        ! QT2;
  p_m_ws_p      ( k ) :    QTP3;        ! QT3;
  p_m_r_p       ( k ) :    QTP4;        ! QT4;
  p_ws_r_p      ( k ) :    QTP5;        ! QT5;
  p_m_ec_p      ( k ) :    QTP6;        ! QT6;
  p_ws_ec_p     ( k ) :    QTP7;        ! QT7;
```

```
p_r_ec_p      ( k ) :   QTP8;        ! QT8;
up_ec_cp_p    ( k ) :   QTP9;        ! QT9;
up_ec_rp_p    ( k ) :   QTP10;       ! QT10;
up_ec_dp_p    ( k ) :   QTP11;       ! QT11;
up_cp_rp_p    ( k ) :   QTP12;       ! QT12;
up_cp_dp_p    ( k ) :   QTP13;       ! QT13;
up_rp_dp_p    ( k ) :   QTP14;       ! QT14;
rbm_smm_p     ( k ) :   QTP15;       ! QT15;
dw_dp_li_p    ( k ) :   QTP17;       ! QT17;

!Set transportation quantity variables of each time interval in each member;
 p_m              ( k ) : QTPM;        ! QTP3 + QTP4 + QTP6;
 p_ws             ( k ) : QTPWS;       ! QTP5 + QTP7;
 p_r              ( k ) : QTPR;        ! QTP8;
 up_ec            ( k ) : QTPEC;       ! QTP9    + QTP10 + QTP11;
 up_cp            ( k ) : QTPCP;       ! QTP12 + QTP13;
 up_rp            ( k ) : QTPRP;       ! QTP14 ;

!Set inventory cost         variables
      inventory quantity    variables ;
 I_vm_rms      ( k, rms ) :   INC0,     QI0;
 I_rm_rms      ( k, rms ) :   INC1,     QI1;
 I_rrm_smm     ( k, smm ) :   INC2,     QI2;
 I_rm_m        ( k, m   ) :   INC3,     QI3;
 I_p_m         ( k, m   ) :   INC4,     QI4;
 I_p_ws        ( k, ws  ) :   INC5,     QI5;
 I_p_r         ( k, r   ) :   INC6,     QI6;
 I_up_cp       ( k, cp  ) :   INC7,     QI7;
 I_up_rp       ( k, rp  ) :   INC8,     QI8;
 I_up_dp       ( k, dp  ) :   NC9,      QI9;
 I_dw_dp       ( k, dp  ) :   INC11,    QI11;
 I_rbm_dp      ( k, dp  ) :   INC12,    QI12;
 I_rbm_smm     ( k, smm ) :   INC13,    QI13;
 I_dw_li       ( k, li  ) :   INC14,    QI14;

!Set inventory quantity variables of 0 time interval;
 I_vm_rms_0      ( rms ) :   QI00;
 I_rm_rms_0      ( rms ) :   QI01;
 I_rrm_smm_0     ( smm ) :   QI02;
```

```
I_rm_m_0          ( m      ) :   QI03;
I_p_m_0           ( m      ) :   QI04;
I_p_ws_0          ( ws     ) :   QI05;
I_p_r_0           ( r      ) :   QI06;
I_up_cp_0         ( cp     ) :   QI07;
I_up_rp_0         ( rp     ) :   QI08;
I_up_dp_0         ( dp     ) :   QI09;
I_dw_dp_0         ( dp     ) :   QI011;
I_rbm_dp_0        ( dp     ) :   QI012;
I_rbm_smm_0       ( smm    ) :   QI013;
I_dw_li_0         ( li     ) :   QI014;

!Set inventory quantity variables of each time interval;
I_vm_rms_p      ( k ) :   QIP0;          ! QI0 ;
I_rm_rms_p      ( k ) :   QIP1;          ! QI1 ;
I_rrm_smm_p     ( k ) :   QIP2;          ! QI2 ;
I_rm_m_p        ( k ) :   QIP3;          ! QI3 ;
I_p_m_p         ( k ) :   QIP4;          ! QI4 ;
I_p_ws_P        ( k ) :   QIP5;          ! QI5 ;
I_p_r_p         ( k ) :   QIP6;          ! QI6 ;
I_up_cp_p       ( k ) :   QIP7;          ! QI7 ;
I_up_rp_p       ( k ) :   QIP8;          ! QI8 ;
I_up_dp_p       ( k ) :   QIP9;          ! QI9 ;
I_dw_dp_p       ( k ) :   QIP11;         ! QI11 ;
I_rbm_dp_p      ( k ) :   QIP12;         ! QI12 ;
I_rbm_smm_p     ( k ) :   QIP13;         ! QI13 ;
I_dw_li_p       ( k ) :   QIP14;         ! QI14 ;

!Set demand & return product quantity variables;
Q_D_p_ec        ( k, ec  ) : QD;
Q_R_up_ec       ( k, ec  ) : QR, QW;

!Set demand & return product quantity variables of each time interval;
Q_D_p_ec_p      ( k )   : QDP;
Q_R_up_ec_p     ( k )   : QRP;

Endsets
```

Data:

```
!Changeable variable in Lingo;
 RF = 39;                  !   Recycle Fee ;
 S   = 477;                !   Subsidy ;
 w1 = .64;                 !   Weight 1 ;
 Rr = 0.6157635;           !   Return Ratio ;
 tr   = .002;     ! Transition ratio between reusable materials and reused raw materials ;

!Import BL-data from Excel;
     MC1,   MC2, MC3,
     PC0,   PC1, PC2, PC3, PC4, PC5, PC6, PC7, PC8,
     INC0, INC1, INC2, INC3, INC4, INC5, INC6,
     TC1,   TC2, TC3, TC4, TC5, TC6, TC7, TC8,
     QI00, QI01, QI02, QI03, QI04, QI05, QI06,
     QD, QDP
=@OLE( 'C:\LINGO6\Sets.XLS',
   'MC1', 'MC2', 'MC3',
   'PC0', 'PC1', 'PC2', 'PC3', 'PC4', 'PC5', 'PC6', 'PC7', 'PC8',
   'INC0', 'INC1', 'INC2', 'INC3', 'INC4', 'INC5', 'INC6',
   'TC1', 'TC2', 'TC3', 'TC4', 'TC5', 'TC6', 'TC7', 'TC8',
   'QI00', 'QI01', 'QI02', 'QI03', 'QI04', 'QI05', 'QI06',
   'QD',     'QDP'     );

!Export BL-data to     Excel;
 @OLE( 'C:\LINGO6\Sets.XLS',
   'QM1', 'QM2', 'QM3',
   'QMP1', 'QMP2', 'QMP3',
   'QI0', 'QI1', 'QI2', 'QI3', 'QI4', 'QI5', 'QI6',
   'QT0', 'QT1', 'QT2', 'QT3', 'QT4', 'QT5', 'QT6', 'QT7', 'QT8',
   'QIP0', 'QIP1', 'QIP2', 'QIP3', 'QIP4', 'QIP5', 'QIP6',
   'QTP0', 'QTP1', 'QTP2',   'QTP3', 'QTP4', 'QTP5', 'QTP6', 'QTP7', 'QTP8',
   'QTPM', 'QTPWS', 'QTPR'                    )
 = QM1, QM2, QM3,
   QMP1, QMP2, QMP3,
   QI0, QI1, QI2, QI3, QI4, QI5, QI6,
     QT0, QT1, QT2, QT3, QT4, QT5, QT6, QT7, QT8,
     QIP0, QIP1, QIP2, QIP3, QIP4, QIP5, QIP6,
     QTP0, QTP1, QTP2,   QTP3, QTP4, QTP5, QTP6, QTP7, QTP8,
```

```
        QTPM, QTPWS, QTPR ;

    !Import RL-data from Excel;
        TRC2, TRC3,
        PC9,  PC10, PC11, PC12,  PC13,  PC14,  PC15,  PC17,
        INC7, INC8, INC9, INC11, INC12, INC13, INC14,
        TC9,  TC10, TC11, TC12,  TC13,  TC14,  TC15,  TC17,
        QI07, QI08, QI09, QI011, QI012, QI013, QI014,
        QW
    =@OLE( 'C:\LINGO6\Sets.XLS',
        'TRC2', 'TRC3',
        'PC9',  'PC10', 'PC11', 'PC12',  'PC13',  'PC14',  'PC15', 'PC17',
        'INC7', 'INC8', 'INC9', 'INC11', 'INC12', 'INC13', 'INC14',
        'TC9',  'TC10', 'TC11', 'TC12',  'TC13',  'TC14',  'TC15', 'TC17',
        'QI07', 'QI08', 'QI09', 'QI011',
        'QI012', 'QI013', 'QI014',
        'QW'            );

    !Export RL-data to     Excel;
     @OLE( 'C:\LINGO6Sets.XLS',
      'QTR2',   'QTR3',
      'QTRP2', 'QTRP3',
      'QI7',    'QI8',    'QI9',    'QI11',
      'QI12',   'QI13',   'QI14',
      'QT9',    'QT10',  'QT11',  'QT12',  'QT13',  'QT14',  'QT15',  'QT17',
      'QIP7',   'QIP8',   'QIP9',   'QIP11', 'QIP12', 'QIP13', 'QIP14',
      'QTP9',   'QTP10', 'QTP11', 'QTP12', 'QTP13', 'QTP14', 'QTP15', 'QTP17',
      'QTPEC', 'QTPCP', 'QTPRP',
      'QR',       'QRP'     )
     = QTR2,   QTR3,
      QTRP2, QTRP3,
      QI7,    QI8,    QI9,    QI11,   QI12,   QI13,   QI14,
      QT9,    QT10,   QT11,   QT12,   QT13,   QT14,   QT15,   QT17,
      QIP7,   QIP8,   QIP9,   QIP11, QIP12, QIP13, QIP14,
      QTP9,   QTP10, QTP11, QTP12, QTP13, QTP14, QTP15, QTP17,
      QTPEC, QTPCP, QTPRP,
      QR,       QRP   ;

Enddata
```

```
!Objective function in IL;

 Max = w1 * BL + w2 * RL;                ! 4.3- 1 ;

 w1 + w2 = 1;                            ! 4.4-72 ;

!Objective function in BL;

 BL = AR_BL - AMC_BL    - APC_BL                  ! 4.2-32 ;
     - AIC_BL    - ATC_BL    - ARFC_BL ;

 AR_BL     = @SUM(rm_m       ( i, j ):           ! 4.2- 7 ;
                  PC1( i, j ) * QT1( i, j ) ) +
             @SUM(p_m_ws    ( i, j ):
                  PC3( i, j ) * QT3( i, j ) ) +
             @SUM(p_m_r     ( i, j ):
                  PC4( i, j ) * QT4( i, j ) ) +
             @SUM(p_ws_r    ( i, j ):
                  PC5( i, j ) * QT5( i, j ) ) +
             @SUM(p_m_ec    ( i, j ):
                  PC6( i, j ) * QT6( i, j ) ) +
             @SUM(p_ws_ec ( i, j ):
                  PC7( i, j ) * QT7( i, j ) ) +
             @SUM(p_r_ec    ( i, j ):
                  PC8( i, j ) * QT8( i, j ) ) ;

 AMC_BL    = @SUM(M_rm    ( i, j ):            ! 4.2- 1 ;
                  MC1( i, j ) * QM1( i, j ) ) +
             @SUM(M_p     ( i, j ):
                  MC2( i, j ) * QM2( i, j ) ) ;

 APC_BL    = @SUM(vm_rms       ( i, j ):       ! 4.2- 3 ;
                  PC0( i, j ) * QT0( i, j ) ) +
             @SUM(rm_m       ( i, j ):
                  PC1( i, j ) * QT1( i, j ) ) +
             @SUM(rrm_m     ( i, j ):
                  PC2( i, j ) * QT2( i, j ) ) +
             @SUM(p_m_ws    ( i, j ):
                  PC3( i, j ) * QT3( i, j ) ) +
```

```
                @SUM(p_m_r      ( i, j ):
                        PC4( i, j ) * QT4( i, j ) ) +
                @SUM(p_ws_r     ( i, j ):
                        PC5( i, j ) * QT5( i, j ) ) ;

 AIC_BL    = @SUM(I_rm_rms      ( i, j ):              ! 4.2- 4 ;
                        INC0( i, j ) * QI0( i, j ) ) +
                @SUM(I_rm_rms      ( i, j ):
                        INC1( i, j ) * QI1( i, j ) ) +
                @SUM(I_rm_m        ( i, j ):
                        INC3( i, j ) * QI3( i, j ) ) +
                @SUM(I_p_m         ( i, j ):
                        INC4( i, j ) * QI4( i, j ) ) +
                @SUM(I_p_ws        ( i, j ):
                        INC5( i, j ) * QI5( i, j ) ) +
                @SUM(I_p_r         ( i, j ):
                        INC6( i, j ) * QI6( i, j ) ) ;

ATC_BL    = @SUM(rm_m        ( i, j ):              ! 4.2- 5 ;
                        TC1( i, j ) * QT1( i, j ) ) +
                @SUM(p_m_ws     ( i, j ):
                        TC3( i, j ) * QT3( i, j ) ) +
                @SUM(p_m_r      ( i, j ):
                        TC4( i, j ) * QT4( i, j ) ) +
                @SUM(p_ws_r     ( i, j ):
                        TC5( i, j ) * QT5( i, j ) ) +
                @SUM(p_m_ec     ( i, j ):
                        TC6( i, j ) * QT6( i, j ) ) +
                @SUM(p_ws_ec ( i, j ):
                        TC7( i, j ) * QT7( i, j ) ) +
                @SUM(p_r_ec     ( i, j ):
                        TC8( i, j ) * QT8( i, j ) ) ;

ARFC_BL   = @SUM(M_p       ( i, j ):              ! 4.2- 6;
                        RF * QM2( i, j ) ) ;
```

```
!Objective function in RL;

RL = AR_RL + AS_RL - AMC_RL - APC_RL                    ! 4.2-33 ;
    - AIC_RL - ATC_RL - ATRC_RL;

AR_RL   = @SUM(rrm_m          ( i, j ):                 ! 4.2-15;
                PC2 ( i, j ) * QT2( i, j ) ) +
          @SUM(up_cp_rp       ( i, j ):
                PC12( i, j ) * QT12( i, j ) ) +
          @SUM(up_cp_dp       ( i, j ):
                PC13( i, j ) * QT13( i, j ) ) +
          @SUM(up_rp_dp ( i, j ):
                PC14( i, j ) * QT14( i, j ) ) +
          @SUM(rbm_smm        ( i, j ):
                PC15( i, j ) * QT15( i, j ) ) +
          @SUM(dw_dp_li   ( i, j ):
                PC17( i, j ) * QT17( i, j ) ) ;

AS_RL   = @SUM(TR_up_dp ( i, j ):                       ! 4.2-16;
                S * QTR2 ( i, j ) ) ;

AMC_RL   = @SUM(M_rrm   ( i, j ):                       ! 4.2-10;
                 MC3( i, j ) * QM3( i, j ) ) ;

APC_RL = @SUM(up_ec_cp      ( i, j ):                   ! 4.2-11;
                PC9( i, j ) * QT9( i, j ) ) +
          @SUM(up_ec_rp       ( i, j ):
                PC10( i, j ) * QT10( i, j ) ) +
          @SUM(up_ec_dp       ( i, j ):
                PC11( i, j ) * QT11( i, j ) ) +
          @SUM(up_cp_rp       ( i, j ):
                PC12( i, j ) * QT12( i, j ) ) +
          @SUM(up_cp_dp       ( i, j ):
                PC13( i, j ) * QT13( i, j ) ) +
          @SUM(up_rp_dp ( i, j ):
                PC14( i, j ) * QT14( i, j ) ) +
          @SUM(rbm_smm        ( i, j ):
                PC15( i, j ) * QT15( i, j ) ) +
          @SUM(dw_dp_li   ( i, j ):
```

```
                PC17( i, j ) * QT17( i, j ) ) ;

AIC_RL = @SUM(I_rrm_smm        ( i, j ):                    ! 4.2-12;
                INC2 ( i, j ) * QI2( i, j ) ) +
         @SUM(I_up_cp     ( i, j ):
                INC7 ( i, j ) * QI7( i, j ) ) +
         @SUM(I_up_rp     ( i, j ):
                INC8 ( i, j ) * QI8( i, j ) ) +
         @SUM(I_up_dp       ( i, j ):
                INC9( i, j ) *   QI9( i, j ) ) +
         @SUM(I_dw_dp       ( i, j ):
                INC11( i, j ) * QI11( i, j ) ) +
         @SUM(I_rbm_dp        ( i, j ):
                INC12( i, j ) * QI12( i, j ) ) +
         @SUM(I_rbm_smm       ( i, j ):
                INC13( i, j ) * QI13( i, j ) ) +
         @SUM(I_dw_li         ( i, j ):
                INC14( i, j ) * QI14( i, j ) ) ;

ATC_RL =   @SUM(rrm_m     ( i, j ):                         ! 4.2-13;
                TC2( i, j ) *   QT2( i, j ) ) +
         @SUM(up_ec_cp      ( i, j ):
                TC9( i, j ) *   QT9( i, j ) ) +
         @SUM(up_ec_rp   ( i, j ):
                TC10( i, j ) * QT10( i, j ) ) +
         @SUM(up_ec_dp     ( i, j ):
                TC11( i, j ) * QT11( i, j ) ) +
         @SUM(up_cp_rp   ( i, j ):
                TC12( i, j ) * QT12( i, j ) ) +
         @SUM(up_cp_dp   ( i, j ):
                TC13( i, j ) * QT13( i, j ) ) +
         @SUM(up_rp_dp ( i, j ):
                TC14( i, j ) * QT14( i, j ) ) +
         @SUM(rbm_smm ( i, j ):
                TC15( i, j ) * QT15( i, j ) ) +
         @SUM(dw_dp_li   ( i, j ):
                TC17( i, j ) * QT17( i, j ) ) ;
```

```
ATRC_RL = @SUM(TR_up_dp      ( i, j ):
                    TRC2 * QTR2( i, j ) ) +
              @SUM(TR_dw_li      ( i, j ):
                    TRC3 * QTR3( i, j ) ) ;                    ! 4.2-14


  !Manufacture quantity variables of each time interval;
   @For( M_rm_p          ( h ):
         QMP1 ( h ) = @SUM( M_rm ( i, j )    | i #EQ# h :
                        QM1 ( i,j ) ) );
   @For( M_p_p           ( h ):
         QMP2 ( h ) = @SUM( M_p ( i, j )    | i #EQ# h :
                        QM2 ( i,j ) ) );
   @For( M_rrm_p          ( h ):
         QMP3 ( h ) = @SUM( M_rrm ( i, j )    | i #EQ# h :
                        QM3 ( i,j ) ) );

  !Treatment quantity variables of each time interval;
   @For( TR_up_dp_p ( h ):
         QTRP2 ( h ) = @SUM( TR_up_dp ( i, j )    | i #EQ# h :
                        QTR2 ( i,j ) ) );
   @For( TR_dw_li_p ( h ):
         QTRP3 ( h ) = @SUM( TR_dw_li ( i, j )    | i #EQ# h :
                        QTR3 ( i,j ) ) );

  !Transportation quantity variables of each time interval;
   @For( vm_rms_p         ( h ):
         QTP0 ( h ) = @SUM( vm_rms       ( i, j )    | i #EQ# h :
                        QT0 ( i, j ) ) );
   @For( rm_m_p         ( h ):
         QTP1 ( h ) = @SUM( rm_m       ( i, j )    | i #EQ# h :
                        QT1 ( i, j ) ) );
   @For( rrm_m_p       ( h ):
         QTP2 ( h ) = @SUM( rrm_m      ( i, j )    | i #EQ# h :
                        QT2 ( i, j ) ) );
   @For( p_m_ws_p      ( h ):
         QTP3 ( h ) = @SUM( p_m_ws    ( i, j )    | i #EQ# h :
                        QT3 ( i, j ) ) );
   @For( p_m_r_p       ( h ):
```

```
        QTP4 ( h ) = @SUM( p_m_r      ( i, j )    | i #EQ# h :
                              QT4 ( i, j ) ) );
@For( p_ws_r_p      ( h ):
        QTP5 ( h ) = @SUM( p_ws_r     ( i, j )    | i #EQ# h :
                              QT5 ( i, j ) ) );
@For( p_m_ec_p      ( h ):
        QTP6 ( h ) = @SUM( p_m_ec     ( i, j )    | i #EQ# h :
                              QT6 ( i, j ) ) );
@For( p_ws_ec_p     ( h ):
        QTP7 ( h ) = @SUM( p_ws_ec ( i, j )    | i #EQ# h :
                              QT7 ( i, j ) ) );
@For( p_r_ec_p      ( h ):
        QTP8 ( h ) = @SUM( p_r_ec     ( i, j )    | i #EQ# h :
                              QT8 ( i, j ) ) );
@For( up_ec_cp_p          ( h ):
        QTP9    ( h ) = @SUM( up_ec_cp    ( i, j )    | i #EQ# h :
                              QT9 ( i, j ) ) );
@For( up_ec_rp_p          ( h ):
        QTP10 ( h ) = @SUM( up_ec_rp    ( i, j )    | i #EQ# h :
                              QT10 ( i, j ) ) );
@For( up_ec_dp_p        ( h ):
        QTP11 ( h ) = @SUM( up_ec_dp    ( i, j )    | i #EQ# h :
                              QT11 ( i, j ) ) );
@For( up_cp_rp_p      ( h ):
        QTP12 ( h ) = @SUM( up_cp_rp    ( i, j )    | i #EQ# h :
                              QT12 ( i, j ) ) );
@For( up_cp_dp_p        ( h ):
        QTP13 ( h ) = @SUM( up_cp_dp    ( i, j )    | i #EQ# h :
                              QT13 ( i, j ) ) );
@For( up_rp_dp_p      ( h ):
        QTP14 ( h ) = @SUM( up_rp_dp    ( i, j )    | i #EQ# h :
                              QT14 ( i, j ) ) );
@For( rbm_smm_p      ( h ):
        QTP15 ( h ) = @SUM( rbm_smm      ( i, j )    | i #EQ# h :
                              QT15 ( i, j ) ) );
@For( dw_dp_li_p      ( h ):
        QTP17 ( h ) = @SUM( dw_dp_li    ( i, j )    | i #EQ# h :
                              QT17 ( i, j ) ) );
```

```
!Inventory quantity variables of each time interval;
 @For( I_vm_rms_p    ( h ):
        QIP0 ( h ) = @SUM( I_vm_rms ( i, j )    | i #EQ# h :
                           QI0 ( i,j ) ) );
 @For( I_rm_rms_p    ( h ):
        QIP1 ( h ) = @SUM( I_rm_rms ( i, j )    | i #EQ# h :
                           QI1 ( i,j ) ) );
 @For( I_rrm_smm_p ( h ):
        QIP2 ( h ) = @SUM( I_rrm_smm ( i, j )    | i #EQ# h :
                           QI2 ( i,j ) ) );
 @For( I_rm_m_p       ( h ):
        QIP3 ( h ) = @SUM( I_rm_m ( i, j )    | i #EQ# h :
                           QI3 ( i,j ) ) );
 @For( I_p_m_p        ( h ):
        QIP4 ( h ) = @SUM( I_p_m ( i, j )    | i #EQ# h :
                           QI4 ( i,j ) ) );
 @For( I_p_ws_p       ( h ):
        QIP5 ( h ) = @SUM( I_p_ws ( i, j ) | i #EQ# h :
                           QI5 ( i,j ) ) );
 @For( I_p_r_p        ( h ):
        QIP6 ( h ) = @SUM( I_p_r ( i, j )    | i #EQ# h :
                           QI6 ( i,j ) ) );
 @For( I_up_cp_p     ( h ):
        QIP7 ( h )    = @SUM( I_up_cp     ( i, j )    | i #EQ# h :
                           QI7 ( i,j ) ) );
 @For( I_up_rp_p     ( h ):
        QIP8 ( h )    = @SUM( I_up_rp     ( i, j )    | i #EQ# h :
                           QI8 ( i,j ) ) );
 @For( I_up_dp_p     ( h ):
        QIP9 ( h )    = @SUM( I_up_dp     ( i, j )    | i #EQ# h :
                           QI9 ( i,j ) ) );
 @For( I_dw_dp_p     ( h ):
        QIP11 ( h ) = @SUM( I_dw_dp     ( i, j ) | i #EQ# h :
                           QI11 ( i,j ) ) );
 @For( I_rbm_dp_p    ( h ):
        QIP12 ( h ) = @SUM( I_rbm_dp    ( i, j )    | i #EQ# h :
                           QI12 ( i,j ) ) );
 @For( I_rbm_smm_p ( h ):
        QIP13 ( h ) = @SUM( I_rbm_smm ( i, j )    | i #EQ# h :
```

```
                    QI13 ( i,j ) ) );
  @For( I_dw_li_p ( h ):
        QIP14 ( h ) = @SUM( I_dw_li ( i, j )   | i #EQ# h :
                    QI14 ( i,j ) ) );

!The capacities of transportation quantity variables;
  @For( rm_m        ( i, j       ) :
        @BND ( 0, QT1 ( i, j ),   7000 )   );          ! 4.4-39 ;
  @For( rrm_m       ( i, j       ) :
        @BND ( 0, QT2 ( i, j ),   500   )   );          ! 4.4-54 ;
  @For( p_m_ws      ( i, j       ) :
        @BND ( 0, QT3 ( i, j ),   2000 )   );          ! 4.4-40 ;
  @For( p_m_r       ( i, j       ) :
        @BND ( 0, QT4 ( i, j ),   400 )   );          ! 4.4-41 ;
  @For( p_ws_r      ( i, j       ) :
        @BND ( 0, QT5 ( i, j ),   350 )   );          ! 4.4-43 ;
  @For( p_m_ec      ( i, j       ) :
        @BND ( 0, QT6 ( i, j ),   350 )   );          ! 4.4-42 ;
  @For( p_ws_ec     ( i, j       ) :
        @BND ( 0, QT7 ( i, j ),   150 )   );          ! 4.4-44 ;
  @For( p_r_ec      ( i, j       ) :
        @BND ( 0, QT8 ( i, j ),   250 )   );          ! 4.4-45 ;
  @For( up_ec_cp    ( i, j       ) :
        @BND ( 0, QT9 ( i, j ),   12 )   );          ! 4.4-46 ;
  @For( up_ec_rp    ( i, j       ) :
        @BND ( 0, QT10 ( i, j ),   100 )   );          ! 4.4-47 ;
  @For( up_ec_dp    ( i, j       ) :
        @BND ( 0, QT11 ( i, j ),   0 )   );          ! 4.4-48 ;
  @For( up_cp_rp    ( i, j       ) :
        @BND ( 0, QT12 ( i, j ),   20 )   );          ! 4.4-49 ;
  @For( up_cp_dp    ( i, j       ) :
        @BND ( 0, QT13 ( i, j ),   10 )   );          ! 4.4-50 ;
  @For( up_rp_dp    ( i, j       ) :
        @BND ( 0, QT14 ( i, j ),   800 )   );          ! 4.4-51 ;
  @For( rbm_smm     ( i, j       ) :
        @BND ( 0, QT15 ( i, j ),   2500 )   );          ! 4.4-52 ;
  @For( dw_dp_li    ( i, j       ) :
        @BND ( 0, QT17 ( i, j ),   2500 )   );          ! 4.4-53 ;
```

```
! The relationship in BL ;

    ! QTP6 (k)+ QTP7 (k) + QTP8 (k)= QDP (k) ;          ! 4.4-81 ;
      @For( p_m_ec_p       ( i ):
       @For( p_ws_ec_p     ( i ):
        @For( p_r_ec_p       ( i ):
         @For( Q_D_p_ec_p    ( i ):
                  QTP6 ( i ) + QTP7 ( i ) + QTP8 ( i ) = QDP ( i ) ) ) ) );


   !QTP1(k) <= QMP1(k-t)    + QIP1(k-1) ;                ! 4.4-77 ;
    @For(rm_m_p         ( i ) | i #EQ# 1 :
     @For(M_rm_p         ( i ):
            QTP1 ( i ) <= @SUM( I_rm_rms_0 ( h ): QI01 ( h ) ) ) );
    @For(rm_m_p         ( i ) | i #GT# 1 :
     @For(M_rm_p         ( h )| h #EQ# i-1:
      @For(I_rm_rms_p ( h ) :
            QTP1 ( i ) <= QMP1 ( h ) + QIP1 ( h ) ) ) );


   !QTP2(k)    <= QMP3(k-t)    + QIP2(k-1) ;              ! 4.4-87 ;
    @For(rrm_m_p       ( i ) | i #EQ# 1 :
     @For(M_rrm_p       ( i ):
            QTP2 ( i ) <=@SUM( I_rrm_smm_0 ( h ) : QI02 ( h ) ) ) );
    @For(rrm_m_p       ( i ) | i #GT# 1 :
     @For(M_rrm_p       ( h ) | h #EQ# i-1:
      @For(I_rrm_smm_p ( h )    :
            QTP2 ( i ) <= QMP3 ( h ) + QIP2 ( h ) ) ) );


    !QMP1 (k) <= QTP0(k) + QIP0(k-1) ;                  ! 4.4-72 ;
     @For( M_rm_p      ( i ) | i #EQ# 1 :
      @For( vm_rms_p    ( i ):
               QMP1 ( i ) <= QTP0( i )+
                                 @SUM( I_vm_rms_0    ( h ) : QI00 ( h ) )      ) );
     @For( M_rm_p      ( i ) | i #GT# 1 :
      @For( vm_rms_p    ( i ) :
        @For( I_vm_rms_p    ( h ) | h #EQ# i-1 :
               QMP1 ( i ) <= QTP0( i ) +    QIP0 ( h )      ) ) );
```

```
!QMP3 (k) <= tr *( QTP15(k) + QIP13(k-1) ) ;          ! 4.4-73 ;
 @For( M_rrm_p      ( i ) | i #EQ# 1 :
  @For( rbm_smm_p    ( i ):
          QMP3 ( i ) <= t *( QTP15( i )+
                  @SUM( I_rbm_smm_0    ( h ) : QI013 ( h ) ) )    ) );

 @For( M_rrm_p      ( i ) | i #GT# 1 :
  @For( rbm_smm_p    ( i ) :
    @For( I_rbm_smm_p    ( h ) | h #EQ# i-1 :
          QMP3 ( i ) <= t * ( QTP15( i ) +    QIP13 ( h ) )    ) ) );


!QMP2 (k) <= QTP1(k) + QTP2(k) + QIP3 (k-1);           ! 4.4-74 ;
 @For( M_p_p      ( i ) | i #EQ# 1 :
  @For( rm_m_p    ( i ):
   @For( rrm_m_p ( i ):
          QMP2 ( i ) <= QTP1( i ) + QTP2( i ) +
                        @SUM( I_rm_m_0    ( h ) : QI03 ( h ) )    ) ) );

 @For( M_p_p      ( i ) | i #GT# 1 :
  @For( rm_m_p    ( i ) :
   @For( rrm_m_p ( i ) :
    @For( I_rm_m_p    ( h ) | h #EQ# i-1 :
          QMP2 ( i ) <= QTP1( i ) + QTP2( i ) +    QIP3 ( h )    ) ) ) );


! QTPM    (k) <= QMP2(k-t)    + QIP4 (k-1);                ! 4.4-78 ;
 @For( p_m         ( i ) | i #EQ# 1 :
  @For( M_p_p      ( i ):
          QTPM ( i ) <=    @SUM( I_p_m_0 ( h ) : QI04 ( h ) ) ) );

 @For( p_m         ( i ) | i #GT# 1 :
  @For( M_p_p      ( h )| h #EQ# i-1 :
   @For( I_p_m_p      ( h ) :
           QTPM ( i ) <= QMP2( h )    + QIP4 ( h ) ) ) );
```

```
!QTPWS(k) = QTP5(k) + QTP7(k) <= QTP3(k-t) + QIP5 (k-1);        ! 4.4-79 ;
   @For( I_p_ws_0 ( h ) | h #EQ# 1 :
    QI05 ( h ) >=
      @SUM( p_ws_r      ( i, j ) | i #EQ# 1 #AND# j #LE# 3 : QT5 ( i, j ) ) +
      @SUM( p_ws_ec     ( i, j ) | i #EQ# 1 #AND# j #LE# 5 : QT7 ( i, j ) ) ) ;

   @For( I_p_ws_0 ( h ) | h #EQ# 2 :
    QI05 ( h ) >=
      @SUM( p_ws_r      ( i, j ) | i #EQ# 1 #AND# j #GE# 4 : QT5 ( i, j ) ) +
      @SUM( p_ws_ec     ( i, j ) | i #EQ# 1 #AND# j #GE# 6 : QT7 ( i, j ) ) ) ;



   @For( p_m_ws ( g, h ) | h #EQ# 1 :
    @For( I_p_ws ( g, h ) :
      QT3 ( g, h ) + QI5 ( g, h ) >=
      @SUM( p_ws_r      ( i, j ) | i #EQ# g+1 #AND# j #LE# 3 : QT5 ( i, j ) ) +
      @SUM( p_ws_ec     ( i, j ) | i #EQ# g+1 #AND# j #LE# 5 : QT7 ( i, j ) ) ) ) ;

   @For( p_m_ws ( g, h ) | h #EQ# 2 :
    @For( I_p_ws ( g, h ) :
      QT3 ( g, h ) + QI5 ( g, h ) >=
      @SUM( p_ws_r      ( i, j ) | i #EQ# g+1 #AND# j #GE# 4 : QT5 ( i, j ) ) +
      @SUM( p_ws_ec     ( i, j ) | i #EQ# g+1 #AND# j #GE# 6 : QT7 ( i, j ) ) ) ) ;



!QTPR    (k) <= QTP4(k) + QTP5(k) + QIP6 (k-1);        ! 4.4-80 ;
 @For( p_r          ( i ) | i #EQ# 1 :
  @For( p_m_r_p      ( i ):
   @For( p_ws_r_p      ( i ):
        QTPR ( i ) <= QTP4( i ) + QTP5( i ) + @SUM( I_p_r_0 ( h ) :
                      QI06 ( h ) ) ) ) );

 @For( p_r          ( i ) | i #GT# 1 :
  @For( p_m_r_p      ( i ):
   @For( p_ws_r_p      ( i ):
    @For( I_p_r_p ( h ) | h #EQ# i-1 :
          QTPR ( i ) <= QTP4( i ) + QTP5( i ) + QIP6 ( h ) ) ) ) );
```

```
! The relationship in RL ;

    ! The relationship between wastes and returns ;
     @For( Q_R_up_ec ( i, j ):                                    ! 5.2- 1 ;
            QR ( i, j ) = Rr * QW( i, j ) );

    ! Return quantity variables of each time interval;
     @For( Q_R_up_ec_p ( h ):
            QRP( h ) = @SUM( Q_R_up_ec ( i, j ) | i #EQ# h :
                              QR ( i, j ) ) );

  ! QTP9 + QTP10 + QTP11 = QRP ;                    ! 4.4-82 ;
     @For( up_ec_cp_p   ( i ):
      @For( up_ec_rp_p   ( i ):
       @For( up_ec_dp_p   ( i ):
        @For( Q_R_up_ec_p   ( i ):
              QTP9 ( i ) + QTP10 ( i ) + QTP11 ( i ) = QRP ( i ) ) ) ) );


  !QTPCP (k) = QTP12(k) + QTP13(k) <= QTP9(k-t) + QIP7 (k-1);        ! 4.4-83 ;
     @For( I_up_cp_0 ( h ) | h #EQ# 1 :   QI07 ( h ) >=
      @SUM( up_cp_rp ( i, j ) | i #EQ# 1 #AND# j #LE# 2 : QT12 ( i, j ) ) +
       @SUM( up_cp_dp ( i, j ) | i #EQ# 1 #AND# j #EQ# h : QT13 ( i, j ) ) ) ;

@For( I_up_cp_0 ( h ) | h #EQ# 2 : QI07 ( h ) >=
 @SUM( up_cp_rp ( i, j ) | i #EQ# 1 #AND# j #GE# 2 #AND# j #LE# 3 : QT12 ( i, j ) ) +
   @SUM( up_cp_dp ( i, j ) | i #EQ# 1 #AND# j #EQ# h   : QT13 ( i, j ) ) ) ;

     @For( I_up_cp_0 ( h ) | h #EQ# 3 : QI07 ( h ) >=
      @SUM( up_cp_rp ( i, j ) | i #EQ# 1 #AND# j #GE# 4 : QT12 ( i, j ) ) +
       @SUM( up_cp_dp ( i, j ) | i #EQ# 1 #AND# j #EQ# h : QT13 ( i, j ) ) ) ;


      @For( I_up_cp ( g, h )     | h #EQ# 1 : QI7 ( g, h )+
       @SUM( up_ec_cp ( i, j ) | i #EQ# g     #AND# j #LE# 5 : QT9   ( i, j ) ) >=
        @SUM( up_cp_rp ( i, j ) | i #EQ# g+1 #AND# j #LE# 2 : QT12 ( i, j ) ) +
         @SUM( up_cp_dp ( i, j ) | i #EQ# g+1 #AND# j #EQ# h : QT13 ( i, j ) ) ) ;
```

```
@For( I_up_cp ( g, h )      | h #EQ# 2 : QI7 ( g, h )+
   @SUM( up_ec_cp ( i, j ) | i #EQ# g #AND# j #GE# 6
                                    #AND# j #LE# 10 : QT9 ( i, j ) ) >=
      @SUM( up_cp_rp ( i, j ) | i #EQ# g+1 #AND# j #GE# 3
                                    #AND# j #LE# 4 : QT12 ( i, j ) ) +
         @SUM( up_cp_dp ( i, j ) | i #EQ# g+1 #AND# j #EQ# h : QT13 ( i, j ) ) ) ;

      @For( I_up_cp ( g, h )      | h #EQ# 3 : QI7 ( g, h )+
       @SUM( up_ec_cp ( i, j ) | i #EQ# g      #AND# j #GE# 11 : QT9    ( i, j ) ) >=
        @SUM( up_cp_rp ( i, j ) | i #EQ# g+1 #AND# j #GE# 5 : QT12 ( i, j ) ) +
         @SUM( up_cp_dp ( i, j ) | i #EQ# g+1 #AND# j #EQ# h : QT13 ( i, j ) ) ) ;


   !QTPRP    (k) = QTP14(k) <= QTP10(k-t) + QTP12(k-t) + QIP8 (k-1) ;      ! 4.4-84 ;
    @For( up_rp_dp       ( i, j )| i #EQ# 1 :
     @For( I_up_rp_0    ( j ) :    QT14( i, j )       <= QI08 ( j )       ) );

    @For( up_rp_dp       ( g, h ) | g #GT# 1 #AND #h #EQ# 1 :
     @For( I_up_rp       ( l, h ) | l #EQ# g-1 : QT14( g, h ) <= QI8 ( l, h ) +
         @SUM( up_ec_rp ( i, j ) | i #EQ# l #AND# j #LE# 5 : QT10 ( i, j ) ) +
         @SUM( up_cp_rp ( i, j ) | i #EQ# l #AND# j #EQ# h : QT12 ( i, j ) ) ) );

    @For( up_rp_dp       ( g, h ) | g #GT# 1 #AND #h #EQ# 2 :
     @For( I_up_rp       ( l, h ) | l #EQ# g-1 : QT14( g, h ) <= QI8 ( l, h ) +
         @SUM( up_ec_rp ( i, j ) | i #EQ# l #AND# j #GE# 6 : QT10 ( i, j ) ) +
         @SUM( up_cp_rp ( i, j ) | i #EQ# l #AND# j #EQ# h : QT12 ( i, j ) ) ) );


   !QTRP2 (k) <= QTP11(k) + QTP13(k) + QTP14(k) + QIP9(k-1) ;       ! 4.4-75 ;
    @For( TR_up_dp_p     ( i ) | i #EQ# 1 :
     @For( up_ec_dp_p    ( i ):
      @For( up_cp_dp_p    ( i ):
       @For( up_rp_dp_p    ( i ):
                QTRP2 ( i ) <= QTP11 ( i ) + QTP13 ( i ) + QTP14 ( i ) +
                                  @SUM( I_up_dp_0 ( h ) : QI09 ( h ) )      ) ) ) );
```

```
 @For( TR_up_dp_p      ( i ) | i #GT# 1 :
  @For( up_ec_dp_p     ( i ):
   @For( up_cp_dp_p     ( i ):
    @For( up_rp_dp_p     ( i ):
     @For( I_up_dp_p       ( h ) | h #EQ# i-1 :
    QTRP2 ( i ) <= QTP11 ( i ) + QTP13 ( i ) + QTP14 ( i ) + QIP9 ( h ) ) ) ) ) );


!QTP15    (k) <= QTRP2 (k-t)+ QIP12 (k-1) ;                    ! 4.4-85 ;
 @For( rbm_smm_p    ( i ) | i #EQ# 1 :
  @For( TR_up_dp_p     ( i ):
          QTP15 ( i ) <=    @SUM( I_rbm_dp_0 ( h ) : QI012 ( h )    ) ) );

 @For( rbm_smm_p    ( i ) | i #GT# 1 :
  @For( TR_up_dp_p     ( h )| h #EQ# i-1 :
    @For( I_rbm_dp_p     ( h ) :
            QTP15 ( i ) <= QTRP2 ( h ) + QIP12 ( h ) ) ) );


!QTP17    (k) <= QTRP2 (k-t)+ QIP11 (k-1) ;             ! 4.4-86 ;
 @For( dw_dp_li_p    ( i ) | i #EQ# 1 :
  @For( TR_up_dp_p     ( i ):
          QTP17 ( i ) <= @SUM( I_dw_dp_0 ( h ) : QI011 ( h )    ) ) );

 @For( dw_dp_li_p    ( i ) | i #GT# 1 :
  @For( TR_up_dp_P     ( h )| h #EQ# i-1 :
    @For( I_dw_dp_p     ( h ) :
            QTP17 ( i ) <= QTRP2 ( h ) + QIP11 ( h ) ) ) );


!QTRP3 (k) <= QTP17(k) + QIP14(k-1)    ;                ! 4.4-76 ;
 @For( TR_dw_li_p     ( i ) | i #EQ# 1 :
  @For( dw_dp_li_p    ( i ):
        QTRP3 ( i ) <= QTP17 ( i ) + @SUM( I_dw_li_0 ( h ) : QI014 ( h ) ) ) );

 @For( TR_dw_li_p     ( i ) | i #GT# 1 :
  @For( dw_dp_li_p    ( i ):
   @For( I_dw_li_p       ( h ) | h #EQ# i-1 :
     QTRP3 ( i ) <= QTP17 ( i ) +    QIP14 ( h ) ) ) );
```

!Transportation quantity variables of each time interval in each member;

```
@For( p_m              ( i ):
 @For( p_m_ws_p      ( i ):
  @For( p_m_r_p       ( i ):
   @For( p_m_ec_p     ( i ):
          QTPM ( i ) = QTP3 ( i ) + QTP4 ( i ) + QTP6 ( i ) ) ) ) );

@For( p_ws             ( i ):
 @For( p_ws_r_p     ( i ):
  @For( p_ws_ec_p   ( i ):
         QTPWS ( i ) = QTP5 ( i ) + QTP7 ( i ) ) ) );

@For( p_r              ( i ):
 @For( p_r_ec_p     ( i ):
        QTPR ( i ) = QTP8 ( i ) ) );

@For( up_ec            ( i ):
 @For( up_ec_cp_p     ( i ):
  @For( up_ec_rp_p      ( i ):
   @For( up_ec_dp_p     ( i ):
          QTPEC ( i ) = QTP9 ( i ) + QTP10 ( i ) + QTP11 ( i ) ) ) ) );

@For( up_cp            ( i ):
 @For( up_cp_rp_p   ( i ):
  @For( up_cp_dp_p   ( i ):
         QTPCP ( i ) = QTP12 ( i ) + QTP13 ( i ) ) ) );

@For( up_rp            ( i ):
 @For( up_rp_dp_p     ( i ):
        QTPRP ( i ) = QTP14 ( i ) ) );
```

```
!The constraints of inventory quantity variable;

!QI0(k) = QI0(k-1) + QT0(k) - QM1(k);                    ! 4. 4-58 ;
   @For( I_vm_rms ( i, j ) | i #EQ# 1    :
    @For( I_vm_rms_0 ( j ) :
     @For( vm_rms ( i, j ):
      @For( M_rm    ( i, j ):
         QI0 ( i, j ) = QI00 ( j ) + QT0 ( i, j ) - QM1 ( i, j ) ) ) ) );
   @For( I_vm_rms ( i, j ) | i #GT# 1 :
    @For( I_vm_rms ( h, j ) | h #EQ# i-1 :
     @For( vm_rms ( i, j ):
      @For( M_rm    ( i, j ):
         QI0 ( i, j ) = QI0 ( h, j ) + QT0 ( i, j ) - QM1 ( i, j ) ) ) ) );


!QI1(k) = QI1(k-1) + QM1(k) - QT1(k);                    ! 4. 4-59 ;
   @For( I_rm_rms ( i, j ) | i #EQ# 1    :
    @For( I_rm_rms_0 ( j ) :
     @For( M_rm ( i, j ):
      @For( rm_m ( i, j ):
         QI1 ( i, j ) = QI01 ( j ) + QM1 ( i, j ) - QT1 ( i, j ) ) ) ) );
   @For( I_rm_rms ( i, j ) | i #GT# 1 :
    @For( I_rm_rms ( h, j ) | h #EQ# i-1 :
     @For( M_rm ( i, j ):
      @For( rm_m ( i, j ):
         QI1 ( i, j ) = QI1 ( h, j ) + QM1 ( i, j ) - QT1 ( i, j ) ) ) ) );


 !QI2(k) = QI2(k-1) + QM3(k) - QT2(k);                   ! 4. 4-70 ;
   @For( I_rrm_smm ( i, j ) | i #EQ# 1 :
    @For( I_rrm_smm_0 ( j ) :
     @For( M_rrm ( i, j ):
      @For( rrm_m ( i, j ):
         QI2 ( i, j ) = QI02 ( j ) + QM3 ( i, j ) - QT2 ( i, j ) ) ) ) );
   @For( I_rrm_smm ( i, j ) | i #GT# 1 :
    @For( I_rrm_smm ( h, j ) | h #EQ# i-1 :
     @For( M_rrm ( i, j ):
      @For( rrm_m ( i, j ):
         QI2 ( i, j ) = QI2 ( h, j ) + QM3 ( i, j ) - QT2 ( i, j ) ) ) ) );
```

```
!QI3(k) = QI3(k-1) + QT1(k) + QT2(k) - QM2(k);              ! 4. 4-60 ;
    @For( I_rm_m ( i, j ) | i #EQ# 1 :
     @For( I_rm_m_0 ( j ) :
      @For( rm_m ( i, j ):
       @For( rrm_m ( i, j ):
        @For( M_p( i, j ):
          QI3    ( i, j ) =
          QI03 ( j ) + QT1 ( i, j )    + QT2 ( i, j ) - QM2 ( i, j ) ) ) ) ) );
    @For( I_rm_m ( i, j ) | i #GT# 1 :
     @For( I_rm_m ( h, j ) | h #EQ# i-1 :
      @For( rm_m ( i, j ):
       @For( rrm_m ( i, j ):
        @For( M_p( i, j ):
          QI3 ( i, j ) =
          QI3 ( h, j ) + QT1 ( i, j )    + QT2 ( i, j ) - QM2 ( i, j ) ) ) ) ) );


!QI4(k) = QI4(k-1) + QM2(k) - QT3(k) - QT4(k) - QT6(k) ;        ! 4. 4-61 ;
    @For( I_p_m ( i, j ) | i #EQ# 1 :
     @For( I_p_m_0 ( j ) :
      @For( M_p    ( i, j ):
       @For( p_m_ws_p ( i ):
        @For( p_m_r_p    ( i ):
         @For( p_m_ec_p ( i ):
          QI4    ( i, j ) =
          QI04 ( j ) + QM2 ( i, j )
        - QTP3 ( i )    - QTP4 ( i )      - QTP6 ( i )    ) ) ) ) ) );
    @For( I_p_m ( i, j ) | i #GT# 1 :
     @For( I_p_m ( h, j ) | h #EQ# i-1 :
      @For( M_p    ( i, j ):
       @For( p_m_ws_p ( i ):
        @For( p_m_r_p    ( i ):
         @For( p_m_ec_p ( i ):
          QI4    ( i, j ) =
          QI4 ( h, j ) + QM2 ( i, j )
        - QTP3 ( i )       - QTP4 ( i )      - QTP6 ( i )    ) ) ) ) ) );
```

```
!QI5(k) = QI5(k-1) + QT3(k) - QT5(k)- QT7(k);                    ! 4. 4-62 ;
  @For( I_p_ws ( i, j ) | i #EQ# 1 #AND# j #EQ# 1:
    @For( I_p_ws_0 ( j ):
      @For( p_m_ws ( i, j    ):
        QI5 ( i, j ) = QI05 ( j ) + QT3 ( i, j )
        - @SUM( p_ws_r    ( i, g    ) | g #LE# 3 : QT5 ( i, g ) )
        - @SUM( p_ws_ec ( i, h    ) | h #LE# 5 : QT7 ( i, h ) )      ) ) );
  @For( I_p_ws ( i, j ) | i #EQ# 1 #AND# j #EQ# 2:
    @For( I_p_ws_0 ( j ):
      @For( p_m_ws ( i, j    ):
        QI5 ( i, j ) = QI05 ( j ) + QT3 ( i, j )
        - @SUM( p_ws_r    ( i, g    ) | g #GE# 4 : QT5 ( i, g ) )
        - @SUM( p_ws_ec ( i, h    ) | h #GE# 6 : QT7 ( i, h ) )      ) ) );

  @For( I_p_ws ( i, j ) | i #GT# 1 #AND# j #EQ# 1:
    @For( I_p_ws ( l, j ) | l #EQ# i-1 :
      @For( p_m_ws ( i, j    ):
        QI5 ( i, j ) = QI5 ( l, j ) + QT3 ( i, j )
        - @SUM( p_ws_r    ( i, g    ) | g #LE# 3 : QT5 ( i, g ) )
        - @SUM( p_ws_ec ( i, h    ) | h #LE# 5 : QT7 ( i, h ) )      ) ) );
  @For( I_p_ws ( i, j ) | i #GT# 1 #AND# j #EQ# 2:
    @For( I_p_ws ( l, j ) | l #EQ# i-1 :
      @For( p_m_ws ( i, j    ):
        QI5 ( i, j ) = QI5 ( l, j ) + QT3 ( i, j )
        - @SUM( p_ws_r    ( i, g    ) | g #GE# 4 : QT5 ( i, g ) )
        - @SUM( p_ws_ec ( i, h    ) | h #GE# 6 : QT7 ( i, h ) )      ) ) );


!QI6(k) = QI6(k-1) + QT4(k) + QT5(k)- QT8(k);                    ! 4. 4-63 ;
  @For( I_p_r ( i, j ) | i #EQ# 1 #AND# j #EQ# 1:
    @For( I_p_r_0 ( j ) :
      @For( p_m_r ( i, j ):
          QI6 ( i, j ) = QI06 ( j ) + QT4 ( i, j )
    + @SUM( p_ws_r ( i, g )| g #LE# 2 : QT5    ( i, g ) )
    - @SUM( p_r_ec ( i, h )| h #LE# 5 : QT8    ( i, h ) )    ) ) );
```

```
@For( I_p_r ( i, j ) | i #EQ# 1 #AND# j #EQ# 2:
 @For( I_p_r_0 ( j ) :
  @For( p_m_r ( i, j ):
      QI6 ( i, j ) = QI06 ( j ) + QT4 ( i, j )
  + @SUM( p_ws_r ( i, g )| g #GE# 3 #AND# g #LE# 4   : QT5   ( i, g ) )
  - @SUM( p_r_ec ( i, h )| h #GE# 6 #AND# h #LE# 10 : QT8   ( i, h ) )   ) ) );
@For( I_p_r ( i, j ) | i #EQ# 1 #AND# j #EQ# 3:
 @For( I_p_r_0 ( j ) :
  @For( p_m_r ( i, j ):
      QI6 ( i, j ) = QI06 ( j ) + QT4 ( i, j )
  + @SUM( p_ws_r ( i, g )| g #GE# 5 :   QT5   ( i, g ) )
  - @SUM( p_r_ec ( i, h )| h #GE# 11 : QT8   ( i, h ) )   ) ) );
@For( I_p_r ( i, j ) | i #GT# 1   #AND# j #EQ# 1:
 @For( I_p_r ( l, j ) | l #EQ# i-1   :
  @For( p_m_r ( i, j ):
      QI6 ( i, j ) = QI6 ( l, j ) + QT4 ( i, j )
  + @SUM( p_ws_r ( i, g )| g #LE# 2 : QT5   ( i, g ) )
  - @SUM( p_r_ec ( i, h )| h #LE# 5 : QT8   ( i, h ) )   ) ) );
@For( I_p_r ( i, j ) | i #GT# 1   #AND# j #EQ# 2:
 @For( I_p_r ( l, j ) | l #EQ# i-1   :
  @For( p_m_r ( i, j ):
      QI6 ( i, j ) = QI6 ( l, j ) + QT4 ( i, j )
  + @SUM( p_ws_r ( i, g )| g #GE# 3 #AND# g #LE# 4   : QT5   ( i, g ) )
  - @SUM( p_r_ec ( i, h )| h #GE# 6 #AND# h #LE# 10 : QT8   ( i, h ) )   ) ) );
@For( I_p_r ( i, j ) | i #GT# 1   #AND# j #EQ# 3:
 @For( I_p_r ( l, j ) | l #EQ# i-1   :
  @For( p_m_r ( i, j ):
      QI6 ( i, j ) = QI6 ( l, j ) + QT4 ( i, j )
  + @SUM( p_ws_r ( i, g )| g #GE# 5 :   QT5   ( i, g ) )
  - @SUM( p_r_ec ( i, h )| h #GE# 11 : QT8   ( i, h ) )   ) ) );


!QI7(k) = QI7(k-1) + QT9(k) - QT12(k)- QT13(k);                    ! 4. 4-64 ;
@For( I_up_cp ( i, j ) | i #EQ# 1 #AND# j #EQ# 1:
 @For( I_up_cp_0 ( j ) :
  @For( up_cp_dp ( i, j ):
        QI7 ( i, j ) = QI07 ( j ) - QT13 ( i, j )
  + @SUM( up_ec_cp ( i, g ) | g #LE# 5 : QT9   ( i, g ) )
  - @SUM( up_cp_rp ( i, h ) | h #LE# 2 : QT12 ( i, h ) )   ) ) );
```

```
@For( I_up_cp ( i, j ) | i #EQ# 1 #AND# j #EQ# 2:
  @For( I_up_cp_0 ( j ) :
     @For( up_cp_dp ( i, j ):
          QI7 ( i, j ) = QI07 ( j ) - QT13 ( i, j )
   + @SUM( up_ec_cp ( i, g ) | g #GE# 6 #AND# g #LE# 10 : QT9    ( i, g ) )
- @SUM( up_cp_rp ( i, h ) | h #GE# 3 #AND# h #LE# 4    : QT12 ( i, h ) )    ) ) );
@For( I_up_cp ( i, j ) | i #EQ# 1 #AND# j #EQ# 3:
  @For( I_up_cp_0 ( j ) :
    @For( up_cp_dp ( i, j ) :
          QI7 ( i, j ) = QI07 ( j ) - QT13 ( i, j )
    + @SUM( up_ec_cp ( i, g ) | g #GE# 11 : QT9    ( i, g ) )
    - @SUM( up_cp_rp ( i, h ) | h #GE# 5    : QT12 ( i, h ) )    ) ) );
@For( I_up_cp ( i, j ) | i #GT# 1 #AND# j #EQ# 1:
  @For( I_up_cp ( l, j )| l #EQ# i-1 :
    @For( up_cp_dp ( i, j ):
          QI7 ( i, j ) = QI7 ( l, j ) - QT13 ( i, j )
    + @SUM( up_ec_cp ( i, g ) | g #LE# 5 : QT9    ( i, g ) )
    - @SUM( up_cp_rp ( i, h ) | h #LE# 2 : QT12 ( i, h ) )    ) ) );
@For( I_up_cp ( i, j ) | i #GT# 1 #AND# j #EQ# 2:
  @For( I_up_cp ( l, j ) | l #EQ# i-1 :
     @For( up_cp_dp ( i, j ):
          QI7 ( i, j ) = QI7 ( l, j ) - QT13 ( i, j )
   + @SUM( up_ec_cp ( i, g ) | g #GE# 6 #AND# g #LE# 10 : QT9    ( i, g ) )
- @SUM( up_cp_rp ( i, h ) | h #GE# 3 #AND# h #LE# 4    : QT12 ( i, h ) )    ) ) );
@For( I_up_cp ( i, j ) | i #GT# 1 #AND# j #EQ# 3:
  @For( I_up_cp ( l, j ) | l #EQ# i-1 :
    @For( up_cp_dp ( i, j ) :
          QI7 ( i, j ) = QI7 ( l, j ) - QT13 ( i, j )
    + @SUM( up_ec_cp ( i, g ) | g #GE# 11 : QT9    ( i, g ) )
    - @SUM( up_cp_rp ( i, h ) | h #GE# 5    : QT12 ( i, h ) )    ) ) );


!QI8(k) = QI8(k-1) + QT10(k) + QT12(k)- QT14(k);              ! 4. 4-65;
@For( I_up_rp ( i, j ) | i #EQ# 1 #AND# j #EQ# 1:
  @For( I_up_rp_0 ( j ):
    @For( up_rp_dp ( i, j    ):
      QI8 ( i, j ) = QI08 ( j ) - QT14 ( i, j )
      + @SUM( up_ec_rp ( i, g    ) | g #LE# 5 : QT10 ( i, g ) )
      + @SUM( up_cp_rp ( i, h    ) | h #LE# 3 : QT12 ( i, h ) )      ) ) );
```

```
@For( I_up_rp ( i, j ) | i #EQ# 1 #AND# j #EQ# 2:
 @For( I_up_rp_0 ( j ):
  @For( up_rp_dp ( i, j    ):
   QI8 ( i, j ) = QI08 ( j ) - QT14 ( i, j )
   + @SUM( up_ec_rp ( i, g    ) | g #GE# 6 : QT10 ( i, g ) )
   + @SUM( up_cp_rp ( i, h    ) | h #GE# 4 : QT12 ( i, h ) )      ) ) );

@For( I_up_rp ( i, j ) | i #GT# 1 #AND# j #EQ# 1:
 @For( I_up_rp ( l, j ) | l #EQ# i-1 :
  @For( up_rp_dp ( i, j    ):
   QI8 ( i, j ) = QI8 ( l, j ) - QT14 ( i, j )
   + @SUM( up_ec_rp ( i, g    ) | g #LE# 5 : QT10 ( i, g ) )
   + @SUM( up_cp_rp ( i, h    ) | h #LE# 3 : QT12 ( i, h ) )      ) ) );
@For( I_up_rp ( i, j ) | i #GT# 1 #AND# j #EQ# 2:
 @For( I_up_rp ( l, j ) | l #EQ# i-1 :
  @For( up_rp_dp ( i, j    ):
   QI8 ( i, j ) = QI8 ( l, j ) - QT14 ( i, j )
   + @SUM( up_ec_rp ( i, g    ) | g #GE# 6 : QT10 ( i, g ) )
   + @SUM( up_cp_rp ( i, h    ) | h #GE# 4 : QT12 ( i, h ) )      ) ) );

!QI9(k) = QI9(k-1) + QT11(k) + QT13(k) + QT14(k) -QTR2(k) ;      ! 4. 4-66 ;
@For( I_up_dp ( i, j ) | i #EQ# 1 :
 @For( I_up_dp_0 ( j ) :
  @For( up_ec_dp_p ( i ):
   @For( up_cp_dp_p ( i ):
    @For( up_rp_dp_p ( i ):
     @For( TR_up_dp    ( i, j ):
     QI9    ( i, j ) =
     QI09 ( j ) + QTP11 ( i ) + QTP13 ( i ) + QTP14 ( i )
     - QTR2 ( i, j )    ) ) ) ) ) );
@For( I_up_dp ( i, j ) | i #GT# 1 :
 @For( I_up_dp ( h, j )    | h #EQ# i-1 :
  @For( up_ec_dp_p ( i ):
   @For( up_cp_dp_p ( i ):
    @For( up_rp_dp_p ( i ):
     @For( TR_up_dp    ( i, j ):
     QI9 ( i, j ) =
     QI9 ( h, j ) + QTP11 ( i ) + QTP13 ( i ) + QTP14 ( i )
     - QTR2 ( i, j )    ) ) ) ) ) );
```

```
!QI11(k) = QI11(k-1) + QTR2(k) - QT17(k) ;                    ! 4. 4-68 ;
 @For( I_dw_dp ( i, j ) | i #EQ# 1 :
  @For( I_dw_dp_0 ( j ) :
   @For( TR_up_dp    ( i, j ):
    @For( dw_dp_li_p ( i ):
        QI11    ( i, j ) =
        QI011 ( j ) + QTR2 ( i, j ) -    QTP17 ( i )      ) ) ) );
 @For( I_dw_dp ( i, j ) | i #GT# 1 :
  @For( I_dw_dp ( h, j )    | h #EQ# i-1 :
   @For( TR_up_dp    ( i, j ):
    @For( dw_dp_li_p ( i ):
        QI11    ( i, j ) =
        QI11 ( h, j ) + QTR2 ( i, j ) -    QTP17 ( i )      ) ) ) );


 !QI12(k) = QI12(k-1) + QTR2(k) - QT15(k) ;                    ! 4. 4-67 ;
 @For( I_dw_dp ( i, j ) | i #EQ# 1 :
  @For( I_dw_dp_0 ( j ) :
   @For( TR_up_dp    ( i, j ):
    @For( rbm_smm_p ( i ):
        QI12    ( i, j ) =
        QI012 ( j ) + QTR2 ( i, j ) -    QTP15 ( i )      ) ) ) );
 @For( I_dw_dp ( i, j ) | i #GT# 1 :
  @For( I_dw_dp ( h, j )    | h #EQ# i-1 :
   @For( TR_up_dp    ( i, j ):
    @For( rbm_smm_p ( i ):
        QI12    ( i, j ) =
        QI12 ( h, j ) + QTR2 ( i, j ) -    QTP15 ( i )      ) ) ) );


!QI13(k) = QI13(k-1) + QT15(k) - 1/t * QM3(k) ;                ! 4. 4-69 ;
 @For( I_rbm_smm ( i, j ) | i #EQ# 1 :
  @For( I_rbm_smm_0 ( j ) :
   @For( rbm_smm_p ( i ):
    @For( M_rrm    ( i, j ):
        QI13    ( i, j ) =
        QI013 ( j ) + QTP15 ( i ) - 1/t * QM3 ( i, j )    ) ) ) );
```

```
  @For( I_rbm_smm ( i, j ) | i #GT# 1 :
   @For( I_rbm_smm ( h, j )    | h #EQ# i-1 :
    @For( rbm_smm_p ( i ):
     @For( M_rrm          ( i, j ):
          QI13 ( i, j ) =
          QI13 ( h, j ) + QTP15 ( i ) - 1/t * QM3 ( i, j )    ) ) ) );


 !QI14(k) = QI14(k-1) + QT17(k)- QTR3(k) ;                    ! 4. 4-71 ;
  @For( I_dw_dp ( i, j ) | i #EQ# 1 :
   @For( I_dw_dp_0 ( j ) :
    @For( dw_dp_li_p ( i ):
     @For( TR_dw_li    ( i, j ):
          QI14    ( i, j ) =
          QI014 ( j ) + QTP17 ( i ) - QTR3 ( i, j )           ) ) ) );
  @For( I_dw_dp ( i, j ) | i #GT# 1 :
   @For( I_dw_dp ( h, j )    | h #EQ# i-1 :
    @For( dw_dp_li_p ( i ):
     @For( TR_dw_li    ( i, j ):
          QI14 ( i, j ) =
          QI14 ( h, j ) + QTP17 ( i ) - QTR3 ( i, j )      ) ) ) );

End
```

A.5 Program of Case Study

Table A.5-1 Sale Volume from MIC (Unit: pcs)

Year	PC	Monitor	Notebook	Printer
1989	139730	185575	8609	——
1990	172178	224720	11901	——
1991	212161	272121	16453	——
1992	308300	376000	19700	0
1993	312000	381000	31000	73286
1994	366000	447000	55000	175214
1995	428000	522000	64000	277143
1996	591000	727000	77000	298000
1997	765000	889000	112000	434000
1998	894000	1094000	144000	651000
1999	1240000	1250000	198000	807000
2000	1275000	1350000	238580	840000
2001	1317000	1458000	419498	865000
2002	1355000	1531000	579934	899000

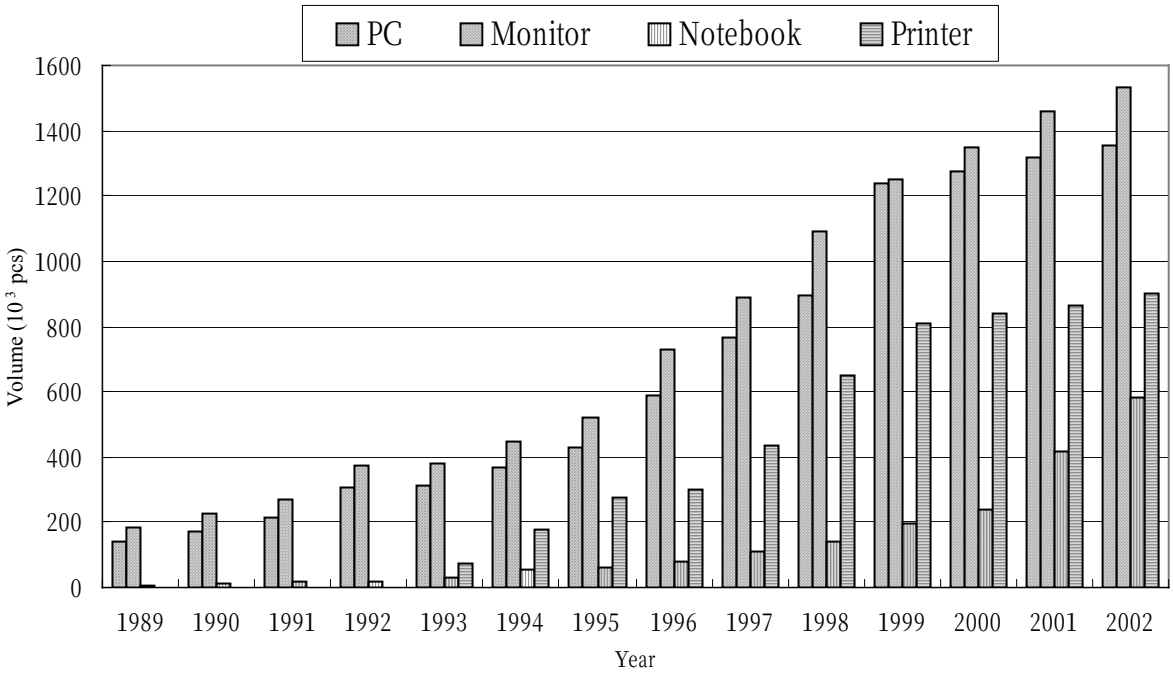

Figure A.5-1 Sale Volume from MIC

Table A.5-2 Estimated Waste Volume from EPA (Unit: pcs)

Year	PC	Monitor	Notebook	Printer
1990	1621	1447	1666	——
1991	10381	10475	3460	——
1992	31432	33636	8133	——
1993	64426	71732	11466	——
1994	106731	122929	16577	748
1995	152288	179934	25197	5327
1996	194014	231378	35315	19512
1997	241040	286004	50529	46704
1998	292494	343278	65810	91053
1999	364230	424464	84868	142844
2000	460593	526605	116816	201895
2001	583321	656249	149729	268527
2002	723860	799420	237574	386378

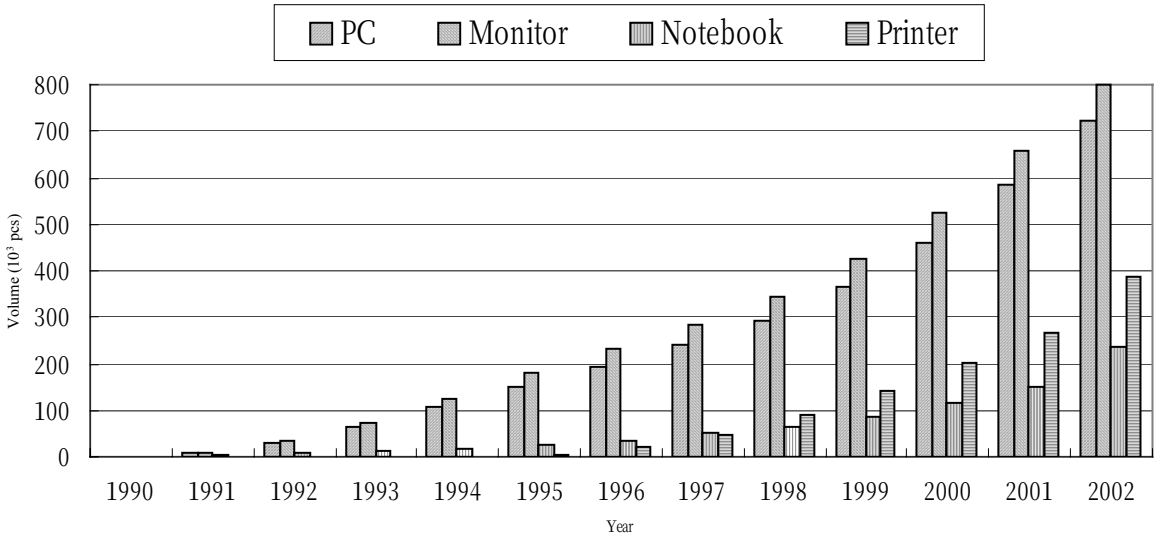

Figure A.5-2 Estimated Waste Volume from EPA

Table A.5-3 Return Volume from EPA (Unit: pcs)

Year	PC	Monitor	Notebook	Printer
1998.6~1998.12	36936	73049	424	——
1999	189177	243915	1027	——
2000	497054	447636	1828	——
2001.1~2001.10	566413	425664	1165	67556

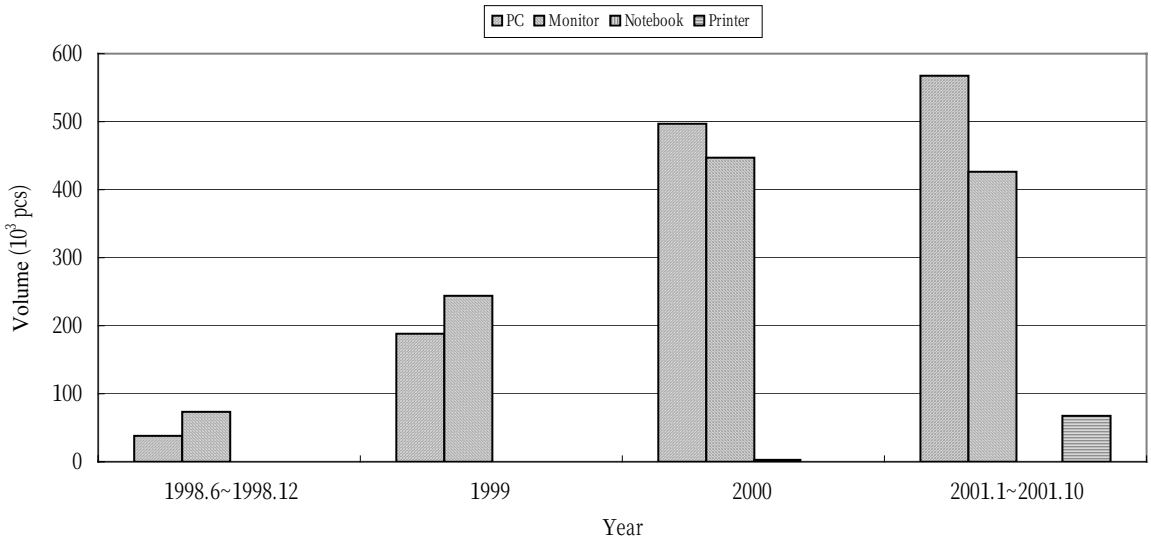

Figure A.5-3 Return Volume from EPA