Chapter 5 Model Application and Validation

In this chapter, a brief introduction of LINGO will be represented in section 5.1. Second, section 5.2 and section 5.3 will represent how the case study will be designed. And then, demands and returns will be decided in section 5.4. Finally, section 5.5 will provide a series of parameters set in this study.

5.1 LINGO

LINGO is a simple tool for utilizing the power of linear and nonlinear optimization to formulate large problems concisely, solve them, and analyze the solution. Optimization helps to find the answer that yields the best result; attains the highest profit, output, or happiness; or achieves the lowest cost, waste, or discomfort. Often, theses problems involve making the most efficient usage of existing resources — including money, time, machinery, staff, inventory, and more. Optimization problems are often classified as linear or nonlinear, depending on whether the relationships in the problem are linear with respect to the variables. [60]

There are some characteristics about LINGO described as follows: [61]

1. LINGO could be programmed by macro.
2. Matrixes could represent multi-dimensions data. This way could not only abbreviate the length of programming but also display data more clearly.
3. The bugs of the programs could be detected and responded quickly.

In this thesis, LINGO is a tool to solve the profit-maximization problem of the integrated logistics model.

5.2 Problem Statement of Case Study

In Taiwan, there is still no manufacturer, which is possessed of its own disassembly plant to treat useless products automatically. On the other hand, manufacturers always pay recycling-and-treatment fees, depending on the quantities of demand products manufactured by them, to the RMF. Then, the RMF give subsidy, depending on the quantities of useless products treated by them, to disassembly plants. So, there is no opportunity to get a complete data about integrated logistics from a manufacturer or a disassembly plant. Nevertheless, the relative data can still be received by collecting separately.

Although manufacturers and disassembly plants have power, separately, in BLS and RLS, the main stress falls on manufacturers in the ILM. In other words, the operations and planning are mainly for manufacturers.

Because the ILM can only deal with one item in the same time, the notebook is chosen as an example. According to the market survey about the sales volumes of notebook in Taiwan, ASUS is one of three main domestic brands. And the data of sales volumes of notebook from ASUS are enough and available. So, the manufacturer, ASUS, of notebooks is decided in the case study.

5.3 Case Design

In this case study, we suppose a raw material supplier, a manufacturer, two wholesalers, and three retailers in the BLS and a landfill/ incinerator, a secondary material market, a disassembly plant, two recycle plants, and three collecting points in the RLS. Finally, there are five end-customers and RMF in the integrated logistics system. Figure 5.3-1 represents the members in the case study.

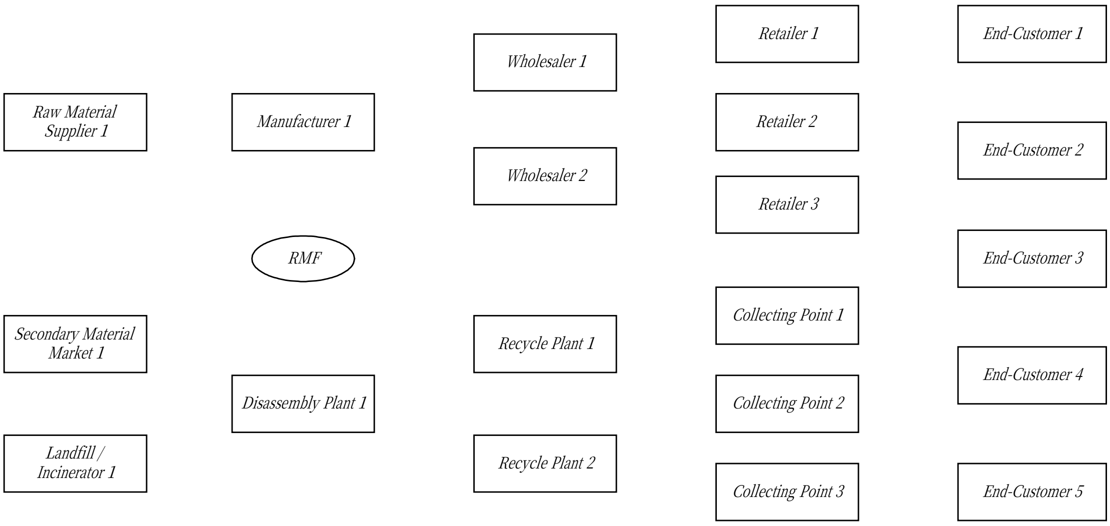

Figure 5.3-1 Members in Case Study

5.4 Demands and Returns

Because demands are given from ILM, we have to get them at first. Before getting demands, we have to figure out the relationships, described concisely as following equations, between demands and returns.

$$\text{Returns} = \text{Reruen ratio}(\gamma) \times \text{Estimated waste volumes} \tag{5.2-1}$$

$$\text{Estimated waste volumes}_{y+1} = \sum_{y} \text{Waste ratio}_y(\omega_y) \times \text{Demands}_y \tag{5.2-2}$$

where, y: Year

As aforementioned eq. (5.2-1) represents, we have to estimate the waste volumes in 2002 before getting returns. And the waste ratio is showed as Table 5.4-2. Because there are 60% of volumes from person and 40% of volumes from factory, we take ω_3 as the waste ratio to estimate the waste volumes in 2002. Over the years in ASUS, the domestic sales volumes of notebook are listed in Table 5.4-1. [62,63, 64, 65] After calculating, we get the estimated waste volumes of notebook in 2002 are 18587 pcs.

As Table 5.4-1 shows, the domestic sales volumes of notebook from ASUS in 2002 are 74214 pcs. And the estimated waste volumes of notebook in 2002 are 18587 pcs. Demands are supposed to distribute as Poisson distribution with λ_D, which equals the domestic sales volumes divided by k (time intervals). Finally, returns are supposed to distribute as Poisson distribution with λ_R, which equals the estimated waste volumes multiplied by return ratio (γ) and divided by k (time intervals). By the way, estimated waste are supposed to distribute as Poisson distribution with λ_{EW}, which equals the estimated waste volumes divided by k (time intervals).

Table 5.4-1 Domestic Sales Volumes of Notebook from ASUS

Year	1997	1998	1999	2000	2001	2002
Sales volume (pcs)	54	1,530	15723*	42281	62627	74214*

* Estimated in this study

Table 5.4-2 The Waste Ratio for Each Year

Used years	Waste ratio (ω_1) (Person)	Waste ratio (ω_2) (Factory)	Waste ratio (ω_3) (ω_3=0.6×ω_1+ 0.4×ω_2)
1	0.2258	0.0112	0.13996
2	0.1613	0.0317	0.10946
3	0.4194	0.1667	0.31832
4	0.0645	0.1976	0.11774
5	0.0646	0.3078	0.16188
6	0.0323	0.1166	0.06602
7	0	0.0693	0.02772
8	0.0323	0.0283	0.03070
9	——	0.0142	0.00568
10	——	0.0283	0.01132

Source: [66]

Table 5.4-3 Demands of Members in Each Time Interval (Unit: pcs)

i=0	j=1	j=2	j=3	j=4	j=5	j=1~5
k	$Q_{p\text{-}P}$	$Q_{p\text{-}P}$	$Q_{p\text{-}P}$	$Q_{p\text{-}P}$	$Q_{p\text{-}P}$	Total
1	1253	1292	1257	1247	1241	6290
2	1365	1185	1222	1243	1248	6263
3	1195	1203	1212	1254	1185	6049
4	1216	1263	1147	1235	1254	6115
5	1202	1193	1243	1249	1276	6163
6	1251	1258	1235	1174	1189	6107
7	1151	1259	1265	1251	1227	6153
8	1264	1189	1239	1209	1248	6149
9	1201	1316	1165	1234	1235	6151
10	1236	1199	1237	1165	1218	6055
11	1266	1230	1223	1262	1250	6231
12	1189	1184	1180	1273	1269	6095
Total	14789	14771	14625	14796	14840	73821

Table 5.4-4 Estimated Waste of Members in Each Time Interval (Unit: pcs)

i=0	j=1	j=2	j=3	j=4	j=5	j=1~5
k	Q_{ew}	Q_{ew}	Q_{ew}	Q_{ew}	Q_{ew}	Total
1	360	320	326	307	330	1643
2	278	341	321	291	322	1553
3	312	288	319	325	311	1555
4	331	320	328	299	289	1567
5	324	309	306	324	320	1583
6	310	334	324	330	326	1624
7	295	308	300	318	276	1497
8	307	307	296	272	322	1504
9	309	300	332	299	356	1596
10	305	333	290	312	312	1552
11	283	289	331	300	305	1508
12	252	322	324	297	311	1506
Total	3666	3771	3797	3674	3780	18688

In this case study, λ_D and λ_{EW} are, separately, 1237 and 310. So the detailed demands and estimate waste, in each end-customer and month in 2002, are listed separately in Table 5.4-3 and Table 5.4-4. In which, Q_{ew} is represented for the quantity of estimate waste.

5.5 Parameters Setting

Because many data are the top secret of private companies, it is not very available to get them. So, some parameters are got from Internet or reports, the others are supposed rationally in this study. The parameters for data generation in this study are listed as follows.

1. The unit cost is an integer value selected from uniform distribution of [Lower, Upper] NT dollars. The detailed ranges of unit cost are listed from Table 5.5-1 to Table 5.5-10. And the detailed cost parameters are listed from Table A.2-1 to Table A.2-24.

2. The unit inventory cost is double of the unit selling price or the unit procurement cost, except derivative waste.

3. It is more economical to procure virgin material than reusable material.

4. Transition ratios ($\tau_{a/b}$) are suppose to be 1, except $\tau_{rbm/rrm}$. The detailed data of transition ratios are listed in Table 5.5-11.

5. Purchase lead-times in BLS and transport lead-times in RLS are supposed to be a time interval; except end-customers purchase demand products from retailers and transport useless products to return nodes. The detailed data of lead-times are listed in Table 5.5-12.

6. Expect the capacities of transportation; all of the capacities are unbound. The detailed capacities of transportation are listed in Table 5.5-13. Besides, the capacities of transportation are the same, when branches are in the same layer. So, the superscript is represented for the layer.

7. In this case study, the initial inventory of each product is list in Table 5.5-14. In other words, the quantity of each product stocked in time interval k＝0 is set in advance. By the way, the superscript is represented for the branches of the layer. Besides, the cost of initial inventory does not be considered in the ILM.

8. The unit added value cost is included in the unit manufacture cost or the unit selling price, because it is too detailed and less important to the notebook.

Table 5.5-1 The Range of Cost in the Raw Material Supplier

i=4	M_{rm}	P_{vm}	I_{vm}	I_{rm}	$T_{rms\text{-}m}$
Upper limit	4018	28126	56252	80360	10
Lower limit	1722	12054	24108	34440	5

Table 5.5-2 The Range of Cost in the Manufacturer

i=3	M_p	P_{rm}	P_{rrm}	I_p	I_{rm}	T
Upper limit	5640	40180	42189	114800	82369	10
Lower limit	2360	17220	18081	49200	35301	5

Table 5.5-3 The Range of Cost in the Wholesaler

i=2	P_p	I_p	T
Upper limit	57400	155600	10
Lower limit	24600	77600	5

Table 5.5-4 The Range of Cost in the Retailer

i=1	P_p	I_p	T
Upper limit	77800	162600	10
Lower limit	38800	72200	5

Table 5.5-5 The Range of Cost in the End-Customer

i=0	P_p
Upper limit	81300
Lower limit	36100

Table 5.5-6 The Range of Cost in the Collecting Point

i=-1	P_{up}	I_{up}	T
Upper limit	100	350	10
Lower limit	100	350	5

Table 5.5-7 The Range of Cost in the Recycle Plant

i=-2	P_{up}	I_{up}	T
Upper limit	150	400	10
Lower limit	150	400	5

Table 5.5-8 The Range of Cost in the Disassembly Plant

i=-3	P_{up}	I_{up}	I_{rbm}	I_{dw}	T	$T_{dw\text{-}li}$	TR	R
Upper limit	200	606	72	11	10	5	124	36
Lower limit	200	606	72	5	5	2	115	36

Table 5.5-9 The Range of Cost in the Secondary Material Market

i=-4	M_{rrm}	P_{rbm}	I_{rbm}	I_{rrm}	$T_{smm\text{-}m}$
Upper limit	4219	29532	59065	84378	10
Lower limit	1808	12657	25313	36162	5

Table 5.5-10 The Range of Cost in the Landfill/ Incinerator

i=-5	I_{dw}	TR
Upper limit	5	6
Lower limit	2	3

Table 5.5-11 Transition Ratios

Ratios	$\tau_{vm/rm}$	$\tau_{rm/p}$	$\tau_{rbm/up}$	$\tau_{dw/up}$	$\tau_{rbm/rrm}$
Value	1	1	1	1	0.002

Table 5.5-12 Lead-times

BLS	Time interval	RLS	Time interval
$t^{4}_{rm\text{-}m}$	1	$t^{-4}_{rrm\text{-}m}$	1
$t^{3}_{p\text{-}ws}$	1	$t^{-3}_{rbm\text{-}smm}$	1
$t^{3}_{p\text{-}r}$	1	$t^{-3}_{dw\text{-}li}$	1
$t^{3}_{p\text{-}ec}$	1	$t^{-2}_{up\text{-}dp}$	1
$t^{2}_{p\text{-}r}$	1	$t^{-1}_{up\text{-}rp}$	1
$t^{2}_{p\text{-}ec}$	1	$t^{-1}_{up\text{-}dp}$	1
$t^{1}_{p\text{-}ec}$	0	$t^{0}_{up\text{-}cp}$	0
––	––	$t^{0}_{up\text{-}rp}$	0
––	––	$t^{0}_{up\text{-}dp}$	0

Table 5.5-13 The Capacities of Transportation (Unit: pcs)

BLS	Upper	Lower	RLS	Upper	Lower
$Q^{4}_{rm\text{-}m}$	7000	0	$Q^{-4}_{rrm\text{-}m}$	500	0
$Q^{3}_{p\text{-}ws}$	2000	0	$Q^{-3}_{rbm\text{-}smm}$	2500	0
$Q^{3}_{p\text{-}r}$	400	0	$Q^{-3}_{dw\text{-}li}$	2500	0
$Q^{3}_{p\text{-}ec}$	350	0	$Q^{-2}_{up\text{-}dp}$	800	0
$Q^{2}_{p\text{-}r}$	350	0	$Q^{-1}_{up\text{-}rp}$	20	0
$Q^{2}_{p\text{-}ec}$	150	0	$Q^{-1}_{up\text{-}dp}$	10	0
$Q^{1}_{p\text{-}ec}$	250	0	$Q^{0}_{up\text{-}cp}$	12	0
––	––	––	$Q^{0}_{up\text{-}rp}$	100	0
––	––	––	$Q^{0}_{up\text{-}dp}$	0	0

Table 5.5-14 The Initial Inventory of Each Product (Unit: pcs)

BLS		Quantity	RLS		Quantity
i=4	$Q^{1}_{vm\text{-}I}(0)$	250	i=-1	$Q^{1}_{up\text{-}I}(0)$	350
	$Q^{1}_{rm\text{-}I}(0)$	700		$Q^{2}_{up\text{-}I}(0)$	260
i=3	$Q^{1}_{rm\text{-}I}(0)$	2000		$Q^{3}_{up\text{-}I}(0)$	285
	$Q^{1}_{p\text{-}I}(0)$	4700	i=-2	$Q^{1}_{up\text{-}I}(0)$	150
i=2	$Q^{1}_{p\text{-}I}(0)$	1700		$Q^{2}_{up\text{-}I}(0)$	230
	$Q^{2}_{p\text{-}I}(0)$	1600	i=-3	$Q^{1}_{up\text{-}I}(0)$	470
i=1	$Q^{1}_{p\text{-}I}(0)$	490		$Q^{1}_{rbm\text{-}I}(0)$	450
	$Q^{2}_{p\text{-}I}(0)$	230		$Q^{1}_{dw\text{-}I}(0)$	380
	$Q^{2}_{p\text{-}I}(0)$	150	i=-4	$Q^{1}_{rbm\text{-}I}(0)$	200
−−	−−	−−		$Q^{1}_{rrm\text{-}I}(0)$	20
	−−	−−	i=-5	$Q^{1}_{dw\text{-}I}(0)$	200