Fall 2017

Maximizing Profit of Certification Services Provided by NRTLs

Bhawinee Banchongraksa
Portland State University

Chatchai Kubpiyajanya
Portland State University

Mufeed Yacoub
Portland State University

Tiffany Tran
Portland State University

Maximizing Profit of Certification Services Provided by NRTLs

Course Title: Operations Research
Course Number: ETM 540/640, Fall 2017
Instructor: Dr. Timothy Anderson
Term: Fall
Year: 2017
Author(s): Bhawinee Banchongraksa, Chatchai Kubpiyajanya
Mufeed Yacoub, Tiffany Tran

ETM OFFICE USE ONLY

Report No.:
Type: Student Project
Note:

Table of Contents

1. Introduction

Nationally Recognized Testing Laboratories (NRTLs) are independent third-party organizations recognized by the Occupational Safety & Health Administration (OSHA) to provide evaluation, testing and certification of products. All NRTLs conduct testing and certification are based on safety standards developed by organizations, such as Underwriters Laboratories (UL). In order to remain competitive in their respective markets, NRTLs must continually find new business lines to provide services to and maintain. NRTLs accomplish this goal by seeking out companies to which they can provide their certification services at a profit.

One of the biggest challenges NRTLs face in their annual operations, is finding a process with which to select companies to provide their services to. Due to the constraints, different monetary and time investments involved in pursuing new business streams, it is a substantial added value to have model with which to factor in all constraints while simultaneously maximizing the profit of services provided.

In this paper, Linear Programing Optimization is utilized to build a model which can be used to take in sets of data of the certification standards in the desired local market, along with all relative constraints so as to yield a set of standards which maximize profit. A case study of a mock NRTL company located in Oregon is applied to test this model.

2. Data Gathering

Gathering all data needed for the model, as seen in the table cutout below, consists of several steps. First, standards and their quantities in the desired region(s) are identified by using the publicly accessible UL directory [1]. From there, a list can be generated by selecting a specific City, or State. Second, a standard's activity level is identified by calculating the average standard update rate from its ten-year history, which can be obtained from public sites, such as SAI Global [2]. The average update rate helps the model identify standards with higher potential to generate revenue because of their high update rate, because those standards require more upkeep and maintenance services. Third, the number of shifts are assigned to each standard. A shift translates to quote amount for testing and certification services to be provided. The shift amount is largely determined based on previously issued quotes. Lastly, the equipment and training cost. These costs take into account additional equipment and training required to be able to provide certification and testing services to such standards that are new to the NRTL.Equipment and training costs are determined based on expert opinion.

	A	B	D	E	F	G	H	I	J	K
1	Company Name	Category Name	UL standard#	2nd standard	# of stnds	# of shifts	# of standard updates per year	Additional equipment cost	Additional training cost	Labor & overhead
21	FOUCH ELECTRIC MFG CO	Boxes, Junction and Pull	50	50E	3	13	0.5	0	0	10800
24	PLATT ELECTRIC SUPPLY INC	Processed Wire	62		3	6	0.5	0	0	5200
27	BODEN STORE FIXTURES INC	Wired Cabinets	65		3	8	0.25	0	0	6600
30	FOUCH ELECTRIC MFG CO	Panelboards	67		1	8	1	0	0	7200
31	JENSORTER L L C	Animal Care Appliances	73		1	7	0.5	0	0	6000
32	BLOUNT INC	Gardening Appliances	82		1	8	1	0	0	7200
33	AUTHENTIC MODELS AMERICAS INC	Luminaires, Portable	153		5	8	1.25	0	0	7400
39	COMMERCIAL DEHYDRATOR SYSTEMS INC	Commercial Cooking Appliances	197	1889	3	14	0.5	0	0	11600
42	NORTHWEST REGULATOR SUPPLY INC, DBA AMFOR ELECTRONICS	Garage Equipment	201		1	7	0.125	0	0	5700
43	UNISOURCE CO	Tubing, Refrigerant - Component	207	1963	1	14	0.5	0	0	11600
44	UNISOURCE MFG INC	Fittings, Accessory	213	2351A	1	13	0.5	0	0	10800
45	MALARKEY ROOFING PRODUCTS	Roofing Membranes	263		1	8	0.25	0	0	6600
46	CHEMORI AMERICAS LLC	Smoke-automatic Fire Detectors	268		3	12	0.25	0	1950	9800
49	ONITY INC	Access Control System Units	294		1	10	0.5	0	1950	8400

3. Literature Review

Prior to implementing our model, we have come across a research paper that studies the characteristics and components within the Production Planning and Control (PCC) model and discovered that our model is partially similar to how a PCC model would look like. A PCC model requires linkage between the company's operation decisions and the requirements being placed on the company by the market [3]. That is, production decision should consider not only what is optimal for the company, but also how the market will respond to the company's production decisions. Likewise, our model seeks to maximize a single NRTL's profit while trying to meet as much of market demands as possible within the company's capability by allocating limited resources to different production activities.

On the other hand, our model also differs in a certain way. From the general model which has resource constraints and profit maximization, we adapt the binary variables to determine the costs of investment and the combined standard availability. We use only number of shift and investment as the main limited resources. Therefore, the model can be adjusted for any standard provider company due to the ease of constraint adjustment. The market demand in the model is treated as the constraint to control the company to not outperform itself; in other word, to not waste our resources for the redundant service.

4. Approach

4.1 Mathematical Formulation

Parameters

n : UL standard #n (48, 508A, 891, etc.).

A_n : numbers of UL standard #n provided by Nationally Recognized Testing Laboratory (NRTL).

B_n = 1 if it is possible to choose standard #n.

= 0 otherwise.

I_n: investment on equipment and training expertise for standard #n.

I: total budget availability.

M_n: market demand of UL standard #n.

S_n: number of labor shifts required to perform UL standard #n.

S: total availability of labor shifts.

R_n: revenue per shift of providing UL standard #n service.

C_n: costs of labor for standard #n.

Decision Variables

A_n: number of UL standard #n provided by NRTL.

B_n = 1 if NRTL should focus on standard #n.

= 0 otherwise.

Objective

The objective of this project is to maximize the profit returning to NRTL by determining which UL standard NRTL should direct investments to, given information about constraints such as total available number of labor shifts, market demand and budget availability annually.

$$Maximize\ \Sigma\left(A_n*(R_n*S_n-C_n)-(I_n*B_n)\right)$$

Constraints

Total number of labor shifts used should not exceed the availability of labor shifts.

$$\Sigma\, A_n.\, S_n \leq S \quad \forall\ n$$

Total additional equipment and training expertise expenditures (one time investment) should not exceed the allowable budget.

$$\Sigma\, I_n.\, B_n \leq I \quad \forall\ n$$

Numbers of each UL standard provided should not exceed the market demand for that standard (NRTL should not outperform its capacity)

$$A_n \leq M_n \quad \forall \; n$$

Linking constraint

$$A_n - B_n M_n <= 0 \qquad \forall n, \; B_n \in \{0,1\}$$

Non-Negativity and Binary Condition

$$A_n \geq 0; \qquad B_n \text{ are binary}$$

The service of two combination standards (RHS) depends on the independent service of the particular one of those two standards (LHS)

$$B_{48} >= B_{48,\ 897}$$
$$B_{508A} >= B_{508A,\ 698A}$$
$$B_{508} >= B_{508,\ 60947\text{-}5\text{-}1}$$
$$B_{60950\text{-}1} >= B_{60950\text{-}1,\ 60950\text{-}21}$$
$$B_{684} >= B_{684,\ 2166}$$
$$B_{61010\text{-}1} >= B_{61010\text{-}1,\ 61010\text{-}031}$$
$$B_{10C} >= B_{10B,\ 10C}$$
$$B_{508} >= B_{508,\ 61131\text{-}2}$$
$$B_{486A\text{-}486B} >= B_{486A\text{-}486B,\ 1059}$$
$$B_{1598} >= B_{1598,\ 8750}$$
$$B_{746D} >= B_{746D,\ 94}$$
$$B_{891} >= B_{891,\ 334}$$

The service of two combination standards (RHS) depends on both standards in its combination (LHS)

$$B_{758} + B_{486A\text{-}486B} >= 2{*}B_{758,\ 486A\text{-}486B}$$

4.2 Linear Program Excel Model

Data are structured in the table as below (see full table in Appendix A). There are 100 standards in total that are focused on. Most of them are individual standard while some of them are combination of two standards. The number of standard (# of stnds) shows demand of each standard required in the market. Sum of the number of shifts (# of shifts) and the number of standard updates per year (# of standard updates per year) is the total shifts required per service (total shifts per service). The additional equipment and expertise training costs are one time investment costs. Some standards require these additional investments but some do not. The rates at which these standards require investment on equipment and training also differ. The labor and overhead cost for each standard varies by the total number of shifts required for each standard. The revenue per shift is an average estimated based on experiences with the industry. There are an average of $1,950 per shift for individual standard and $3,900 (double the amount) per shift for combination of two standards.

Standard number	UL standard	2nd standar	# of stnds	# of shifts	# of standard updates per year	Additional equipment cost	Additional expertise training cost	Labor & overhead	Revenue per shift	Total shifts per service
23	499		1	12	1	0	0	10400	1950	13
24	508	61131-2	1	15	0.5	0	2925	12400	3900	15.5
25	508	60947-5-1	3	15	0.25	0	2925	12200	3900	15.25
26	508		2	11	0.25	0	2925	9000	1950	11.25
27	521		3	9	0.5	0	975	7600	1950	9.5
28	580		2	9	0.25	0	1950	7400	1950	9.25
29	674		3	13	0.5	3000	2925	10800	1950	13.5
30	723		2	7	0.25	0	1950	5800	1950	7.25
31	758	486A-486B	2	13	1	0	1950	11200	3900	14
32	758		2	7	0.25	0	1950	5800	1950	7.25
33	763		1	7	0.25	0	1950	5800	1950	7.25
34	790		3	10	0.25	2000	1950	8200	1950	10.25

Structured Data Table

Objective function and variable decisions are showed in the table below (see full table in Appendix B). The model uses Solver to maximise profit by changing 100 variable cells of number of standard #n provided by NRTL and 100 variable cells of binary variable. The objective is to maximize profit. The formula in the objective cell (*Maximize* $\Sigma (A_n*(R_n*S_n-C_n)-(I_n*B_n))$) can basically be explained that it is the sum of the number of standards chosen to be provided by NRTL multiplied by their profit, which is revenue less costs of labor, and lastly deducted by their one-time investment cost. The one-time investment cost is multiplied by binary variable (B_n) which is 1 if it is possible to choose standard #n, and 0 otherwise.

Standard number	Number of STD#n provided by NRTL	Profit for each time	Binary Variable	Expenditure on equipment and training (1 time	Total Profit after expenditure deduction in each	Binary V x #of STD.			Gross profit from every STD.
1	0	7187.5	b 1	0	0	1			max 403000
2	0	7043.75	b 1	0	0	2			
3	0	10062.5	b 1	0	0	15			
4	0	46500	b 1	0	0	3			
5	3	41850	b 1	0	125550	3			
6	0	7475	b 1	0	0	3			

Objective Function and Variable Decision Table

The model is subjected to the following constraints: the availability of labor shifts, the allowable budget of investment, market demand, the linking constraint (see Appendix C), combination standards constraints (see Appendix D), non-negativity, and integrality (set in Solver). In this case, The availability of labor shifts are limited to 130 shifts and the allowable budget or investment is limited to $20,000. The number of standards chosen to be provided by NRTL should not exceed the number of market demands of those standards because the exceeding number will not generate profits. The linking constraint not only links the number of standards #n chosen to the market demand limitation, it also controls the standard #n to be chosen only when B_n is 1. The combination standards can be seen in two conditions. In our case, we have only combination of two standards. First, the service of two combination standards (RHS) depends on the independent service of the particular one of those two standards (LHS) (e.g. $B_{48} \;\; >= \;\; B_{48,\; 897}$), meaning that a service of two combination standards could not be chosen without selection of independent service of the particular one of those two standards. Second condition requires that the service of two combination standards (RHS) depends on both standards in its combination (LHS) (e.g. $B_{758} + B_{486A\text{-}486B} \;\; >= \;\; 2{*}B_{758,\; 486A\text{-}486B}$), meaning that the service of two combination standards could not be chosen without selection of both standards in its combination.

5. Result analysis

Final result shows that NRTL should focus on providing services in the following standards in order to maximize profit:

Result					
Standard number	**UL standard#**	**2nd standard**	**Number of STD#n provided by NRTL**	**Total Profit after expenditure deduction in each STD.**	**Gross profit from every STD.**
5	50	50E	3	125550	403000
15	213	2351A	1	41850	
64	1598	8750	1	48050	
66	1610	1635	1	48825	
81	1004-1	1004-3	1	55025	
87	5085-1	5085-3	2	83700	

Result Table

We found an optimal solution. Solver runs for less than one minute to achieve this result. It is noticed that the model chooses only standards that do not require additional investments on equipment and training (which is one time investment cost). Since the objective is to maximize profit, it is reasonable that Solver avoids choosing standards that will incur more investment cost to the company. This selection makes budget constraint for equipment and training become redundant. Although the result is optimal, it is not entirely realistic in the real market where some firms would prefer to pay extra money for those investments in order to get themselves the edge in competition. Hence, a possible extension of this project might include adding a new constraint that requires company to spend a minimum amount of investment on equipment and training. It will definitely alter the optimal values of decision variables and decrease the gross profit.

The result also shows that all of the standards chosen by the model are combination standards. This is due to the fact that combination standards typically generate more profit than an individual standard. Meanwhile, binary results in our analysis indicate “1” for many standards, not only for those that are chosen as optimal decision output. These binary results suggest possible “profitability” if the company chooses to provide services in those standards considering the strong market demands for those services. However, given the limited availability of resources in our studied NRTL, only some of them may be suitable for choosing optimal solution.

6. Summary/Conclusion.

Our primary purpose in implementing this project is to discover and construct a model that can be utilized to maximize profit for a single NRTL, given the constraints in local market demands, supply of labor hours and budget availability. The scale of the project can be expanded to include bigger market (in our case, we only deal with major industrial cities in Oregon). Goals and constraints might vary among different NRTLs, but we hope that the underlying idea of this project will be applicable to most NRTLs.

One might also consider this model an extension stemming from the production planning model in which market demand is taken into company's operation decisions along with company-specific requirements. Distinguishably, our model adapts binary variables into the objective functions as well as the constraints to limit the model from outperforming the company's actual capacity.

7. Limitations and Future Research

In this project, we were able to incorporate a large amount of data from various client companies who requested certification services from NRTL for their products into constructing a profit optimization model. However, we believe that there is still a lot of room to grow with this project. In this section, we will discuss a number of limitations our group had faced and the potential improvements for the project that we would like to suggest.

Limitation

1. *Data imprecision*: We did not have full access to all data needed for the implementation of the project. Variables, such as price paid per shift, equipment and training budget availability, were estimated based upon experiences with the industry. As a result, the model might not be realistic of the actual state of the company.

2. *Solver limitation*: Solver might not be a suitable software for this kind of model due to its restricted capacity. We actually used Open Solver to obtain final results in our model because reducing decision variables to no more than 200 and constraints to no more than 100 seemed

more troublesome than having to work with something we were not so familiar with, like Open Solver. The nature of this project requires researchers' familiarity with a variety of software packages that can handle a large amount of data.

Improvement

1. *Adoption of other optimization softwares*: As mentioned above, Solver's capacity can limit the expansion of the model. Adoption of other optimization softwares will allow deeper investigation of the project, as well as increase the range of the model's application to bigger region where demand for NRTL services is higher.

2. *Adding constraints that capture company's goals that are not solely monetary*: As mentioned above, the budget constraint becomes redundant because Solver avoids selecting standards that come with incurring costs. It may sound reasonable, but probably not a single company will expect to run their business smoothly without ever having to invest in equipment or expertise training. They need to make these investments in order to maintain their competitive advantage in the market. One way the model can take into account this goal is by setting a minimum amount of investment capital that firm must spend on some standards' additional equipment and training. This constraint will direct the model to choose the standards that yield highest profit return given the amount of money invested.

References

[1] “UL Certification Directory,” 2017. [Online]. Avalible: http://database.ul.com/cgi-bin/XYV/template/LISEXT/1FRAME/index.html

[2] “SAI Global Store,” 2017. [Online]. Avalible: https://infostore.saiglobal.com/en-us/Search/Standard/?productFamily=STANDARD

[3] M. Bonney, “Reflections on Production Planning and Control (PCC).,” *GESTÃO & PRODUÇÃO*, vol. 7, no. 3, pp. 181–207, 2000.

Appendix A

Structured Data Table

Standard number	UL standard	2nd standar	# of stnds	# of shifts	# of standard updates per year	Additional equipment cost	Additional expertise training cost	Labor & overhead	Revenue per shift	Total shifts per service
1	20		1	6	0.25	0	0	5000	1950	6.25
2	38		2	6	0.125	0	0	4900	1950	6.125
3	48		15	8	0.75	0	0	7000	1950	8.75
4	48	879	3	14	1	0	0	12000	3900	15
5	50	50E	3	13	0.5	0	0	10800	3900	13.5
6	62		3	6	0.5	0	0	5200	1950	6.5
7	65		3	8	0.25	0	0	6600	1950	8.25
8	67		1	8	1	0	0	7200	1950	9
9	73		1	7	0.5	0	0	6000	1950	7.5
10	82		1	8	1	0	0	7200	1950	9
11	153		5	8	1.25	0	0	7400	1950	9.25
12	197	1889	3	14	0.5	0	0	11600	3900	14.5
13	201		1	7	0.125	0	0	5700	1950	7.125
14	207	1963	1	14	0.5	0	0	11600	3900	14.5
15	213	2351A	1	13	0.5	0	0	10800	3900	13.5
16	263		1	8	0.25	0	0	6600	1950	8.25
17	268		3	12	0.25	0	1950	9800	1950	12.25
18	294		1	10	0.5	0	1950	8400	1950	10.5
19	458		1	10	0.125	0	0	8100	1950	10.125
20	464		2	12	0.5	0	1950	10000	1950	12.5
21	471		2	9	1	0	0	8000	1950	10
22	489		1	10	0.75	0	0	8600	1950	10.75
23	499		1	12	1	0	0	10400	1950	13
24	508	61131-2	1	15	0.5	0	2925	12400	3900	15.5
25	508	60947-5-1	3	15	0.25	0	2925	12200	3900	15.25
26	508		2	11	0.25	0	2925	9000	1950	11.25
27	521		3	9	0.5	0	975	7600	1950	9.5
28	580		2	9	0.25	0	1950	7400	1950	9.25
29	674		3	13	0.5	3000	2925	10800	1950	13.5
30	723		2	7	0.25	0	1950	5800	1950	7.25
31	758	486A-486B	2	13	1	0	1950	11200	3900	14
32	758		2	7	0.25	0	1950	5800	1950	7.25
33	763		1	7	0.25	0	1950	5800	1950	7.25
34	790		3	10	0.25	2000	1950	8200	1950	10.25
35	796		3	5	0.125	0	0	4100	1950	5.125
36	817		14	8	0.5	0	0	6800	1950	8.5
37	827		6	8	0.75	4000	3900	7000	1950	8.75
38	842		1	12	0.75	0	3900	10200	1950	12.75
39	857		3	11	0.25	0	3900	9000	1950	11.25
40	864	2166	3	15	1.5	0	0	13200	3900	16.5
41	864		6	8	0.5	0	0	6800	1950	8.5
42	875		1	8	1	0	0	7200	1950	9
43	891		2	9	0.125	0	1950	7300	1950	9.125
44	891	334	1	15	0.25	0	1950	12200	3900	15.25
45	916		1	11	1	0	1950	9600	1950	12
46	962		1	10	1.25	0	0	9000	1950	11.25
47	969		4	7	0.25	0	0	5800	1950	7.25
48	1008		1	11	1	0	1950	9600	1950	12
49	1012	1310	1	14	2	0	0	12800	3900	16
50	1026		3	7	0.25	0	0	5800	1950	7.25
51	1037		2	12	0.25	0	3900	9800	1950	12.25
52	1059	486A-486B	1	15	1.125	0	3900	12900	3900	16.125

Structured Data Table (continue)

Standard number	UL standard#	2nd standard	# of stnds	# of shifts	# of standard updates per year	Additional equipment cost	Additional expertise training cost	Labor & overhead	Revenue per shift	Total shifts per service
53	1082		1	10	0.333	6000	3900	8266.4	1950	10.333
54	1254		1	10	0.333	6000	3900	8266.4	1950	10.333
55	1294		1	8	0.25	0	0	6600	1950	8.25
56	1436		1	9	0.25	3000	3900	7400	1950	9.25
57	1450		1	12	0.5	4000	3900	10000	1950	12.5
58	1459		1	9	0.125	0	975	7300	1950	9.125
59	1472		1	9	0.25	0	0	7400	1950	9.25
60	1481		1	9	0.125	0	3900	7300	1950	9.125
61	1557		1	11	0.25	4000	3900	9000	1950	11.25
62	1565		1	8	0.333	0	0	6666.4	1950	8.333
63	1573		1	8	0.333	0	0	6666.4	1950	8.333
64	1598	8750	14	14	1.5	0	0	12400	3900	15.5
65	1598		5	8	0.333	0	0	6666.4	1950	8.333
66	1610	1635	1	15	0.75	0	0	12600	3900	15.75
67	1640		1	9	0.333	0	975	7466.4	1950	9.333
68	1651		1	10	0.125	0	975	8100	1950	10.125
69	1703		2	12	1.5	0	1950	10800	1950	13.5
70	1773		1	10	0.125	0	1950	8100	1950	10.125
71	1951		2	9	0.75	0	0	7800	1950	9.75
72	1993		1	8	0.125	0	0	6500	1950	8.125
73	2039		1	11	0.25	3000	3900	9000	1950	11.25
74	2054		1	10	0.125	0	0	8100	1950	10.125
75	2108		1	8	1	0	0	7200	1950	9
76	2129		2	12	0.5	2000	3900	10000	1950	12.5
77	2218		3	10	0.125	0	3900	8100	1950	10.125
78	2808		2	11	0.25	0	1950	9000	1950	11.25
79	60065		2	10	0.5	0	0	8400	1950	10.5
80	62133		1	10	0.5	0	1950	8400	1950	10.5
81	1004-1	1004-3	2	16	1.75	0	0	14200	3900	17.75
82	10B	10C	5	18	0.333	2000	1950	14666.4	3900	18.333
83	10C		2	12	0.25	2000	1950	9800	1950	12.25
84	1598C		1	8	0.75	0	0	7000	1950	8.75
85	244A		2	10	0.25	0	0	8200	1950	10.25
86	486C		1	8	0.75	0	0	7000	1950	8.75
87	5085-1	5085-3	2	13	0.5	0	0	10800	3900	13.5
88	508A		41	10	1.5	0	975	9200	1950	11.5
89	508A	698A	9	17	1.75	0	975	15000	3900	18.75
90	508C		2	12	0.25	0	1950	9800	1950	12.25
91	60601-1		1	12	0.125	4000	3900	9700	1950	12.125
92	60947-1	60947-4-1	4	15	0.25	0	975	12200	3900	15.25
93	60950-1		21	11	0.125	0	0	8900	1950	11.125
94	60950-1	60950-21	6	17	0.25	0	0	13800	3900	17.25
95	61010-1		11	10	0.333	0	0	8266.4	1950	10.333
96	61010-1	61010-031	7	15	0.75	0	0	12600	3900	15.75
97	62368-1		2	10	0.25	0	0	8200	1950	10.25
98	746D		6	9	0.25	0	975	7400	1950	9.25
99	746D	94	1	14	2.125	0	975	12900	3900	16.125
100	486A-486B		0	6	0.75	0	0	5400	1950	6.75

Appendix B

Objective Function and Variable Decision Data Table

Standard number	Number of STD#n provided by NRTL	Profit for each time	Binary Variable	Expenditure on equipment and training (1 time payment)	Total Profit after expenditure deduction in each STD.	Binary V x #of STD.	Gross profit from every D.
1	0	7187.5	1	0	0	1	max 403000
2	0	7043.75	1	0	0	2	
3	0	10062.5	1	0	0	15	
4	0	46500	1	0	0	3	
5	3	41850	1	0	125550	3	
6	0	7475	1	0	0	3	
7	0	9487.5	1	0	0	3	
8	0	10350	1	0	0	1	
9	0	8625	1	0	0	1	
10	0	10350	1	0	0	1	
11	0	10637.5	1	0	0	5	
12	0	44950	1	0	0	3	
13	0	8193.75	1	0	0	1	
14	0	44950	1	0	0	1	
15	1	41850	1	0	41850	1	
16	0	9487.5	1	0	0	1	
17	0	14087.5	0	1950	0	0	
18	0	12075	0	1950	0	0	
19	0	11643.75	1	0	0	1	
20	0	14375	0	1950	0	0	
21	0	11500	1	0	0	2	
22	0	12362.5	1	0	0	1	
23	0	14950	1	0	0	1	
24	0	48050	0	2925	0	0	
25	0	47275	0	2925	0	0	
26	0	12937.5	0	2925	0	0	
27	0	10925	0	975	0	0	
28	0	10637.5	0	1950	0	0	
29	0	15525	0	5925	0	0	
30	0	8337.5	0	1950	0	0	
31	0	43400	0	1950	0	0	
32	0	8337.5	0	1950	0	0	
33	0	8337.5	0	1950	0	0	
34	0	11787.5	0	3950	0	0	
35	0	5893.75	1	0	0	3	
36	0	9775	1	0	0	14	
37	0	10062.5	0	7900	0	0	
38	0	14662.5	0	3900	0	0	
39	0	12937.5	0	3900	0	0	
40	0	51150	1	0	0	3	
41	0	9775	1	0	0	6	
42	0	10350	1	0	0	1	
43	0	10493.75	0	1950	0	0	
44	0	47275	0	1950	0	0	
45	0	13800	0	1950	0	0	
46	0	12937.5	1	0	0	1	
47	0	8337.5	1	0	0	4	
48	0	13800	0	1950	0	0	
49	0	49600	1	0	0	1	
50	0	8337.5	1	0	0	3	

Objective Function and Variable Decision Data Table (continue)

Standard number	Number of STD#n provided by NRTL	Profit for each time	Binary Variable	Expenditure on equipment and training (1 time payment)	Total Profit after expenditure deduction in each STD.	Binary V x #of STD.			Gross profit from every STD.
51	0	14087.5	0	3900	0	0			
52	0	49987.5	0	3900	0	0			
53	0	11882.95	0	9900	0	0			
54	0	11882.95	0	9900	0	0			
55	0	9487.5	1	0	0	1			
56	0	10637.5	0	6900	0	0			
57	0	14375	0	7900	0	0			
58	0	10493.75	0	975	0	0			
59	0	10637.5	1	0	0	1			
60	0	10493.75	0	3900	0	0			
61	0	12937.5	0	7900	0	0			
62	0	9582.95	1	0	0	1			
63	0	9582.95	1	0	0	1			
64	1	48050	1	0	48050	14			
65	0	9582.95	1	0	0	5			
66	1	48825	1	0	48825	1			
67	0	10732.95	0	975	0	0			
68	0	11643.75	0	975	0	0			
69	0	15525	0	1950	0	0			
70	0	11643.75	0	1950	0	0			
71	0	11212.5	1	0	0	2			
72	0	9343.75	1	0	0	1			
73	0	12937.5	0	6900	0	0			
74	0	11643.75	1	0	0	1			
75	0	10350	1	0	0	1			
76	0	14375	0	5900	0	0			
77	0	11643.75	0	3900	0	0			
78	0	12937.5	0	1950	0	0			
79	0	12075	1	0	0	2			
80	0	12075	0	1950	0	0			
81	1	55025	1	0	55025	2			
82	0	56832.3	0	3950	0	0			
83	0	14087.5	0	3950	0	0			
84	0	10062.5	1	0	0	1			
85	0	11787.5	1	0	0	2			
86	0	10062.5	1	0	0	1			
87	2	41850	1	0	83700	2			
88	0	13225	0	975	0	0			
89	0	58125	0	975	0	0			
90	0	14087.5	0	1950	0	0			
91	0	13943.75	0	7900	0	0			
92	0	47275	0	975	0	0			
93	0	12793.75	1	0	0	21			
94	0	53475	1	0	0	6			
95	0	11882.95	1	0	0	11			
96	0	48825	1	0	0	7			
97	0	11787.5	1	0	0	2			
98	0	10637.5	0	975	0	0			
99	0	49987.5	0	975	0	0			
100	0	7762.5	1	0	0	0			

Appendix C

Constraints Table

Constraints				
	Shift Constraint			
	Total Shift		Shift Constraint	
	130	<=	≤ 130	
	Market Demand Constraint(			
	Number of STD#n provided by NRTL	<=	# of stnds	(Using solver)
	Investment Constraint			
	0	<=	≤ 20000	
	Binary Constraint			
	Number of STD#n provided by NRTL	<=	**Binary V x #of STD.**	(Using solver)

Appendix D

Combination Standard Constraints table

	Combination STD. Constraint						
Standard number	**UL standard**	**2nd standar**	standard number		LHS		RHS
4	48	879	3	null	1	>=	1
24	508	61131-2	26	null	0	>=	0
25	508	60947-5-1	26	null	0	>=	0
31	758	486A-486B	32	100	1	>=	0
40	864	2166	41	null	1	>=	1
44	891	334	43	null	0	>=	0
52	1059	486A-486B	null	100	1	≥	0
64	1598	8750	65	null	1	>=	1
82	10B	10C	null	83	0	>=	0
89	508A	698A	88	null	0	>=	0
94	60950-1	60950-21	93	null	1	>=	1
96	61010-1	61010-031	95	null	1	>=	1
99	746D	94	98	null	0	>=	0