SUPPLY CHAIN PROGRAMS SELECTION USING SENSITIVITY ANALYSIS AND MULTI-OBJECTIVE LINEAR PROGRAMMING MODEL

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ABSTRACT

Business and supply chain management strategy has a significant importance, and calls for serious research attention in recent years. The aim of this study is to propose an integrated approach to determine the most suitable supply chain programs, based on Sensitivity Analysis (SA) and Multi-Objective Linear Programming model (MLP). All programs are evaluated through five criteria (productivity, quality, cost, time and feasibility). Sets of weight of these criteria are built by using Sensitivity Analysis. Multi-Objective Linear Programming model is applied to select suitable strategic actions according to multiple conflicting objectives under a budget constraint. A case study from the Sai Gon-Mien Tay Beer Company is given to illustrate the proposed methodology.

Keywords: Multi-Objective Linear Programming model, Business strategy, Supply chain management, Sensitivity analysis, Strategy selection

1. INTRODUCTION

According to Porter (1996), strategy is defined as the creation of a unique and valuable position, involving a different set of activities. It also refers as a method or technique chosen to bring about an achievement of a goal or solution to a problem. For a business to be successful, business owners need to ensure that their business is operating as effectively as possible, by developing and implementing appropriate strategies and actions to manage all capabilities across business and the supply chain. Different authors have suggested different techniques to identify business and supply chain management strategy. Zarei et al. (2011) used Quality Function Deployment (QFD) approach to identify the most appropriate Lean enablers, in order to increase the leanness of the food supply chain. Jia & Bai (2011) suggested an approach for manufacturing strategy development based on fuzzy set and QFD. Despite the success of these studies on strategy development, these researches focus much on qualitative method. However, by using qualitative method, it is more difficult to assess the performance of the process with accurate quantitative value. Also, these methods are not suitable to solve problems in a hierarchical decision structure and conflicting objectives.

To deal with a complex problem, which has some conflicting objectives, Multi-Objective Linear Programming Model (MLP) should be used (Baky, 2010). Multi-Objective Linear Programming Model (MLP) is concerned with mathematical optimization problems, involving more than one objective function to be optimized simultaneously (Wilamowsky et al., 1990). In the MLP problem, optimizing all objective functions at the same time is not possible because of the conflicting nature of the objectives (Pandian & Jayalakshmi, 2013), so that optimal decisions need to be taken in the presence of trade-offs between two or more conflicting objectives. There are different methods for weighting criteria in the objective function, such as Analytic Hierarchy

Process (AHP), Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), and Sensitivity Analysis (SA), etc.

For instance, Ayağ et al. (2013) developed crucial logistics requirements and supply chain management strategies for the dairy industry by using an integrated approach of Analytic Hierarchy Process (AHP), fuzzy-QFD matrix, and MLP model. In this study, AHP is used to evaluate weights of objective functions. This study measured the outcomes of a program by a quantitative calculation. However, in the uncertainty environment, a specific solution cannot be suitable for all circumstances. Developing a model, in which difference situations are defined and mentioned, is necessary for business and supply chain management. Alawneh et al. (2014) developed a linear programming formulation for optimizing a supply chain management system for a Steel Company. Sensitivity analysis is conducted in order to draw useful conclusions regarding the factors that play the most important role in the efficiency of the supply chain. Sensitivity analysis allows determining how different values of an independent variable impact a particular dependent variable under a given set of assumptions. The proposed approach provides a comprehensive deterministic linear programming model to minimize the annual cost of the steel company's supply chain.

This research aims at developing a methodology for business and supply chain management programs formulation and implementation based on Multi-objective Linear Programming Model (MLP). Sensitivity Analysis (SA) is used to evaluate objective functions in the model. The paper is divided into four sections. The first section introduces the background of the problem of the study. Then, an integrated MLP and SA framework is presented. A case study is given to illustrate the proposed methodology in the third section. The last section includes the concluding remarks, suggestions, and limitations of the study.

2. METHODOLOGY

In this study, MLP is used to select suitable programs to be implemented, to maximize the value among five conflicting objective functions under a limited investment budget. Sensitivity analysis on weight is used to build various weighting sets among five conflicting criteria, aiming to maximizing the value of the objective function. The proposed methodology can be presented by following steps:

Step 1: Identifying program

The list of strategic programs has been identified from the literature (see Table 1). They are considered as specific actions for improving business and supply chain performance.

Table 1. List of supply chain management programs

Item	Programs	Source
1	Program of 5S	Chiadamrong and Tham (2017)
2	Just-In-Time (JIT)	Bottani and Rizzi (2006); Zarei *et al.* (2011); Ayağ *et al.* (2013)
3	Vendor Manage Inventory (VMI)	Chiadamrong and Tham (2017)
4	Material Requirements Planning (MRP) systems	Bottani and Rizzi (2006)
5	Electronic Data Interchange (EDI)	Bottani and Rizzi (2006); Ayağ et al. (2013)
6	International quality standard such as ISO 9001	Chiadamrong and Tham (2017)
7	Statistical Process Control (SPC)	Chiadamrong and Tham (2017)

8	Preventive Maintenance (PM)	Chiadamrong and Tham (2017)
9	Supply Chain Management software (SCM)	Bottani and Rizzi (2006)
10	Advanced Manufacturing Systems and Automation	Issam and Wafa (2006); Chiadamrong and Tham (2017)
11	On the job training	Issam and Wafa (2006); Zarei *et al.* (2011)
12	Systematic job recruitment process	Issam and Wafa (2006); Chiadamrong and Tham (2017)
13	Job enlargement	Chiadamrong and Tham (2017)
14	Job enrichment	Chiadamrong and Tham (2017)
15	Customer behavior analysis	Issam and Wafa (2006)
16	Incentive programs such as bonuses, profit sharing, and welfare	Chiadamrong and Tham (2017)
17	Customer Relationship Management software (CRM)	Chiadamrong and Tham (2017)
18	Enterprise Resource Planning (ERP)	Bottani and Rizzi (2006)

Step 2: Identifying criteria

Normally, companies have different criteria (or objectives) when they consider what strategic actions should be implemented. These objectives can somehow conflict with each other. For example, a high benefit strategy may require high implementing cost. In this study, three criteria, i.e., Benefit value, implementing resource, and feasibility to be implemented, are selected to evaluate programs. In which, benefit value is measured by productivity and quality, while implementing resource is measured by cost and time. So, there are totally five objectives in the objective function. They are defined as following:

Productivity: The percentage of increasing productivity by implementing program.

Quality: The percentage of reducing waste product by implementing program.

Cost: Cost of implementing program. This is the estimated implementing expense if company has to proceed with each program.

Time: Time of implementing program.

Feasibility: Feasibility to implement strategy. Feasibility to implement provides the benefit and drawback of each program. This is to evaluate the feasibility to implement such programs in the company.

These five objectives present the overall view of decision makers, who make a decision on which programs should be implemented. The relative importance of these objectives is further explored by the sensitivity analysis on their assigned weights. The recommend ranges of these criteria are also identified as in Table 2.

Table 2. Recommend ranges of criteria

Range	Criteria				
	Benefit value		Implementing costs ($US)	Implementing time (months)	Feasibility
	Productivity	Quality			
(1)	None	None	< 10,000	< 3	Maybe impossible
(2)	Increase < 10%	Decrease < 10%	10,000 – 25,000	3-6	Possible with some difficulty
(3)	Increase 10 - 20 %	Decrease 10 - 20 %	25,000 – 100,000	7-12	Likely possible
(4)	Increase 20 - 30%	Decrease 20 - 30%	100,000 – 250,000	13-24	Totally possible
(5)	Increase > 30 %	Decrease > 30 %	> 250,000	>24	Vital to implement

Step 3: Building sets of objectives' weight

In this study, sensitivity analysis is used for determining the weight of five objectives (Productivity, Quality, Cost, Time and Feasibility). The set of weight is determined as = { respectively. In the assumption that the lowest possible value of is 0.1 (equation 1) and total weights of five criteria equals 1 (equation 2) and the step of changing criterion weight in each scenario is 0.1, total possible 111 weighted sets for the five criteria are obtained. Sets of weight of five objectives are shown in Table 4.

$$0.1 \leq w_y \quad (1)$$

$$\sum_{y=1}^{i} w_y = 1 \quad (2)$$

Step 4: Building the mathematical model

The notations and mathematical model are presented as follows:

N: Total number of programs.

P_j: The percentage of increasing productivity by implementing program j.

Q_j: The percentage of reducing waste product by implementing program j.

C_j: Cost of implementing program j. This is the estimated implementing expense if company has to proceed with each program.

T_j: Time of implementing program j.

F_j: Feasibility to implement program j.

Xj: Binary decision variable that equals 1 if program j is selected, and 0 otherwise.

w_y : Weight of criterion y.

The mathematical model for choosing suitable programs under a limited budget with five objectives is shown below:

$$Max\ Z = w_1 \sum_{j=1}^{N} P_j * X_j + w_2 \sum_{j=1}^{N} Q_j * X_j - w_3 \sum_{j=1}^{N} C_j * X_j - w_4 \sum_{j=1}^{N} T_j * X_j + w_5 \sum_{j=1}^{N} F_j * X_j \quad (3)$$

$$\sum_{j=1}^{N} C_j * X_j \leq Budget \qquad (4)$$

$$X_j \in \{0,1\}, \forall j \qquad (5)$$

Equation (3) is the objective function. Equation (4) ensures that the total budget is not exceeded, and equation (5) represents the binary decision variables.

Step 5: Selecting data from the company
Questionnaire is sent to company to evaluate programs through five criteria (Productivity, Quality, Cost, Time and Feasibility).

Step 6: Analyzing data
Data is analyzed using equation (3), (4), and (5).

3. CASE STUDY

In this study, Sai Gon-Mien Tay Beer Company is chosen as an example to illustrate the proposed methodology. The Sai Gon-Mien Tay Beer Company is directly under the Saigon Beer-Alcohol-Beverage Joint Stock Corporation. It is located in Can Tho City with more than 1,000 employees. Although there are many famous beer brands in the market, Saigon Beer is still the Vietnamese brand leading the Vietnamese beer market and is on the way to conquer difficult markets like Germany, America, Japan, and Netherlands etc.

Data collected from the company is shown in Table 3.

Table 3. Data from Sai Gon-Mien Tay Beer Company

Strategy	Range				
	Benefit		Cost	Time	Feasibility
	Productivity	Quality			
1	3	2	2	2	5
2	3	3	3	3	5
3	3	2	3	3	5
4	4	3	4	3	5
5	4	2	4	2	4
6	4	4	3	4	5
7	3	3	3	3	5
8	3	1	2	2	5
9	3	1	3	2	4
10	4	3	5	5	5
11	2	1	2	4	5
12	3	3	3	3	5
13	3	2	3	3	3
14	3	3	3	3	3
15	3	3	3	2	3
16	4	4	4	2	5
17	3	3	4	2	3
18	5	4	5	4	5

The data in Table 3 should be explained as below:

For example, if the company implements program number 1, the company can increase 10-20 percent of productivity or decrease less than 10 percent of defecting product. This program takes 10,000 -20,000 USD and about 3-6 months for the implementing process. In addition, it is very necessary to be implemented in the company.

Table 4. Results

No	Objective's weight					Objective function value	Selected programs
	W_1	W_2	W_3	W_4	W_5		
1	0.2	0.2	0.2	0.2	0.2	9.4	1,2,3,6,7,8,12,15,16
2	0.6	0.1	0.1	0.1	0.1	19.2	1,2,3,6,7,8,12,15,16
3	0.5	0.2	0.1	0.1	0.1	18.8	1,2,3,6,7,8,12,15,16
4	0,5	0.1	0.2	0.1	0.1	13.7	1,2,3,6,7,8,12,15,16
5	0.5	0.1	0.1	0.2	0.1	13.9	1,2,6,7,8,9,12,15,16
6	0.5	0.1	0.1	0.1	0.2	20.7	1,2,4,6,7,8,11,12,16
7	0.4	0.3	0.1	0.1	0.1	18.5	1,2,6,7,8,12,14,15,16
8	0.4	0.1	0.3	0.1	0.1	8.2	1,2,3,6,7,8,12,15,16
9	0.4	0.1	0.1	0.3	0.1	8.7	1,2,6,7,8,9,12,15,16
10	0.4	0.1	0.1	0.1	0.3	22.3	1,2,4,6,7,8,11,12,16
11	0.4	0.2	0.2	0.1	0.1	13.3	1,2,6,7,8,12,14,15,16
12	0.4	0.2	0.1	0.2	0.1	13.5	1,2,3,6,7,8,12,15,16
13	0.4	0.2	0.1	0.1	0.2	20.2	1,2,4,6,7,8,11,12,16
14	0.4	0.1	0.2	0.2	0.1	8.4	1,2,3,6,7,8,12,15,16
15	0.4	0.1	0.2	0.1	0.2	15.2	1,2,4,6,7,8,11,12,16
16	0.4	0.1	0.1	0.2	0.2	15.3	1,2,3,6,7,8,12,15,16
17	0.3	0.4	0.1	0.1	0.1	18.2	1,2,6,7,8,12,14,15,16
18	0.3	0.1	0.4	0.1	0.1	2.7	1,2,3,6,7,8,12,15,16
19	0.3	0.1	0.1	0.4	0.1	4	1,4,5,8,9,15,16,17
20	0.3	0.1	0.1	0.1	0.4	23.9	1,2,4,6,7,8,11,12,16
21	0.3	0.3	0.2	0.1	0.1	13	1,2,6,7,8,12,14,15,16
22	0.3	0.3	0.1	0.2	0.1	13.2	1,2,6,7,8,12,14,15,16
23	0.3	0.3	0.1	0.1	0.2	19.8	1,2,3,6,7,8,12,15,16
24	0.3	0.2	0.3	0.1	0.1	7.8	1,2,6,7,8,12,14,15,16
25	0.3	0.2	0.1	0.3	0.1	8.2	1,2,6,7,8,9,12,15,16
26	0.3	0.2	0.1	0.1	0.3	21.8	1,2,4,6,7,8,11,12,16
27	0.3	0.1	0.2	0.1	0.3	16.8	1,2,4,6,7,8,11,12,16
28	0.3	0.1	0.2	0.3	0.1	3.3	1,4,5,6,8,12,15,16
29	0.3	0.1	0.1	0.2	0.3	16.8	1,2,4,6,7,8,11,12,16
30	0.3	0.1	0.1	0.3	0.2	10	1,2,3,6,7,8,12,15,16
31	0.3	0.1	0.3	0.2	0.1	2.9	1,2,3,6,7,8,12,15,16
32	0.3	0.1	0.3	0.1	0.2	9.7	1,2,4,6,7,8,11,12,16
33	0.3	0.1	0.2	0.2	0.2	9.8	1,2,3,6,7,8,9,12,16
34	0.3	0,2	0.1	0.2	0.2	14.9	1,2,3,6,7,8,12,15,16
35	0.3	0.2	0.2	0.1	0.2	14.7	1,2,4,6,7,8,11,12,16
36	0.3	0.2	0.2	0.2	0.1	8	1,2,3,6,7,8,12,15,16
37	0.2	0.5	0.1	0.1	0.1	17.9	1,2,6,7,8,12,14,15,16

38	0.2	0.1	0.5	0.1	0.1	0.1	1
39	0.2	0.1	0.1	0.5	0.1	0.4	1,16
40	0.2	0.1	0.1	0.1	0.5	25.5	1,2,4,6,7,8,11,12,16
41	0.2	0.4	0.2	0.1	0.1	12.7	1,2,6,7,8,12,14,15,16
42	0.2	0,4	0.1	0.2	0.1	12.9	1,2,6,7,8,12,14,15,16
43	0.2	0.4	0.1	0.1	0.2	19.5	1,2,6,7,8,12,15,16,19
44	0.2	0.3	0.3	0.1	0.1	7.5	1,2,6,7,8,12,14,15,16
45	0.2	0.3	0.1	0.3	0.1	7.9	1,2,6,7,8,12,14,15,16
46	0.2	0.3	0.1	0.1	0.3	21.3	1,2,4,6,7,8,11,12,16
47	0.2	0.2	0.4	0.1	0.1	2.3	1,2,6,7,8,12,15,16
48	0.2	0.2	0.1	0.4	0.1	3.3	1,4,5,8,12,15,16,17
49	0.2	0.2	0.1	0.1	0.4	23.4	1,2,4,6,7,8,11,12,16
50	0.2	0.1	0.4	0.2	0.1	0.1	1
51	0.2	0.1	0.4	0.1	0.2	4.3	1,2,3,6,7,8,11,12,16
52	0.2	0.1	0.4	0.2	0.1	0.1	1
53	0.2	0.1	0.3	0.3	0.1	0.1	1
54	0.2	0.1	0.3	0.1	0.3	11.3	1,2,4,6,7,8,11,12,16
55	0.2	0.1	0.2	0.4	0.1	0.2	1,16
56	0.2	0.1	0.2	0.1	0.4	18.4	1,2,4,6,7,8,11,12,16
57	0.2	0.1	0.2	0.3	0.2	4.5	1,2,3,6,7,8,9,12,16
58	0.2	0.1	0.2	0.2	0.3	11.3	1,2,4,6,7,8,11,12,16
59	0.2	0.1	0.1	0.4	0.2	4.8	1,2,4,5,7,8,11,16
60	0.2	0.1	0.1	0.2	0.4	18.4	1,2,4,6,7,8,11,12,16
61	0.2	0.1	0.1	0.3	0.3	11.5	1,2,4,6,7,8,9,12,16
62	0.1	0.6	0.1	0.1	0.1	17.6	1,2,6,7,8,12,15,16,19
63	0.1	0.1	0.6	0.1	0.1	0	
64	0.1	0.1	0.1	0.6	0.1	0	
65	0.1	0.1	0.1	0.1	0.6	27.1	1,2,4,6,7,8,11,12,16
66	0.1	0.5	0.2	0.1	0.1	12.4	1,2,6,7,8,12,15,16,19
67	0.1	0.5	0.1	0.2	0.1	12.6	1,2,6,7,8,12,15,16,19
68	0.1	0.5	0.1	0.1	0.2	19.3	1,2, 6,7,8,12,15,16,19
69	0.1	0.4	0.3	0.1	0.1	7.2	1,2,6,7,8,12,15,16,19
70	0.1	0.4	0.1	0.3	0.1	7.6	1,2,6,7,8,12,15,16,19
71	0.1	0.4	0.1	0.1	0.3	21.0	1,2,3,6,7,8,12,16,19
72	0.1	0.4	0.2	0.2	0.1	7.5	1,2,6,7,8,12,15,16,19
73	0.1	0.4	0.2	0.1	0.2	16.7	1,2,6,7,8,12,15,16,19
74	0.1	0.4	0.1	0.2	0.2	14.3	1,2,6,7,8,12,15,16,19
75	0.1	0.3	0.4	0,1	0.1	2.1	1,2,6,7,8,12,15,16,19
76	0.1	0.3	0.1	0.4	0.1	2.8	1,2,5,7,12,15,16,17
77	0.1	0.3	0.1	0.1	0.4	23	1,2,3,6,7,8,12,16,19
78	0.1	0.3	0.3	0,2	0.1	2.3	1,2,6,7,8,12,15,16,19
79	0.1	0.3	0.3	0.1	0.2	8.9	1,2,3,6,7,8,12,16,19
80	0.1	0.3	0.2	0.3	0.1	2.5	1,2,6,7,8,12,15,16,19
81	0.1	0.3	0.2	0.1	0.3	15.8	1,2,4,6,7,8,11,12,16
82	0.1	0.3	0.1	0.2	0.3	16.1	1,2,3,6,7,8,12,16,19
83	0.1	0.3	0.1	0.3	0.2	9.3	1,2,6,7,8,12,15,16,19
84	0.1	0.3	0.2	0.2	0.2	9.1	1,2,6,7,8,12,15,16,19
85	0.1	0.2	0.5	0.1	0.1	0	
86	0.1	0.2	0.1	0.5	0.1	0.3	16

87	0.1	0.2	0.1	0.1	0.5	25	1,2,4,6,7,8,11,12,16
88	0.1	0.2	0.4	0.2	0.1	0	
89	0.1	0.2	0.4	0.1	0.2	3.8	1,2,3,6,7,8,12,16,19
90	0.1	0.2	0.3	0.3	0.1	0	
91	0.1	0.2	0.3	0.1	0.3	10.9	1,2,3,6,7,8,12,16,19
92	0.1	0.2	0.2	0,4	0.1	0.1	16
93	0.1	0.2	0.2	0.1	0.4	17.9	1,2,4,6,7,8,11,12,16
94	0.1	0.2	0.2	0.3	0.2	4.1	1,2,6,7,8,12,15,16,19
95	0.1	0.2	0.2	0.2	0.3	11	1,2,3,6,7,8,12,16,19
96	0.1	0.1	0.5	0.2	0.1	0	
97	0.1	0.1	0.5	0.1	0.2	0.5	1,8
98	0.1	0.1	0.4	0.3	0.1	0	
99	0.1	0.1	0.4	0.1	0.3	6	1,2,3,6,7,8,11,12,16
100	0.1	0.1	0.4	0.2	0.2	0.5	1,8
101	0.1	0.1	0.3	0.3	0.2	0.5	1,8
102	0.1	0.1	0.3	0.2	0.3	5.9	1,2,3,6,7,8,11,12,16
103	0.1	0.1	0.2	0.5	0.1	0	
104	0.1	0.1	0.2	0.1	0.5	20	1,2,3,6,7,8,11,12,16
105	0.1	0.1	0.2	0.4	0.2	0.7	1,8,16
106	0.1	0.1	0.2	0.2	0.4	12.9	1,2,3,6,7,8,12,16,19
107	0.1	0.1	0.2	0.3	0.3	6	1,2,3,6,7,8,9,12,16
108	0.1	0.1	0.1	0.5	0.2	0.9	1,8,16
109	0.1	0.1	0.1	0.2	0.5	20	1,2,4,6,7,8,11,12,16
110	0.1	0.1	0.1	0.4	0.3	6.2	1,2,3,6,7,8,9,12,16
111	0.1	0.1	0.1	0.3	0.4	13	1,2,3,6,7,8,12,16,19

By solving Equation (3), all 111 solutions with various weighting patterns are obtained (Table 4). Solutions are summarized as below:

+ The case (number 65), in which weights of five objectives (Productivity, Quality, Cost, Time and Feasibility) are (0.1, 0.1, 0.1, 0.1, 0.6) respectively, gives the highest objective function value, at 27.1. In this case, program number 1 (5S), 2 (JIT), 4 (MRP), 6 (ISO), 7 (SPC), 8 (PM), 11 (On the job training), 12 (Systematic recruitment), and 16 (Incentive programs) are selected.

+ In contrast, six cases (number 63, 64, 85, 88, 90, 96, 98, 103), in which weights of five objectives (Productivity, Quality, Cost, Time and Feasibility) are (0.1; 0.2; 0.5; 0.1; 0.1), (0.1; 0.2; 0.4; 0.2; 0.1), (0.1; 0.2; 0.3; 0.3; 0.1), (0.1; 0.1; 0.5; 0.2; 0.1), (0.1; 0.1; 0.4; 0.3; 0.1) and (0,1; 0,1; 0,2; 0.5; 0,1) give the lowest objective function value, at 0.

+ It can be seen that program number 1 (5S), 8 (PM) and 16 (Incentive programs) are selected in most cases due to their low implementing cost or time.

+ Program 10 (Automation), 13 (Job enlargement), 14 (Job enrichment),17 (CRM), 18 (ERP) are not selected in all cases due to their high implementing cost and time, low benefit value or not feasible to be implemented in the company.

As a result, the company can select suitable programs based on their preference of the relative importance among five conflicting criteria under a limited investment budget, in order to yield the highest objective function values among these objectives.

4. CONCLUSION

This study makes significant contributions by providing a Multi-Objective Linear Programming model (MLP) to select suitable supply chain management programs for improving business and supply chain performance. Sensitivity Analysis is used to build sets of weight of five criteria. From the results, it can be seen that the programs, which have low implementing cost and time are preferred to be selected, while programs which have high implementing cost and time, low benefit and feasibility are eliminated during the selection. Beside the contributions, there are also some limitations and more opportunities for future research. The first limitation of this study is that the study considers limited programs and criteria. Further studies in the future can develop a research model by adding other effective programs as well as criteria. In addition, the range of criteria and possible budget are approximated number. So, it may cause some limitations in the results. Further study should use exactly number to get better solutions.

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