PROJECT REPORT

ON

"A CASE OF SUPPLIER SELECTION WITH MULTIPLE CRITERIA IN QUANTITY DISCOUNT SETUP"

For the partial fulfillment of

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UNDER THE GUIDANCE OF

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BY

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DECLARATION

This is to certify that the minor project work presented on the topic '**A CASE OF SUPPLIER SELECTION WITH MULTIPLE CRITERIA IN QUANTITY DISCOUNT SETUP**' is an original work. The work has been carried out by:

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INTRODUCTION

CHAPTER - I

Selection of Supplier is a multi-criteria decision making problem which includes both qualitative and quantitative metrics. Often, a tradeoff is necessary among these quantitative and qualitative metrics, which may even be conflicting, in order to select the best suppliers from among the options available. When Volume discounts are applicable, these problems become more complex as in addition to selecting the supplier, further the quantities that are needed to be purchased from each supplier needs to be ascertained to be able to fully utilize the volume discounts being given.

In this problem MIP(Mixed Integer Programming) along with AHP (Analytical Hierarchy Process) has been used together to ascertain the suppliers for the item as well as the quantity that needs to be purchased from them, based on multiple criteria, each having a different weight.

LITERATURE REVIEW

CHAPTER - II

Supplier selection is a very important component in Supply Chain Management. In the present global scenario, it becomes necessary to cut the production and variable costs to sustain and survive in the high competition. In the past, there has been a lot of research on supplier selection process as well as supply chain management. There is a lot of literature available about the process of supplier selection as well as evaluation.

Extensive research is done on the available literature and is reviewed. Researchers and practitioners describe supplier selection as a number of phenomena which determine suitable suppliers in the supply chain.

Managing supply chain partnerships for competitive advantage is receiving considerable interest among both academic researchers and industrialists, according to Christopher and Juttner (2000). According to Atluntas B.M, Bayraktar D and Cebi .F (2006), supplier selection and evaluation are very critical to any organization.

In the past four decades, the activity of supplier selection has undergone an enormous change due to high technology advancement. It is impossible to produce low cost, high quality products without proper suppliers in today's competitive scenario (Weber et al., 1991). There is no definite method for supplier selection in the earlier literature. But the retailer is provided with some criteria to evaluate the supplier and select him. The decision making is done on the basis of how well the supplier can cater to his needs and the requirements of his customers. Dickson (1966) gave 23 criteria which can be used for the process of supplier selection or evaluation. But, the criteria for selection depend on the requirements of the firm. A detailed review of supplier selection is given in Aissaoui et al. (2007). Supplier selection is classified into 3 categories in the past literature (Wu Bei et. al 2006 and Srinivas Talluri 2002).

1) Conceptual approach, giving importance to supplier selection and its strategies;

2) Empirical study, where the relationship between various attributes in supplier selection and the effect of one over the other and on the selection process is studied deeply; and

3) Analytical models, where a model to solve the supplier selection problem and multi-criteria decision making problem is presented.

2.1 Conceptual Approach

Supplier selection process is of paramount importance in any supply chain. A supply chain is said to be successful or efficient if the right quantity and desired quality of the final product is delivered at the right place in the right time (Mandal, A. and Deshmukh, S. G. (1994) & Sarkis, J. and Talluri, S. (2002)). Supply Chain Management is the link between each and every element in the manufacturing and supply processes, starting from the raw material to the end consumer (New and Payne (1995) & Scott and Westbrook (1991)). Selecting the right vendors reduces the purchase costs and improves the corporate competitiveness significantly (Ghodsypur and O'Brien (2001)). Supplier selection is one of the order quantities and order timing decisions (Slack et al. 2004). Organizations have realized that they cannot attain success without satisfactory vendors (Handfield and Nichols, 1999).

2.2 Analytical Models

Many models and methods have been developed to solve the problem of supplier selection in the past literature. Each method takes various different criteria into consideration while selecting the suppliers. The objective of the supply chain is to maximize the difference between what the final product is worth to the customer and the effort the supply chain expends in fulfilling the customer needs. For this, the initial step is the selection of proper supplier, suitable to the requirements of the situation. There is a huge literature about the supplier selection procedures available. Matrix method, Analytical Hierarchy Process (AHP), Data Envelopment Analysis (DEA), Structural Equation Modeling (SEM), Analytic Network Process (ANP) are a few methods to name. The literature of retailing provides the retailer with sets of criteria in vendor selection. A combination of the criteria from the literature of the reading with the rating scheme of industrial purchasing yields a sophisticated, systematic decision matrix approach (John S. Berens (1972)) to supplier evaluation and selection which under certain conditions can eliminate much bias and incomplete evaluation of vendors. Charles A. Weber (1996), Marcello Braglia and Alberto Petroni(2000), Jian Liu, Fong Yuen, Vinod Lal (2000), Srinivas Talluri, Ram Narasimhan(2005) & Reza Farzipoor Saen and Majid Zohrehbandian (2008) studied deeply and discussed about Data envelopment analysis (DEA) process of vendor selection. Vendor selection is multi-objective in nature. Little has been done to develop techniques for measuring vendors' performance on multiple criteria. Charles A. Weber (1996) used data envelopment analysis (DEA) as a tool for measuring the performance of vendors on multiple criteria. Supplier selection is sometimes very complicated, owing to a variety of uncontrollable and unpredictable factors which affect the decision. Marcello Braglia and Alberto Petroni(2000) describe a multiple attribute utility theory based on the use of data envelopment analysis (DEA), aimed at helping purchasing managers to formulate viable sourcing strategies in the changing market place. Jian Liu, Fong Yuen, Vinod Lal (2000) used DEA to compare suppliers for supplier selection and performance improvement.

Analytical Hierarchy Process (AHP) is deeply discussed by many authors. Analytic Hierarchy Process method was developed by Saaty (1990) to assist in multi-criteria decision problems. The new method overcomes the difficulties associated with the categorical and simple linear weighted average criteria ranking methods. It provides a more systematic way of deriving the weights to be used and for scoring the performance of vendors (S. Yahya and B. Kingsman (1999)). Dyer and Forman (1992) claim that the AHP will be an effective methodology for group decision making. The usage of pairwise comparison in AHP was applied by Narasimhan (1983) and Nydick and Hill (1992). Eon-Kyung Lee, Sungdo Ha and Sheung-Kown Kim (2000) proposed an effective supplier development methodology for enhancing supply chain performance using AHP. C. Murlidharan, N. Anatharaman and S.G. Deshmukh (2001) used AHP for vendor/supplier rating in purchasing scenario. Web based casting supplier evaluation using analytical hierarchy process was discussed by M. M. Akarte, N. V. Surendra, B. Ravi, N. Rangaraj (2001)

PROBLEM SETTING

CHAPTER - III

There are four suppliers that sell one item. The buyer has a few criteria based on which he/she will be selecting a supplier. Following are the deciding criteria-

- Price
- On-time delivery
- Defects
- Technical level
- Reliability
- Period of Warranty
- Turn-around for repair
- Supply Capacity

For each criteria, the buyer is having a different priority level. The priorities are represented through their weights.

Criteria	Weight
Price	0.2961
Technical level	0.1867
Defects	0.1658
Reliability	0.0553
On-time delivery	0.0804
Supply capacity	0.0676
Repair turnaround	0.0466
Warranty period	0.1015

Supplier	Price	Technical level	Defects	Reliability	On-time delivery	Supply capacity	Repair turnaround	Warranty period	Supplier weigh
A	0.338	0.2	0.0732	0.2121	0.2392	0.2564	0.2353	0.1818	0.2273
B	0.2503	0.2	0.1463	0.2242	0.2392	0.1805	0.2353	0.3636	0.2274
C	0.2209	0.3	0.1951	0.2727	0.2738	0.2018	0.1765	0.2727	0.2404
D	0.1908	0.3	0.5854	0.2909	0.2478	0.3613	0.3529	0.1818	0.3049
Global Weight	0.2961	0.1867	0.1658	0.0553	0.0804	0.0676	0.0466	0.1015	

This model has four parts:

- Sets and notations
- Decision variables

- Objective functions
- Constraints to objective function.

The Model shall be written in Python and will be solved using Gurobi.

S_i	Set of suppliers offering item i
K_j	Set of items offered by supplier j
w_j	Final weight of supplier j
R_j	Set of discount interval of supplier j
m_j	The number of discount intervals in supplier j's discount schedule
r	Discount interval $1 <= r <= m_j$
b_{jr}	Upper limit in interval r of supplier j's discount schedule, $0 = b_{jo} < b_{j1} <...<b_{j,mj}$
d_{jr}	Discount coefficient associated with interval r of supplier j's discount schedule
p_{ij}	Unit price of item i quoted by supplier j
q_{ij}	Defective rate of item i offered by supplier j
Q_i	The buyer's maximum acceptable defective rate of item i
ti_j	On-time delivery rate of item i offered by supplier j
T_i	The buyer's minimum acceptable on-time delivery rate of item i
Ci_j	Maximum supply capacity of item i offered by supplier j
D_i	Total demand of item i

It should be noted that here in this problem, only one item has been considered, therefore the index i will always be 1. Again-

- Final weight considered for each supplier i is obtained from AHP.
- **Set of discount interval in supplier *j* discount schedule** is related with the idea of **economies of scale**. Economies of scale implies the idea of doing things more efficiently with increasing size. In this case, the more product that the buyer buys, the more discount that the supplier gives. example of discount interval is given in the table below

Business volume (in thousand $)	Discount (%)
0 to under 10000	0
10000 to under 20000	10
20000 and over	20

- **Quotation of Unit price of item *i* by supplier *j*** deals with the prices that are being offered by the suppliers. For this problem, the prices being offered are given below.

Supplier	Price ($/unit)
1	411
2	555
3	629
4	728

- Defective rate of item i offered by supplier j related with the technical level criteria for each supplier.

Supplier	Defective rate
1	0.08
2	0.04
3	0.03
4	0.01

- The minimum defect rate of item i that is acceptable to buyer is the parameter about the threshold of the buyer to accept defective product and this parameter is related to quality.
- On-time delivery rate of item i offered by supplier j is related to the on-time delivery criteria for each supplier. The higher the number, the faster the delivery of the goods.

Supplier	On-time delivery rate
1	0.83
2	0.83
3	0.95
4	0.86

Decision variable

The decision variable required for this problem are

X_{ij}	Units of item i purchased from supplier j
V_{jr}	Business volume in discount interval r purchased from Supplier j
y_{jr}	Binary Integer variable that is equal to 1 if business volume purchased from supplier j falls within of the discount schedule, 0 otherwise

There are two continuous variables; X_{ij} for the number of goods and V_{ij} to indicate the business volume in order to determine the discount interval. There is also one binary variable y_{jr} to represent in which discount interval that the buyer bought the goods.

Objective function

This problem has four objective.

1. Since in this problem the performance of supplier is represented by weight, therefore the objective is to **maximize the total weighted quantity of purchasing**.

$$\text{Max.} \quad Z_1 = \sum_{i \in K_j} \sum_{j \in S_i} w_j X_{ij}$$

2. The buyer decision is to **minimize the total purchase cost** by considering the cumulative price breaks.

$$\text{Min.} \quad Z_2 = \sum_{j \in S_i} \sum_{r \in R_j} (1 - d_{jr}) V_{jr}$$

3. To improve product quality and satisfaction of customer, the buyer expects to **minimize the number of defective items.**

$$\text{Min.} \quad Z_3 = \sum_{i \in K_j} \sum_{j \in S_i} q_{ij} X_{ij}$$

4. Due to production schedule, the buyer will want to **maximize the number of items delivered on time.**

$$\text{Max.} \quad Z_4 = \sum_{i \in K_j} \sum_{j \in S_i} t_{ij} X_{ij}$$

As this problem is multi-objective, we need to use Gurobi to be able to consider all of these objectives. Therefore, we use a function by Gurobi to linearize the problem.

model.setObjectiveN(expression, index, priority(opt))

The expression above linearises the objective function. It has been assumed that all of the objective functions have equal priority.

Constraints

The constraints for this problem has been divided into four major parts.

Capacity constraint

Each supplier has a different number of product that they can provide. This condition is bounded by the capacity constraint.

$$\sum_{i \in K_j} X_{ij} \leqslant C_{ij}, \quad j \in S_i.$$

Discount constraint

This constraint represents the discount prices for the goods

$$b_{j,r-1} y_{jr} \leqslant V_{jr} < b_{jr} y_{jr}, \quad j \in S_i, \quad r \in R_j,$$

$$\sum_{r \in R_j} y_{jr} \leqslant 1, \quad j \in S_i.$$

Demand constraint

The buyer has a demand that need to be satisfied. The sum of assigned order quantities has to satisfy the demand. This condition is constrained by a demand constraint.

$$\sum_{j \in S_i} X_{ij} = D_i, \quad i \in K_j.$$

Quality constraint

The buyer's has a quality requirement to be satisfied. To satisfy the quality constraint, an equation is formulated below.

$$\sum_{i \in K_j} \sum_{j \in S_i} q_{ij} X_{ij} \leqslant Q_i D_i$$

Delivery constraint

Similar like quality, the buyer also has a requirement for delivery which constrained by this constraint

$$\sum_{i \in K_j} \sum_{j \in S_i} (1 - t_{ij}) X_{ij} \leqslant (1 - T_i) D_i$$

PYTHON CODE

CHAPTER - IV

Python Code:

```
# -*- coding: utf-8 -*-
"""
Created on Fri Apr 23 22:08:15 2021

@author: Abhishek
"""
from gurobipy import*
model = Model("VSOA")

I = {1}
J = {1,2,3,4}
R = {0,1,2,3}
J,w = multidict({1:0.2273, 2:0.2274, 3:0.2474, 4:0.3049})
J,q = multidict({1:0.08, 2:0.04, 3:0.03, 4:0.01})
J,t = multidict({1:0.83, 2:0.83, 3:0.95, 4:0.86})
J,C = multidict({1:400, 2:700, 3:600, 4:500})
J,p = multidict({1:411, 2:555, 3:629, 4:728})
I,D = multidict({1:800})
I,Q = multidict({1:0.02})
I,T = multidict({1:0.9})
d = {(1,1):0, (1,2):0.1, (1,3):0.2,
    (2,1):0, (2,2):0.1, (2,3):0.2,
    (3,1):0, (3,2):0.1, (3,3):0.2,
```

```
    (4,1):0,  (4,2):0.1,  (4,3):0.2}
b = {(1,0):0,  (1,1):10000,  (1,2):20000,  (1,3):10000000,
    (2,0):0,  (2,1):10000,  (2,2):20000,  (2,3):10000000,
    (3,0):0,  (3,1):10000,  (3,2):20000,  (3,3):10000000,
    (4,0):0,  (4,1):10000,  (4,2):20000,  (4,3):10000000}

y = {}
for j in J:
    for r in R:
        y[j,r] = model.addVar(vtype="b", name="y(%s,%s)"%(j,r))

x = {}
for i in I:
    for j in J:
        x[i,j] = model.addVar(lb=0, vtype="c", name="x(%s,%s)"%(i,j))
v = {}
for j in J:
    for r in R:
        v[j,r] = model.addVar(vtype="c", name="v(%s,%s)"%(j,r))

model.setObjectiveN(-quicksum(w[j]*x[i,j] for i,j in x),0)

model.setObjectiveN(quicksum((1-d[j,r])*v[j,r] for j in J for r in range(1,4)),1)
```

```
model.setObjectiveN(quicksum(q[j]*x[i,j]  for i,j  in x),2)

model.setObjectiveN(-quicksum(t[j]*x[i,j]  for i,j  in x),3)

model.ModelSense  = GRB.MINIMIZE

model.addConstr(quicksum(v[j,r]  for r in range(1,4)  for j in J) == quicksum(p[j]*x[1,j]  for j in J))

for j in J:
   for i in I:
      model.addConstr(x[i,j]  <= C[j])

for j in J:
   model.addConstr(quicksum(y[j,r]  for r in range(1,4))  <= 1)

for j in J:
   for r in range(1,4):
      model.addConstr(b[j,r-1]*y[j,r]  <= v[j,r])

for j in J:
   for r in range(1,4):
      model.addConstr(v[j,r]  <= (b[j,r]-1)*y[j,r])

for i in I:
```

```
    model.addConstr(quicksum(x[i,j] for j in J) == D[i])

for i in I:
    model.addConstr(quicksum(x[i,j]*q[j] for j in J) <= D[i]*Q[i])

for i in I:
    model.addConstr(quicksum((1-t[j])*x[i,j] for j in J) <= (1-T[i])*D[i])

model.optimize()

assert model.Status == GRB.Status.OPTIMAL

nSolutions = model.SolCount
nObjectives = model.NumObj
print('Problem has', nObjectives, 'objectives')
print('Gurobi found', nSolutions, 'solutions')


solutions = []
#for s in range(nSolutions):
#    model.params.SolutionNumber = s
#    print('Solution', s, ':', end='')
for o in range(nObjectives):
    model.params.ObjNumber = o
```

```
    print('Objective value ',o+1, ': ', model.ObjNVal, end='')
solutions.append(model.getAttr('Xn',x))
solutions


EPS = 0.00000001
for (i,j) in x:
    if x[i,j].X > EPS:
        print("Item %1s bought from supplier %1s is: %3s"%(i,j, x[i,j].X))
```

RESULTS

CHAPTER - V

Results

Python 3.8.3 (default, Jul 2 2020, 17:30:36) [MSC v.1916 64 bit (AMD64)]

Type "copyright", "credits" or "license" for more information.

IPython 7.16.1 -- An enhanced Interactive Python.

runfile('C:/Users/Abhishek/Desktop/Supplychain nAssignment/Supplychain python Code.py', wdir='C:/Users/Abhishek/Desktop/Supplychain nAssignment')

Academic license - for non-commercial use only - expires 2021-06-15

Using license file C:\Users\Abhishek\gurobi.lic

Gurobi Optimizer version 9.1.1 build v9.1.1rc0 (win64)

Thread count: 4 physical cores, 8 logical processors, using up to 8 threads

Optimize a model with 36 rows, 36 columns and 88 nonzeros

Model fingerprint: 0xd07566b4

Variable types: 20 continuous, 16 integer (16 binary)

Coefficient statistics:

Matrix range [1e-02, 1e+07]

Objective range [1e-02, 1e+00]

Bounds range [1e+00, 1e+00]

RHS range [1e+00, 8e+02]

Multi-objectives: starting optimization with 4 objectives (1 combined) ...

Multi-objectives: optimize objective 1 (weighted) ...

Optimize a model with 36 rows, 36 columns and 88 nonzeros

Variable types: 20 continuous, 16 integer (16 binary)

Coefficient statistics:

Matrix range [1e-02, 1e+07]

Objective range [8e-01, 1e+00]

Bounds range [1e+00, 1e+00]

RHS range [1e+00, 8e+02]

Presolve removed 13 rows and 13 columns

Presolve time: 0.00s

Presolved: 23 rows, 23 columns, 65 nonzeros

Variable types: 15 continuous, 8 integer (8 binary)

Root relaxation: objective 4.328397e+05, 4 iterations, 0.00 seconds

Nodes | Current Node | Objective Bounds | Work

Expl Unexpl | Obj Depth IntInf | Incumbent BestBd Gap | It/Node Time

*   0   0   0   432839.71636 432839.716   0.00%   -   0s

Explored 0 nodes (4 simplex iterations) in 0.02 seconds

Thread count was 8 (of 8 available processors)

Solution count 1: 432840

Optimal solution found (tolerance 1.00e-04)

Best objective 4.328397163636e+05, best bound 4.328397163636e+05, gap 0.0000%

Multi-objectives: solved in 0.02 seconds, solution count 1

Problem has 4 objectives

Gurobi found 1 solutions

Objective value 1 : -221.1321212121212Objective value 2 : 433764.84848484845Objective value 3 : 16.0Objective value 4 : -720.0Item 1 bought from supplier 2 is: 24.242424242424242

Item 1 bought from supplier 3 is: 363.63636363636374

Item 1 bought from supplier 4 is: 412.12121212121207

CONCLUSION

CHAPTER - VI

Conclusion

The model was solved in 0.52 seconds and an optimal solution was found by Gurobi. This is the objective value of the model.

Objective Function
Objective 1 (maximize the total weighted quantity of purchasing)
Z1 = 221.1321

Objective 2 (minimize the total purchase cost)
Z2 = 433764.8485

Objective 3 (minimize the number of defective items)
Z3 = 16.0000

Objective 4 (maximize the number of items delivered on time)
Z4 = 720.0000

The variable result can be stated as below-

(1, 1): 0.0000
(1, 2): 24.2424
(1, 3): 363.6364
(1, 4): 412.1212

From the result, we can see that the buyer will be using a mix of three suppliers in order to satisfy his demands. The buyer will order 24.2424 from supplier B, 363.6364 from supplier C, and 412.1212 from supplier C.

We may see that the result is proportional to the overall weight of the supplier.