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Research Report: MISI-2016-6
Facility Location: Quantitative scenario development for regret based approach
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Facility Location: Quantitative scenario development for regret based approach

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Summary: This thesis furthers Intuitive Logics School's scenario development literature by formulating an approach for quantitative scenario development. It uses existing literature to build a mixed integer linear program model for facility location. Major parameters which affect the model are shortlisted. High and low values of these parameters are obtained based on expert opinions and calculations. These values are converted into changes in input data for the model. The most important parameter which affects facility location is further identified. A minimization of regret approach, as used in literature before is applied to obtain a robust solution for facility location for the sponsor organization.

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KEY INSIGHTS

1. Formulation of an approach for realistic quantitative scenario development which can be used as a tool for facility location decisions

2. Identification of the most important parameters which affect facility location

3. The approach helps the organization to narrow down on the most robust decision for facility location considering realistic scenarios which might play out in the future.

Introduction

Global Chem Inc. is one of the largest Chemical companies in Asia Pacific with operations spanning 25 countries in the region. It has production sites all over the world including in Asia Pacific. Asia Pacific contributed about 20% of the company's global sales in 2014. Most of the products sold in Asia Pacific are shipped from other continents where they are manufactured. The Company has been experiencing over 15% compound annual growth rate (CAGR) in the Asia Pacific regions largely due to its growth in China, India and the South East Asian Region.

This demand growth has also led to increase in the number of warehouses and inventory held by the company in the region. This growth in demand also make it imperative for the company's distribution network to perform robustly for different scenarios which might play out in the future. Thus it is critical for a company to determine the optimal number and location of warehouses to operate (from the candidate list) to efficiently cater to the growing demand. It is also imperative for the company to formulate an approach to develop realistic scenarios which the company might face in the future which would affect the design of its distribution network. This development of an approach for the company to develop realistic scenarios and study the effect of different scenarios on distribution network design and arrive at the most optimal decision for the company is the main subject of this report.

Literature Review

Facility Location Literature

Pioneering work in the field of dynamic facility location was done by Ballou (1968) using dynamic programming. The problem of deciding where to locate a set of intermediate facilities (such as Distribution Centers) was examined first by Elson (1972) who used the mixed integer linear programming tool to decide on the location of warehouses. This study was followed up by Geoffrion and Graves (1974) who developed a multi-commodity capacitated single-period version of the problem which was formulated as a mixed integer linear program. Extensions for uncapacitated models were developed by Chardaire, Sutter and

Costa (1996) who dealt with the multi-period, or dynamic, uncapacitated facility location problem (DUFLP). Hinojosa, Puerto and Fernandez (2000) studied a problem combining dynamic aspects with multi-level facility location in a multi-commodity distribution network. This problem was later extended by Hinojosa et al (2008) to integrate inventory holding costs in the objective function.

Scenario planning literature

Intuitive Logics School (ILS) has received most of the attention in the scenario planning literature (Bradfield et al (2005)). This approach was earlier proposed by Herman Kahn at the Rand Corporation in the 1960s. Intuitive logic approach was used by Pierre Wack and his colleagues at Royal Dutch Shell as shown by Wack (1985). The intuitive logics approach embraces and integrates consideration of the full set of political, economic, social, technological, ecological and legal (PESTEL) factors that will shape the future. Application of the approach enables the following regarding scenario development:

1. Identification of the driving forces of the future that are present in the broad business environment and will impact an “focal decision”
2. Consideration of the range of possible and plausible outcomes of each of these forces;
3. Understanding of how the forces interact with each other in terms of cause and effect

Focal Decision

The major decision facing the company is referred to as the focal decision by Schwartz (1991) and cited by Ringland (1998, p. 228) who suggested that when developing scenarios, to begin with "from the inside out" rather than "from the outside in". That is, begin with a specific decision or issue, then build out towards the environment.

Intuitive logics approach does not use any mathematical algorithm and mainly relates to qualitative scenario development as described by Ulf Pillkahn (2008). The salient features of the ILS are stated by Fahey and Randall (1998). However they also state that ILS is not tied to mathematical or computer algorithms and hence has a limitation in quantitative scenario development. This study fills the gap in ILS literature of generating quantitative scenarios for a particular mathematical model and will study the effects of the same on the focal decision concerning an organization.

Regret based approach for facility location

The most widely used method for robust decision making for facility location has been the regret based approach as stated by Synder (2006). The regret is defined as the difference (absolute or percentage) between the cost of a solution in a given scenario and the cost of the optimal solution for that scenario. Models that seek to minimize the maximum (absolute or relative) regret across all scenarios are called minimax (absolute or relative) regret models. minimizing expected regret is equivalent to minimizing expected cost. To see this, consider a general min-expected-absolute-regret problem with variable decisions $x_1 \dots\dots.. x_n$ feasible set X with scenarios s ∈ S, objective function coefficient c_{is} , scenario probabilities q_s and optimal scenario objective value z_s

Min $\sum q_s * R_s$……………………………………1

Subject to $R_s = \sum_1^n c_{is} x_i - z_s$ for all s ∈ S……...2

Substituting the regret variable R_s into the objective function we would obtain the following

$Min \ \sum_{s \in S} q_s * (\sum_1^n c_{is} x_i - z_s)$ for x ∈ X……….3

The different major models suggested in literature using the regret approach have all used computational data for testing the model.

This study works towards development of an approach for quantitative scenario development to create realistic scenarios for Global Chem Inc. for the planning horizon of its concern. The model for the analysis has been developed as a combination of models used previously in literature as stated above. The regret based approach as described above would also be used to facilitate robust decision making.

Methodology

A mixed integer linear program is developed with the objective function minimizing the present value of distribution network cost. This cost includes the following:

1. Discounted inbound transportation costs from plants to warehouses
2. Discounted outbound transportation costs from warehouses to customer regions
3. Discounted inventory holding costs
4. Discounted fixed costs of opening warehouses
5. Discounted operating costs of warehouses
6. Discounted closing costs of warehouses

Data collection

Historical data is collected from Global Chem Inc for the study. The organization has done ABC segmentation to determine its class A SKUs based on profitability and the study is undertaken for these SKUs. Data was hence collected for 73 products which are manufactured in 4 plants. The candidate list of warehouses contained 7 warehouses from where the products are dispatched for 7 customer region. Data for 13 time periods was collected for analysis.

The data used is as follows:

1. Demand by SKUs by time periods by customer regions

2. Candidate list of possible warehouse locations
3. Candidate list of production countries by product by time periods
4. Inventory holding policy (days of coverage for different SKUs over different time periods)
5. Transportation costs for different SKUs from production countries to candidate list of warehouse locations over different time periods T
6. Transportation costs for different SKUs from candidate list of warehouses to different customer regions over different time periods
7. Costs of opening, closing and operating different warehouses over different time periods

Major Parameters Identification

Data was also collected for quantitative scenario developed after recognizing the major parameters which affect the model.

The parameters which affect the model mentioned above and hence the distribution network design were identified to be as follows:

1. Price of oil
2. Benchmark Interest Rates in the region of concern
3. Real estate prices in the region of concern
4. Demand growth forecasts for concerned region

The major parameters which affect the model were understood by a closer look at the objective function and the constraints of the model. Since the objective function depends on the inbound and outbound transportation costs and there is a correlation of the same with the price of oil (reference Global Chem Inc.), the price of oil is a significant parameter which affects the model. Since the objective function also consists of the inventory holding costs, these costs are a function of the benchmark interest rates of different regions. Since the objective function also contains fixed costs of opening warehouses, the commercial real estate prices in the concerned region also affect the objective function and hence the distribution network design. Also since the model is subject to constraints of demand satisfaction, the increase in demand growth would affect the number of warehouses which are operated and hence distribution network design

Data collection for major parameters

1. Price of oil

Various experts have forecasted the price of oil within a wide range for the next 2-3 years. The volatility for the price of oil for last 24 months of this report being written was close to 200% as compared to the lowest prices during the last 24 months. Expert opinions on the price of oil range from \$30/barrel to \$90/barrel as suggested by David (2016) and CNBC (2015). However, to translate the price of oil variations into transportation cost variations, it is essential for an organization to understand the correlation using historical data. Using data for the past 24 months to understanding difference in transportation costs and its correlation to the price of oil would help the organization understand the impact of the price of oil on its transportation costs along with its correlation.

2. Real estate prices in the region of interest

Data estimation for real estate prices were based on following the real estate index on the major stock exchanges in the region. However to translate the real estate index on major stock exchanges to purchase cost estimates for new warehouses in regions of interest would require the organization to develop a correlation for the same using historical data and quotes from suppliers of warehouses. The Real Estate Climate Index on major stock exchange of the Asian region (Hong Kong Stock Exchange) was considered as representative of the region. The real estate climate index change (difference between minimum and maximum index value) over the last 24 months was close to 17% during the past 24 months as shown by the China Real Estate Climate Index (2016).

3. Benchmark interest rates in the region

Benchmark interest rates in the region of interest are difficult to estimate due to the international nature of the operations and source of funds which may vary for different country offices. Hence for the same, the benchmark interest rate for Global Chem Inc's largest market which accounted for over 53% sales of the entire region was considered for analysis and the changes for the same as forecasted by experts were considered for the calculation of inventory holding costs for the company. The established consensus in the OM literature is that the appropriate approach is to use the weighted-average cost of capital (WACC), as inventory holding cost, which takes into account the required return on the firm's equity and the cost of its debt.

4. Demand growth in the region of interest

The demand growth for the chemical market was shown to be linked to the GDP growth of the region. Expert opinions have shown as below, the Chemicals market growth to be on average 4% more than GDP growth based on last 10 years data as shown by AT.Kearney (2015). Expert opinions on the GDP growth for the largest market varied from 5% to 7% in the next 3 years as forecasted by Forbes (2015) and Chinese government projections (2015) and hence chemical demand growth was estimated in the range of 9% to 11% for the analysis.

Results

The optimization results were run for 'current state' pertaining to 'As-is' data shared by the company. The end points for the different parameters as mentioned above were determined and converted to changes in input data and results of the changes in the 'focal decision' of the company were observed.

Comparison of Results	Current State	9% Demand growth	11% Demand Growth
Number of warehouses opened	5	5	5
Which warehouses were opened	SG, SC, MY, ID, TH	SG, SC, MY, ID, TH	SG, SC, MY, ID, TH
Warehouse-time periods of Operations	59	62	65

Table 1: End point testing for Demand growth on Focal Decision

Similarly, the exercise was repeated for other parameters as shown in Tables 2, 3 and 4.

Comparison of Results	Current State	3.85% Benchmark Rate	4.1% benchmark Rate
Number of warehouses opened	5	5	5
Which warehouses were opened	SG, CN, MY, ID, TH	SG, CN, MY, ID, TH	SG, CN, MY, ID, TH
Warehouse-time periods of Operations	59	59	59

Table 2: End point testing for interest rate on focal decision

Comparison of Results	Current State	8.5% reduction in Fixed costs	8.5% increase in fixed costs
Number of warehouses opened	5	5	5
Which warehouses were opened	SG, CN, MY, ID, TH	SG, CN, MY, ID, TH	SG, CN, MY, ID, TH
Warehouse-time periods of Operations	59	62	57

Table 3: End point testing for real estate prices on focal decision

Comparison of Results	Current State	100% increase in Price of Oil	200% increase in price of Oil
Number of warehouses opened	5	6	7
Which warehouses were opened	SG, CN, MY, ID, TH	SG, CN, MY, ID, TH, JP	SG, CN, MY, ID, TH, JP, SK
Warehouse-time periods of Operations	59	71	91

Table 4: End point testing for price of oil on focal decision

As can be seen in tables 1,2,3 and 4, the focal decision of the company i.e. the number of warehouses to operate does not change with changes in parameters of demand growth, interest rates and real estate prices. However the parameter of the price of oil when changed in the ranges as predicted by expert opinions causes a change in the focal decision of the company. Hence this parameter is used for further analysis and for the application of the regret based approach.

Considering the 'current state' data shared by Global Chem Inc. for 73 products produced in 4 plants and a candidate list of 7 warehouses with 7 customer regions and 13 time periods, the application of the regret based approach yields results as shown in Table 5. The 'current state' results in the GAMS optimizer yield the focal decision of opening 5 warehouses. The regret based approach is applied to the data provided by Global Chem Inc. to arrive at the following focal decision which would minimize the regret across all scenarios of increased prices of oil. The prices of oil are increased in a step wise manner for different scenarios.

Optimal Value	23671157	23691174	23711191	23740877	23755476	23774838	23783028	23783692	
Company Decision	Price of Oil increase as compared to Current state								
	25%	50%	75%	100%	125%	150%	175%	200%	Total Regret
5 WH	1.00%	1.90%	3.20%	4.70%	6.60%	9.00%	9.50%	11.50%	16.50%
6 WH	5.20%	6.40%	6.90%	1.00%	2.30%	6.10%	7.30%	8.00%	6.00%
7 WH	10.20%	9.00%	6.60%	5.90%	4.80%	2.80%	4.70%	7.10%	0.00%

Table 5: Regret based approach application to Global Chem Inc

As can be seen from table 5, the focal decision to open 7 warehouses minimizes the regret across all scenarios of prices of oil.

Conclusion:

This study works towards formulation of an approach for quantitative scenario development for an organization. The quantitative scenarios were developed for the mixed integer linear program using expert opinions, calculations along with changes in input data. This study does not implicitly consider costs which related to international distribution networks like taxes, incentives by country governments, social, political and cultural differences. However the model does make provisions to inputs such factors into the model and consider the same for decision making up changing the input data. The current study works towards eliminations of parameters individually which do not cause a large change in the focal decision of the company. Hence the parameters of benchmark interest rates, demand growth and real estate prices were not considered for further analysis. However the study does not take all parameters in combination and determine the specific data input in the input data and hence the environment where the focal decision of the company becomes non-optimal. Hence future research can undertake analysis of all parameter changing together and determine the points in input data which change the focal decision of the company and not just the price of oil as has been done in the above study.