Supplier Portfolio Selection and Optimum Volume Allocation: A Knowledge Based Method

Romana Aziz[1], Jos van Hillegersberg [2]

Abstract:
Selection of suppliers and allocation of optimum volumes to suppliers is a strategic business decision. This paper presents a decision support method for supplier selection and the optimal allocation of volumes in a supplier portfolio. The requirements for the method were gathered during a case study that was conducted within the logistics unit of Shell Chemicals Europe. The proposed method is based on the classical view by Sprague and Carlson of sequence and interaction of the different phases of decision making in a decision support system and supports Kraljic's portfolio approach for supplier management. This method aims to help the managers in making decisions on the allocation of volumes to suppliers while simultaneously trying to satisfy conflicting objectives of improvement in benefit and reduction in risk. A mathematical model to structure the problem is presented, knowledge elicited from the managers is used to parameterize the mathematical model and a multi-objective, hierarchical optimization procedure produces 'trade-off' outputs. The managers can also conduct interactive post optimization 'what-if' analysis.

Keywords: Supplier selection, portfolio management, decision support, volume allocation

1 Introduction

Successful supply chain management requires the management and selection of an effective portfolio of suppliers (Halldorsson et al, 2007 & Hertz and Alfredsson, 2003). The most widely used approach for supplier portfolio management is the Kraljic matrix (Kraljic, 1983). In this approach all suppliers are not managed in the same way, they are categorized into four segments: bottleneck, noncritical, strategic and leverage and each segment is handled differently. Kraljic advises managers to optimize their supplier portfolio by minimizing risks and maximizing benefits and buying power. Based on the Kraljic's segment approach many other authors have introduced similar supplier portfolio management approaches, e.g., Gelderman and Van Veele (2003) and Bensaou (1999).

In the current literature, there are some methods and models for supplier portfolio selection as well. These include multi criteria decision making models (Handfield et al, 2002), statistical techniques (Carr and Pearson, 2002), data analysis methods (Liu et al., 2000) and the analytic network process (Jharkharia and Shankar, 2007). In these approaches the suppliers are either selected or rejected on the basis of some criteria and a portfolio is formed.

We conducted a case study within the logistics unit of Shell Chemicals Europe (SCE) (Aziz et al., 2010). One of the objectives of this case study was to establish if the existing methods for supplier selection reported in the literature were applicable and useful in practice. During our case study we interviewed the logistic managers and contract managers and observed their decision making process for contracting the third

[1] _Corresponding author: Romana Aziz, Department of Information Systems & Change Management, School of Management and Governance, University of Twente, r.aziz@utwente.nl, T: + 31 (0) 53 489 5358, F: +31 (0) 53 489 2159_

[2] _Jos van Hillegersberg, Department of Information Systems & Change Management, School of Management and Governance, University of Twente_

party logistic services suppliers. We also analyzed how the volumes were allocated to the selected suppliers. The analysis of the decision making process at SCE was used to augment our understanding of the suppler portfolio selection and volume allocation problem. The insights gained during this case study confirmed that there were many shortcomings in the existing practices and methods for supplier selection and hence they failed to fully address the needs of the decision makers. Three important shortcomings were identified during the SCE case study in the existing methods for supplier selection and volume allocation and due to these shortcomings the existing models were not applicable and useful in practice. The identified shortcomings were:

1. Decision makers cannot study the degree and direction of change in the portfolio effectiveness (benefits and risks) with varying the volume level on the selected suppliers.
2. Decision makers are not enabled to do post optimization analysis with input allocation scenarios.
3. The supplier portfolio of an organization is assumed to be a single segment and hence the existing methods cannot be implemented for a hierarchical or multi segment portfolio as proposed by Kraljic.

The results of the SCE case study established that there is a need for a supplier selection method that addresses the above mentioned shortcomings. In this paper we present a method for supplier selection and volume allocation which overcomes the above mentioned shortcomings in the existing methods and solves the following problem:

Select a set of suppliers and decide volume levels for them
such that
Benefit to organization is maximized
and
Volume level does not exceed available volume
Organizational risk preference requirements are upheld

Moreover the decision makers should be able to organize their portfolio as hierarchical or multi segment and the method should enable them to observe fluctuations in supplier performance and portfolio effectiveness related with variations in allocated volume levels.

Development of a decision support method is an applied science and therefore the research presented in this paper is interdisciplinary. The proposed method is based on techniques from several areas such as knowledge elicitation, optimization, statistical methods, operations research and cognitive psychology and provides an integrated and complete support to the decision making process. Collaboration with practitioners is an important feature of any successful research in an applied science field. The research presented in this paper is characterized by feedback from logistics managers of Shell Chemicals Europe. We worked together with the managers to formulate the problem. After that we structured the problem and developed a solution proposal. The managers incorporated their theoretical and practical knowledge and experience into this process.

The research goal is to structure the supplier portfolio selection and volume allocation problem and provide a method to help the decision making process. The main contribution of this paper is in the proposal of an original method to tackle the supplier portfolio selection and volume allocation problem. In the next section we introduce the proposed method and the criteria used in our method for supplier selection. After that we explain the various steps in our method. This is followed by a description of the mathematical model and then conclusions are presented.

2 The proposed method

The proposed method is based on decision calculus ideas of Little (2004). These ideas are:

1. Different managers may differ on response rates (elasticities) but they agree on relativities of response rates leading to the same optimized solution.
2. The mathematical model is simple, robust, easy to control, adaptive, as complete as possible and easy to communicate.

In this approach the pool of all possible suppliers from which we select and to which we allocate volume levels is called the portfolio. It is possible that at the end of the decision making process there may be some suppliers that have not been selected. Therefore the final portfolio might be different from the initial portfolio but to make the description easier we refer to all the suppliers submitted for selection appraisal as the portfolio.

Our method is also based on decision analysis. Decision analysis can be viewed as a means of generating dialogue about problem formulation and more importantly the identification of available options, rather

than just a means for the identification of the optimal solution. In addition to the identification of the optimum allocation, our method allows the decision makers to formulate interactively 'what-if' type of input allocation scenarios and see the resulting optimum volume allocations. Also we can optimize a multi segment (hierarchical) supplier portfolio in addition to a single segment supplier portfolio. Below we describe the key concepts and steps of our proposed method.

2.1 Criteria

We use the Kraljic criteria to evaluate and select a portfolio from the proposed pool of potential suppliers:
– Benefit
– Certainty (inverse of risk)

The benefit of a supplier is the advantages (tangible & intangible) the supplier will bring to the portfolio in terms of enhanced efficiency, increased competitive advantage, reduced costs and profits etc. It is the contribution the supplier will make to the portfolio if selected. For any supplier there is a minimum volume level below which the relationship is not viable. Above this minimum volume level the expected benefit increases with increasing volume. Above a certain volume level the benefit levels off or taper down (diminishes) as shown in Figure 1. This is due to decreased shipper leverage because of increased dependency on the supplier. Benefit is measured on a short term level or on a life cycle level (long term) and it is measured on an appropriate locally determined scale.

The risks associated with a supplier include volume assurance risks, operational risks, and service level risks. The risks reduce within reasonable limits by increasing volume on a supplier up to a certain volume level after which they usually increase due to higher dependence and reduced leverage and influence (Figure 2). Certainty is the inverse of risk (Figure 3).

Different suppliers have different minimum and maximum volume levels. Also different suppliers have the same types of benefit and risk curves but with different degrees of curvature within the minimum and maximum volume limits.
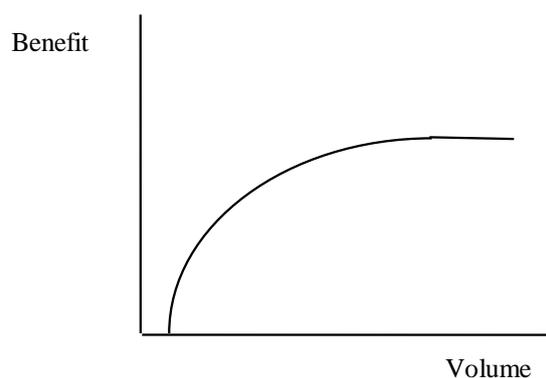

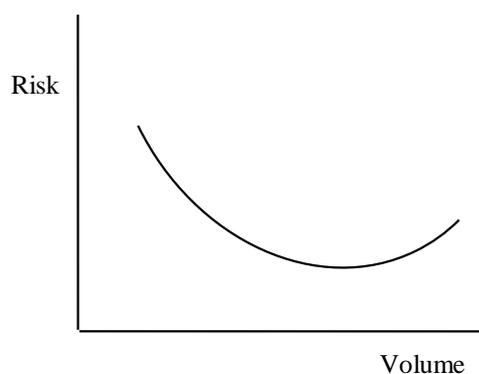Figure 1: Benefit vs. volume profile of a supplier

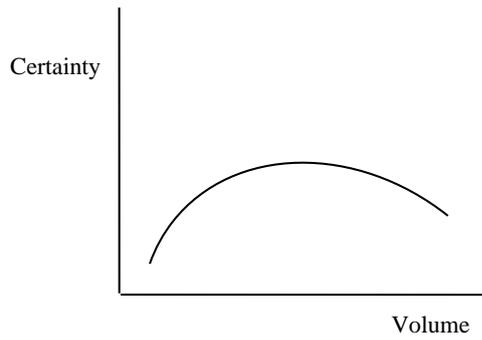Figure 2: Risk vs. volume profile of a supplier

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Figure 3: Certainty vs. volume profile of a supplier

To allow optimization of various sets of suppliers, suppliers are grouped into categories (CATEGORY1, CATEGORY2 … CATEGORYn) as shown in Figure 4, according to some criteria. The Kraljic critera can be used or the managers can determine their own criteria based on, e.g., size, expertise, geographical coverage, specialty, strategic importance etc. One supplier can be included in only one category. Managers have the flexibility to classify the proposed pool of suppliers into categories according to suitable criteria that enhances their decision making procedure.
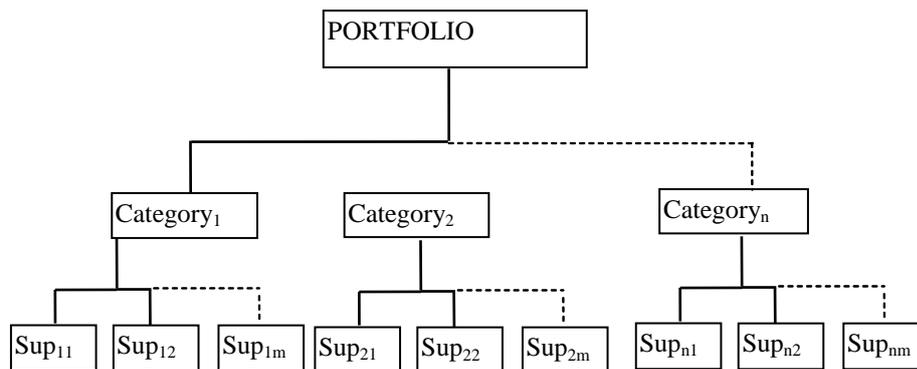

Figure 4: Schematic representation of a portfolio of suppliers as used in the proposed method

The proposed method tackles the full problem across all the categories. It allocates the total volume among all the categories and for any category among its suppliers such that the benefit is maximized within a preferred level of risk within local (category) and global (portfolio) volume constraints. This is a hierarchical (two level) optimization problem. An example of such a hierarchical problem is shown in Figure 5. This figure shows the allocation of volume to an organizational supplier portfolio consisting of three segments or categories and each category has three, four and two suppliers respectively.
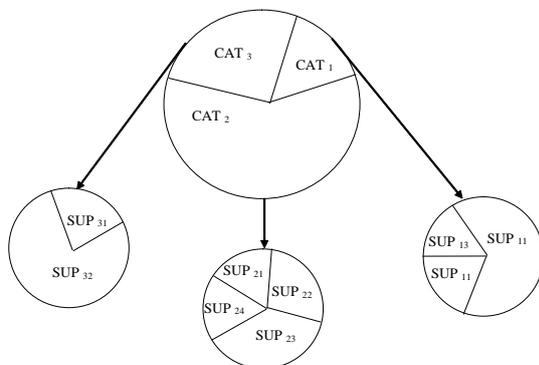

Figure 5: Two level optimal allocation of volume to suppliers

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3 Steps in the method

The method is based on the classical view by Sprague and Carlson (1982) of sequence and interaction of the different phases of decision making in a decision support system shown in Figure 6. Figure 7 shows the details of the steps in the method.

3.1 Phase I: Problem Formulation and Scenario Generation

The first step is to study all the suppliers and classify them into categories for the purpose of analysis. Once the pool of proposed suppliers has been grouped into categories according to some criteria the next step is to collect the following baseline data about all the suppliers:

– A minimum volume level below which the relationship with supplier is not viable and hence not worth doing
– The level requested or currently proposed
– A top limit above which the benefit levels off and diminishes (or tapers down) and there is little advantage

The decision makers are also asked to provide for the portfolio:

– Portfolio certainty index at the currently proposed levels of volume
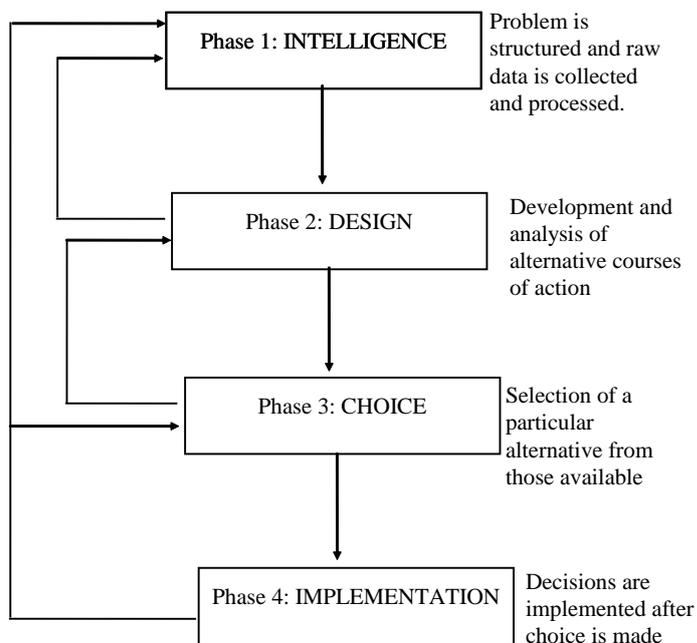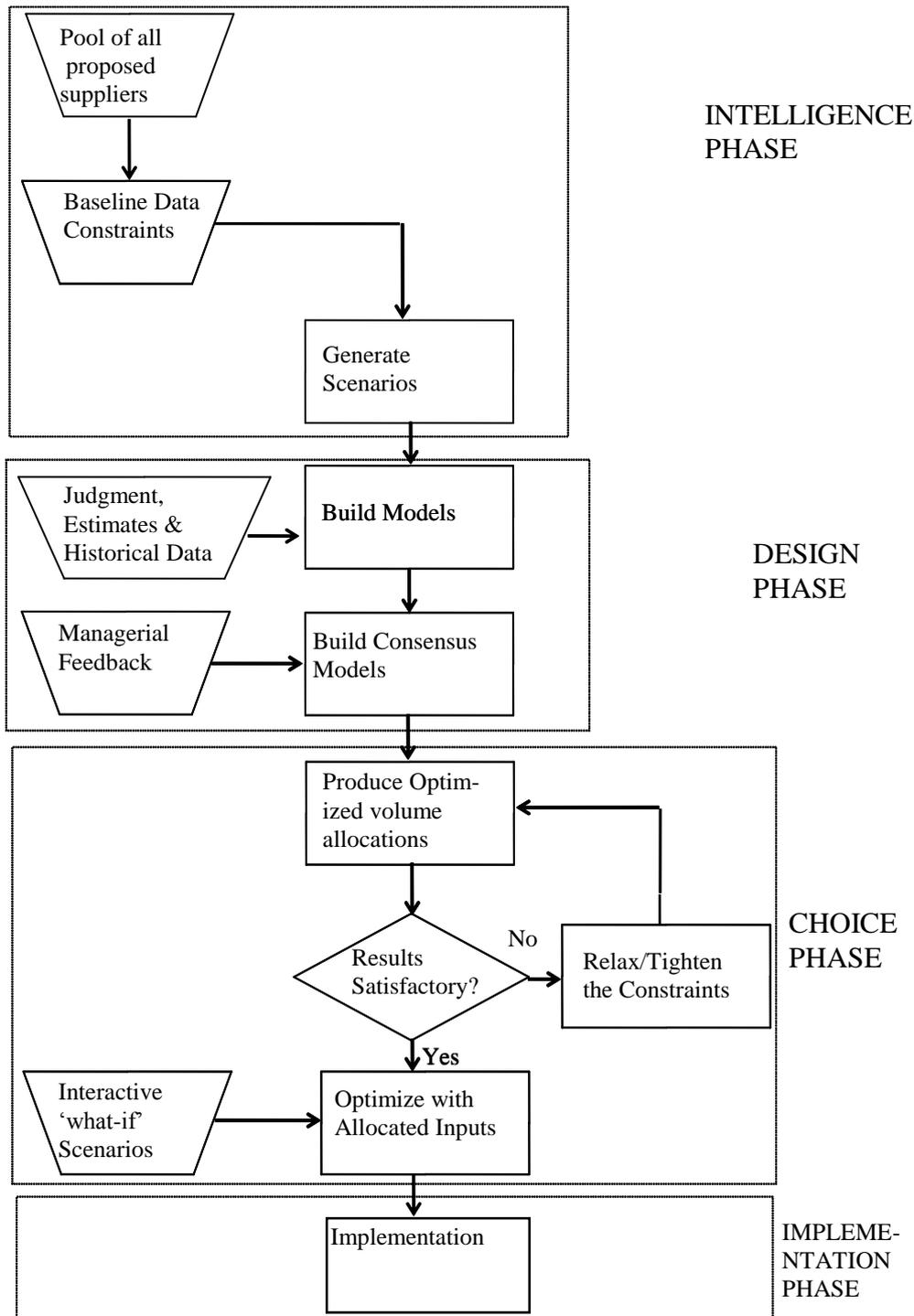– Minimum acceptable level of portfolio certainty index

Figure 6: Sequence and interaction of the different phases of decision making in a decision support system (adapted from Sprague and Carlson)

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┌─────────────────────────────────────┐
│  ╱ Pool of all  ╲                    │   INTELLIGENCE
│ ╱  proposed      ╲                   │   PHASE
│ ╲  suppliers     ╱                   │
│   │                                  │
│   ▼                                  │
│  ╱ Baseline Data ╲                   │
│ ╱  Constraints    ╲──────┐           │
│ ╲                  ╱      │           │
│                          ▼           │
│                   ┌──────────────┐   │
│                   │ Generate     │   │
│                   │ Scenarios    │   │
│                   └──────────────┘   │
└─────────────────────────────────────┘
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INTELLIGENCE PHASE

Judgment, Estimates & Historical Data → **Build Models**

DESIGN PHASE

Managerial Feedback → Build Consensus Models

Produce Optimized volume allocations

Results Satisfactory? — No → Relax/Tighten the Constraints

CHOICE PHASE

Yes

Interactive 'what-if' Scenarios → Optimize with Allocated Inputs

Implementation

IMPLEME-NTATION PHASE

experience, estimates or historical data.

Figure 7: The different steps in the method

Using the minimum and maximum supplier volume levels as constraints or bounds, the system produces an appropriate number of unique what-if scenarios for each category which span the decision space uniformly. A typical scenario is shown in Figure 8. For each category in addition to the set of randomly generated scenarios, there are three more scenarios representing the minimum, proposed / current and maximum volume levels of every supplier in that category. In every scenario

the first three columns are computer generated, whereas the last two columns are for eliciting managerial judgment based

3.2 Phase II: Knowledge Elicitation and Parameter Estimation

Managerial expertise is elicited by acquiring the response of the managers to the scenarios. The absolute value is not important, what is important is the relativity. In other words we stress on ranking rather than rating. Eckernode (1962) has reported that Ranking is most efficient method of knowledge elicitation. For each scenario the manager is asked to assess the impact of the proposed supplier volume mix on the category's benefit and certainty keeping in view the inter relationships and cross effects between the suppliers. Managers are asked to estimate for each scenario:

– A scale to measure benefit.
– A scale to measure certainty.

The managers answer the scenarios according to their experience, intuition and historical data. The underlying assumption in eliciting the expertise from the managers in this way is that by virtue of their experience in the organization they are the best source of information. On the basis of their knowledge they can easily quantify benefit and certainty. This evaluation technique draws upon the traditional analytical skills of the managers and tends to be familiar territory for them. This approach has an intuitive appeal for the managers and they find a number based approach very easy to respond to particularly when they are asked to make estimates for different levels of volume for a supplier.

In our technique we question the experts about the likely results of the different volume levels and ask them to estimate the rankings, rather than ratings. Moreover they are briefed that the term benefit encompasses tangible and intangible benefits. On the basis of their experience and knowledge managers feel an intuitive ease in quantifying the tangible and intangible benefits. By identifying the nature of the intangible benefits it is possible to quantify every benefit. Even in the case when the relationship between cause and effect is very indirect the managers can estimate the outcome because of their analytical skill and their past experience.

The scenarios can be answered by one or preferably more managers. There are two ways to elicit the response of the managers:

– On-line interactive
– Group session

In case the on-line interactive procedure is adopted for knowledge elicitation then the scenarios can be hosted or posted to the managers and they can fill them up on-line and send them back. Alternatively the managers can get together in a group session and the scenarios are distributed in printed form. One manager can play the role of the session leader and managers can discuss the outcome of each what-if scenario and enter their response on the printed form. In this case the managerial responses are entered into the database so that the knowledge modeling module can access them. At this stage the managers have the choice of long term planning or short term planning or both. They decide their period of planning and fill up the scenarios accordingly.

Estimation of managerial responses to different volume levels for each supplier is a key step in the method. Using the responses to the scenarios a Knowledgebase is built up to relate volume for each supplier and the different criteria used for supplier evaluation. The knowledge modeling module estimates the parameters of the mathematical models from the managers' responses. The scaling factors and elasticity coefficients (i.e., percentage change in benefit/certainty of a supplier for a percentage change in supplier volume) are calculated to calibrate both sets of mathematical models (benefit vs. volume & certainty vs. volume). For every manager taking part in the decision process model the parameter estimation module calculates:

– certainty elasticity for each supplier
– benefit elasticity for each supplier
– scaling factors for benefit and certainty models of each category

Managerial feedback is solicited at this level and they are requested to respond to the calculated values of elasticities. If the value of a certain elasticity coefficient is regarded as unrealistic or inaccurate then the managers have the option to disregard it. Or they can go back to the scenarios and decide if they have been inconsistent in their responses.

Next step in the method calculates a consensus model for certainty and a consensus model for benefit for each category of suppliers. A consensus model is built by discarding the extreme values of coefficients

and taking an average of the rest. At this point if the chief decision maker attaches a higher level of credibility to the judgment of a certain manager (or his/her own) then the consensus model is built by taking weighted averages after discarding the extreme values.

Suppliers	Allocated Volume	Percent Variation From Proposed Volume	Benefit (1-100)	Certainty (0-0.9)
Supplier 1	110300	16.11		
Supplier 2	398900	17.32		
Supplier 3	1161700	-3.19		
Supplier 4	150300	-16.5		
Supplier 5	139700	11.76		
Total	1960900			

Figure 8: A typical scenario.

3.3 Phase III: Optimization and Post Optimization Analysis

The method then enables the decision makers to operate optimization mechanisms for each criterion, in order to see the effect of the different mixes of supplier volumes on the total levels of benefit and risk. Decision makers can incorporate their preferences by studying the different levels of tradeoff between certainty and benefit. The decision makers have the option to generate a portfolio volume mix for any point on the Pareto curve (Figure 9).
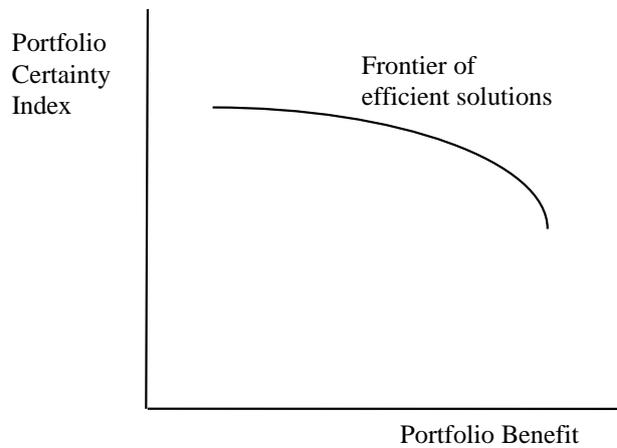

Figure 9: Pareto optimum: Tradeoff between benefit and certainty

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                    ┌─────────────────┐
                    │  Optimization   │
                    └────────┬────────┘
              ┌──────────────┴──────────────┐
   ┌──────────────────┐          ┌──────────────────────┐
   │ Category         │          │ Portfolio            │
   │ (Single Segment) │          │ (Multiple segment,   │
   │                  │          │ Hierarchical)        │
   └────────┬─────────┘          └──────────┬───────────┘
      ┌─────┴──────┐                  ┌──────┴───────┐
┌───────────┐ ┌──────────┐   ┌───────────────┐ ┌───────────────┐
│ Optimize  │ │ Optimize │   │ Optimize      │ │ Optimize      │
│ Benefit   │ │ Certainty│   │ Benefit       │ │ Certainty with│
│           │ │          │   │ with Certainty│ │ Benefit       │
│           │ │          │   │ Constraint    │ │ Constraint    │
└───────────┘ └──────────┘   └───────────────┘ └───────────────┘
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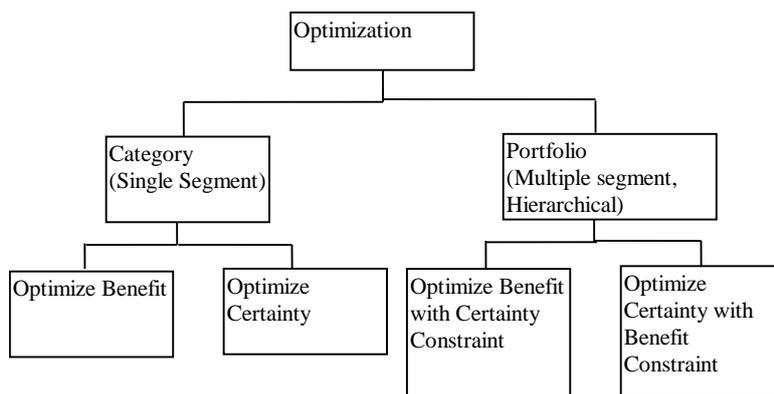
Figure 10: Optimization options available to decision makers

The method can do two types of optimization, single level (for one segment) and hierarchical (for all segments) as shown in Figure 10.

A single level optimization is done for one category or segment at a time. In single level optimization the current volume level of each category is optimally reallocated among its suppliers. The decision makers can run a single level optimization for every category and they can generate a volume mix that maximizes the benefit of that category. They have also the option to run the single level optimization for each category to generate the certainty optimizing volume mix.

In hierarchical optimization all the categories are considered as a portfolio and a benefit maximizing volume mix is generated which meets the desired level of risks. The organization wide available volume is allocated among all the categories and for every category among its component suppliers so as to maximize the portfolio benefit while meeting a preferred level of portfolio certainty index. Similarly the decision makers can generate a volume mix for the whole portfolio that maximizes portfolio certainty for a preferred level of portfolio benefit index.

In a real world situation the managers are most commonly interested in maximizing the profits (benefits) while taking minimum risks. In our case study with Shell Chemicals Europe we had learnt that the decision makers were most interested in maximizing profits, reliability, security and safety aspects. Therefore, the type of optimization that the managers will perform most often is the hierarchical benefit maximization with a certainty constraint.

3.3.1 Post Optimization analysis with input allocations:

The optimization approach will have the ability to perform post optimization analysis. The managers can choose an input allocation scenario and see the impact on the effectiveness of the whole portfolio. For example they can unselect some or all the suppliers in a particular category, and see how the benefit and the certainty of the portfolio varies. This helps them in targeting any suppliers that are good candidates for elimination.

3.3.2 Examples of post optimization analysis:

Managers can choose allocations for some of the input variables and see the results by performing some interactive 'what-if' input allocation scenarios. Suppose that the decision makers had organized the portfolio according to Kraljic's (1983) portfolio management technique and had divided the suppliers into three categories namely leverage, strategic and bottleneck, then they can run 'what-if' type input allocation scenarios like:
–   Reduce all bottleneck suppliers to minimum volume.
–   Eliminate all bottleneck suppliers
–   Go for a maximum volume on all leverage suppliers
–   Go for a maximum volume on some selected suppliers
–   Eliminate some selected suppliers
–   In turn give each category its maximum volume and let the other categories divide the balance to achieve best benefit.

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4 Mathematical Model

Acclaimed criteria (Lilien et al 1992) for a sound mathematical model are :

– **Theoretical Soundness**: Is there an empirical and theoretical reason to believe a model should have certain characteristics.
– **Descriptive Soundness:** Does the model fit the data well, in essence this criterion addresses the question of goodness of fit to historical and judgmental data.
– **Normative Soundness:** Two models may fit equally well, but one may produce normative suggestions that are unreasonable. Therefore, a third criterion for model form selection deals with finding a model that produces decision-making guidelines that are believable.

Although managers in general tend to use the models like a black box and they are concerned only with the inputs of the model and interested in the outputs, we presented this model to a group of practitioners in logistics and they agreed with the theoretical soundness of the model. The descriptive soundness of a model can be measured by calculating the goodness of fit coefficient. Goodness of fit coefficient can give some degree of evidence about the consistency of data elicited from the experts. The value of a model is determined by the quality and accuracy of its input data; and the quality and accuracy of input data is directly proportional to the quality and experience of the model users. The normative soundness can be validated through a successful case study.

Before the description of the mathematical model a list of symbols used in the model appears in Table 1.

Symbol	Description
σ	Scaling factor for the portfolio certainty model
α_m	Scaling factor for category m benefit model
δ_m	Certainty elasticity of the category m
θ_m	Scaling factor for category m certainty model
β_{mn}	Benefit elasticity of the supplier n in the category m
γ_{mn}	Certainty elasticity of the supplier n in the category m
C_{index}	Portfolio Certainty Index
C_{limit}	Preferred minimum limit of portfolio certainty index
C_m	Certainty of category m
m	Number of supplier categories in the portfolio
s_m	number of suppliers in the category m
B_m	Benefit of category m
B_{port}	Portfolio Benefit
V_{mn}	Volume of the supplier n in the category m
V_{mn}^{max}	Maximum Volume level of supplier n in the category m
V_{mn}^{min}	Minimum Volume level of supplier n in the category m
u_{global}	Total available Volume for the whole portfolio
u_i	Volume of category i, where i =1 to m
u_m	Volume of category m
u_m^{max}	Maximum Volume of category m
u_m^{min}	Minimum Volume of category m

Table 1: Symbols used in the mathematical model

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If m is the total number of categories in the portfolio and p_m is the number of suppliers in the category m then the Benefit R_m of the category m is given by the Cobb Douglas (Douglas, 1976) response function:

$$B_m = \alpha_m V_{m1}^{\beta_{m1}} V_{m2}^{\beta_{m2}} \cdots V_{ms_m}^{\beta_{ms_m}}$$

$$= \alpha_m \prod_{n=1}^{s_m} V_{mn}^{\beta_{mn}} \qquad (1.1)$$

where:

Benefit elasticity is defined as the percent change in the benefit of a supplier for a percent increase in supplier volume.

$$\text{benefit elasticity} = \frac{\partial benefit}{benefit} \cdot \frac{volume}{\partial volume}$$

The benefit elasticities of the suppliers are estimated by capturing the historical data, supplier profiles data from questionnaires and interviews and the knowledge of the experts / managers.

The equation (1.1) is the standard Cobb Douglas response function. It is non linear in parameters but can be linearized:

$$B_m = \alpha_m \prod_{n=1}^{s_m} V_{mn}^{\beta_{mn}}$$

$$= \alpha_m V_{m1}^{\beta_{m1}} V_{m2}^{\beta_{m2}} \cdots V_{ms_m}^{\beta_{ms_m}}$$

$$LnB_m = Ln\alpha_m + \beta_{m1} LnV_{m1} + \beta_{m2} LnV_{m2} + \cdots + \beta_{ms_m} LnV_{ms_m}$$

(where Ln = Natural Logarithm)

In this linearized form a multiple regression algorithm can be used to calibrate the parameters (scaling factor and elasticities) of the benefit response function. The equation (1.1) is also called the constant elasticities model.

Similarly the certainty C_m of the category m is given by:

$$C_m = \theta_m \prod_{n=1}^{s_m} V_{mn}^{\gamma_{mn}}$$

The benefit of the whole portfolio of the organization B_{port} is defined as the sum of the benefit of all the categories in the portfolio:

$$B_{port} = \sum_{i=1}^{m} B_i$$

The portfolio certainty index is defined as:

$$C_{index} = \sigma u_1^{\delta_1} u_2^{\delta_2} \cdots u_m^{\delta_m}$$
$$= \sigma \prod_{n=1}^{m} u_n^{\delta_n}$$

4.1 Objective Function for maximizing category Benefit

The objective function to maximize the benefit of category m consisting of pm suppliers for a fixed category volume level um will be:

$$\underset{V_{m1} \cdots V_{mn}}{Max} B_m = \alpha_m \prod_{n=1}^{s_m} V_{mn}^{\beta_{mn}}$$

Subject to the constraints :

$$V_{mn}^{\min} \leq V_{mn} \leq V_{mn}^{\max}$$

$$\sum_{n=1}^{s_m} V_{mn} = u_m$$

where:

$$\alpha_m > 0$$
$$V_{mn}^{\max} \geq V_{mn}^{\min} > 0$$

4.2 Objective Function for maximizing category Certainty

The objective function to maximize the certainty of category m consisting of pm suppliers for a fixed category volume level um will be:

$$\underset{V_{m1} \cdots V_{mn}}{Max} C_m = \theta_m \prod_{n=1}^{s_m} V_{mn}^{\gamma_{mn}}$$

Subject to the constraints :

$$V_{mn}^{\min} \leq V_{mn} \leq V_{mn}^{\max}$$

$$\sum_{n=1}^{s_m} V_{mn} = u_m$$

where:

$$\theta_m > 0$$
$$V_{mn}^{\max} \geq V_{mn}^{\min} > 0$$

4.3 Objective Function for Hierarchical Optimization

The problem is to maximize the benefit of the portfolio subject to a preferred level of portfolio certainty index for a fixed portfolio volume. The objective function of this problem is:

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$$\underset{u_1 \cdots u_m}{Max} B_{port} = \sum_{i=1}^{m} \hat{B}_i(u_i)$$

Subject to the constraints :

$$u_i^{min} \le u_i \le u_i^{max}$$

$$\sum_{i=1}^{m} u_i = u_{global}$$

$$\sigma \prod_{i=1}^{m} u_i^{\delta_i} \ge C_{limit}$$

Where:

$$\sigma \ge 0$$

$$u_i^{max} \ge u_i^{min} > 0$$

$$\sum_{i=1}^{m} u_i^{min} \le u_{global} \le \sum_{i=1}^{m} u_i^{max}$$

$\hat{B}_i(u_i)$ is the optimal value of $B_i(u_i)$

and is obtained by solving the following for each category CAT i for

$i = 1,...,m$:

$$\underset{V_{i1} \cdots V_{in}}{Max} B_i = \alpha_i \prod_{n=1}^{s_i} V_{in}^{\beta_{in}}$$

Subject to the constraints :

$$V_{in}^{min} \le V_{in} \le V_{in}^{max}$$

$$\sum_{n=1}^{s_i} V_{in} = u_i$$

where:

$$\alpha_i > 0$$

$$V_{in}^{max} \ge V_{in}^{min} > 0$$

$$\sum_{n=1}^{s_i} V_{in}^{min} \le u_i \le \sum_{n=1}^{s_i} V_{in}^{max}$$

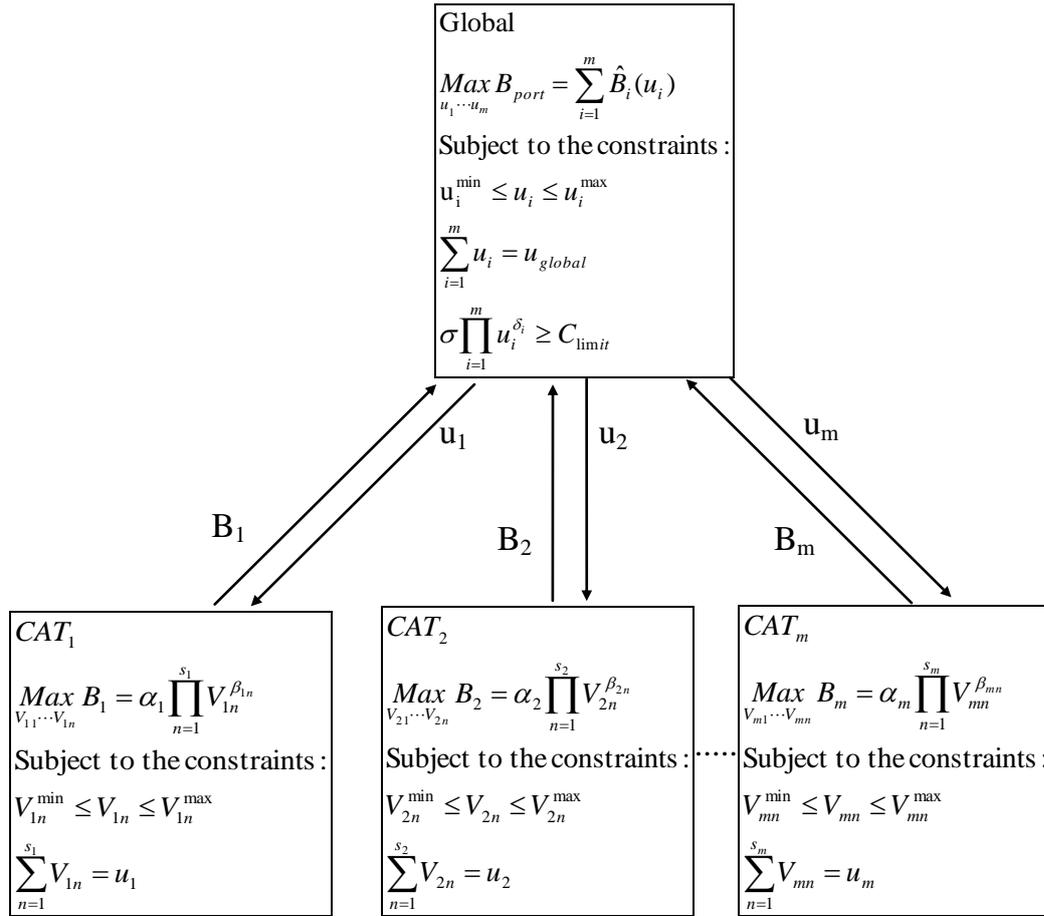Figure 11 represents the hierarchical optimization model schematically.

Figure 11: Schematic representation of the hierarchical optimization model

5 Conclusions

The main contribution of this paper is in the proposal of an original method to tackle the supplier portfolio selection and volume allocation problem. The proposed method can optimize a hierarchical multi segment portfolio. The decision makers can allocate the total volume among all the categories and for any category among its suppliers such that the benefit is maximized within a preferred level of risk while local (category / segment) and global (portfolio) volume constraints are upheld. The main benefit of this method is its practical, problem solving power achieved by overcoming the shortcomings in the existing methods. It allows the decision makers to study the degree and direction of change in the portfolio effectiveness (benefits and risks) by varying the volume level on the selected suppliers and to do post optimization analysis with input allocation scenarios. The method is applicable to hierarchical or multi segment portfolios.

The proposed method is grounded in traditional operations research techniques which have been extended in a novel way to cope with the volume allocation problem within the supplier selection activity of an organization. Elasticity estimates have been successfully applied to summarize the effect of marketing mix variables on retail sales. This is the first proposal that applies the effect of elasticity estimates to supplier volume allocation outcomes. To our knowledge there is no other system or method reported in the literature that allows the decision makers to study the effect of varying volume levels on the overall outcome of the supplier portfolio and treats conflicting criteria such as benefit and risks in a hierarchical portfolio.

The proposed method is complete as it encompasses: conceptual framework to solve the problem, mathematical models to structure the problem, guidelines and instructions about what needs to be done in order to

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use the methodology, explanations of the application of the method from start to finish and advice about how to interpret the results.

The future work in this research is to develop a software tool to support the method. Once we have developed the software tool we will conduct a case study to help the managers to apply our methodology. It is planned that more useful feedback will be generated by the interactive and iterative participation of the managers which will enable us to further refine our proposed method.

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