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# Solving a stochastic demand multi-product supplier selection model with service level and budget constraints using Genetic Algorithm

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ABSTRACT

This study presents a stochastic demand multi-product supplier selection model with service level and budget constraints using Genetic Algorithm. Recently, much attention has been given to stochastic demand due to uncertainty in the real world. Conflicting objectives also exist between profit, service level and resource utilization. In this study, the relationship between the expected profit and the number of trials as well as between the expected profit and the combination of mutation and crossover rates are investigated to identify better parameter values to efficiently run the Genetic Algorithm. Pareto optimal solutions and return on investment are analyzed to provide decision makers with the alternative options of achieving the proper budget and service level. The results show that the optimal value for the return on investment and the expected profit are obtained with a certain budget and service level constraint.


## 1. Introduction

Both Genetic Algorithms (GAs) and Supply Chain Management (SCM) are relatively new research areas that capture the interest of many researchers due to their significant contributions. A GA is a promising search technique which based on the mechanics of natural selection and natural genetics. Holland (1975) and his team applied their understanding of the adaptive processes of natural systems to design software for creating artificial systems that retained the robustness of natural systems. During the last decade, GA has been commonly used to solve complex-structured global optimization problems with many variables. Khouja, Michalewicz, and Wilmot (1998) studied the application of GA for solving lot-sizing problems. Poulos, Rigartos, Tzafestas, and Koukos (2001) derived a Pareto-optimal GA for warehouse optimization. Aytug, Khouja, and Vergara (2003) made a review of using GA to solve production and operations management problems. Altiparmak, Gen, Lin, and Paksoy (2006) used a GA approach to optimize supply chain networks with various constraints and constant demand. Liao and Rittscher (2007) developed a multi-objective supplier selection model under normal distribution demand and lead time. Ha and Krishnan (2008) used a hybrid approach to supplier selection and order allocation for the maintenance of a competitive supply chain. Demirtas and Ustun (2008) used an analytic network process and a mixed integer linear programming for supplier selection decisions.

In supply chain, the importance of a single order problem has been increasing due to the shortening life cycle of products for the recent years. Hadley and Whitin (1963) derived a constrained multi-item problem in a single period. Khouja (1995) developed a newsboy model in which multiple discounts are used to sell excess inventory. Khouja and Mehrez (1996) extended Khouja's model (1995) to consider multi-items. Lau and Lau (1996) derived a capacitated multi-product single period inventory model.

In this study, a supplier selection for a single buyer with multi-product and stochastic demand in a single period considering service level and budget constraints is developed using GA. This paper is organized as follows: a mathematical model with various constraints is derived in Section 2. The GA solution procedure is illustrated in Section 3. A numerical example and sensitivity analysis are carried out in Sections 4 and 5. Finally, concluding remarks are given in Section 6.

## 2. Mathematical modeling and analysis

The mathematical model in this paper is developed based on the following assumptions:

(a) A multi-supplier, single buyer and multi-product with service level and budget constraints are assumed.
(b) Each product is supplied only by a single supplier.
(c) The production rate of each supplier is instantaneous.

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(d) A stochastic demand with a known probability density function for each product is assumed.
(e) Shortage is allowed.
(f) A single period with a salvage value at the end of the selling season is considered.
(g) Fixed cost is neglected.

The following notation is used:

$x_j$ stochastic demand of product $j$, $j = 1, 2, 3, \ldots, n$
$f_j(x_j)$ demand's probability density function for product $j$
$a_j$ demand's lower bound for product $j$
$b_j$ demand's upper bound for product $j$
$P_{ij}$ selling price per unit of product $j$ supplied by supplier $i$
$Q_j$ order quantity of product $j$
$C_{ij}$ purchase cost per unit of product $j$ by supplier $i$
$Y_{ij}$ {1, if product $j$ is supplied by supplier $i$; 0, else}
$L_{ij}$ salvage value of product $j$ supplied by supplier $i$ at the end of the selling season
$S_{ij}$ shortage cost per unit of product $j$ supplied by supplier $i$
S.L. service level
ROI return on investment
EP expected profit

The study is illustrated by Fig. 1.

The purchase cost (PC) is

$$PC = \sum_{i=1}^{m}\sum_{j=1}^{n} C_{ij}Q_jY_{ij} \quad (1)$$

The shortage cost (SC) is

$$SC = \sum_{i=1}^{m}\sum_{j=1}^{n} Y_{ij}S_{ij}\int_{Q_j}^{b_j}(x_j - Q_j)f_j(x_j)dx_j \quad (2)$$

The salvage value (SV) is

$$SV = \sum_{i=1}^{m}\sum_{j=1}^{n} Y_{ij}L_{ij}\int_{a_j}^{Q_j}(Q_j - x_j)f_j(x_j)dx_j \quad (3)$$

The expected sales revenue (SR) is

$$SR = \sum_{i=1}^{m}\sum_{j=1}^{n} Y_{ij}P_{ij}\left[\int_{Q_j}^{b_j} Q_jf_j(x_j)dx_j + \int_{a_j}^{Q_j} x_jf_j(x_j)dx_j\right] \quad (4)$$

The expected profit (EP) is the sum of the sales revenue and salvage value, minus the purchase and shortage costs. That is

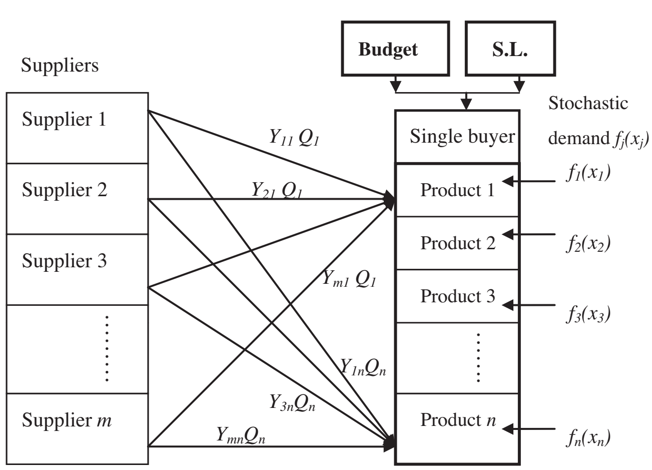

**Fig. 1.** An illustration of the supplier selection model.

$$\begin{aligned} EP = &\sum_{i=1}^{m}\sum_{j=1}^{n} Y_{ij}P_{ij}\left[\int_{Q_j}^{b_j} Q_jf_j(x_j)dx_j + \int_{a_j}^{Q_j} x_jf_j(x_j)dx_j\right] \\ &- \sum_{i=1}^{m}\sum_{j=1}^{n} C_{ij}Q_jY_{ij} - \sum_{i=1}^{m}\sum_{j=1}^{n} Y_{ij}S_{ij}\int_{Q_j}^{b_j}(x_j - Q_j)f_j(x_j)dx_j \\ &+ \sum_{i=1}^{m}\sum_{j=1}^{n} Y_{ij}L_{ij}\int_{a_j}^{Q_j}(Q_j - x_j)f_j(x_j)dx_j \end{aligned} \quad (5)$$

The problem of this study is a nonlinear programming subject to service level and budget constraints. That can be stated as follows:

$$\text{Maximize} \quad EP = EP(Q_j, Y_{ij}) \quad (6)$$

$$\text{Subject to} \quad \int_{a_j}^{Q_j} f_j(x_j)dx_j \geqslant \text{minimum S.L. required}, \quad j = 1, 2, 3, \ldots, n, \quad (7)$$

$$\sum_{i=1}^{m}\sum_{j=1}^{n} C_{ij}Q_jY_{ij} \leqslant \text{available budget} \quad (8)$$

$$\sum_{i=1}^{m} Y_{ij} = 1 \quad (9)$$

$$Y_{ij} = \{1, \text{ if product } j \text{ is supplied by supplier } i;\ 0, \text{ else}\} \quad (10)$$

$$Q_{ij} \geqslant 0 \quad (11)$$

Eq. (7) shows the actual service level of product $j$ when $Q_j$ is ordered. The constraint in Eq. (9) ensures that each product is supplied only by a single supplier. The number of variables in Eq. (6) is $mn + n$.

## 3. Genetic Algorithm solution procedure

Using a direct analogy to this natural evolution, GA presumes a potential solution in the form of an individual that can be represented by strings of genes. Throughout the genetic evolution, some fitter chromosomes tend to yield good quality offspring which are inherited from their parents through reproduction.

This study derives the number of deliveries per period to minimize the total cost. The objective function is EP($Q_j$, $Y_{ij}$) with decision variables $Q_j$ and $Y_{ij}$. The GA deals with a chromosome of the problem instead of decision variables. The values of $Q_j$ and $Y_{ij}$ can be determined by the following GA procedures:

(a) *Representation*: Chromosome encoding is the first problem that must be considered in applying GA to solve an optimization problem. In here, phenotype chromosome could represent a real numbers and an integer numbers. For each chromosome, the real numbers or integer numbers representation are used as follows:

$$x = (Q_j, Y_{ij}), \quad i = 1, 2, 3, \ldots, m,\ j = 1, 2, 3, \ldots, n$$

(b) *Initialization*: Generate a random population of $n$ chromosomes (which are suitable solutions for the problem), where $n = 70$.
(c) *Evaluation*: Assess the fitness EP($x$) of each chromosome $x$ in the population.
(d) *Selection schemes:* Select two parent chromosomes from a population based on their fitness using a roulette wheel selection technique, thus ensuring high quality individuals has a higher chance of becoming parents than low quality individuals.
(e) *Crossover*: Approximately 40% crossover probability exists, indicating the probability that the parents will cross over to form new offspring. If no crossover occurs, the offspring are the exact replicas of the parents.