asor

BULLETIN

ISSN 0812-860X

VOLUME 28 NUMBER 2 June 2009

Editor: Ruhul A Sarker

Published by:
THE AUSTRALIAN SOCIETY FOR OPERATIONS RESEARCH INC.
Registered by Australia Post - PP 299436/00151. Price $5.00

The Australian Society for Operations Research Incorporated

Operations Research is the application of the methods of science to complex problems arising in the direction and management of large systems of men, machines, materials and money in industry, business government and defence. The distinctive approach is to develop a scientific model of the system, incorporating measurements of factors such as chance and risk, with which to predict and compare the outcomes of alternative decisions, strategies or controls. The purpose is to help management determine its policy and actions scientifically.

ISSN 0812-860X Publisher: The Australian Society for Operations Research Inc.
Place of Publication: Canberra, Australia Year of Publication: 2009

Editorial

In this issue, S. Jain and K. Lachhwani have contributed a technical paper on *An Algorithm for Multi-objective Linear plus Fractional Program*. In addition, N. H. Shah has contributed a paper on *Vendor's Optimal Policy for Time-Dependent Deteriorating Inventory with Exponentially Decreasing Demand and Partial Backlogging*. D. Tengku has prepared a general note on *Choosing the Right Tool for Business and Engineering Improvements*. We are delighted to be publishing them here for the Bulletin readers. The information on 2009 ASOR conference is also provided. Hope to see you in the conference.

I am pleased to inform you that the electronic version of ASOR Bulletin is now available at the ASOR national web site: http://www.asor.org.au/. Currently, the electronic version is prepared only as one PDF. We like to thank our web-master Dr Andy Wong for his hard work in redesigning and smoothly managing our national web site. Your comments on the new electronic version, as well as ASOR national web site, is welcome.

ASOR Bulletin is the only national publication of ASOR. I would like to request all ASOR members, ASOR Bulletin readers and OR organizations in the country to contribute to the ASOR Bulletin. The editorial policy is available either from the Bulletin web site or from the inside back cover of the Bulletin. The detailed instructions for preparing the manuscripts is available in the URL: http://www.asor.org.au/.

Address for sending contributions to the ASOR Bulletin:

A/Prof. Ruhul A Sarker
Editor, ASOR Bulletin
School of ITEE, UNSW@ADFA
Northcott Drive, Canberra 2600
Australia
Email: r.sarker@adfa.edu.au

ASOR Bulletin
Volume 28, Number 2, June 2009, pp.2-8
ISSN0812-860X | eISSN1446-6678

An Algorithm for Multi-objective Linear plus Fractional Program

Sanjay Jain[a] and Kailash Lachhwani[b]

[a]Department of Mathematical Sciences, Government College, Ajmer, Ajmer-305 001, India.
E-mail: drjainsanjay@gmail.com
[b]Department of Mathematics, Government Engineering College, Bikaner, India

Abstract
In this paper, we develop an algorithm to solve multiobjective linear plus fractional program (MOL+FP) i.e. $f(X)+\frac{g(X)}{h(X)}$ by converting MOL+FP program into fuzzy programming problem. The algorithm works for the minimization of the perpendicular distances between the parallel hyper planes at the optimum points of the objective functions. A compromise optimum solution is obtained as a result of minimization of supremum perpendicular distance. Suitable membership function has been defined as a supremum perpendicular distance. Numerical example has been considered to support the developed algorithm.

Key words: Multiobjective Linear plus Fractional program, Distance function, Membership function.

1. Introduction
Real world decision making problem are generally of multiobjective in nature which had been well recognized by operational researchers. They have discussed different approaches to tackle multiobjective programming problems. The development of approaches in this field has been traced out by Roy (1971), Mac Crimmon (1973), Starr and Zeleny (1979), and Hwang and Masud (1979) are only a few examples.

They examined three approaches to multicriteria optimization. These are:
1. Additive weighting of the attributes.
2. Goal programming using the L_1-norm $\|d\|_1 = \sum_{i=1}^{r}|d_i|$ as a measure of the weighted deviations from the targets sets, and
3. Goal programming using the $L_\infty - \text{norm}$ $\|d\|_\infty = \max_{i=1,2,..r}|d_i|$ as a measure of the weighted deviations from the goals (MINMAX goal programming).

But the criteria involved in MCDM are often fuzzy in nature. The concept of decision making in fuzzy environment has been introduced by Bellman and Zadeh (1970). Since then many other research workers used and / or modified the concept of real world decision making problems. Example may be cited as Wallenius (1975), Zimmermann (1978,1981), Yager (1979), Hanan (1981), Narasimhan (1980), Rubin and Narasimhan (1981), Ying-Yung (1983), Feng (1983), Luhandjula (1984), Chanas (1989), Rommelfanger (1989), Dutta et. al (1992), Gupta and Chakraborty (1997, 2002) Stancu Minasian (2003), Cabeller et. al (2004) and Jain et al (2006). Wallenius (1975) investigated on comparative evaluation of some interactive approaches to multicriteria optimization. Zimmermann (1978) developed fuzzy mathematical programming to solve the problems with several objective functions and discussed for both equivalent and non equivalent objectives. Mathematical programming with fuzzy constraints and preference on the objectives was developed by Yager (1979). Hanan (1981) focused on the efficiency of the product operator in fuzzy programming with multiple objectives and developed the linear programming model for multiple goals. Narasimhan (1980) in one of his paper discussed goal programming in fuzzy environment. In another paper Rubin and Narasimhan (1981) investigated on the fuzzy goals and their priorities. Feng (1983) considered a vector maximum problem and solved using fuzzy mathematical programming to solve multiobjective linear programming. Luhandjula (1984) used a linguistic variable approach in order to present a procedure for solving multiple objective fractional programming problems. Rommelfanger (1989) investigated on the fuzzy linear optimization problems with several objectives and suggested an approach for interactive decision making in fuzzy environment.

Later Dutta et. al (1992) modified the linguistic approach of Luhandjula (1984) such as to obtain efficient solution to problem. Gupta and Chakraborty (1997, 2002) used fuzzy mathematical programming approach to solve multiobjective linear fractional programming problems (MOLFPP). Stancu- Minasian et. al (2003) pointed out certain short coming in the work of Dutta et. al (1992) and gave the correct proof of the theorem which validates the obtaining of the efficient solutions under certain hypothesis. Caballero et. al (2004) gave the controlled estimation method for multiobjective fractional programming problems. Jain et. al (2006) discussed solution of multiobjective fractional programming problems in which objective functions are in the form of sum of the linear function and fractional function.

A multiobjective linear plus fractional program (MOL+FP) seeks to optimize more than one objective functions in the form $f(X)+\dfrac{g(X)}{h(X)}$ i.e. sum of linear function and a ratio of two linear functions of non-negative variables subject to linear constraints under the assumption that the set of feasible solutions is a convex polyhedral with a finite number of extreme points and that the denominator of the objective functions is non-zero on the constraint set. The present paper deals with a solution procedure for vector maximum MOL+FP problems. The standard MOL+FP model has been reduced to fuzzy programming model. The methodology has been developed to minimize the perpendicular distance between two hyper planes $\mathrm{Z_i(X)} = \overline{Z_i}$ and $\mathrm{Z_i(X)} = \underline{\mathrm{Z_i}}$ where $\overline{Z_i}$ and $\underline{\mathrm{Z_i}}$ are the maximum and minimum values of the function $\mathrm{Z_i(X)}$ in the feasible region. The fuzzy model has been developed by defining suitable membership functions. Using fuzzy parameters, maximization of the fuzzy parameters affects the minimization of the perpendicular distances. As a result the value of the objective functions converges to a point close to ideal point and a compromise optimum solution is obtained. The present method has significant importance for this particular case.

The paper is organized as follows: In section 2, we discuss the problem MOL+FP and associated symbols and notations. In section 3, we give the proposed solution algorithm of MOL+FP. An example is considered in the section 4 and concluding remark, strengths and weaknesses of algorithm and particular cases of methodology are discussed in consequently in last section.

2. The Problem

The general MOL+F program may be formulated as:

$$\text{Max } \{Z_1(X), Z_2(X), \ldots\ldots\ldots\ldots, Z_k(X)\} \qquad \ldots(1)$$

where $$Z_i(X) = (L_i X + l_{0i}) + \frac{C_i X + c_{oi}}{D_i X + d_{oi}} \qquad \forall\ i = 1, 2, \ldots\ldots., k$$

subject to, $AX = b$

and $X \geq 0$

Here L_i, C_i and D_i $(i = 1, 2, \ldots\ldots, k)$ are row vectors with n-components. X and b are column vectors with n and m components respectively; A is m by n matrix and c_{oi}, d_{oi} $(i = 1, 2, \ldots\ldots, k)$ are scalars. It is assumed that $D_i X + d_{oi} > 0$ over L where $\mathrm{L} = \{X : AX = b,\ X \geq 0\}$.

3. Solution of Multiobjective Linear plus Fractional Program

In this section, we propose fuzzy programming approach with defining suitable membership function for multiobjective linear plus fractional program (MOL+FP). Firstly we define the distance function d with unit weight as

$$d_i(X) = \left|\overline{Z_i} - Z_i(X)\right| \qquad \forall\ i = 1, 2, \ldots\ldots., k \qquad \ldots(2)$$

$\overline{Z_i}$ is the maximum value of $Z_i(X)$,i.e. it is the distance from X to the hyper plane $\overline{Z_i} = Z_i(X)$ .This distance depends upon X. At X $= \overline{X}$ (ideal point in X-space), d = 0 and at $X = \underline{X}$ (nadir point in X-space), $Z_i(X) = \underline{Z_i}$, we get the maximum value of $d_i(X)$ as

$$\overline{d_i} = \left|\overline{Z_i} - \underline{Z_i}\right| \quad \forall\ i = 1, 2, \ldots.., k \qquad \ldots(3)$$

Treating this criterion involved to be of equal importance, the vector maximum problem (1) may be modeled as follows:

Find an action X$\in S$

Which minimizes Max $\left\{\left|\overline{Z_i} - Z_i(X)\right|,\ i = 1, 2, \ldots, k\right\}$ …(4)

where L=$\{X : AX = b,\ X \geq 0\}$

We define the membership $\mu_i\left(d_i\left(\mathrm{X}\right)\right)$ as follows:

$$\mu_i\left(d_i\left(\mathrm{X}\right)\right) = \begin{cases} 0 & if\ \mathrm{d}_i\left(\mathrm{X}\right) \geq p \\ \dfrac{p - d_i\left(\mathrm{X}\right)}{p} & if\ 0 < d_i\left(\mathrm{X}\right) < p \\ 1 & if\ \mathrm{d}_i\left(\mathrm{X}\right) \leq 0 \end{cases}$$

Where $p = \sup\left\{\overline{d_i}\right\} \quad \forall \quad i = 1, 2, 3, \ldots\ldots., k$

If λ be the minimum of all $\mu_i\left(d_i\left(\mathrm{X}\right)\right)$, then

$$\mu_i(d_i(X)) \geq \lambda \qquad \forall \quad i = 1, 2, 3, \ldots\ldots., k$$

i.e. $\overline{Z_i} - Z_i(\mathrm{X}) \leq -p\lambda + p$

$$-\left(L_i X + l_{0i}\right)(D_i X + d_{oi}) - (C_i X + c_{oi}) + \overline{Z_i}(D_i X + d_{oi}) \leq (-p\lambda + p)(D_i X + d_{oi})$$

Now the problem reduces to

$$\text{Max}\,\lambda$$

subject to, $-\left(L_i X + l_{0i}\right)(D_i X + d_{oi}) - (C_i X + c_{oi}) + \overline{Z_i}(D_i X + d_{oi})$

$$\leq (-p\lambda + p)(D_i X + d_{oi}) \quad \forall\ i = 1, 2, \ldots.., k$$

$$AX = b$$

and $X \geq 0 \quad \forall\ i = 1, 2, \ldots\ldots., k$ …(5)

which is a non-linear programming problem and can be solved by non-linear techniques.

4. Numerical Example

To support our method, we illustrate the following example.

$$\text{Maximize } \{Z_1(X), Z_2(X)\}$$

where $Z_1(X) = 2x_1 + \dfrac{2x_1 + 6x_2}{x_1 + x_2 + 1}$ and $Z_1(X) = (x_1 + x_2) + \dfrac{x_1 + x_2}{x_1 - x_2 + 1}$

subject to, $x_1 + 2x_2 + 3x_3 = 15$

$$2x_1 + x_2 + 5x_3 \quad = 20$$
$$x_1 + 2x_2 + x_3 + x_4 = 10$$
and $$x_1,\ x_2,\ x_3,\ x_4 \geq 0$$

using the fractional programming techniques used by Gupta and Chakraborty (1997,2002) with using theoretical concept given by Jain et. al (2006) to solve the above problem with individual objective functions respectively, we obtain individual optimal solution as :

$$Max\ Z_1 = 8.3333 \text{ with } x_1 = \frac{5}{2},\ x_2 = \frac{5}{2},\quad x_3 = \frac{5}{2},\ \ x_4 = 0$$

with $Max\ Z_2 = 10 \text{ with } x_1 = \frac{5}{2},\ x_2 = \frac{5}{2},\quad x_3 = \frac{5}{2},\ \ x_4 = 0$.

Now we proceed with our proposed method.

Step 1. Calculating $\overline{d_i} = \left|\overline{Z_i} - \underline{Z_i}\right| \quad \forall\ i = 1,2,.....,k$

$$\overline{d_1} = \left|\overline{Z_1} - \underline{Z_1}\right| = 8.3333$$
$$\overline{d_2} = \left|\overline{Z_2} - \underline{Z_2}\right| = 10$$

Step 2. $p = \ \sup\ \left\{\overline{d_i}\right\} = 8.3333$

Using proposed methodology, the above MOQFP reduced to following fuzzy model:

$$\text{Max. } \lambda$$
subject to, $$\overline{Z_i} - Z_i(\mathrm{X}) \leq -p\lambda + p$$
i.e.
$$-\left(L_i X + l_{0i}\right)(D_i X + d_{oi}) - (C_i X + c_{oi}) + \overline{Z_i}(D_i X + d_{oi}) \leq (-p\lambda + p)(D_i X + d_{oi})$$
$$\Rightarrow 4.3333x_1 + 2.3333x_2 - 2x_1^2 - 2x_1x_2 \leq -8.3333\lambda$$
$$\Rightarrow 8x_1 - 12x_2 - x_1^2 + x_2^2 \leq -8.3333\lambda - 1.6667$$
$$AX = b$$
$$\Rightarrow x_1 + 2x_2 + 3x_3 \quad = 15$$
$$\Rightarrow 2x_1 + x_2 + 5x_3 \quad = 20$$
$$\Rightarrow x_1 + 2x_2 + x_3 + x_4 = 10$$
and $$x_1,\ x_2,\ x_3,\ x_4,\ \lambda \geq 0$$

Using the non-linear programming techniques, the compromise optimal solution of problem is obtained as: $x_1 = \frac{5}{2},\ x_2 = \frac{5}{2},\quad x_3 = \frac{5}{2},\ \ x_4 = 0,\ \lambda\text{=}1 \text{ with } Z_1^* = \frac{25}{3},\quad Z^*{}_2 = 10$.

which is the best compromise optimal solution since both the objective functions individually optimize at this point and same optimal solution can be obtained if we solve with individual objective functions as explained in tabular form below table 1. This also verifies our proposed methodology.

Objective function	Constraints	Optimal solution
Single objective problem $Z_1(X) = 2x_1 + \dfrac{2x_1 + 6x_2}{x_1 + x_2 + 1}$	$x_1 + 2x_2 + 3x_3 = 15$ $2x_1 + x_2 + 5x_3 = 20$ $x_1 + 2x_2 + x_3 + x_4 = 10$ and $x_1,\ x_2,\ x_3,\ x_4 \geq 0$	$Max\ Z_1 = 8.3333$ with $x_1 = \frac{5}{2},\ x_2 = \frac{5}{2},$ $x_3 = \frac{5}{2},\ x_4 = 0$ Solution with earlier approaches.
Single objective problem $Z_1(X) = (x_1 + x_2) + \dfrac{x_1 + x_2}{x_1 - x_2 + 1}$	$x_1 + 2x_2 + 3x_3 = 15$ $2x_1 + x_2 + 5x_3 = 20$ $x_1 + 2x_2 + x_3 + x_4 = 10$ and $x_1,\ x_2,\ x_3,\ x_4 \geq 0$	$Max\ Z_2 = 10$ with $x_1 = \frac{5}{2},\ x_2 = \frac{5}{2},$ $x_3 = \frac{5}{2},\ x_4 = 0$ Solution with earlier approaches.
Multiobjective problem $Z_1(X) = 2x_1 + \dfrac{2x_1 + 6x_2}{x_1 + x_2 + 1}$ $Z_2(X) = (x_1 + x_2) + \dfrac{x_1 + x_2}{x_1 - x_2 + 1}$	$x_1 + 2x_2 + 3x_3 = 15$ $2x_1 + x_2 + 5x_3 = 20$ $x_1 + 2x_2 + x_3 + x_4 = 10$ and $x_1,\ x_2,\ x_3,\ x_4 \geq 0$	$Max\ Z_1 = 8.3333,\ Z_2 = 10$ with $x_1 = \frac{5}{2},\ x_2 = \frac{5}{2},$ $x_3 = \frac{5}{2},\ x_4 = 0$ Solution with proposed methodology.

Table 1: Different type fractional programming problem with solution

5. Concluding Remarks

Compromise solution depends on the choice of nadir point (lowest justifiable value) of the objective functions as shown in figure 1. Here it is assumed that Z be the ideal point and N and N' be the two different minimum aspiration levels and their compromise solution are P and P' respectively, When the justifiable value changes, the compromise solution also changes. In the figure, if because NZ and N'Z are the direction in which the decision parameter λ maximizes. In our methodology to find minimum aspiration level we have used minimum value of each objective function. This point is the ideal point of the vector minimization problem of the same objective functions with same constraints which generally lies outside the feasible region. Knowing the nadir point (worst point) and zenith point (ideal point) we can find the direction of the decision parameter λ in which λ maximizes. Considering the region by taking the lowest justifiable value each objective function gets equal importance in the optimization process.

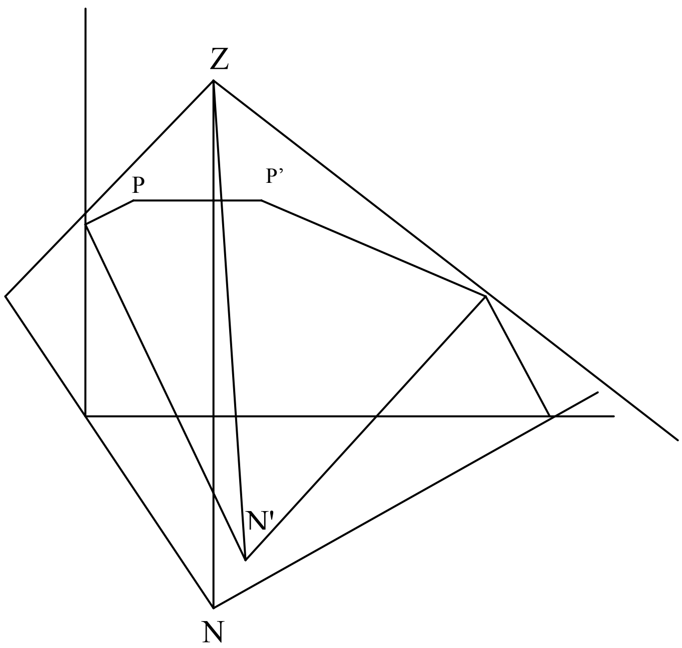


Fig. 1: Representation of compromise solution

6. Strengths and Weaknesses of Proposed Algorithm

The proposed algorithm can become a very powerful tool to solve multi objective linear plus fractional programs because it reduces large computational efforts and complexity in the algorithm in comparison of other existing methods available to solve e.g. method given by Luhandjula (1983) for multi objective linear programming problems. Also the solution, it provides is more efficient solution due to systematical new approach of minimization of perpendicular distances of hyper planes at optimal points, in compared to earlier given procedures.

However, due to use of very basic calculation of distance membership function values, it becomes very tedious in case of large multi objective linear plus fractional programs.

7. Particular Cases

If we take $D_i = 0, \quad \forall\ i = 1, 2, ..., k$ then it reduced into MOLPP. This discussion also holds in this case as given by Gupta and Chakraborty (1997) with weight $\dfrac{1}{\left\{\sum c_{ij}^2\right\}^{1/2}}$ in defining distance function $d_i(\mathrm{X})$.

References

[1] B. Roy. "Problems and Methods with multiple objective functions", Mathematical Programming, Vol. 1, No. 2, Nov., pp. 239-266, 1971.

[2] C.L. Hwang, and A.S. Masud, "Multiobjective Decision making: methods and Applications (A state-of-Art Survey)", Lecture Notes in Economics and Mathematical Systems, Vol. 164, Springer, Berlin, 1979.

[3] Chanas, S, "Fuzzy programming in multi objective linear programming a parametric approach", Fuzzy sets and system, 29, p. 303 – 313, 1989.

[4] D. Dutta, R.N. Tiwari and R. Rao, "Multiple objective linear fractional programming problem- A fuzzy set theoretic approach", Fuzzy sets and systems, 52(1) , 39-45, 1992.

[5] E.L. Hanan, "On the efficiency of the product operator in fuzzy programming with multiple objective," Fuzzy sets and systems, 2, p. 259, 1979.

[6] E.L. Hanan, "Linear programming with multiple goals," Fuzzy sets and systems, 6, p. 235, 1981.

[7] F. Ying – Yung, "A method using fuzzy mathematics to solve vector maximum problem," Fuzzy sets and systems, 9, p. 125, 1983.

[8] H. J. Zimmermann, “Fuzzy programming and linear programming with several objectives function,” Fuzzy sets and systems, 1 p. 45, 1978.
[9] H. J. Zimmermann, “Fuzzy mathematical programming,” Computers & operations research, 4, p. 291 – 298, 1981.
[10] I.M. Stancu- Minasian and B. Pop, “On a fuzzy set approach to solving multiple objective linear fractional programming problems”, Fuzzy sets and systems, 134, 397-405, 2003.
[11] J. Wallenius, “Comparative evaluation of some interactive approaches to multicriteria optimization,” Management science, 21, p. 1387, 1975.
[12] K. R. MacCrimmon, “An overview of multiple objectives Decision Making. In “Multiple Criteria Decision Making”, (J.L. Cochrone and M. Zeleny, Eds.), University of South Caroline Press, Columbia, South Carolina, pp. 18-24, 1973.
[13] M. K. Starr, and M. Zeleny, “MCDM-State and future of the Arts. In Multiple Criteria Decision Making”' (M.K. Starr and M. Zeleny, Eds.), North Holland, New York, pp. 5-29, 1979.
[14] M. K. Luhandjula, “Fuzzy approaches for multiple objective linear fractional optimization”, Fuzzy sets and systems, 13(1) , 11-23, 1984.
[15] M. Chakraborty, and S. Gupta, “Fuzzy mathematical programming for multi objective linear fractional programming problem”, Fuzzy sets and systems, 125. p. 335-342, 2002.
[16] P. A. Rubin and R. Narasimhan, “Fuzzy goal programming with nested priorities,” Michigan state university, 1981.
[17] R. E. Bellmann, and L. A. Zadeh, “Decision making in fuzzy environment”, Management Science 17,p. 141, 1970.
[18] R. R. Yager, “Mathematical programming with fuzzy constraints and preference on the objective,” Kybernates, 8, 1979.
[19] R. Narasimhan, “Goal programming in fuzzy environment,” Decision science, 11, p. 326, 1980.
[20] Rommelfanger, H, “Interactive decision making in fuzzy Linear Optimization problems”, European Journal of Operational Research, 41, p. 210 – 217, 1989.
[21] R. Caballero and M. Hernandez, “The controlled estimation method in multiobjective linear fractional problem”, Fuzzy Sets and systems, 31, p. 1821-1832, 2004.
[22] S. Gupta, and M. Chakraborty, “Multi objective linear programming: A fuzzy programming approach,” International journal of management and system, vol.13, No.2, p. 207 – 214, 1997.
[23] S. Jain, and A. Mangal, “Solution of multiobjective fractional programming problem”, Journal of Indian Academy of Mathematics, Vol. 28, No. 1, p. 133-144, 2006.
[24] Y.J. Feng, “A method using fuzzy mathematical programming to solve vector maximum problem,” Fuzzy sets and systems, 9, p. 129 – 136, 1983.

ASOR Bulletin
Volume 28, Number 2, June 2009, pp9-14
ISSN0812-860X | eISSN1446-6678

Vendor's Optimal Policy for Time-Dependent Deteriorating Inventory with Exponentially Decreasing Demand and Partial Backlogging

Nita H. Shah
Department of Mathematics, Gujarat University, Ahmedabad, Gujarat, India
E. mail : nita_sha_h@rediffmail.com

Abstract
The inventory model for time-dependent deteriorating items with exponentially decreasing demand is formulated. The shortages are allowed and partially backlogged. The backlogging rate is considered to be a variable and is dependent on the waiting time for the next replenishment. The objective is to minimize total cost of an inventory system. A numerical example is considered to support the model and the sensitivity analysis is carried out.

Keywords: Time-dependent deterioration, exponentially decreasing demand, partial backlogging.

1. Introduction
Medicines, chemicals, food-stuff, fashion goods, vegetables and fruits etc deteriorate with passage of time. Pioneered by Ghare and Schrader (1963), the researchers are engaged in developing the inventory models for deteriorating items. The review articles by Nahmias (1982), Shah and Shah (2000) and Goyal and Giri (2001) give up to date citation of the literature published on deteriorating inventory models.

The concept of exponentially decreasing demand for an inventory model was first given by Hollier and Mak (1983). Hariga and Benkherouf (1994) generalized Hollier and Mak (1983)'s model for both exponentially growing and declining markets. Wee (1995a, 1995b) derived a deterministic lot-size model for deteriorating items in which demand decreases exponentially over a fixed time horizon. Later Benkherouf (1998) established that the optimal procedure given by Wee (1995a) is independent of the demand rate. Su et al. (1998) developed a production inventory model for deteriorating items with an exponentially declining demand over a fixed planning horizon.

In the above cited articles, most of the research is done under the assumption that shortages are completely backlogged. However, in practice, some customers would wait for backlogging during the shortage period and some would not. Hence, the opportunity cost due to lost sales should be taken into account while modeling. Wee (1995b) formulated a deteriorating inventory model in which backlogging rate was assumed to be a constant fraction of demand rate during the shortage period. For the vendor dealing with fashionable goods or air lines, the length of waiting time for the next replenishment is the critical factor in determining whether backlogging will be accepted or not. The longer the waiting time is, the smaller the backlogging rate would be and vice-versa. i.e. the backlogging rate is variable and dependent on the waiting time for the next replenishment. Chang and Dye (1999) analyzed an EOQ model when shortages are allowed. During the shortage period, the backlogging rate is dependent on the length of the waiting time for the next replenishment. Ouyang et al. (2005) developed an EOQ model under the assumptions of constant rate of deterioration of units, exponentially decreasing demand and the backlogging rate varying inversely to the waiting time for the next replenishment.

In this paper, an attempt is made to develop an optimal policy for the items which are subject to deteriorate with passage of time. As deterioration of units occurs with time, more likely that vendor faces shortages. Some of the fruits and leafy vegetables loose their utility at the end of the day and so are likely to be lost sales. The demand is exponentially declining and backlogging rate is inversely proportional to the waiting time for the next replenishment. The total inventory cost per time unit is minimized by simultaneously optimizing the time at which shortages starts and the cycle time. A numerical example is considered to support the model and the sensitivity analysis is carried out.

2. Notations and Assumptions

The proposed model is developed with the following notations and assumptions:

2.1 Notations

h : inventory holding cost per unit per time unit
C : purchase cost of an item per time unit
A : ordering cost pr order
π_B : shortage cost per unit short per time unit
π_L : opportunity cost due to lost sales per unit
t_1 : time at which shortages start (decision variable)
T : cycle time (decision variable)
W : the maximum inventory level for each ordering cycle
S : the maximum amount of demand backordered for each ordering cycle
Q : the purchase quantity for each ordering cycle
I(t) : the inventory level at time t, $0 \le t \le T$.

2.2 Assumptions

1. The inventory system deals with single item.
2. The planning horizon is infinite.
3. The replenishment rate is infinite and replenishment is instantaneous.
4. The demand rate, R(t) is known and declines exponentially, i.e.
   $R(t) = \begin{cases} ae^{-bt} & , I(t) > 0 \\ R & , I(t) \le 0 \end{cases}$ where a (> 0) is initial demand and $0 < b < 1$ governs the decreasing rate of demand.
5. The units in inventory deteriorate with respect to time t and follows two parameter weibull distribution (say) $\theta(t) = \alpha\beta t^{\beta-1}$ where $0 < \alpha < 1$ and $\beta > 0$. There is no repair or replacement of deteriorated units during the cycle time. Also $0 < b < \alpha$.
6. During the shortage period, the backlogging rate is variable and is dependent on the length of the waiting time for the next replenishment (Ouyang et al. (2005)). The proportion of the customers who would like to accept backlogging at time t is decreasing with the waiting time (T – t) for the next replenishment. i.e. for the negative inventory, the backlogging rate, $B(t) = \dfrac{1}{1+\delta(T-t)}$ where δ (> 0) denotes backlogging parameter and $t_1 \le t \le T$.

3. Mathematical Model

The one replenishment cycle depicting inventory level due to exponentially decreasing demand, deterioration and partial backlogging is shown in Figure 1.

The cycle starts with maximum inventory level W. The inventory depletes due to demand and deterioration of units during $[0, t_1]$. The inventory reaches to zero at t_1 and thereafter, shortages occur during the time inventory $[t_1, T]$ and it is partially backlogged. The differential equation representing positive inventory level, I(t) at any instant of time t ($0 \le t \le t_1$) is given by

$$\frac{dI(t)}{dt} + \theta(t)I(t) = -\,ae^{-bt}, \quad 0 \le t \le t_1 \tag{3.1}$$

with the initial condition I(0) = W. The solution of the differential equation (3.1) is

$$I(t) = a\left[t_1 - t + \frac{\alpha t_1^{\beta+1}}{\beta+1} - \alpha t_1 t^{\beta} + \frac{\alpha\beta t^{\beta+1}}{\beta+1} - \frac{b}{2}(t_1^2 - t^2) + \frac{\alpha\beta b}{2(\beta+2)}(t_1^{\beta+2} - t^{\beta+2})\right], \ 0 \le t \le t_1 \tag{3.2}$$

Using I(0) = W, the maximum inventory level for a cycle is

$$W = a\left[t_1 + \frac{\alpha t_1^{\beta+1}}{\beta+1} - \frac{bt_1^2}{2} + \frac{\alpha\beta b t_1^{\beta+2}}{2(\beta+2)}\right] \tag{3.3}$$

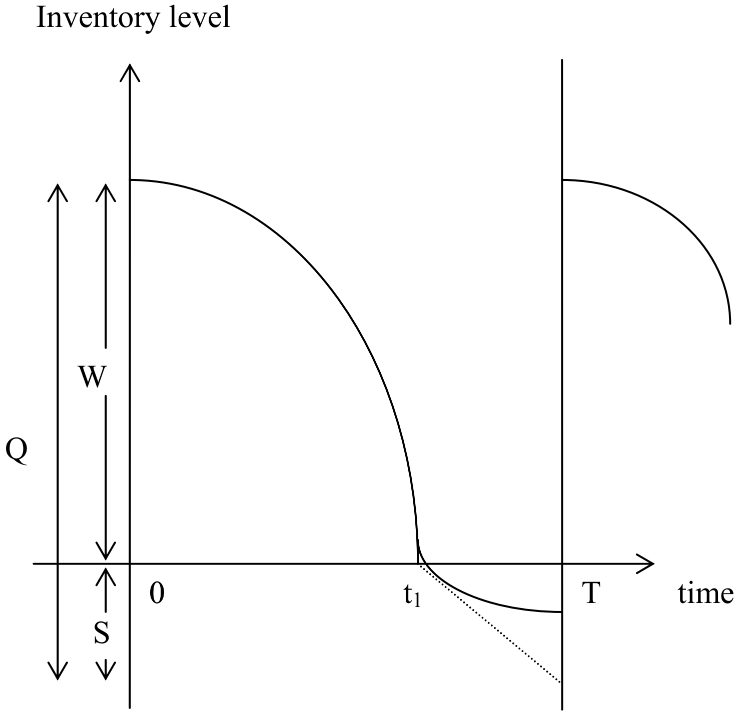


Fig. 1 Inventory – time status

During the shortage period $[t_1, T]$, the state of demand backlogged is governed by the differential equation

$$\frac{dI(t)}{dt} = - \frac{R}{1+\delta(T-t)}, \quad t_1 \le t \le T \tag{3.4}$$

with the boundary condition $I(t_1) = 0$. The solution of differential equation (3.4) is

$$I(t) = \frac{R}{\delta} \{ \ln[1 + \delta(T-t)] - \ln[1 + \delta(T-t_1)] \} \tag{3.5}$$

The maximum amount of demand backlogged per cycle is

$$S = - I(T) = \frac{R}{\delta} \ln[1 + \delta(T - t_1)] \tag{3.6}$$

Hence, the purchase quantity is

$$Q = W + S \tag{3.7}$$

The inventory holding cost per cycle is

$$IHC = h \int_0^{t_1} I(t)\, dt$$

$$= ah \left[\frac{t_1^2}{2} + \frac{\alpha\beta t_1^{\beta+2}}{(\beta+1)(\beta+2)} - \frac{bt_1^3}{3} + \frac{\alpha\beta bt_1^{\beta+3}}{2(\beta+2)} - \frac{\alpha\beta bt_1^{\beta+3}}{2(\beta+2)(\beta+3)} \right] \tag{3.8}$$

The deterioration cost per cycle is

$$DC = C\left[W - \int_0^{t_1} R(t)dt\right] = a\alpha C\left[\frac{t_1^{\beta+1}}{\beta+1} + \frac{b\beta t_1^{\beta+2}}{2(\beta+2)}\right] \tag{3.9}$$

The shortage cost per cycle is

$$SC = \pi_B\left[-\int_{t_1}^{T} I(t)dt\right] = \frac{\pi_B R}{\delta^2}\left[\delta(T-t_1) - \ln[1+\delta(T-t_1)]\right] \tag{3.10}$$

The opportunity cost due to lost sales per cycle is

$$LS = \pi_L\left[R\int_{t_1}^{T}\left[1 - \frac{1}{1+\delta(T-t)}\right]dt\right] = \frac{\pi_L R}{\delta}\left[\delta(T-t_1) - \ln[1+\delta(T-t_1)]\right] \tag{3.11}$$

Therefore, the total cost; $K(t_1, T)$ of the inventory system per time unit is

$$K(t_1, T) = \frac{1}{T}[IHC + DC + OC + SC + LS] \tag{3.12}$$

To determine the optimum values of t_1 and T to minimize the total cost of an inventory system per time unit, the necessary conditions are

$$\frac{\partial K}{\partial t_1} = \frac{1}{T}\left\{\begin{array}{l} ah\left(t_1 + \frac{\alpha\beta t_1^{\beta+2}}{\beta+1} - bt_1^2 + \frac{\alpha\beta b t_1^{\beta+2}}{2} - \frac{\alpha\beta b t_1^{\beta+2}}{2(\beta+2)}\right) + aC\left(\alpha t_1^{\beta} + \frac{\alpha\beta b t_1^{\beta+1}}{2}\right) \\ -\frac{\pi_B R}{\delta}\left(1 - \frac{1}{1+\delta(T-t_1)}\right) - \frac{\pi_L R\delta}{1+\delta(T-t_1)} \end{array}\right\} = 0 \tag{3.13}$$

And

$$\frac{\partial K}{\partial T} = \frac{1}{T}\left\{\pi_L R\left(1 - \frac{1}{1+\delta(T-t_1)}\right) - \frac{\pi_B R}{\delta}\left(\frac{1}{1+\delta(T-t_1)} - 1\right)\right\}$$

$$+\frac{1}{T^2}\left\{\begin{array}{l} ah\left(\frac{t_1^2}{2} + \frac{\alpha\beta t_1^{\beta+2}}{(\beta+1)(\beta+2)} - \frac{bt_1^3}{3} + \frac{\alpha\beta b t_1^{\beta+3}}{2(\beta+2)} - \frac{\alpha\beta b t_1^{\beta+3}}{2(\beta+2)(\beta+3)}\right) \\ +aC\left(\frac{\alpha t_1^{\beta+1}}{\beta+1} + \frac{\alpha\beta b t_1^{\beta+2}}{2(\beta+2)}\right) + A - \frac{\pi_B R}{\delta}\left(\ln[1+\delta(T-t_1)] + \delta(T-t_1)\right) \\ -\frac{\pi_L R}{\delta}\left(\ln[1+\delta(T-t_1)] - \delta(T-t_1)\right) \end{array}\right\} = 0 \tag{3.14}$$

The sufficiency condition is $\frac{\partial^2 K}{\partial t_1^2}\frac{\partial^2 K}{\partial T^2} - \left(\frac{\partial^2 K}{\partial t_1 \partial T}\right)^2 > 0$ (3.15)

The equations (3.13) and (3.14) can be solved for t_1 and T simultaneously by mathematical software. Hence, the optimal maximum inventory level (W), the minimum total cost (K) per time unit, the optimal maximum demand backlogged (S) and hence optimal procurement quantity can be obtained.

4. Numerical Example and Sensitivity Analysis

Consider an inventory system with following parametric values in proper units:

$[a, \alpha, \delta, b, \beta, h, C, A, \pi_B, \pi_L, R] = [12, 0.08, 2, 0.03, 1.5, 0.5, 1.5, 10, 2.5, 2, 8]$

Then we obtain the optimal shortage point $t_1 = 1.3961$ time units and cycle length $T = 1.7730$ time units. Therefore, the optimum maximum inventory level (W) is 17.30 units and S = 2.25 units of the maximum demand backlogged. The optimal purchase quantity (Q) is 19.55 units per order and the minimum total cost per time unit is $ 11.17. In table 1, the effects of changes in the parameters a, b, C, A, π_B, π_L, R, α, β and δ on decision variables and total inventory cost per time unit are exhibited. At a one time parameter is changed by – 50%, – 25%, + 25% and + 50% while keeping remaining unaltered.

Table 1 Sensitivity analysis

Changes in	%	t_1	T	W	Q	K
a	+50	-20.23	-9.51	18.32	18.79	15.26
	+25	-11.47	-5.72	9.93	10.12	8.35
	-25	16.11	9.10	-12.04	-12.20	-10.36
	-50	41.36	25.21	-27.23	-27.48	-23.79
b	+50	0.67	0.40	-0.27	-0.29	-0.31
	+25	0.29	0.20	-0.13	-0.14	-0.16
	-25	-0.32	-0.20	0.13	0.14	0.15
	-50	-0.64	-0.40	0.26	0.36	0.15
C	+50	-5.79	-3.33	-6.11	-4.90	3.23
	+25	-3.03	-1.77	-3.21	-2.58	1.66
	-25	3.37	2.00	3.58	2.89	-1.77
	-50	7.14	6.31	7.60	6.17	-3.65
A	+50	18.51	24.68	19.89	21.41	22.51
	+25	9.90	12.65	10.56	11.26	11.87
	-25	-11.68	-13.79	-12.27	-12.85	-13.56
	-50	-25.76	-29.66	-27.21	-28.22	-29.69
π_B	+50	1.67	-3.55	1.77	-0.55	1.98
	+25	0.92	-2.02	0.97	-0.30	1.09
	-25	-1.16	2.74	-1.22	0.37	-1.36
	-50	-2.65	6.66	-2.80	0.85	-3.12
π_L	+50	2.40	-4.97	2.54	-0.80	2.84
	+25	1.39	-2.98	1.47	-0.46	1.64
	-25	-2.00	4.91	-2.12	0.65	-2.36
	-50	-5.13	14.20	-5.42	1.63	-6.02
R	+50	3.34	-6.67	3.54	2.49	3.96
	+25	2.06	-4.31	2.18	1.54	2.43
	-25	-3.77	9.90	-3.99	-2.85	-4.44
	-50	-12.56	46.84	-13.18	-9.60	-14.56
α	+50	-7.31	-4.30	-5.54	-4.31	3.80
	+25	-3.91	-2.34	-2.95	-2.30	1.97
	-25	4.60	2.83	3.42	2.70	-2.16
	-50	10.14	6.35	7.49	5.94	-4.54
β	+50	-6.03	-4.71	-6.56	-5.79	0.11
	+25	-3.31	-2.12	-3.60	-5.79	0.05
	-25	4.05	5.77	4.40	3.89	-0.04
	-50	Infeasible	Solution			
δ	+50	1.34	-1.34	1.42	-0.76	1.59
	+25	0.74	-0.70	0.78	-0.43	0.87
	-25	-0.90	0.78	-0.95	0.57	-1.06
	-50	-2.03	1.65	-2.16	0.29	-2.40

4.1 Observations

Increase in the fixed demand decreases shortage time point and cycle time while procurement quantity, maximum inventory level and total cost of the inventory system per time unit increase. The shortage time point is very sensitive to changes in ‘a’.

Increase in decreasing demand parameter ‘b’ decreases total cost and increases all other decision variables. It is observed that the objective function and decision variables are insensitive to changes in ‘b’.

Increase in purchase cost ‘C’ decreases t_1, T, W and Q whereas increase in K. The decision variables and minimum cost are very sensitive to changes in the ordering cost ‘A’. All decision variables and total cost increases with increase in ordering cost. The retailer should keep a watch on orders because optimal solution is very sensitive to ordering cost.

Optimal values of T and Q decrease and t_1, W, K increase with increase in shortage cost ‘π_B’ per unit short or ‘π_L’ lost sale cost. t_1, T, W and K are low sensitive to changes in π_B and π_L. The decision variables and total cost of inventory system are highly sensitive to changes in R. Increase in R decreases cycle time and increases all other decision variables.

Increase in deterioration rate ‘α’ and shape parameter ‘β’ decreases t_1, T, W and Q whereas increases total cost of inventory system. The retailer should control deterioration rate by adopting advance technology for stocking units in the warehouse. T and Q decrease while t_1, W and Q increase with increase in backlogging parameter ‘δ’. These changes are slowly sensitive to changes in ‘δ’.

5. Conclusions

In the presented formulation, the effect of time dependent deterioration on lot-size model is incorporated when demand decreases exponentially and partial backlogging is allowed. The rate of deterioration follows two parameter weibull distributions and backlogging rate is inversely proportional to the waiting time for the next replenishment. It is observed that both added constraints are very critical in optimization of total cost. This model can be extended when demand is probabilistic and decreasing. The model can be applied to the product whose demand is changing linearly by terminating exponential series. The model developed here is more general and applicable for time dependent demand.

References

[1] Benkherouf, L., 1998: “Note on a deterministic lot-size inventory model for deteriorating items with shortages and a declining market”. Computers and Operations Research, 25, 63 – 65.

[2] Chang, H. J. and Dye, C. Y., 1999: “An EOQ model for deteriorating items with time varying demand and partial backlogging”. Journal of the Operational Research, 50, 1176 – 1182.

[3] Ghare, P. M. and Schrader, G. H., 1963: “A model for exponentially decaying inventory system”. International Journal of Production Research, 21, 449 – 460.

[4] Goyal, S. K. and Giri, B. C., 2001: “Recent trends in modeling of deteriorating inventory”. European Journal of Operational Research, 134, 1 – 16.

[5] Hariga, M. and Benkherouf, L., 1994: “Optimal and heuristic replenishment models for deteriorating items with exponential time varying demand”. European Journal of Operational Research, 79, 123 – 137.

[6] Hollier, R. H. and Mak, K. L., 1983: “Inventory replenishment policies for deteriorating items in a declining market”. International Journal of Production Research, 21, 813 – 826.

[7] Nahmias, S., 1982: “Perishable inventory theory : A review”. Operations Research, 30, 680 – 708.

[8] Ouyang, L-Y, Wu, K-S and Cheng, M-C, 2005: “An inventory model for deteriorating items with exponential declining demand and partial backlogging”. Yugoslav Journal of Operations Research, 15(2), 277 – 288.

[9] Shah, Nita H. and Shah, Y. K., 2000: “Literature survey on inventory model for deteriorating items”. Economic Annals, 44, 221 – 237.

[10] Su, C-T, Lin, C-W and Tsai, C-H, 1999: “A deterministic production inventory model for deteriorating items with an exponential declining demand”. OPSEARCH, 36(2), 95 – 106.

[11] Wee, H. M., 1995a: “A deterministic lot-size inventory model for deteriorating items with shortages and declining market”. Computers and Operations Research, 22, 345 – 356.

[12] Wee, H. M., 1995b: “Joint pricing and replenishment policy for deteriorating inventory with declining market”. International Journal of Production Economics, 40, 163 – 171.

ASOR Bulletin
Volume 28, Number 2, June 2009
ISSN0812-860X | eISSN1446-6678

Choosing the Right Tool for Business and Engineering Improvements[C]

Dan Tengku

Consultant and Trainer, Hearne Scientific Software Pty. Ltd.

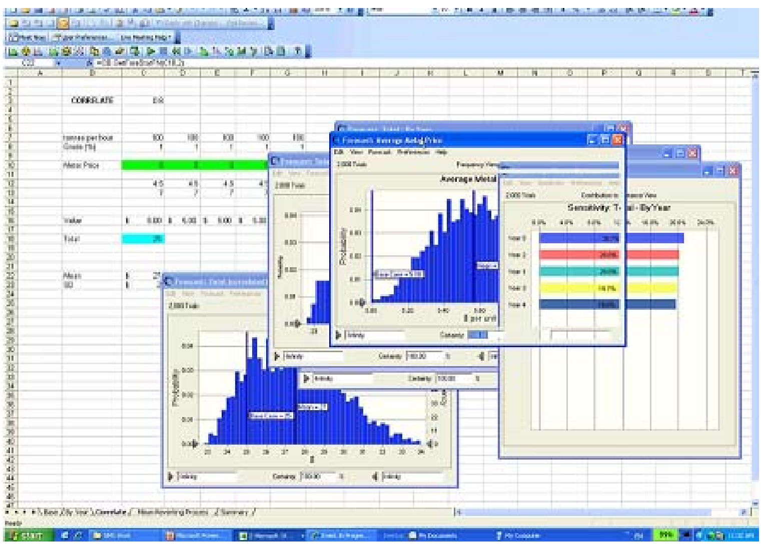
Need to minimise cost, maximise throughput, optimise design, model uncertainty or start other performance improvement projects?

Hearne Scientific Software provides products, support, training and consultancy services in Monte Carlo simulation, optimisation and discrete-event simulation.

There are a number of philosophies, strategies and tools that can lead to some of these results including Six Sigma, Continuous Improvement, Total Productive Maintenance, simulation and others. However, many providers of these tools often market the benefits in general terms such as ‘optimised performance’ and ‘business performance transformation’. Understanding how they work and whether they are suitable for your purpose can therefore be challenging. Furthermore, adopting the wrong tool is quite common and often leads to mediocre results while requiring considerable effort.

This article reviews the most important tools for making decisions in business and engineering. The focus will be on those that are computational in nature, which can forecast detailed and measurable results. These tools are first classified into three general categories: Monte Carlo simulation, optimisation and discrete-event simulation. They cover a wide range of decisions in business and engineering, and have been used in every segment of business including exploration, production, marketing, distribution and business planning. Benefits such as multi-million dollar cost savings, reduced inventory and lead time have been reported. Next is a brief description for each type of tool and how they match to various situations.

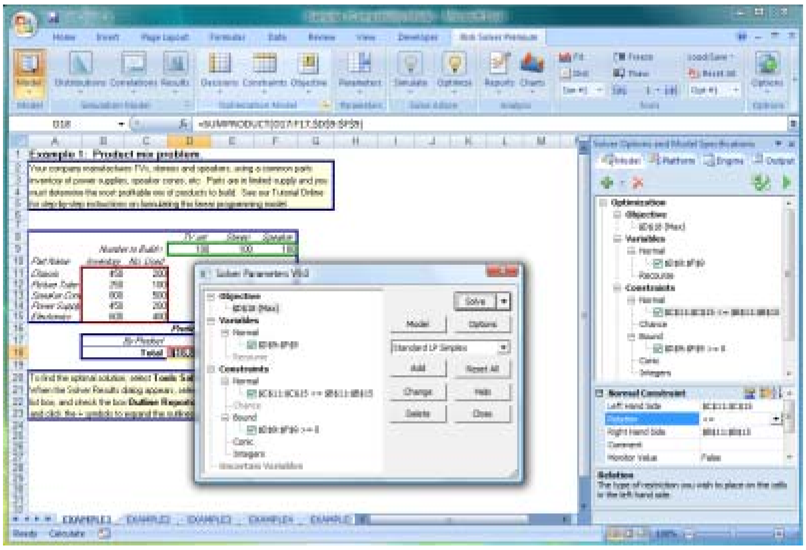
Monte Carlo Simulation



Monte Carlo simulation is a method for studying systems that contain uncertainty. Any system will have at least some randomness. For instance, the projected sales forecast or equipment reliability cannot be known with certainty and affects the profit as well as throughput respectively. In some cases, the uncertainty is negligible and we do not need to employ Monte Carlo simulation, while in others, it is substantial. When constructing a model, first a set of relationships that relate inputs to outputs is defined. For example, sales forecast, materials and labour costs affect the revenue and profit. Second, probability distributions are assigned to one or more of the inputs. Often, these models are a snapshot over a period of time. The simulation is then run using a Monte Carlo simulation software such as Crystal Ball. The simulation results give the probabilities of achieving various outputs, thereby providing more complete information for making decisions compared to deterministic models. The analyst can then simulate the effects of changing the input on the output such as reducing product defects by switching to a more reliable production machine. These 'tweaks' to the model are normally performed manually. However, commercial simulation packages typically offer an optional optimiser that help to automate this task.

Monte Carlo simulation should be used when uncertainty plays an important part in the system and when the model can be reasonably represented as a snapshot over time. Example applications include performing discounted cash flow analyses with uncertainty as well as predicting reserves and production capacity. Production systems however, vary dynamically over time and have accumulating inventory. If these factors are expected to affect the output significantly, then other methods should be considered. The most popular Monte Carlo simulation packages are MS Excel add-ins due to their ease of use and adaptability to existing Excel documents.

Optimisation



Optimisation is a class of methods concerned with achieving some optimal result. Among others, the objective can be to minimise cost /downtime or maximise profit /throughput. The model consists of relationships between inputs and the objective. Some of the inputs are allowed to vary and are known as the decision variables. For example, a transportation model describes how products should be shipped along various routes. Decision variables may include how much product should be shipped along each route in order to minimise transportation costs. The optimisation software is then used to obtain the combination of decision variables that leads to the minimum cost. Instead of the analyst having to ‘tweak’ the inputs until a desirable result is obtained, the optimum result is given by the software.

Optimisation is very flexible and has been used in mine planning and scheduling, site rehabilitation, equipment selection for ore extraction as well as transportation. Two types of optimisation tools are commonly available: MS Excel add-ins and standalone applications. Excel add-ins such as Solver and What’s Best! are easy to pick up and suitable for analysts who are not familiar with optimisation. Standalone applications and development tools such as LINGO and LINDO API are more suited for those with some experience.

It is also important to distinguish dedicated optimisation suites from optimiser add-ins to Monte Carlo simulation and discrete-event simulation. While optimiser add-ins can provide very good results, it is virtually impossible to obtain a truly optimal result due to the complexity of combining simulation and optimisation. However, using optimisation software and formulating the model in a particular way, a truly optimal solution can be achieved.

Optimisation should be used when the number of possible ‘tweaks’ is very large and cannot be effectively performed manually or by optimiser add-ins. Although optimisation is flexible and can be used to model systems with time dependency, this is quite complicated and should be left to optimisation consultants and researchers. A snapshot model over a period of time is favoured. If the system is dynamic and changes over time, then we should look to discrete-event simulation.

Discrete-event Simulation

Discrete-event simulation is more specific to modelling repetitive processes such as manufacturing and services operations. First we specify how the system should behave such as ore and truck routing rules, worker shifts, equipment processing rates and downtimes. The discrete-event simulation software then simulates the detailed system operation over time, imitating the actual system. The simulation screen displays the movement and activity of individual elements in the system. The software then provides statistics such as inventory levels, downtimes, throughput, vehicle/people movements and costs. Through these statistics, we can track the performance of individual elements in the system. Because it is possible to consider uncertainty by assigning probability distributions to various parameters such as machine processing time and routing, it is analogous to a sophisticated Monte Carlo simulation.

To improve the system, we can perform virtual experiments by tweaking various parameters such as adding machines or shortening distances for vehicle travel and observing the effect on some parameter of interest such as manufacturing cost or defect rate. Alternatively, there are also optimiser add-ons that can help to automate this. These capabilities make discrete-event suites well suited for Six Sigma and Lean projects.

Discrete-event simulation software, such as ProModel Suite provide by far the most detailed representation of the actual system, and therefore have the potential to yield more accurate results. Expectedly they tend to be more costly than Monte Carlo and optimisation software. However, cheaper, stripped down versions such as the Process Simulator provide a convenient starting point. Discrete-event simulation should be used when it is important to model the behaviour of the system over time and when it is necessary to model the intricacies of the system operation in detail. However, because today's discrete-event simulation packages can account for uncertainty and offer optimisation features, they are able to provide the benefits of all three types of tools. Simulation models have been constructed for ore production and processing as well as rail, port and shipping operations. Project objectives may include capacity planning, debottlenecking, investment analysis, cost minimisation and Lean Six Sigma implementation.

This review provides a brief background of each type of decision tool and how they are suited for different situations. There are however, numerous software available for each type of tool. Feel free to contact Hearne Scientific Software for advice on modelling your system or on selecting an appropriate tool.

[C]Published as a general note – the editor is not responsible for any claim made in this note

Forthcoming Conferences

SimTecT 2009 Simulation Conference
15-16 June 2009, Adelaide
http://www.siaa.asn.au/simtect/2009/2009.htm

Third International Conference on Game Theory and Management (GTM2009)
June 24 - 26, 2009, St. Petersburg, Russia
http://www.gametheorysociety.org/conferences/

Optimisation Techniques at 2009 IEEE 7th Int. Conf. in Industrial Informatics (INDIN), June 24-26, 2009, Cardiff UK
http://www.indin2009.com/

The forth International Symposium on Scheduling (IntSS09)
4 - 6 July 2009, Nagoya, Japan
http://www.fujimoto.mech.nitech.ac.jp/iss2009/

EURO XXIII 2009 Conference
July 5 – 8, 2009, Bonn
http://www.euro-2009.de

International Conference on Computers & Industrial Engineering (CIE39)
July 6 - 8, 2009, Troyes, France
http://www.utt.fr/cie39/

The 7th International Conference on Data Envelopment Analysis
July 10-12, 2009, Philadelphia, USA
http://www.DEAzone.com/DEA2009/info.htm

18th World IMACS Congress and International Congress on Modelling and Simulation (MODSIM09) 13–17th July 2009, Cairns, Australia
http://www.mssanz.org.au/modsim09/

Data Envelopment Analysis (DEA) stream, Operational Research Society Conference (OR51) 8-10, September 2009, Warwick University, UK
http://www.DEAzone.com/DEAatOR51

The 20th National Conference of the Australian Society for Operations Research 2009
28-30 September 2009, Gold Coast, Australia
http://www.asor.org.au/conf2009/index.php?page=1

Workshop on Supply Chain and Related Issues
5-6 November 2009, University of Sydney
Contact: Erick Li [E.Li2@econ.usyd.edu.au]

The 22nd Australasian Joint Conference on Artificial Intelligence (AI'09)
1-4 December, 2009, Melbourne, Australia
http://www.infotech.monash.edu.au/ai09

The 1st Annual Global Conference on Systems and Enterprises
December 2-4, 2009, NTU, Singapore
Contact: piplani@pmail.ntu.edu.sg

2009 IEEE Int. Conference on Industrial Engineering and Engineering Management
8-11 December 2009, Hong Kong
www.ieem2009.org

International Conference on Logistics and Transport, ICLT2009
17-19 December 2009, Imperial Mae Ping Hotel, Chiang Mai, Thailand
www.thaivcml.com/ICLT

Int. Conference on Industrial Engineering and Operations Management (IEOM 2010)
9-10 January 2010, Dhaka, Bangladesh
http://qbx6.ltu.edu/aali/IEOM2010.htm

The 3rd International Conference on Health Informatics (HEALTHINF 2010)
20–23 January 2010, Valencia, Spain
http://www.healthinf.biostec.org

THE 20th NATIONAL CONFERENCE of AUSTRALIAN SOCIETY FOR OPERATIONS RESEARCH

incorporating

THE 5th INTERNATIONAL INTELLIGENT LOGISTICS SYSTEM CONFERENCE
Holiday Inn Surfers Paradise, Gold Coast, Australia

September 27th - 30th 2009

Dear colleagues,

On behalf of The Australian Society for Operations Research Inc., we are pleased to invite members and non-members to the ASOR 20th National Conference incorporating the 5th International Intelligent Logistics Systems Conference. We envisage a conference focusing on the broad range of areas in which operations research, logistics and operations research practitioners' work, within the theme "Making the Future Better by Operations Research". ASOR gives you a unique opportunity to keep up-to-date with operations research issues in Australia and overseas. We welcome you to attend the conference and participate in specialized workshops and sessions relating to your specific areas of interest and have informal discussions with researchers and practitioners. We expect everyone who attends this conference to receive value from the program and enjoy the atmosphere and surroundings of this first class venue.

For further information, please visit our conference web-site:
http://www.asor.org.au/conf2009/index.php?page=1

We look forward to seeing you at the Conference.

Yours sincerely,
Erhan Kozan
Chair,
ASOR Conference 2009

ASOR BULLETIN

Editorial Policy

The ASOR Bulletin is published in March, June, September and December by the Australian Society of Operations Research Incorporated.

It aims to provide news, world-wide abstracts, Australian problem descriptions and solution approaches, and a forum on topics of interests to Operations Research practitioners, researchers, academics and students.

Contributions and suggestions are welcomed, however it should be noted that technical articles should be brief and relate to specific applications. Detailed mathematical developments should be omitted from the main body of articles but can be included as an Appendix to the article. Both refereed and non-refereed papers are published. The refereed papers are *peer reviewed* by at least two independent experts in the field and published under the section 'Refereed Paper'.

Articles must contain an abstract of not more than 100 words. The author's correct title, name, position, department, and preferred address must be supplied. References should be specified and numbered in alphabetical order as illustrated in the following examples:

[1] Higgins, J.C. and Finn, R. Managerial Attitudes Towards Computer Models for Planning and Control. Long Range Planning, Vol. 4, pp 107-112. (Dec. 1976).

[2] Simon, H.A. The New Science of Management Decision. Rev. Ed. Prentice-Hall, N.J. (1977).

Contributions should be prepared in MSWord (doc or rtf file), suitable for IBM Compatible PC, and a soft copy should be submitted as an email attachment. The detailed instructions for preparing /formatting your manuscript can be found in the ASOR web site.

Reviews: Books for review should be sent to the book review subeditor A/Prof. G.K.Whymark, c/- the editors. Note that the subeditor is also interested in hearing from companies wishing to arrange reviews of software.

Advertising: The current rate is $300 per page, with layout supplied. Pro-rata rates apply to half and quarter pages and discounts are available for advance bookings over four issues.

Subscriptions: ASOR Bulletin electronic version is free for all members and non-members which is accessible through ASOR web site.

Deadlines: The deadline for each issue (for all items except refereed articles) is the first day of the month preceding the month of publication.

Editor: Address all correspondence and contributions to:

A/Prof. Ruhul A Sarker,
School of ITEE, UNSW@ADFA
Northcott Drive, Canberra ACT 2600
Tel: (02) 6268 8051 Fax: (02) 6268 8581
Email: r.sarker@adfa.edu.au