NEW AVERAGING METHOD FOR RISK REDUCTION IN COASTAL REGION

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ABSTRACT

In this paper, a new statistical averaging method (NSAM) has been proposed to solve multi-objective linear programming problem (MOLPP) by using a new arithmetic averaging method, a new geometric averaging method and a new harmonic averaging method. The statistical averaging method (SAM), which also includes an arithmetic averaging, a geometric averaging and a harmonic averaging, has also been proposed to solve the same MOLPP. All the results obtained by solving the MOLPP using those stated methods have been compared to the results obtained using Chandra Sen's method which is a well-known technique for making single objective linear programing problem (LPP) from multi-objective LPP.

Key Words: Multi-Objective Linear Programming Problem; Chandra Sen's Technique; Statistical Averaging Method; New Statistical Averaging Method.

1. INTRODUCTION

Mathematical programming or linear programming is one of the most widely used technique in operation research (OR). Many practical problems in operation research can be expressed as linear programming (LP) problems.

Sulaiman and Sadiq [1] used mean and median to study the multi-objective function (MOF) by solving multi-objective linear programming problem (MOLPP). Hamad-Amin [2] used arithmetic mean to study MOLPP. Sulaiman and Mustafa [3] transformed the MOLPP to the single objective linear programming problem using harmonic mean for values of functions. A popular technique named as Chandra Sen's technique has been used to solve the multi-objective linear fractional programming problem (MOLFPP) by Sen [4]. To solve these problems, there are several methods which were discussed by Abdil-Kadir and Sulaiman [5]. Nahar and Alim [6] proposed a new geometric average technique to solve MOLFPP. The paper published by Sing [7] shows a useful study about the optimality condition in fractional programming. Sulaiman and Othman [8] conducted a study on MOLFPP.

In this paper, SAM (such as arithmetic mean, geometric mean and harmonic mean) has been applied by using optimal values of each objective function. Again NSAM has been applied by choosing minimum values among optimal values of multi-objective functions. To investigate the risk reduction capacity in the coastal area four parameters such as population density, erosion, cropping intensity and shelter have been considered as inputs.

2. OPTIMIZATION

The study of operation research is of great importance to the researcher because of their applications in many branches of science and engineering. Some of the earlier researchers studied the problems related with optimization technique. At first George Bernard Dantzig develop simplex method in 1950. The simplex method is an iterative procedure for solving a linear programming in a finite number of steps and provides all the information about the program.

The concept of optimization is now well rooted as a principle underlying the analysis of many complex decision or allocation problem by Ye and Luerberger [9]. Optimization problem can be classified in a number of different ways. One way is illustrated below.

3. STATISTICAL AVERAGING METHODS

3.1 Arithmetic Mean or Mean (A.M):

Arithmetic mean or simply the mean of a variable is defined as the sum of the observations divided by the number of observations. It is denoted by the symbol $\bar{x}$.If the variable x assumes n values $x_1, x_2, \cdots, x_n$ then the mean is given by

$$\bar{x} = \frac{x_1 + x_2 + \cdots + x_n}{n} = \frac{1}{n}\sum_{i=1}^{n} x_i$$

3.2 Geometric Mean (G.M):

The geometric mean of a series containing n observations is the n^{th} root of the product of the values. If $x_1, x_2, \cdots x_n$ are observations then

$$G.M = \sqrt[n]{x_1.x_2\cdots x_n} = (x_1.x_2.\cdots.x_n)^{1/n}$$

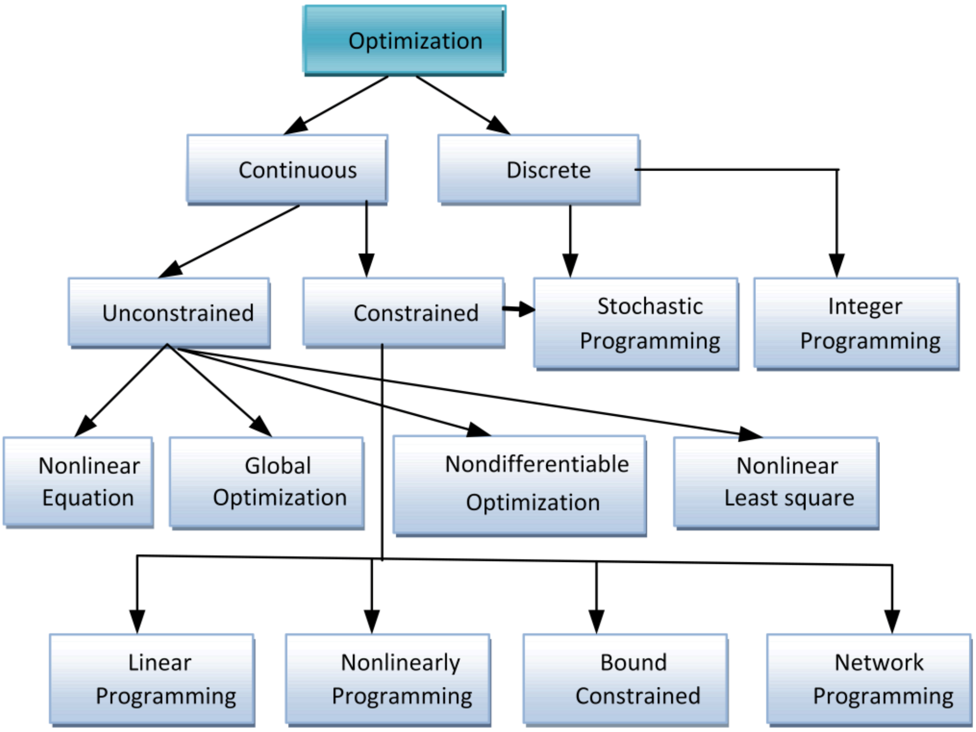

Figure 1: Classification of Optimization.

The geometric mean can be understood in terms of geometry. The geometric mean of two numbers *a* and *b*, is the length of one side of a square whose area is equal to the area of rectangle with sides of lengths *a* and *b*. Similarly, the geometric mean of three numbers *a*, *b*, and *c*, is the length of one edge of a cube whose volume is the same as that of a cuboid with sides whose lengths are equal to the three given numbers.

3.3 Harmonic Mean (H.M):

Another measure of central tendency, which is sometimes used, is the harmonic mean. It is defined as the reciprocal of the A.M of the reciprocals of the individual values. For a series of *n* values $x_1, x_2, \cdots x_n$ the harmonic mean is

$$H = \frac{n}{\frac{1}{x_1} + \frac{1}{x_2} + \cdots + \frac{1}{x_n}} = \frac{n}{\sum_i (\frac{1}{x_i})}$$

4. METHODOLOGIES FOR SOLVING MOLPP

4.1 Multi-Objective Program

A general multi-objective program is a problem of the type by Ruzibiza [10]:

$$\begin{cases}\min[f_1(x),\cdots,f_k(x)], \quad k\geq 2\\ x\in X=\{x\in\Re^n / g_j(x)\leq 0;\ j=1,2,\cdots,m\}\end{cases}$$

where $f_i(x); i=1,2,\cdots,k$ and $g_j(x),\ j=1,2,\cdots,m$ are real-valued function of $\Re^n$. Many real-life problems may be cast in the form of above.

Multi-objective programming is used in application for many real-world problems including problems in the fields of engineering, mining and finance.

4.2 Convexity

A function is convex if a line drawn between any two points on the function remains on or above the function in the interval between the two points. In other words, a set *C* is convex if a line segment between any two points in *C* lies in *C*. Here are some more examples of convex and non-convex sets

Convex function: A function $f:\Re^n\to\Re$ is convex if for all $x,y\in\Re^n$ and $\alpha\in[0,1]$ we have

$$f(\alpha x+(1-\alpha)y)\leq \alpha f(x)+(1-\alpha)f(y).$$

Convex multi-objective program: Consider the multi-objective program

$$\begin{cases}\min[f_1(x),\cdots,f_k(x)], k\geq 2\\ x\in X=\{x\in\Re^n / g_j(x)\leq 0;\ j=1,\cdots,m.\}\end{cases}$$

If the feasible set X is convex and if the objective functions $f_i(x); i=1,\cdots,k$ are convex, then program is said to be a convex multi-objective program

4.3 Mathematical Model of MOLPP

The mathematical form of MOLPP is given as follows:

$$\begin{aligned}&Max\ Z_1=C_1^t x+r_1\\ &Max\ Z_2=C_2^t x+r_2\\ &\cdots\cdots\cdots\cdots\cdots\\ &Max\ Z_r=C_r^t x+r_r\\ &Min\ Z_{r+1}=C_{r+1}^t x+r_{r+1}\\ &\cdots\cdots\cdots\cdots\cdots\\ &Min\ Z_s=C_s^t x+r_s\end{aligned} \qquad (1)$$

subject to

$$\begin{aligned}&Ax=b\\ &x>0\end{aligned} \qquad (2)$$

where *r* is the number of objective function that to be maximized, *s* is the number of objective functions that is to be maximized and minimized and (*s-r*) is the number of objective function that is to be minimized.

4.4 Solving MOLPP by Different Methods

We obtain a single value corresponding to each of the objective functions of MOLPP in equation (1). They are being optimized individually subject to the constraints in equation (2) as follows:

$$\begin{aligned}
&Max\ Z_1 = \phi_1\\
&Max\ Z_2 = \phi_2\\
&\dots\dots\dots\dots\dots\\
&Max\ Z_r = \phi_r\\
&Min\ Z_{r+1} = \phi_{r+1}\\
&\dots\dots\dots\dots\dots\\
&Min\ Z_s = \phi_s
\end{aligned} \tag{3}$$

where $\phi_1, \phi_2, \cdots\cdots \phi_s$ are values of the objective functions.

4.4.1 Chandra Sen's Method:

The method used by Chandra Sen to obtain a single objective LPP from multi-objective LPP can be expressed as in equation (4)

$$Max\ Z = \sum_{i=1}^{r} \frac{Z_i}{|\phi_i|} - \sum_{i=r+1}^{s} \frac{Z_i}{|\phi_i|} \tag{4}$$

where $\phi_i \neq 0, i = 1, 2, \quad \cdots s$ subject to the constraints in equation (2) and the optimum value of the objective functions φ_i may be positive or negative.

4.4.2 Proposed Statistical Averaging Method:

The proposed statistical averaging method to obtain a single objective LPP from multi-objective LPP can be expressed as in equation (5) for arithmetic mean, in equation (6) for geometric mean and in equation (7) for harmonic mean, respectively.

$$Max\ Z = \sum_{i=1}^{r} \frac{Z_i}{A.M(AA_i)} - \sum_{i=r+1}^{s} \frac{Z_i}{A.M(AL_i)} \tag{5}$$

$$Max\ Z = \sum_{i=1}^{r} \frac{Z_i}{G.M(AA_i)} - \sum_{i=r+1}^{s} \frac{Z_i}{G.M(AL_i)} \tag{6}$$

and

$$Max\ Z = \sum_{i=1}^{r} \frac{Z_i}{H.M(AA_i)} - \sum_{i=r+1}^{s} \frac{Z_i}{H.M(AL_i)} \tag{7}$$

where $AA_i = |\phi_i|$, $i = 1 \cdots r$ and $AL_i = |\phi_i|$, $i = 1 + r \cdots s$

4.4.3 Proposed New Statistical Averaging Method:

In this sub-section the MOLPP has been solved using the proposed new arithmetic averaging technique.

Let $m_1 = \min\langle AA_i \rangle$, where $AA_i = |\phi_i|$, ϕ_i is maximum value of Z_i, $i = 1 \cdots r$. And $m_2 = \min\langle AL_i \rangle$, where, $AL_i = |\phi_i|$ is minimum value of Z_i, $i = r + 1 \cdots s$

New arithmetic averaging technique:

$$Max\ Z = \left(\sum_{i=1}^{r} Z_i - \sum_{i=r+1}^{s} Z_i \right) / A.Av \tag{8}$$

New geometric averaging technique:

$$Max\ Z = \left(\sum_{i=1}^{r} Z_i - \sum_{i=r+1}^{s} Z_i \right) / G.Av \tag{9}$$

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New harmonic averaging technique:

$$Max\ Z = \left(\sum_{i=1}^{r} Z_i - \sum_{i=r+1}^{s} Z_i \right) / H.Av \qquad (10)$$

where, $A.Av = \dfrac{m_1 + m_2}{2}$, $G.Av = \sqrt{m_1 m_2}$, and $H.Av = \dfrac{2}{\dfrac{1}{m_1} + \dfrac{1}{m_2}}$

4.5 Flow Chart for Solving MOLPP Using NSAM

The procedure of obtaining solution of the MOLPP using NSAM as mentioned in the previous sections has been presented in the flow chart as shown in Figure 2. Suppose that we have few maximum type objective functions and few minimum type objective functions with same constraints. For each objective function with same constraints we have to solve by simplex method. Then separate maximum type optimal values by AA_i and minimum type optimal values by AL_i. In both type we only consider positive values. Now we can define all maximum type objective functions by *SM* after addition. Similarly, we can define all minimum type objective functions by *SN* after addition. We have to chose m_1 from all AA_i by taking minimum values and similarly m_2 from all AL_i. Now we have to perform arithmetic averaging, geometric averaging and harmonic averaging between m_1 and m_2. We get single objective function by using equation (8), (9), and (10). Solving these single objective function with same constraints we get results as shown in Figure 2.

5. RISK REDUCTION OF COASTAL AREA IN BANGLADESH

In this section a discussion has been given about damages and losses of natural calamities of coastal region in Bangladesh. A real life example has been given in this section and solution by applying Chandra Sen's method and our proposed SAM and NSAM.

The coastal area of Bangladesh is frequently affected by various hazards like storm surges, floods, salinity and erosion caused by tropical cyclones, like Sidr. Risks due to the hazards are serious concern for living beings along the coasts. As natural calamities cannot be reduced, some preventive measures may reduce those risks. This research focuses on the reduction of the risks of those damages caused by the hazards. In this paper, to assess the risk reduction caused by natural calamities, four items such as cropping intensity, shelter, erosion and population density have been taken as inputs to the proposed SAM and NSAM model.

Table A-1 in the appendix shows the normalized data of cropping intensity, shelter, erosion and population density of 153 coastal areas in Bangladesh. These normalized data have been prepared from the raw data of the coaster areas. The data normalization has been performed using the equation as in (11).

$$Z_i = \frac{X_i - \min(X)}{\max(X) - \min(X)} \times 100 \qquad (11)$$

where $X_i = (X_1, X_2, \cdots X_{153})$ and Z_i is i^{th} normalized data.

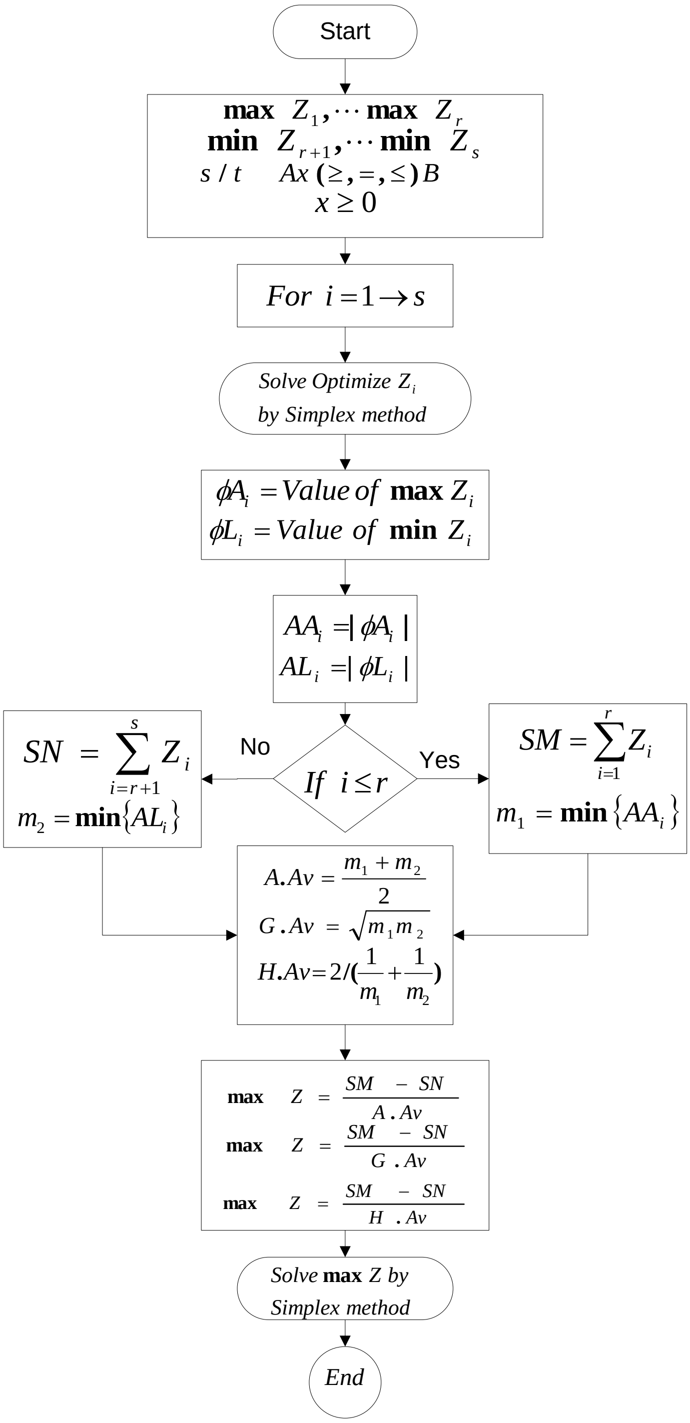

Figure 2: Flowchart of the proposed method in MOLPP

5.1 Problem Formulation

The proposed SAM and NSAM have applied for risk reduction in four coastal regions in Bangladesh, as shown in Table 1.

Our decision variables are x_1, x_2, x_3, x_4 which are risk and vulnerability indicators. x_1 for cropping intensity, x_2 for shelter, x_3 for erosion and x_4 for population density. Constant vector is terminated value for risk reduction capacity (on expert opinion). Decision variables are in different scales. For this reason, these variables have been normalized. Constraints are established based on the data of four coastal areas. The risk reduction coefficients of the objective functions are calculated using weighted method

Table 1

Data based on the data of four coastal areas

Coastal areas	**Cropping intensity**	**Shelter**	**Erosion**	**Population density**
kutubdia	13	100	0	10
Maheskl	2	37	0	18
Pekua	6	47	0	27
Manpura	5	96	28	0
sum	26	280	28	55
	26/389 = 0.067	280/389 = 0.72	28/389 = 0.072	55/389 = 0.1413

$$\begin{aligned} &Max\ Z = 0.067x_1 + 0.72x_2 \\ &Min\ Z = 0.072x_3 + 0.1413x_4 \\ &Max\ Z = -0.072x_3 - 0.1413x_4 \\ &Min\ Z = -0.067x_1 - 0.72x_2 \end{aligned} \qquad (12)$$

Rearranging equation (12), we get

$$\begin{aligned} &Max\ Z_1 = 0.067x_1 + 0.72x_2 \\ &Max\ Z_2 = -0.072x_3 - 0.1413x_4 \\ &Min\ Z_3 = 0.072x_3 + 0.1413x_4 \\ &Min\ Z_4 = -0.067x_1 - 0.72x_2 \end{aligned} \qquad (13)$$

Subject to

$$\begin{aligned} &13x_1 + 100x_2 + 0 + 10x_4 \le 100 \\ &2x_1 + 37x_2 + 0 + 18x_4 \le 90 \\ &6x_1 + 47x_2 + 0 + 27x_4 \le 98 \\ &5x_1 + 96x_2 + 28x_3 + 0 \le 92 \end{aligned} \qquad (14)$$

5.2 Problem Solution

5.4.3 Chandra Sen's Approach:

For each objective function using same constraints and by applying simplex algorithm we get

$$\begin{aligned}\phi_1 &= 0.7058 \text{ with } (0.5348, 0.9305, 0, 0)\\ \phi_2 &= 0 \text{ with } (0, 0, 0, 0)\\ \phi_3 &= 0 \text{ with } (0, 0, 0, 0)\\ \phi_4 &= -0.7058 \text{ with } (0.5348, 0.9305, 0, 0)\end{aligned} \tag{15}$$

Table 2 shows solution table shows non-negative values.

Table 2

Optimal values of objective functions

I	φ_i	x_i	AA_i=| φ_i |	AL_i=| φ_i |
1	0.7058	(0.5348, 0.9305, 0, 0)	0.7058	
2	0	(0, 0, 0, 0)	0	
3	0	(0, 0, 0, 0)		0
4	-0.7058	(0.5348, 0.9305, 0, 0)		0.7058

By using Chandra Sen's method, we get the following single objective function,

$$\begin{aligned}Max\ Z &= \frac{Z_1}{\phi_1} - \frac{Z_4}{\phi_4}\\ &= \frac{1}{0.7058}(0.067x_1 + 0.72x_2) - \frac{1}{0.7058}(-0.067x_1 - 0.72x_2)\\ &= \frac{1}{0.7058}(0.067x_1 + 0.72x_2) + \frac{1}{0.7058}(0.067x_1 + 0.72x_2)\\ &= 0.189x_1 + 2.040x_2\end{aligned}$$

Thus by using Chandra Sen's method we get the following single objective linear programming problem

$$Max\ Z = 0.189x_1 + 2.040x_2 \tag{16}$$

subject to

$$\begin{aligned}&13x_1 + 100x_2 + 0 + 10x_4 \le 100\\ &2x_1 + 37x_2 + 0 + 18x_4 \le 90\\ &6x_1 + 47x_2 + 0 + 27x_4 \le 98\\ &5x_1 + 96x_2 + 28x_3 + 0 \le 92\end{aligned}$$

By simplex algorithm we get the result

$$Max\ Z = 1.9993 \text{ with } (0.5348, 0.9305, 0, 0)$$

5.2.2 Statistical Averaging Method

Arithmetic averaging method: By applying arithmetic mean between 0.7058 and 0; *A.M* (0.7058, 0) = 0.3529. Thus we get

$$\begin{aligned}Max\ Z &= \sum_{i=1}^{r} \frac{Z_i}{A.M(AA_i)} - \sum_{i=r+1}^{s} \frac{Z_i}{A.M(AL_i)}\\ &= \frac{1}{0.3529}(0.067x_1 + 0.72x_2 - 0.072x_3 - 0.1413x_4)\\ &\quad - \frac{1}{0.3529}(0.072x_3 + 0.1413x_4 - 0.067x_1 - 0.72x_2)\\ &= x_1(0.189 + 0.189) + x_2(2.04 + 2.04)\\ &\quad + x_3(-0.204 - 0.204) + x_4(-0.4 - 0.4)\\ &= 0.378x_1 + 4.08x_2 - 0.408x_3 - 0.8x_4\end{aligned}$$

Thus we get the following single objective linear programming problem

$$Max\ Z = 0.378x_1 + 4.08x_2 - 0.408x_3 - 0.8x_4 \tag{17}$$

subject to

$$\begin{aligned}13x_1 + 100x_2 + 0 + 10x_4 &\le 100\\ 2x_1 + 37x_2 + 0 + 18x_4 &\le 90\\ 6x_1 + 47x_2 + 0 + 27x_4 &\le 98\\ 5x_1 + 96x_2 + 28x_3 + 0 &\le 92\end{aligned}$$

By simplex algorithm we get the following result

$$Max\ Z = 3.9985\ with\ (0.5348,\ 0.9305,\ 0,\ 0)$$

Geometric averaging and harmonic averaging method. By applying geometric mean and harmonic mean between 0.7058 and 0

G.M (0.7058, 0) = 0 and *H.M* (0.7058, 0) = 0

As result of mean is zero, we will go to our new statistical averaging method.

5.2.3 New Statistical Averaging Method (NSAM):

Choosing minimum from the optimal values of maximum type and minimum type in Chandra Sen's method we get

$$m_1 = 0.7058, \quad m_2 = 0.7058$$

$$A.Av = \frac{1}{2}(0.7058 + 0.7058) = 0.7058$$

$$G.Av = \sqrt{(0.7058 \times 0.7058)} = \sqrt{0.498} = 0.7058$$

$$H.Av = \frac{2}{\dfrac{1}{0.7058} + \dfrac{1}{0.7058}} = \frac{2}{1.417 + 1.417} = \frac{2}{2.834} = 0.706$$

Hence for new arithmetic averaging method as in equation (8), we get

$$Max\ Z = \left(\sum_{i=1}^{r} Z_i - \sum_{i=r+1}^{s} Z_i\right) / A.Av$$

$$\begin{aligned}Max\ Z &= \frac{1}{0.7058}(0.067x_1 + 0.72x_2 - 0.072x_3 - 0.1413x_4)\\ &\quad - \frac{1}{0.7058}(0.072x_3 + 0.1413x_4 - 0.067x_1 - 0.72x_2)\\ &= x_1(0.095 + 0.095) + x_2(1.020 + 1.02)\\ &\quad + x_3(-0.1020 - 0.102) + x_4(-0.2 - 0.2)\\ &= 0.19x_1 + 2.04x_2 - 0.204x_3 - 0.4x_4\end{aligned}$$

Thus we get single objective function

$$Max\ Z = 0.19x_1 + 2.04x_2 - 0.204x_3 - 0.4x_4 \qquad (18)$$

subject to

$$\begin{aligned}13x_1 + 100x_2 + 0 + 10x_4 &\le 100\\ 2x_1 + 37x_2 + 0 + 18x_4 &\le 90\\ 6x_1 + 47x_2 + 0 + 27x_4 &\le 98\\ 5x_1 + 96x_2 + 28x_3 + 0 &\le 92\end{aligned}$$

By simplex algorithm we get the result

Max Z=1.9998 with (0.5348, 0.9305, 0, 0)

5.3 Result Comparison

Table 3 shows that with the same values of parameters $(x_1, x_2, x_3, x_4) = (0.5348, 0.9305, 0, 0)$ the

SAM gives maximum value of Z_{max} followed by NSAM and then Chandra Sen's method. The values of Z_{max} have also been plotted in Fig. 3 for a graphical comparison among those methods. The maximum value of Z_{max} indicates a minimum risk of damage due to the natural calamities at the coastal areas of Bangladesh.

Table 3

Results comparison

Chandra Sen's Method	Statistical Averaging Method (SAM)	New Statistical Averaging Method (NSAM)
Z_{max}= 1.9993 with (0.5348, 0.9305, 0, 0)	Z_{max}= 3.9985 with (0.5348, 0.9305, 0, 0)	Z_{max}= 1.9998 with (0.5348, 0.9305, 0, 0)

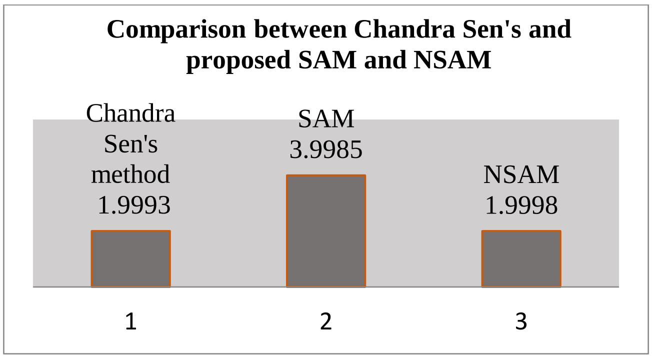

Figure 3: Comparison of the maximum values of the objective functions obtained using different methods.

6. CONCLUSION

In this paper, a single objective LPP has been derived from MOLPP using the SAM and NSAM. The derived objective function has been validated with a numerical example. The proposed SAM and NSAM have been applied to a real-life problem at the coastal areas of Bangladesh. In the real-life problem cropping intensity, shelter, erosion and population density have been considered as parameters of the objective function. Among the four parameters, if erosion and population density are considered minimum, the objective function becomes maximum when solved using SAM and NSAM. In this paper, the simplex method which has been used to solve the problem gives zero values for erosion and population density for the maximum value of the objective function. The maximum value of the objective function indicates the minimum risk of damage due to natural calamities at the coastal areas of Bangladesh. The results obtained using SAM and NSAM have also been compared with the results obtained using Chandra Sen's Method which is also used to derive a single objective LPP from MOLPP. The SAM and NSAM reduce the risk of damage better than Chandra Sen's Method.

Appendix A

Table A-1

Data of coastal area in Bangladesh [11] – [15]

Name of coaster areas	**Cropping intensity**	**Shelter**	**Erosion**	**Population Density**
Amtali	1.803	20.508	0.068055	4.390
Bamna	10.995	17.856	0	14.942
Barguna Sadar	3.425	13.837	0	9.499
Betagi	6.202	40.793	0	12.657
Patharghata	3.277	29.151	0	5.597
Agailjhara	7.581	3.457	0	19.409
Babuganj	6.200	0.920	0	16.585
Bakerganj	2.579	1.235	2.480147	14.326
Banari Para	7.456	3.486	0	23.055
Gaurnadi	5.500	1.370	0	26.906
Hizla	4.969	4.421	59.92037	2.003
Barisal Sadar(Kotwali)	3.673	0.000	5.449342	36.457
Mehendiganj	3.312	3.861	43.77026	13.196
Muladi	4.937	3.695	0.756473	11.938
Wazirpur	3.661	0.550	0	19.024
Bhola Sadar	3.857	15.000	27.64523	21.489
Burhanuddin	5.179	28.166	26.29114	15.841
Char Fasson	1.404	31.692	11.5664	5.340
Daulatkhan	8.365	33.712	19.37093	8.395
Lalmohan	4.400	54.593	7.945344	13.119
Manpura	4.854	96.129	28.19112	0.000
Tazumuddin	6.053	47.820	30.03354	1.078
Jhalokati Sadar	4.190	1.194	0	29.576
Kanthalia	6.017	3.118	0	15.815

Table A-1

Data of coastal area in Bangladesh [11] – [15]

Name of coaster areas	**Cropping intensity**	**Shelter**	**Erosion**	**Population Density**
Nalchity	4.313	3.336	0	16.200
Rajapur	5.540	3.479	0	17.895
Bauphal	2.177	8.913	4.701089	10.783
Dashmina	4.623	26.168	9.388283	3.748
Dumki	11.641	3.656	0	14.377
Galachipa	1.074	31.796	4.935256	2.054
Kala Para	1.976	47.245	2.13865	7.163
Mirzaganj	6.180	3.183	0	13.427
Patuakhali Sadar	2.704	4.081	0	17.150
Bhandaria	5.167	4.359	0	17.997
Kawkhali	9.540	5.525	0	17.356
Mathbaria	2.255	6.879	0	14.352
Nazirpur	3.271	0.716	0	14.994
Pirojpur Sadar	5.003	0.790	0	19.897
Nesarabad (Swarupkati)	3.252	4.284	0	21.772
Zianagar	7.795	10.036	0	15.687
Chandpur Sadar	6.161	1.386	21.03839	33.479
Faridganj	4.097	0.651	0.135738	38.588
Haim Char	10.248	3.536	100	15.712
Hajiganj	4.199	0.782	0	39.409
Kachua	4.526	3.380	0	36.354
Matlab Dakshin	8.211	0.000	0	36.431
Matlab Uttar	3.731	0.000	0	23.543
Shahrasti	6.428	0.000	0	32.734
Anowara	6.511	32.909	0.792869	35.250
Bayejid Bostami	0.000	1.833	0	46.213

Table A-1

Data of coastal area in Bangladesh [11] – [15]

Name of coaster areas	Cropping intensity	Shelter	Erosion	Population Density
Banshkhali	2.284	42.536	0	24.108
Bakalia	0.000	2.458	0	59.564
Boalkhali	6.710	3.473	0	40.026
Chandanaish	4.056	0.000	0	24.365
Chandgaon	0.000	7.052	0	38.383
Chittagong Port	61.821	3.101	4.528336	38.511
Double Mooring	0.000	1.073	2.821948	100.000
Fatikchhari	1.035	0.000	0	12.195
Halishahar	0.000	2.557	0	52.503
Hathazari	3.096	0.000	0	39.743
Kotwali	0.000	0.807	0	87.163
Khulshi	0.000	1.391	0	58.151
Lohagara	2.602	0.000	0	22.490
Mirsharai	2.091	26.238	0.956453	15.944
Pahartali	0.000	4.742	0.387202	51.220
Panchlaish	0.000	1.179	0	80.745
Patiya	3.251	2.201	0.167117	58.742
Patenga	0.000	10.708	5.146568	99.050
Rangunia	2.343	1.143	0	18.819
Raozan	3.035	0.800	0	28.344
Sandwip	2.246	72.781	38.48086	4.108
Satkania	2.646	1.007	0	29.910
Sitakunda	2.988	24.976	1.571422	15.302
Chakaria	1.673	22.593	0	18.922
Cox'S Bazar Sadar	3.888	20.537	0	46.367
Kutubdia	12.670	100.000	0	9.653
Maheshkhali	2.159	36.991	0	17.510

Table A-1

Data of coastal area in Bangladesh [11] – [15]

Name of coaster areas	**Cropping intensity**	**Shelter**	**Erosion**	**Population Density**
Pekua	6.362	46.681	0	26.290
Ramu	1.871	20.828	0	12.221
Teknaf	1.925	17.586	0	12.195
Ukhia	3.144	17.438	0	15.071
Chhagalnaiya	6.176	4.831	0.396235	29.166
Daganbhuiyan	5.231	0.000	0	40.822
Feni Sadar	3.206	2.771	0.407802	52.914
Fulgazi	8.545	3.241	0	24.775
Parshuram	7.415	1.278	0	21.823
Sonagazi	3.715	23.121	9.326996	18.408
Kamalnagar	4.696	15.064	37.15646	12.914
Lakshmipur Sadar	2.010	3.397	3.331249	31.322
Roypur	5.280	5.163	5.084716	30.783
Ramganj	4.869	0.452	0	38.049
Ramgati	5.677	29.690	47.33282	18.691
Begumganj	3.071	0.000	0	53.890
Chatkhil	5.129	0.000	0	39.461
Companiganj	2.329	20.101	18.40038	11.630
Hatiya	1.515	37.393	24.33727	2.439
Kabirhat	5.759	5.902	0	22.028
Senbagh	3.606	0.000	0	40.308
Sonaimuri	4.362	0.000	0	44.390
Subarnachar	1.766	40.149	7.808925	7.651
Noakhali Sadar (Sudharam)	2.455	2.210	0	34.917
Gopalganj Sadar	1.684	0.000	0	17.407
Kashiani	2.490	0.000	0	13.350

Table A-1

Data of coastal area in Bangladesh [11] – [15]

Name of coaster areas	Cropping intensity	Shelter	Erosion	Population Density
Kotali Para	1.548	0.000	0	11.374
Muksudpur	2.319	0.000	0	18.845
Tungi Para	5.190	0.000	0	14.891
Bhedarganj	2.952	1.530	4.542345	19.564
Damudya	7.570	0.000	0	25.648
Gosairhat	5.104	4.915	28.85906	15.302
Naria	2.821	0.558	0	23.954
Shariatpur Sadar	3.881	0.000	0	25.571
Zanjira	3.160	2.663	0	14.968
Bagerhat Sadar	2.163	0.485	0	21.104
Chitalmari	4.553	1.861	0	23.825
Fakirhat	4.589	0.000	0	21.130
Kachua	6.843	0.000	0	21.258
Mollahat	4.660	1.974	0	23.851
Mongla	4.159	47.279	0	20.873
Morrelganj	1.555	3.508	0	19.307
Rampal	2.150	10.001	0	20.488
Sarankhola	4.776	36.875	0	21.104
Abhaynagar	3.318	0.000	0	22.003
Bagher Para	4.008	0.000	0	12.811
Chaugachha	3.556	0.000	0	16.791
Jhikargachha	3.372	0.000	0	19.666
Keshabpur	3.331	0.000	0	19.897
Kotwali	2.279	0.000	0	38.562
Manirampur	2.114	0.000	0	18.870
Sharsha	2.999	0.000	0	20.796
Batiaghata	3.218	3.009	0	21.438

Table A-1

Data of coastal area in Bangladesh [11] – [15]

Name of coaster areas	**Cropping intensity**	**Shelter**	**Erosion**	**Population Density**
Dacope	2.190	22.894	0	21.104
Daulatpur	56.629	0.000	0	21.155
Dumuria	1.879	2.958	0	21.694
Dighalia	12.548	0.000	0	22.105
Khalishpur	68.555	0.000	0	21.207
Khan Jahan Ali	37.509	0.000	0	22.234
Khulna Sadar	70.537	0.000	0	21.181
Koyra	2.722	17.315	0	21.617
Paikgachha	1.674	6.771	0	21.001
Phultala	17.176	0.000	0	21.926
Rupsa	7.033	1.439	0	21.926
Sonadanga	100.000	0.000	0	22.080
Terokhada	5.447	0.000	0	22.850
Kalia	2.646	0.000	0	13.504
Lohagara	3.071	0.000	0	15.327
Narail Sadar	2.550	0.000	0	13.094
Assasuni	1.744	4.325	0	22.208
Debhata	5.269	5.151	0	21.412
Kalaroa	4.455	0.000	0	20.205
Kaliganj	2.160	5.168	0	21.592
Satkhira Sadar	2.254	0.000	0	21.515
Shyamnagar	1.351	9.740	0	22.670
Tala	2.394	0.862	0	20.976

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