An Optimization Methodology (DEA Analysis) : A Case Study in Similipal

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Abstract

In the growing face of deforestation, conservation is the only way to save forest and its precious wild animals, from the human encounter. “Project Tiger “(1973) at Similipal is a welcome step on the direction of tiger conservation, whose population is on the verge of extinction. For the proper protection, preservation and propagation of tiger and forest in the Similipal Tiger Reserve (STR) funds have been allocated from time to time by central govt., state govt. & various NGOs of national and international repute. The responsibility of managing the earmarked fund rests with the management of STR. This paper observes the interrelationship of funds with the trend of tiger population & other variables by using suitable econometric model. Some standard results have been explained. Also it examines the level of efficiency of fund utilization for eight financial years taking the help of Data Envelopment Analysis (DEA).

Key words: Similipal Tiger Reserve, Regression Analysis, Multi Layer Perception, Data Envelopment Analysis, Decision Making Unit.

1. INTRODUCTION

"Forest" plays a significant role in the development of a country. Perhaps it is the only substitute which maintains the atmospheric balance between man and universe[11]. It made positive contribution to the state income, tribal and rural development and forest based industries[10].

In the growing face of deforestation, wilderness protection is a growing necessity for modern societies, and this is particularly true for areas where population density is extremely high[5] like India. "Project Tiger" (1973) at Similipal is a welcome step on the direction of tiger conservation, whose population is on the verge of extinction. Similipal, the 8th Biosphere Reserve (1994) of India is situated in the biotic province, Chhotanagpur plateau in the heart of the erstwhile Mayurbhanj State. It is a symbol of honor for the people of Orissa. It is emotionally attached as a place of religious sanctity & cultural assimilation [6]. Similipal is a perennial source of livelihood to the villagers living in more than twelve hundred villages in its periphery. The northern part of Orissa blessed with many perennial rivers originating from Similipal, which maintains the ground water table in the eastern part of India and regulates the rainfall in the region. It is not only a compact mass of hills & forests, streams and rivers but it is the lifeline of millions of people living in eastern part of India [8]. For the proper protection, preservation and propagation of forests & its wild animals in the STR funds has been allocated time to time by central govt., state govt. & various NGOs of national and international repute. The management should channelise these funds consciously so that maximum return can be achieved.

The main objective of this paper is to explore two basic questions:

I. How far the expenditure per annum and the trend of tiger population & other related variables are inter-related or inter-dependent on each other.
II. How efficiently the fund allocated has been utilized.

To deal with the first objective, help of regression analysis with data of eight financial years has been taken. Making a close observation of R^2 (i.e. the residual sum of squares), which measures the proportion of the variation in the dependent variable accounted for by the explanatory variable(s) and the adjusted R^2, which measures R^2 adjusted for the df (i.e. degree of freedom) associated with the sums of squares, the conclusion has been drawn.

So far as the second objective is concerned, this paper incorporates DEA (i.e. Data Envelopment Analysis), one of the best methodologies to evaluate efficiency of non-profitable zones.

2. OBJECTIVES

Throughout the study, we use data obtained from the office of the Field Director, STR and the website of Similipal Reserve. Tiger census of the reserve has not been done annually, rather in irregular basis. Also year of accounting, period of tourist visit to the reserve & census year of tiger population have some mismatch. To sort out these inconvenience we made minor adjustments. The number of tiger carried forward from the previous census report to the next years for which census report is unavailable. In total we consider eight samples. Though the sample size is not very high, still prediction on the light of the study is quite convincing.

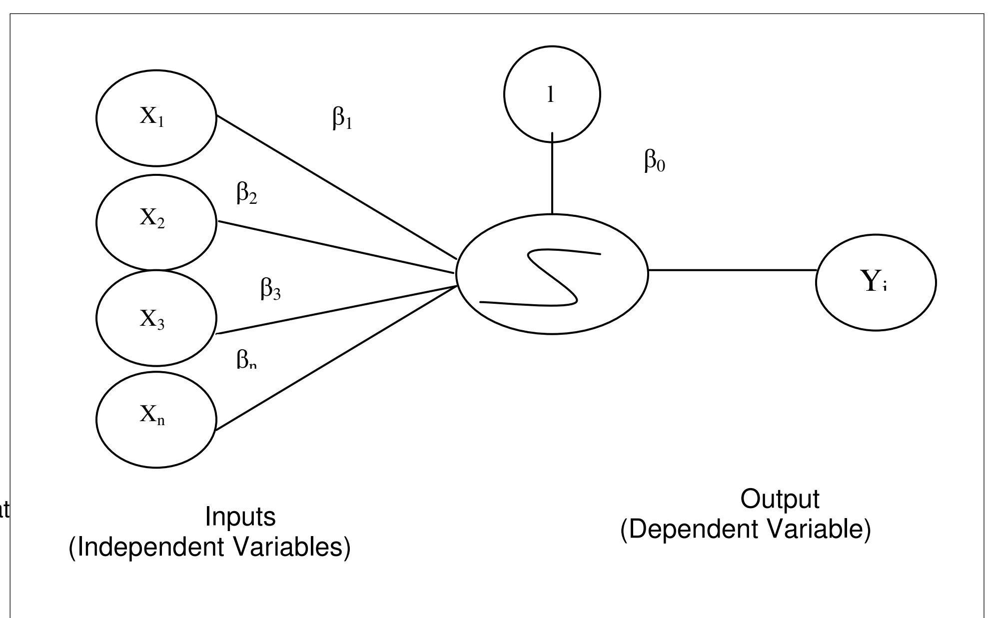
Among the five variables studied here (i.e. NT, NTI, EXP, TPT, EPT) EXP appears the most exogenous and directly controllable. To some extent NT (i.e. Number of Tourist) is also controllable. The management of STR always tried to restrict tourists of Indian & Foreign origin to a manageable level, which can be shown from the figure given in table-1.

Year	Indian	Foreign	Total
1980-81	5979	39	6018
1981-82	4632	36	4668
1982-83	5601	46	5647
1983-84	7270	34	7304
1984-85	5078	23	5101
1985-86	8414	35	8450
1986-87	8458	44	8500
1987-88	11248	54	11302
1988-89	14994	51	15045
1989-90	15176	81	15257
1990-91	14002	88	14090
1991-92	12579	87	12656
1992-93	19260	72	19332
1993-94	17493	132	17625
1994-95	16908	148	17056
1995-96	20236	134	20370
1996-97	21133	140	21273
1997-98	24413	161	24574
1998-99	19377	163	19540
1999-00	13403	84	13487
2000-01	22166	105	22271
2001-02	22508	146	22654
2002-03	21651	172	21823
2003-04	17125	192	17317
2004-05	19401	171	19573

TABLE 1: Tourists to Similipal
Source : www.projecttiger.nic.in/similipal.html

3. ECONOMETRIC MODEL

An econometric model can be configured as a perception to predict tiger population trend using related variables. However, the activation function used with Multi Layer Perception (MLP) is a sigmoid function. Therefore, a similar econometric model will be a regression model[7]. Fig-1 illustrates the model.



(Fig-1: Econometric model)

The mathematical representation of this econometric model is

FIGURE 1: Econometric model

The mathematical representation of this econometric model (Fig.1) is

$$y_i = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \text{------} + \beta_i x_i + e_i \qquad (6.1)$$

It is assumed that the random component has a normal distribution with mean zero and variance δ^2. Equation (6.1) can be simplified as [2]

$$y_i (x) = \beta_0 + \sum_{i=1}^{n} \beta_i x_i + e_i \qquad (6.2)$$

where $e_i \sim n\ (0, \delta^2)$. The objective of this regression problem is to find the coefficients β_i that minimize the sum of squared errors,

$$y_i (x) = \frac{1}{2} \sum_{i=1}^{l} [y_i - \sum_{i=1}^{n} \beta_i x_i]^2 \qquad (6.3)$$

To find the coefficient for the model, a data set that includes the independent variables and associated known values of the dependent variable is needed.

3.1 Empirical Results

Taking all the related variables as static NTI varies directly with the EXP. The trend line shown in fig-2 strongly recommended the positive relationship.

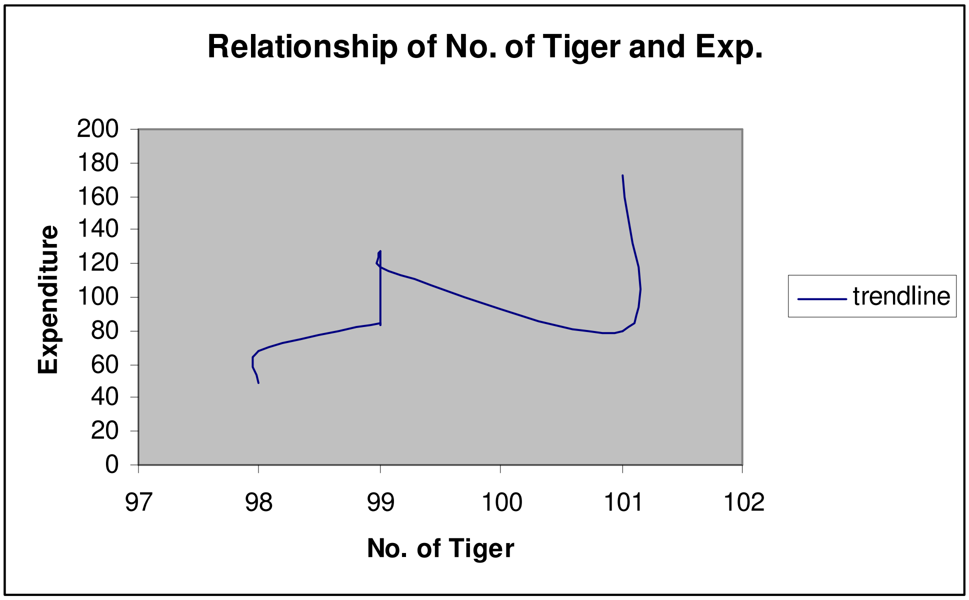


FIGURE 2

However, as one of the our objectives is to evaluate interdependency of variables, regression analysis of the form (6.1) can be re-written in the form

$$Y= aX_1^{b1} X_2^{b2} X_3^{b3} X_4^{b4} \qquad (6.4)$$

Where Y is NTI, and a, b_1, b_2, b_3, b_4 are the parameters of the equation. Each exogenous variable has a significant effect on NTI as shown in table-2.

Variable	Variable	Correlation	Variable	Variable	Correlation
NTI	Exp	0.5973579	Exp	TPT	-0.06443
NTI	NT	-0.371804	Exp	EPT	0.9996948
NTI	TPT	-0.423316	NT	TPT	0.9983827
NTI	EPT	0.5798011	NT	EPT	-0.01806
Exp	NT	-0.02643	TPT	EPT	-0.05531

TABLE 2 : Correlation Summary

The actual linear regression equation is

$$NTI=99.12(EXP)^{.082}(NT)^{.005}(TPT)^{-.51}(EPT)^{-8.77} \qquad (6.5)$$

Variable	Mean	Standard Deviation	Regression Coefficient	Standard Error	t	Prob.>|t|
NTI	99.25	1.164965	Dependent	Variable		
Constant			98.72707	1.679101	58.79758	0.000010
Exp	97.805	39.32392	0.2199304	0.4252266	0.5172075	0.6407273
NT	20154.88	3510.505	0.004390	0.002541	1.727404	0.1825463
TPT	203.125	36.57258	-0.430534	0.2474729	-1.73972	0.180286
EPT	0.9832501	0.3875597	-22.0288	42.44359	-0.519014	0.6396084
Se = 0.6265025		R-square = 0.89871		R-adjusted = 0.76367		

TABLE 3: Regression Summary

Using the table:3 with NTI as the dependent variable provided a very good fit, with R-square(R^2 measures the proportion of the variation in the dependent variable accounted for by the explanatory variable(s)) value of 0.89871 and an adjusted R-squared (the term adjusted means adjusted for the df i.e. degree of freedom associated with the sums of squares) value of 0.76367. Analysis of variance for the above model has been shown in table-4.

Source	Degree of Freedom	Sum of Square	Mean Square	F Value	Prob.>F
Regression	4	10.44847	2.612118	6.654989	0.0756863
Error	3	1.177516	0.3925053		
Total	7	11.62599			

TABLE 4: Analysis of Variance

Prediction & residual analysis on the basis of eq (6.5) has been sited on Table-5, which shows a very little deviation of predicted value & the actual data.

Number	Actual	Prediction	Std. Dev. Prediction	Residual	% Residual	Standardized Residual
1	98	98.3176	0.5651977	-0.317596	-0.323031	-0.774357
2	98	98.51984	0.3460571	-0.519844	-0.527654	-1.26747
3	99	99.17167	0.5723393	-0.171669	-0.173102	-0.418559
4	99	99.41219	0.311497	-0.412193	-0.414630	-1.00500
5	99	99.26794	0.4259256	-0.267944	-0.269920	-0.653296
6	99	99.50827	0.4226389	-0.508270	-0.510781	-1.23925
7	101	101.2841	0.5989521	-0.284080	-0.280478	-0.692639
8	101	101.4429	0.6202983	-0.442947	-0.436646	-1.07998

TABLE 5: Prediction and Residual Analysis

Standard deviation of prediction fluctuates in between 0.31 to 0.62. The deviation can be shown from table-5.

The eq (6.5) can be represented as

NTI = 99.12418+ 0.082434EXP+ 0.0051838NT- 0.5111402TPT -8.775664EPT (6.6)

Another regression analysis of the form

$$Y= a X_1^{b1} X_2^{b2} \tag{6.7}$$

can be considered to study the relationship among the variables , with NT as the dependent variable, and EXP & NTI as the independent variables. Here other independent variables included in (6.5) are droped for better observation of interdependency among the said variables.

4. DEA

Data Envelopment Analysis (DEA) is a new technique developed in operation research and management science over the last two decades for measuring efficiency of Decision Making

Units (DMUs) in the public and private sectors. It has been extensively applied in performance evalution and benchmarking of schools, hospitals, banks etc.[4] .

DEA is a multi-factor productivity analysis model for measuring the relative efficiencies of a homogenous set of decision making units(DMUs). The efficiency score in the presence of multiple input and output factors is defined as

$$\text{Efficiency} = \frac{\text{Weighted sum of outputs}}{\text{Weighted sum of inputs}} \qquad (7.1)$$

4.1 Mathematical Model

Given a set of n units, each operating with m inputs and s outputs, let y_{rj} be the amount of r^{th} output from unit j, and x_{ij} be the amount of the i^{th} input to the j^{th} unit. The relative efficiency of a particular unit is obtained by the optimal values of the objective function in the following fractional linear program [9].

Model 1:

$$\max h_{j0}(u, v) = \frac{\sum_{r=1}^{s} u_r y_{rj0}}{\sum_{i=1}^{m} v_i x_{ij0}}$$

subject to

$$\sum_{r=1}^{s} u_r y_{rj} - \sum_{i=1}^{m} v_i x_{ij} \leq 0 \qquad j = 1,2,3\ldots..,n$$

$$u_r, v_i \geq \epsilon, \ \forall\ r,i$$

The decision variables $u = (i\ u_1, u_2,\ldots,u_r,\ldots,u_s)$ and $v = (v_1,v_2,\ldots v_i,\ldots,v_m)$are respectively the weights given to the outputs and to the m inputs. To obtain the relative efficiencies of all the units, the model is solved n times , for one unit at time. Model1 allows for great weight flexibility and the weights are restricted to the extent that they should not be zero. To make the efficiency of any unit not greater than one, Model1 gets converted in to Model 2.

Model 2:

$$\max h_{j0} = \sum_{r=1}^{s} u_r y_{rj0}$$

subject to

$$\sum_{i=1}^{m} v_i x_{ij0} = 1$$

$$\sum_{r=1}^{s} u_r y_{rj} - \sum_{i=1}^{m} v_i x_{ij} \leq 0 \quad j = 1,2,\ldots,n$$

$$u_r, v_i \geq \epsilon \,, \ \forall\, r,i$$

The above problem is run n-times in identifying the relative efficiency scores of all the DMUs. Each DMU selects input and output weights that maximize its efficiency score. But in general, a DMU is said to be efficient if it obtains score of 1 and a score of less than 1 implies that it is less efficient.

4.2 Empirical Results

Model:2 of DEA is run over all eight years(1998-2005). Performance of STR taking three outputs (NT,NTI and TPT) and three inputs (EPT,EXP and EPSK). The values of inputs and outputs are sited in table:6.

Year	NT(u1)	NTI(u2)	TPT(u3)	EPT(v1)	Exp(v2)	EPSK(v3)
1998 (DMU1)	24.574	98	0.25076	50.3061	49.3	1.7927
1999 (DMU2)	19.54	98	0.19939	69.0306	67.65	2.46
2000 (DMU3)	13.487	99	0.13623	85.8081	84.95	3.0891
2001	22.271	99	0.22496	84.1515	83.31	3.0295

(DMU4)						
2002 (DMU5)	22.654	99	0.22883	128.0909	126.81	4.6113
2003 (DMU6)	21.823	99	0.22043	119.5556	118.36	4.304
2004 (DMU7)	17.317	101	0.17146	78.7129	79.5	2.8909
2005 (DMU8)	19.573	101	0.19379	170.8515	172.56	6.2749

TABLE 6 : Values of outputs and inputs for DEA

NB: *NT :no. of tourist (in '000), NTI :no. of Tiger, TPT :Tourist per Tiger (in '000), EPSK: Expenditure per square Kilometer (in '000, input), Exp :Total Expenditure (in lakhs,input), EPT : Expenditure per Tiger (in '000, input)*

Weights and efficiencies of DMUs are given on table:7. by observing the efficiencies (i.e. h_{j0}) of various DMU it can be concluded that DMU1 is the most efficient unit which indicates efficient use of funds in year 1998(ignoring time lage effect). Efficiencies of DMU4,DMU5,DMU6 and DMU8 are near unity. But DMU3 has the lowest efficiency level among eight DMUs, indicating average performance in year 2000.

DMU	U1	U2	U3	V1	V2	V3	h
1	0.00968	0.00775	0.01047	0.019878	0.020284	0.557818	1
2	0.0077	0.00775	0.00833	0.014486	0.014782	0.406504	0.91162
3	0.00531	0.00783	0.00569	0.011654	0.011772	0.323719	0.84756
4	0.00877	0.00783	0.00939	0.011883	0.012003	0.330087	0.9726
5	0.00892	0.00783	0.00955	0.007807	0.007886	0.216859	0.97943
6	0.0086	0.00783	0.0092	0.008364	0.008449	0.232342	0.96488
7	0.00682	0.00799	0.00716	0.012704	0.012579	0.345913	0.92632
8	0.00771	0.00799	0.00809	0.005853	0.005795	0.159365	0.95947

TABLE 7: weights and efficiencies of DMUs

For the conceptual understanding of the principle behind DEA, we consider only two outputs i.e. TPT and EPT. The performance of all DMUs in terms ofn these two outputs has been depicted in fig.3. one can note that DMU5 and DMU1 lie at the extreme end of the graph. In DEA terminology those two units are said to be the most efficient units.

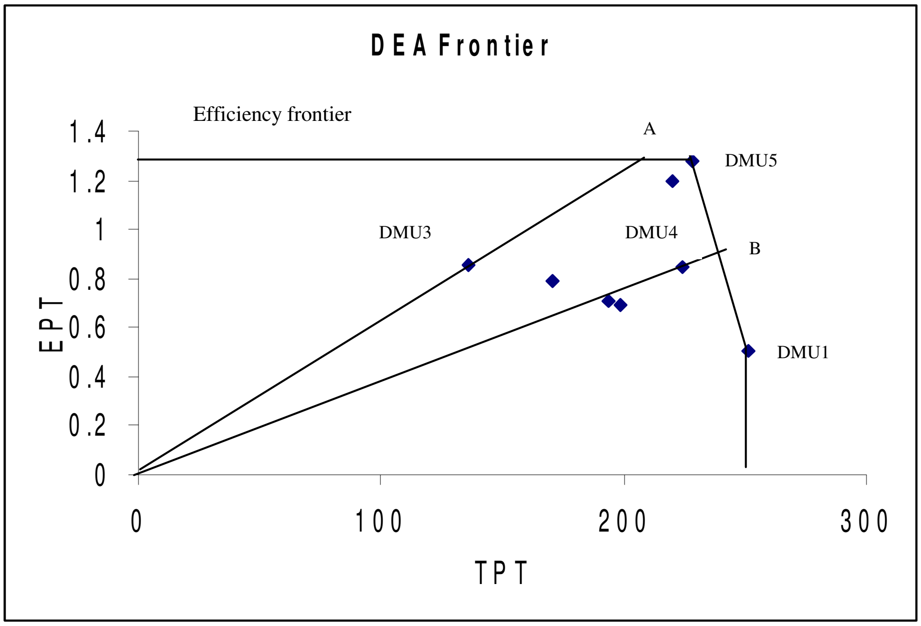


FIGURE 3: DEA frontier analysis considering only two outputs

5.CONCLUSION AND FUTURE WORK

The findings of the study shows that the trend of tiger population basically depends on the amount of fund allocated. Other variables considered on this paper also have close relation with the trend of expenditure. However, so far as the efficiency score on the basis of DEA is concerned, for most of the years the allocated funds have been properly utilized.

As conservation of forest has far bearing effect on environmental scenario of the locality, inclusion of benefits accrues to the environment (viz. less air pollution, less fluctuation of climate, proper water table maintenance etc.) may be included as another output variable in discussed model, which will certainly enhance the confidence level of the result drawn. But due to unavailability of numerical equivalent data we are compel to restrain ourselves to do so. Hence any future work on this line may highlight above-mentioned environmental benefits as single variable or multiple variables considering each one independently.

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