Journal of Green Engineering (JGE)

Volume-10, Issue-3, March 2020

Data Envelopment Analysis for Checking Sustainable Efficiency in Cloud Computing Engineering

[1]S. Manoj Kumar and [2]R. Venkateswarlu

[1] *Research Scholar, Department of Management, GITAM (Deemed to be University), Gandhi nagar, Rushikonda, Visakhapatnam, Andhra Pradesh, India.*
E-mail: smkumar1212@gmail.com
[2] *Professor, Department of Management, GITAM (Deemed to be University), Gandhi nagar, Rushikonda, Visakhapatnam, Andhra Pradesh, India.*
E-mail: venkateswarlu.rangavajhala@gitam.edu

Abstract

The importance of cloud technologies in Information Technology Engineering has been growing world-wide which has brought significant changes and opportunities to various sectors across the Globe. The current study is related to calculating the relative efficiency of cloud companies using Data Envelopment Analysis(DEA) i.e., decision making units (DMUs) for IT Companies. This study provides dimension of Cloud Company's efficiency using DEA with data in 2017 among the 10 Cloud Companies. This study uses Number of Employees, Year of Establishment and no of companies using that particular cloud as input variables whereas Annual Revenue and Annual Income are the output variables for the DEA Analysis. Results indicate DEA is fairly methodology in relates to efficiency of DMUs.

Keywords: Data Envelopment Analysis, decision making units, Cloud, efficiency, Constant Returns to Scale and VRS, Variable returns to scale

Journal of Green Engineering, Vol. 10_3, 868–881.

Alpha Publishers

1 Introduction

Data Envelopment Analysis (DEA) is a accepted model created by Charnes et al. in the year 1978. This was wide studied everywhere across. This has been used to compute DMU's and in return find the relative efficiencies. It indicates DMU's productivity, means the division of total weighted outputs to the total weighted inputs, later collate each other to find the DMU efficient. DEA achieves the weights optimal for input and output of everything and no constraints have been applied on the weights. DEA is efficient and adaptable analysis for effectiveness in globe. Broad practical use for DEA is there in alternative fields manufacturing, logistics, telecommunication, healthcare, and even in sports. DEA arranges into two categories, effectiveness equals to 100% effective and ineffectiveness with minimal than 100% effectiveness.

The cloud is a technology that offers resources, backup facilities, development tools in the form of services accessible through the Internet. These cloud trends shift by a variety of organizations has resulted in the requisite of providers to invest in cloud infrastructure and data center related contributions like security and management services. According to an Article in zdnet top Cloud service providers available in the market are Microsoft, Amazon Web Services, Sales Force, Citrix, Google, IBM, SAP, Oracle, Workday & VM Ware. In this paper we will be measuring the efficiency of top ten Cloud Companies (DMUs) with DEA.

2 Related works

Charnes A et al. [1] used Data Envelopment Analysis model for developing measures of decision making efficiency with special reference to possible use in evaluating public programs.

Shammari [2] used Multi criteria Data Envelopment Analysis model for measuring the productive efficiency of hospitals.

Cook et al. [3] used DEA for application to service performance and sales in branches of the bank.

Giokas et al. [4] used Data Envelopment Analysis for Evaluating Productiveness in Telecommunications.

Tongzon [5] used Data Envelopment Analysis for Australia and various other ports to improve port efficiency.

Haas [6] used Data Envelopment Analysis for Productive Efficiency of English Football Teams.

Abbott [7] used Data Envelopment Analysis to find efficiency for Australian universities.

Raul Sanhueza et al. [8] used Data Envelopment Analysis for Efficiency Determination of the Electric Power Distribution.

Sun [9] used Data Envelopment Analysis in the Taiwanese Army for joint maintenance shops.

Ramanathan [10] used Data Envelopment Analysis for hospitals in Oman.

Eleren et al. [11] used DEA for private deposit banks in Turkey.

Cullinane et al. [12] used DEA for Improving Container Port Efficiency.

Tauer et al. [13] used DEA Analysis for measuring efficiencies for college in the academic departments.

Alirezaee et al. [14] used Data Envelopment Analysis in relates to Model Improvement for Computational Difficulties in the Present of Special DMU's.

Barros [15] used DEA Analysis for Technical efficiency of UK airports.

Wahab et al. [16] used DEA Analysis for assessing machine flexibility in the systems manufacturing.

Bhagavath [17] used DEA for Transportation Measurement.

Sozen et al. [18] used DEA for thermal power station in Istanbul.

Griffin et al. [19] used DEA for determining policy-efficient management strategies in fisheries.

Salah et al. [20] used DEA for Assessment of academic department's efficiency.

Khezrimotlagh et al. [21] used Data Envelopment Analysis for assessing the Efficiency of Airports.

Scalco et al. [22] used DEA in the police military of Brazil.

Kamrul et al. [23] used DEA for Efficiency in the Production when the situation was worst.

David Meza and Ki Young Jeong [24] used data envelopment analysis for six sigma project during the implementation in NASA.

Amin et al. [25] used DEA Technique for Hospitals Productivity Measurement.

Mazyar et al. [26] used DEA for Construction Project Success ranking.

Georgios [27] used DEA in the organizations to find the efficiency.

Hiroto Narimatsu et al. [28] used DEA in creating a Risk Model for Obesity.

Edward et al. [29] used DEA Approach for Ranking Journals.

Saifulsyahira et al. [30] used DEA in the Primary Care centers.

Xiao et al. [31] used DEA for the decision-making.

Angeliki et al. [32] used DEA in public hospital sector when there was economic crisis in Greece.

Abbas Mardani et al. [33] used DEA for State of the Art and Recent Development Trends in Energy and Environmental Economics.

Eva Grmanová and Eva Ivanová [34] used DEA for calculating the banks efficiency in Slovakia.

Rajyalakshmi et al. [35] used Data Envelopment Analysis Algorithm for Cricket Team Selection.

Bhishma and Venkateswarlu [36] studied the efficiency and productivity of Indian public and private insurance non life organizations.

3 Data Envelopment Analysis

"When numerous inputs and numerous outputs are considered for Particular organization DEA model efficiency is defined as

Efficiency = (weighted total of outputs) / (weighted total of inputs)

Here, the underlying assumption is that weights related to selected inputs and outputs have already been fixed as deemed acceptable for that specific firm in its operating background.

Data Envelopment Analysis (DEA) is a non-parametric approach for deriving the performance of a group of peer entities wherever various units are converted to multiple outputs. It uses linear programming method to conclude the efficiency limit. The points, which lie on the limit include the efficient companies and the inefficient companies lie below the limit.

DEA was initially come about by Charnes, Cooper and Rhodes (1978) (CCR model) to assess the relative efficiency of public sector not-for-profit organizations presuming constant return to scale. The effectiveness score of the companies varies between 0 and 1. The companies having an efficiency score of 1 are the relatively effective companies. The other companies having efficiency score less than 1 are relatively not effective. Our purpose to be noted here is that the term 'relatively efficient' means that the companies are effective in relation to alternative companies in the sample. The CCR model permits the individual companies to alter its own weights accordingly so that it becomes relatively effective. So, the efficiency score is the fraction of the weighted set of inputs to the weighted set of outputs"[1].

The CCR Model [1] is demonstrated below:

"Let there be i range of companies to be evaluated. Every company absorbs l different inputs to produce m different outputs. More precisely, company k consumes G_{lk} of l^{th} input and produces H_{lk} of the m^{th} output. (where j = 1,2,3 …i). We further assume that G_{lk} >= 0 and H_{mk} >=0.

The model is as follows:

CCR Model in Fractional Form

$$\text{Max } EC = \left(\sum_{m=1}^{M} U_{mC}.H_{mC} \Big/ \sum_{l=1}^{L} V_{lC}.G_{lC}\right) \quad (1)$$

Subject to

$$\left(\sum_{m=1}^{M} U_{mC}.H_{mk} \Big/ \sum_{l=1}^{L} V_{lC}.G_{lk}\right) \leq 1 \quad (2)$$

(for k = 1,2,3…..i)

$$U_{mC} \geq 0,\ V_{lC} \geq 0,\ \varepsilon \geq 0 \quad (3)$$

Where

EC = Efficiency of the a particular company (say C)
H_{mC} = Amount of m^{th} output produced by the company C
G_{lC} = Amount of l^{th} input consumed by the company C
H_{mj} = Amount of m^{th} output produced by j^{th} company
G_{lj} = Amount of l^{th} input consumed by the j^{th} company
U_{mC} = Weight assigned to the m^{th} output of the company C
V_{lC} = Weight assigned to the l^{th} input of base company C
ε = A sufficiently small positive number

The above fractional form can be transformed to the following equivalent linear programming form

$$\text{Max } EC = \left(\sum U_{mC}.\ H_{mC}\right) \quad (4)$$

Subject to

$$\sum_{l=1}^{L} V_{lB}.G_{lB} = 1 \quad (5)$$

$$\sum_{m=1}^{Q} U_{mC}.H_{mj} - \sum_{l=1}^{P} V_{lC}.G_{lC} \leq 0 \text{ for } (k = 1,2,3,\ldots..i) \quad (6)$$

$$U_{mC},\ V_{mC} \geq \varepsilon \geq 0 \quad (7)$$

We are interested in the relative effectiveness of the company C with reference to all the other organizations in the sample. Relative efficiency means we are comparing the ratio of the weighted outputs (virtual output) to the weighted inputs (virtual input) relative to the company C. The objective

is to maximize EC (ratio of the virtual output to virtual input) by comparing the inputs and outputs of all the other companies such that none of them have efficiency greater than 1. It is noted that the unknown weights U_{mC} and V_{mC} are obtained through optimization"[1].

4 Research Methodology

We have used DEAP Version 2.1 to calculate the efficiencies of Top 10 Cloud Companies. CRS, Constant Returns to Scale and VRS, Variable returns to scale will be evaluated. We have calculated the results by using DEAP 2.1 software developed by the University of Queenland Australia from the below:

"https://economics.uq.edu.au/cepa/software"[37].

Attributes selection is vital in DEA in relates to aim for study.

4.1 Sample Selection

The paper relies on study of 10 Cloud companies with DEAP Analysis. The companies were therefore chosen that they were doing the best in Cloud Technologies with data in 2017.

4.2 Classification of Input and Output Attributes

In any software organization important factor is Number of Employees, Added to that Reputation also plays an important role which is Year of Establishment and No of companies using that particular cloud in the Service Industry are the Input Variables. Output variables chosen for the study are Annual Revenue and Annual Income.

Income, for example, shows how well the company utilizes its resources and reduces its expenditure and operational costs to effectively increase the company's income. On the other hand, revenue only shows us how many products the company has managed to sell and the prices at which they are sold but doesn't depict the utilization of resources in an efficient way.

Inputs

X1 = Number of Employees

X2 = Year of Establishment

X3 = No of companies using that particular cloud

Outputs

Y1 = Annual Revenue

Y2 = Annual Income

Table 1: Outline statistics for Attributes of inputs and outputs

S.No	DMU	Founded in Year	No of Years of Establishment	No of Employees in Units(1000)	Annual Revenue in Billion $	Annual Net Income in Billion $	No of Companies using Cloud Units (1000)
1	Microsoft	1975	44	125	90	20	1054.65
2	Amazon Web Services	2002	17	566	18	1.3	1198.04
3	Sales Force	1999	20	30	8	0.18	31.54
4	Citrix	1989	30	8	3.3	0.32	7.24
5	Google	1998	21	85	31	5.43	772.84
6	IBM	1911	108	380	79	5.8	2.59
7	SAP	1972	47	88	37	4.5	0.44
8	Oracle	1977	42	138	37	9	6.32
9	Workday	2005	14	8	2.4	0.32	0.05
10	VM Ware	1998	21	20	7	1.18	4.83

Annual Revenue and Annual Income are the output variables. Number of Employees, Year of Establishment and No of companies using that particular cloud are the inputs.

Table2: Efficiency Summary

Firm	CRS	VRS
Microsoft	1	1
Amazon Web Services	0.197	0.955
Sales Force	0.583	0.993
Citrix	0.912	1
Google	0.507	0.988
IBM	1	1
SAP	1	1
Oracle	1	1
Workday	0.776	1
VM Ware	0.977	1

5 Results

Ten Cloud Companies have been assessed for calculating their efficiency with data in 2017. Initially we have got resolved DEAP model while not considering any uncertainties in data. Table 2 shows the CRS and VRS models results. It is noticed that four cloud companies viz., Microsoft, IBM, SAP, Oracle are precisely competent and form the efficient leading edge. Annual Revenue of the companies depends upon the Reputation of the company and since when it is founded and not on size of the Employees. Other companies attain efficiency scores ranging from 0.197 to 0.977, and the average of efficiency value is 0.79.

VRS, Variable Returns to Scale for companies Microsoft, Citrix, IBM, SAP, Oracle, Workday & VM Ware is 1. So these companies are Technically Efficient. Below are the reasons for the other companies why these are not Technically Efficient and may focus on that.

1. Amazon Web Services was unable to achieve the Annual Revenue compared to Microsoft, IBM, SAP, Oracle though the No employees were less in size which is very larger compared to Microsoft, IBM, SAP, Oracle. Amazon Web Services is having all scale of clients from smaller to larger which is technically inefficient and need to focus on larger clients.

2. Sales Force was unable to achieve the Annual Revenue compared to Microsoft, IBM, SAP, Oracle because the No employees were less in size which is lesser compared to Microsoft, IBM, SAP, Oracle which means Sales Force should grow bigger in Size and need to focus on all various clients.

3. Citrix was unable to achieve the Annual Revenue compared to Microsoft, IBM, SAP, Oracle because the No employees were less in size which is very lesser compared to Microsoft, IBM, SAP, Oracle which means Citrix should grow bigger in Size and need to focus on all various clients.

4. Google was unable to achieve the Annual Revenue compared to Microsoft, IBM, SAP, Oracle because no of companies using cloud companies are less which means Google should focus on giant clients. Employee Number is Moderate.

5. Workday was unable to achieve the Annual Revenue compared to SAP, Oracle, Microsoft, IBM because the No employees were very lesser compared to Microsoft, IBM, SAP, Oracle which means Workday should grow bigger in Size and need to focus on all various clients.

6. VMWare was unable to achieve the Annual Revenue compared to SAP, Oracle, Microsoft, IBM because the No employees were very lesser compared to Microsoft, IBM, SAP, Oracle which means VMWare should grow bigger in Size and need to focus on larger clients.

6 Conclusion

By means of DEA organization can evaluate effectiveness of the Individual units, giving every unit an objective index of effectiveness, within a considerable set of units, even within the case of difference about the relative importance of the outputs. Profitability and productivity will be improved through a better shaping of the aims and processes of the performance analysis. This method permits identification of the efficiencies and potential ways to improve efficiency.

The analysis of each individual units is related in the current situation of competitiveness. This is why DEA models which are worked on identifying and taking improvement of diversity – taking under consideration every decision unit as a sole entity – permit versatile evaluations through personalized evaluations.

In CRS model 4 units Microsoft, IBM, SAP, Oracle are efficient where as in VRS model 7 units Microsoft, Citrix, IBM, SAP, Oracle, Workday & VM Ware are efficient. Three companies Citrix, Workday & VM Ware are ineffective companies in the CRS model but those became effective cloud companies in the VRS model.

From Table 2 effectiveness of all the companies as per the VRS model are better than the CRS model. Sales Force created 58.30% in CRS model compared to 99.30% in VRS model.

The overall VRS model shows additional performance of Cloud companies compared to CRS model. The mean efficiency scores are 0.7952

i.e 79.52% and 0.9936 i.e 99.36%. Efficiency scores clearly mentions ample of space is existing in relates to development of Cloud Companies.

References

[1] A. Charnes, W. W Cooper and E. Rhodes, ”Measuring the efficiency of decision making units. European Journal of Operational Research”, Vol. 2,no.6, pp.429-44, 1978.

[2] M. Al-Shammari, “A multi-criteria Data Envelopment Analysis model for measuring the productive efficiency of hospitals”, International Journal of Operations & Production Management, Vol.19,no.9,pp.879-890, 1999.

[3] D. Wade Cook, Moez Hababou & J.H Hans Tuenter, “Multicomponent efficiency measurement and shared inputs in Data Envelopment Analysis: An application to sales and service performance in bank branches”, Journal of Productivity Analysis, Vol.14,no.3,pp.209-224, 2000.

[4] D.I.Giokas & G.C.Pentzaropoulos, “Evaluating Productive Efficiency in Telecommunications: Evidence from Greece”, Telecommunication Policy, Vol.24,no.8,pp.781-794, 2000.

[5] Jose Tongzon, “Efficiency measurement of selected Australian and other international ports using data envelopment analyses”, Transportation Research Part A, Vol.35,no.2,pp.107-122, 2001.

[6] J. Dieter Haas, “Productive Efficiency of English Football Teams – A Data Envelopment Analysis Approach”, Managerial and Decision Economics, Vol.24,no.5,pp.403-410, 2003.

[7] M. Abbott, C. Doucouliagos, “The efficiency of Australian universities: a Data Envelopment Analysis”, Economics of Education Review, Vol. 22,no.1,pp.89-97, 2003.

[8] Raul Sanhueza, Hugh Rudnick, Hector Lagunas, “DEA Efficiency for Determination of the Electric Power Distribution Added Value”, IEEE Transactions on Power Systems, Vol.19,no.2,pp.919-925, 2004.

[9] S. Sun, “Assessing joint maintenance shops in the Taiwanese Army using Data Envelopment Analysis”, Journal of Operations Management, Vol.22,no.3,pp.233-245, 2004.

[10] R. Ramanathan, “Operations assessment of hospitals in the Sultanate of Oman”, International Journal of Operations & Production Management, Vol.25,no.1,pp.39-54, 2005.

[11] A. Eleren, E. Ozgur, "Efficiency Analysis of private deposit banks in Turkey: A Data Envelopment Analysis Application", Afyon Kocatepe University GGBF Journal, Vol.8,no.2,pp.53-76, 2006.

[12] K. Cullinane, T.F. Wang, "Data Envelopment Analysis (DEA) and Improving Container Port Efficiency", Research in Transportation Economics, Vol.17,no.1,pp.517–566, 2007.

[13] W. Loren Tauer, O. Harold Fried, E. William Fry, "Measuring efficiencies of academic departments within a college", Education Economics, Vol.15,no.4,pp.473–489, 2007.

[14] M.R. Alirezaee, M. Afsharian, "Model Improvement for Computational Difficulties of DEA Technique in the Present of Special DMU's", Applied Mathematics and Computations, Vol.186,no.2,pp.1600-1611, 2007.

[15]C.P Barros, "Technical efficiency of UK airports", Journal of Air Transport Management, Vol.14,no.4,pp.175-178, 2008.

[16] M.I.M.Wahab, Desheng Wu, Chi Guhn Lee, "A generic approach to measuring the machine flexibility of manufacturing systems," European Journal of Operational Research, Vol.186,no.1,pp.137-149, 2008.

[17]V. Bhagavath, "Technical Efficiency Measurement by Data Envelopment Analysis: An Application in Transportation", AJBR Alliance Journal of Business Research,Vol.2,no.1,pp.60-72, 2009.

[18] A. Sozen, I. Alp and A. Ozdemir, "Assessment of operational and environmental performance of the thermal power plants in Turkey by using Data Envelopment Analysis", Energy Policy , Vol.38,no.10,pp. 6194–6203, 2010.

[19] W. L. Griffin, R. T. Woodward, "Determining policy-efficient management strategies in fisheries using Data Envelopment Analysis (DEA)", Marine Policy, Vol.35,no.4,pp.496–507, 2011.

[20] R. Salah Agha, Ibrahim Kuhail, Nader Abdelnabi, Mahmoud Salem, Ahmed Ghanim , "Assessment of academic departments efficiency using data envelopment analysis", Journal of Industrial Engineering and Management, Vol.4,no.2,pp.301-325, 2011.

[21] D. Khezrimotlagh, S. Salleh and Z. Mohsenpour, "Airport Efficiency with Arash Method in Data Envelopment Analysis", Journal of Basic and Applied Scientific Research, Vol.2,no.12,pp.12502-12507, 2012.

[22] P. R. Scalco, A. L. Amorim, A. P. Gomes , "Technical efficiency of the Military Police of the Brazilian state of Minas Gerais", Nova Economia, Vol.22,no.1,pp.165-190, 2012.

[23] Md. Kamrul Hossain, Anton Abdulbasah Kamil, Adli Mustafa, and Md. Azizul Baten, "Efficiency in the Worst Production Situation Using Data Envelopment Analysis", Advances in Decision Sciences, Vol.2013,pp.1-9, 2013.

[24] David Meza, Ki Young Jeong , "Measuring efficiency of lean six sigma project implementation using data envelopment analysis at NASA", Journal of Industrial Engineering and Management, Vol.6,no.2,pp.401-422, 2013.
[25] Amin Torabipour , Maryam Najarzadeh , Mohammad Arab, Freshteh Farzianpour , Roya Ghasemzadeh , "Hospitals Productivity Measurement Using Data Envelopment Analysis Technique", Iranian Journal of Public Health , Vol.43,no.11,pp.1576-1581, 2014.
[26] Mazyar Zahedi Seresht, Mohammadreza Akbarijokar , Shahrzad Khosravi , Hamidreza Afshari , "Construction Project Success ranking through the Data Envelopment Analysis", Journal of Data Envelopment Analysis and Decision Science , Vol.2014,pp.1-13, 2014.
[27] I. Georgios Farantos, "The Data Envelopment Analysis Method and the influence of a phenomenon in organizational Efficiency", Journal of Data Envelopment Analysis and Decision Science, Vol.2015,no.2,pp.101-117, 2015.
[28] Hiroto Narimatsu , Yoshinori Nakata, Sho Nakamura, Hidenori Sato, Ri Sho, Katsumi Otani, Ryo Kawasaki, Isao Kubota, Yoshiyuki Ueno, Takeo Kato, Hidetoshi Yamashita, Akira Fukao, Takamasa Kayama , "Applying Data Envelopment Analysis to Preventive Medicine: A Novel Method for Constructing a Personalized Risk Model of Obesity", Plos One Journal, Vol.10,no.5,pp.1-11, 2015.
[29] C. Edward Rosenthal and J. Howard Weiss, "A Data Envelopment Analysis Approach for Ranking Journals", Omega, Vol.70,no.C,pp.135-147, 2016.
[30] J. Saifulsyahira, R. Mohammad Farhan, Muhammad Hanafiah Juni, "Assessing Efficiency of Primary Care Services: Methodological Issues", International Journal of Public Health and Clinical Sciences, Vol 3,no.4, pp.30-51, 2016.
[31] Xiao Li Meng and Fu Gui Shi, "An extended data envelopment analysis for the decision-making", Journal of Inequalities and Applications, Vol.240,pp.1-16, 2017.
[32] Angeliki. Flokou, Vassilis. Aletras, Dimitris. Niakas, "A window-DEA based efficiency evaluation of the public hospital sector in Greece during the 5-year economic crisis", Plos One Journal, Vol.12,no.5,pp.1-26, 2017.
[33] Abbas. Mardani, Dalia. Streimikiene, Tomas. Balezentis, Muhamad. Zameri Mat. Saman, Khalil. Md Nor and Seyed. Meysam Khoshnava, "Data Envelopment Analysis in Energy and Environmental Economics: An Overview of the State-of-the-Art and Recent Development Trends", Energies, Vol.11,pp.1-21, 2018.
[34] Eva. Grmanová and Eva. Ivanová, "DEA Analysis for measuring the Efficiency of banks in Slovakia", Journal of International Studies, Vol. 11,no.1,pp.257-272, 2018.

[35] V. Rajyalakshmi, M. S. Vani, M. Narendra, M. Pavan Kumar, D. Charan Kumar Reddy, P. vennela , "Cricket Team Selection and Analysis by Using DEA Algorithm in Python", International Research Journal of Engineering and Technology (IRJET), Vol.6,no.3,pp.4177-4184, 2019.

[36] G. S. S. Bhishma Rao, R. Venkateswarlu, "A study on efficiency and productivity of Indian non-life insurers using data envelopment analysis", International Journal of Applied Operational Research, Vol. 5,no.3,pp.1-15, 2015.

[37] DEAP Link software - https://economics.uq.edu.au/cepa/software

Biographies

Manoj Kumar S is a PhD Scholar GITAM University, Rushikonda, Visakhapatnam, Andhrapradesh. He completed B.E in Mechanical Engineering from Andhra University. He obtained M.Tech in Mechanical Engineering, Jawaharlal Nehru Technological University. He has 12 years of IT Experience. His PhD work is in Cloud Computing Cyber security challenges and gaps and also the way Organizations are adopting to Cloud Computing Engineering.

R. Venkateswarlu working as Professor in the GITAM University, Rushikonda, Visakhapatnam, Andhrapradesh. He has over 25 years of

teaching and research experience. Areas of specialization are Operations Research and Applied Mathematics. Extensively published more than 85 research papers international journals including the reputed Journal of Astrophysics and Space Science, Journal of Indian Mathematical Society, International Journal of Applied Mathematical Sciences, Electronic Journal of Theoretical Physics. Guiding research students for their doctoral degrees. Attended several national and international conferences. Alumni of IIMA, Currently researching in Operations Research, Theory of Relativity.