PERFORMANCE EVALUATION OF INDIAN BUSINESS SCHOOLS USING THE MAHALANOBIS TAGUCHI SYSTEM

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Abstract

Grading is a competitive philosophy adopted by many institutions to attract the academic aspirants. Contemporary grading tools are designed to evaluate the institutions status of their performance and success. Generally, the required data is available in multidimensional form for getting the present status of the institutions. However, more multivariate data analysis methods are available for solving these systems, but most of these methods provide analysis based on some statistical assumptions.

In this work, the complementary methodology is proposed for the analysis, which will provide a quantitative measure of the B-Schools performances. The proposed Mahalanobis Taguchi System (MTS) based methodology is a pattern information technology developed by Dr.Taguchi. This method is aimed at providing better prediction ability for multidimensional data through the construction of a multivariate measurement scale. Subsequently, the useful variables under this study are identified using the Orthogonal Arrays and Signal-Noise ratio. This study the Indian B-School data with four variables and four classes are use for this analysis.

Keywords: *Mahalanobis Distance, Mahalanobis Taguchi System, S-N ratio, Orthogonal Array, Business Schools.*

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1. INTRODUCTION

The Master of Business Administration (MBA) is a master's degree in business administration, which attracts people from a wide range of academic disciplines. The MBA designation originated in the United States, emerging from the late 19th century as the country industrialized and companies sought out scientific approaches to management. The core courses in the MBA program are designed to introduce students to the various areas of business such as accounting, marketing, human resources, operations management, etc. Students in some MBA programs have the option to select an area of concentration and focus approximately one-third of their studies in this area.

In India over 1800 B-Schools are there for the offering different programmes related to management studies. The ratings of B-Schools are more impacted by many factors. The following Major four variables are considered for doing the performance estimation.

The four variables set are described below:

1.1 Infrastructure

Infrastructure is sub-divided into physical and academic infrastructure. Physical infrastructure is further broken down into factors such as the institute's build-up area, number and size of classrooms, hostel on campus, and percentage of students provided accommodation, layout plan, physical verification etc. overall ambience of the classrooms and the institute in general.

Academic infrastructure is sub-classified into knowledge centre and teaching aids.

Knowledge centre has sub-parameters like number of books added, management related books added, journals (national and international), e-journals, library records, over all atmospheres in the library etc.

Teaching aids has sub-parameters like use of books and a journal for teaching, including networking, Number of LCD's, computing facilities in classrooms, other equipments etc.

1.2 Education/Academic Structure

Education/Academic structure is sub-divided into faculty, research, consultancy, publications, MDP etc. These parameters are further divided into different factors such as full time and visiting faculty, percentage of PhD, industry experience, ratio of students and faculty, research and consultancy, MDP, number of publications and research papers, books, working papers written(total output), conferences or seminars organized, competency building & soft skills, courses other than MBA programmes, financial structure etc.

1.3 Admission &Delivery Process

Admission and Delivery process is divided into sub-parameters such as admissions, curriculum, and delivery systems. These parameters are again divided into number of sub-factors such as the entrance test, student's profile, percentage of curriculum devoted to core/elective/project work, stipend during summer placements, course designed and offered, course time table etc.

1.4 Placement

Placement is sub-divided into placement (Domestic& International) Entrepreneurship and USP, Social responsibility, social sector initiatives and interventions, networking and industry interface, alumni etc. Placement (Domestic& International) Entrepreneurship is further broken down into different factors such as the offer letters, recruiter's details, % of students finally placed (average domestic, national & international), percentage of entrepreneurship, cost of education and return against investment etc.

With the rapid growth of technology, the required data about the B-Schools are easily collected. But many factors are considered about B-School in classification into different groups. Several statistical multivariate data analysis methods have been already used for the classifications, usually they need to follow some assumption; however, it is difficult to satisfy them all simultaneously. Mahalanobis Taguchi System (MTS) is proposed as a diagnosis and forecasting method for multivariate data. Dr.Taguchi deems that MTS is data analytic and requires no assumptions.

The rest of the paper is organized as follows: section2 describes the concept of Mahalonobis Taguchi System method. Section3 presents proposed methodology analysis using Mahalonobis Taguchi System method. Section4 shows the classification of Indian B-Schools using the MTS method. Section5 presents our conclusions.

2. MAHALANOBIS TAGUCHI SYSTEM

The Mahalanobis Taguchi System is a multivariate data based pattern recognition and diagnosis system. The main objective of the Mahalanobis Taguchi System is to make accurate predictions in multidimensional systems by constructing a measurement scale. In Mahalanobis Taguchi System the variables highly depend on the correlation structure of reference or normal group observations. To construct a reference space, correlation structure of normal group is important to have a distance measure of new observations from mean point of reference group.

In Mahalanobis Taguchi System, the Mahalanobis space is obtained using the standardized variables of reference group or normal group data. The Mahalanobis space can be used to differentiate between the "normal" and "abnormal" groups using the Mahalanobis Distance of objects. Once the Mahalanobis space is established successfully, then the number of variables is reduced using the orthogonal array and signal to noise ratios to evaluate the importance of each variable. The aim of reduction the number of variables is to decrease the cost of conducting the tests and time consumption. The MTS involving 4steps described in detail as follows:

Step1: Construct a Measurement Scale

In order to construct a measurement scale, a set of "normal" data are collected and standardize the variables of these observations to calculate the Mahalanobis Distances (MD). MD measures distances in multidimensional spaces by taking into account the correlation coefficients of variables. Mahalanobis Distance is used to find the nearness of an unknown point from the mean values of a normal group. The scaled Mahalanobis Distance is calculated by dividing the MD value by the number of variables. The Scaled Mahalanobis Distance is calculated using the following formula

$$MD_i = \frac{1}{k} Z_{ij}^T C^{-1} Z_{ij}$$

Where Z_{ij} = standardized vector obtained by standardized values of X_{ij}

$$Z_{ij} = \frac{(X_{ij} - \overline{X}_j)}{SD_j}$$

Where i = 1,2,…,n , j= 1,2,…,k.

$$\overline{X}_j = \frac{\sum_{i=1}^{n} X_{ij}}{n}$$

Where X_{ij} = the i th observation of the j th variable.

$$SD_j = \sqrt{\frac{\sum_{i=1}^{n}(X_{ij} - \overline{X}_i)^2}{n-1}}$$

Where SD_j = the standard deviation of the j th variable.
i = number of samples (*i* = 1, 2 . . . n).
j = number of variables (*j* = 1, 2 . . . k).
k = the total number of variables.
n = the number of observations.
Z_{ij} = the normalized value of the i th observation of the j th variable.
And C = the correlation matrix.

Step2: Validate the Measurement Scale

For validate the measurement scale, the observations outside of the Mahalanobis Space (MS), usually abnormal observations are used. In the MTS, the decision maker chooses solely the variables that are required for creating an MTS measurement scale. So these variables need to examine again to make sure they are properly selected. After the measurement scale is established, the observations outside of MS are used to evaluate for the selected variables are suitable or not. The average, standard deviation and correlation matrix of "normal" observations are used to calculate the MDs in the "abnormal" observations. If the established measurement scale is good, the MDs of "abnormal" observations will be larger than the "normal" observations.

Step3: Screen the Important Variables

The purpose of this step is to find the important variables to assist in the model analysis or diagnosis in the future. In this step the Taguchi's Orthogonal Array (OA) and signal-noise (S-N) ratio are used for screening the variables. OAs and S-N ratios are very useful in the identification of important variables. Inside an OA, every run includes a level combination of variables to find out each variable's impact to the response. In the experiment, every variable will be assigned to column in OA, and every row represents the experiment combination of a run. Generally in the Mahalanobis Taguchi system, for compute the signal to noise ratios the two level orthogonal arrays are always chosen. In Orthogonal arrays layout, Level-1 represents the "presence" of the variables and Level-2 represents the "absence" of the variables. The assigned variables are used to calculate MD values in each run, and then acquire the S-N ratio from these MDs. Signal to noise ratio is defined as the tool to measure the accuracy of the measurement scale. There are many S-N ratio formulas in Taguchi's methods; however, the MTS usually suggests using the larger-the-better S-N ratio. The reason to use larger the better S-N is that the MD in "abnormal" observations is usually larger than the MD in "normal" observations.

The larger the better type SN ratio is obtained as follows:

$$\eta_q = -10\log\left[\frac{1}{t}\sum_{i=1}^{t}\left(\frac{1}{MD_i}\right)^2\right]$$

Where,

η_q is the signal-to-noise ratio for the q^{th} run of the orthogonal array.
t is the abnormal samples number under consideration.

An average S/N ratio at level-1 and level-2 is obtained for each variable. Subsequently, gain in S/N ratio values for each variable is calculated as follows:

$$\textbf{Gain} = (\text{avg. S/N ratio})_{\text{level 1}} - (\text{avg. S/N ratio})_{\text{level 2}}$$

If the gain is positive, the variable is used, if not it is neglected. A confirmation run is performed by constructed an MS with useful variables. The MDs of the abnormal observations are also calculated based on the set of useful variables.

Step4: Future Diagnosis with useful Variables

After getting the set of useful variables, again reconstruct the measurement scale with the help of useful variables. This new measurement scale is used for conducting the future diagnosis. Based on the MD values of the observations, appropriate corrective actions can be taken by the decision maker. The decision to take the necessary actions depends on the value of the threshold. Threshold value can be calculated either using the Taguchi loss function or any probability plots. If unknown samples MD value is greater than the threshold value then it will be treated as abnormal. If unknown samples MD value is less than the threshold value then it will be treated as normal.

3. PROPOSED METHODOLOGY

In this method the randomly generated data about the B-Schools are utilized for the analysis. The proposed methodology is explained in following two subsections.

3.1 Establish the Threshold Values using the all Variables (Full Model)

In this study, initially the data set of B-schools are divided into the Supreme(species1), Super Excellence(species2), Excellence(species3), and Doing Well(species4) groups considering four major variables. Each variable have certain ranges for each group are assumed. Detail numerical ranges of each variable are given in the Table1. For the analysis of this problem according to each variable ranges from Table1 the random data for each group about 150 samples are generated by using the MATLAB random number generator.

Table-1: Business schools variables range in each group

S. No	Variables	Variables Range			
		Species1	Species2	Species3	Species4
1	X1	145 to 160	110 to 145	80 to 110	60 to 80
2	X2	330 to 400	240 to 330	180 to240	120 to 180
3	X3	260 to 320	220 to 260	150 to 220	100 to 150
4	X4	355 to 420	270 to 355	170 to 270	110 to 170

For this analysis of classification of B-schools the following steps are used.

Step1: Define the Problem

In the Mahalanobis Taguchi System (MTS) approach, the “normal” observations are defined to construct the Mahalanobis Space (MS). In this study supreme B-schools (species1) are taken as “reference” group. Using these observations the Mahalanobis Space (MS) are constructed for differentiate the other three different species of B-schools.

Step2: Define Response/Control Variables

Infrastructure (X_1), Education/Academic structure (X_2), Admission &delivery process (X_3), Placement (X_4) are taken as the control factors, and Mahalanobis Distance (MD) as the response variable.

Step3: Construct the MTS Measurement Scale

In this step the “normal” observations data are collected to construct the Measurement Scale. Table2 shows the four different species of B-Schools each with 150 samples. To understand the measuring capability of this measurement scale, the data are subdivided into training samples and test samples by the ratio of 2 to 1. The data are randomly select 100 samples out of each of the 150 samples as the training samples. The species1 are taken as “normal” group to construct the Measurement Scale.

Table-2: B-Schools samples size

Species of B-Schools	Species 1	Species 2	Species 3	Species 4
Training samples	100	100	100	100
Testing samples	50	50	50	50
Total	150	150	150	150

By using the training samples of the normal group, mean, standard deviation and correlation coefficient are calculated. And their values are given below as follows.

The mean of normal training samples are as follows:

M= [153.1133 365.9710 290.6654 387.4688]

The standard deviations of normal training samples are as follows:

SD= [4.3215 20.5684 18.5172 19.1067]

The Correlation Coefficient Matrix of normal training samples is as follows:

$$\begin{bmatrix} +1.0000 & +0.0100 & -0.0670 & +0.1216 \\ +0.0100 & +1.0000 & -0.0031 & -0.0158 \\ -0.0670 & -0.0031 & +1.0000 & -0.0976 \\ +0.1216 & -0.0158 & -0.0976 & +1.0000 \end{bmatrix}$$

The inverse correlation coefficient matrix of normal training samples is as follows:

$$\begin{bmatrix} +1.0183 & -0.0119 & +0.0566 & -0.1185 \\ -0.0119 & +1.0004 & +0.0040 & +0.0176 \\ +0.0566 & +0.0040 & +1.0128 & +0.0920 \\ -0.1185 & +0.0176 & +0.0920 & +1.0237 \end{bmatrix}$$

Using the “inverse matrix method” the MDs for four different species of training samples are calculated. The range of the MDs in species 1 is 0.0394~2.5261with an average value of 0.99, which is very close to 1. This is very close to the theory of the MTS. Table3 shows the MDs range and its average value for training samples in each group. And Figure1 shows the distribution of the MD values for the training samples of the four species.

Table-3: MDs range for “full model” training samples

Species of B-Schools	Species 1	Species 2	Species 3	Species 4
Samples size	100	100	100	100
MDs range	0.0394~ 2.5261	5.658~ 38.471	56.626~ 122.79	149.31~ 219.53
Average	0.9900	19.7371	87.7051	180.4251

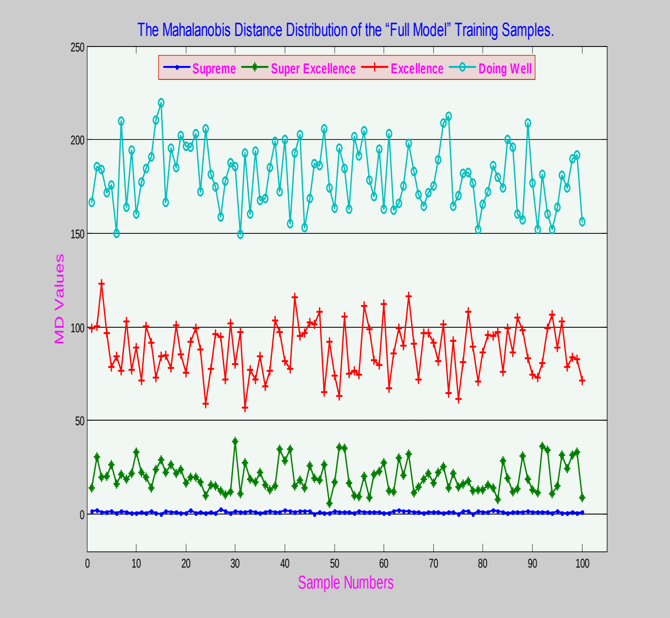

Fig-1: The Mahalanobis Distance Distribution of the "Full Model" Training Samples

Step4: Validate the Ability of the Measurement Scale

If the Mahalanobis Distance (MD) of "abnormal" observation will be larger than the MD of "normal" observation, this is a good measurement scale. In this study, test samples are used to validate and calculate the MD for each observation, then plot the MDs distribution diagram. MDs ranges for testing samples in each group are tabulated in Table4. The result shows that the measurement scale constructed by all four variables is a good one since it clearly differentiates these four different kinds of B-Schools. From the measurement scale created by Mahalanobis Distance four different groups are easily identified from each other, and the identification rate is 100%. However, there is some gap between the scaled Mahalanobis Distances of the four groups. So this requires the establishment of a threshold between four groups to differentiate them. The distributions of the MD values of testing samples of the four species are shown in Figure2.

Table-4: MDs range for "full model" testing samples

Species of B Schools	Species 1	Species 2	Species 3	Species 4
Samples size	50	50	50	50
MDs range	0.0714~ 1.9690	8.637~ 42.544	60.353~ 119.400	146.55~ 217.12

Step5: Establish the Threshold

Generally the threshold value of each group should be higher than the maximum value of that group. So the threshold value for each group is assumed as greater than the maximum value of that group. However, in a real case scenario the value of threshold value is calculated based on the Taguchi's loss function. The assumed threshold values range of each group are given in Table5. Using the mentioned threshold value rages from Table5, the B-schools are classified into different categories using the four variables.

Table-5: Threshold Mahalanobis Distance (MD) range for each group in "full model"

S. No	Group	MD Range
1	Species 1	0~3.1365
2	Species 2	3.1365~46.6172
3	Species 3	46.6172~137.4171
4	Species 4	137.4171~229.6292

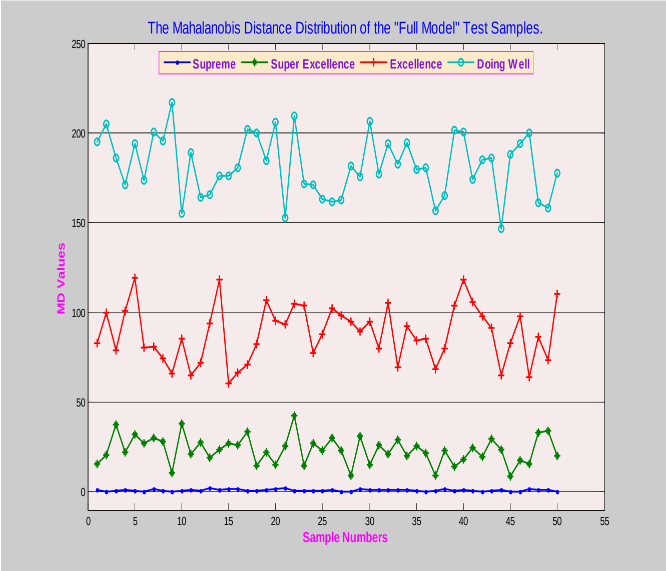

Fig-2: The Mahalanobis Distance Distribution of the "Full Model" Test Samples

3.2. Establish the Threshold Values using the useful Variables (Reduced Model)

In this stage, we are reduced the variables using the OA and S-N ratio as following steps

Step 1: Screen Important Variables

Using the L_8 (2^7) Orthogonal Array and S-N ratio, important variables are selected. Here the samples are taken from species2, species3, and species4 to perform the analysis. Table6 shows the detailed OA allocation, the MDs and the S-N ratio from each sample. In Table6, "1" represents including the variable and "2" represents excluding the variable. The larger-the-better S-N ratio is applied to conduct the analysis. And in Table7 shows the average S-N ratio gain of each variable. Figure3 shows the effect of each variable in this analysis. Figure3 shows that Infrastructure(X1), Education/Academic structure(X2) and Placement(X4) are important variables for classification of B-schools in future.

Table-6: $L_8 (2^7)$ Orthogonal Array and S-N ratio of the B-School samples

Run	X1	X2	X3	X4	MD values										S/N
1	1	1	1	1	13.71	15.32	16.76	8.81	81.76	86.27	160.07	200.27	165.23	156.21	2.8391
2	1	1	1	2	8.21	19.20	21.15	6.49	84.45	96.07	154.65	211.43	181.51	162.86	2.8301
3	1	2	2	1	16.06	11.41	20.51	8.98	102.51	98.11	221.54	284.48	216.96	211.07	2.6909
4	1	2	2	2	6.13	20.49	38.61	4.57	145.20	151.91	293.56	431.93	339.14	308.74	2.6705
5	2	1	2	1	16.83	15.90	11.11	11.64	68.44	73.01	147.00	143.71	136.99	135.08	2.6164
6	2	1	2	2	4.54	27.17	16.64	7.78	51.20	78.02	87.50	83.16	127.99	104.52	2.3130
7	2	2	1	1	22.83	7.01	6.43	11.88	71.80	62.80	146.43	161.48	110.92	120.72	2.4060
8	2	2	1	2	12.74	8.43	6.34	6.44	46.50	47.77	65.41	93.13	60.06	58.68	1.9794

Step2: Construct the Reduced Model MTS Measurement Scale

In this step the reduced model measurement scale are constructed using the useful variables. Here, the training samples from table2 and the variables X1, X2 and X4 are used for construct the measurement scale. Using the "inverse matrix method" the MDs for four different species of training samples are calculated. The range of the MDs in species1 is 0.0066~2.5479 with an average value of 0.99, which is very close to 1. Table8 shows the MDs range and its average value for training samples in each group. And Figure4 shows the distribution of the MD values for the training samples of the four species.

Table-7: Average S/N ratio for different levels of variables

S. No	Variables	Level 1	Level 2	Gain
1	X1	2.7576	2.3287	+0.4289
2	X2	2.6496	2.4367	+0.2129
3	X3	2.5136	2.5727	-0.0590
4	X4	2.6381	2.4482	+0.1898

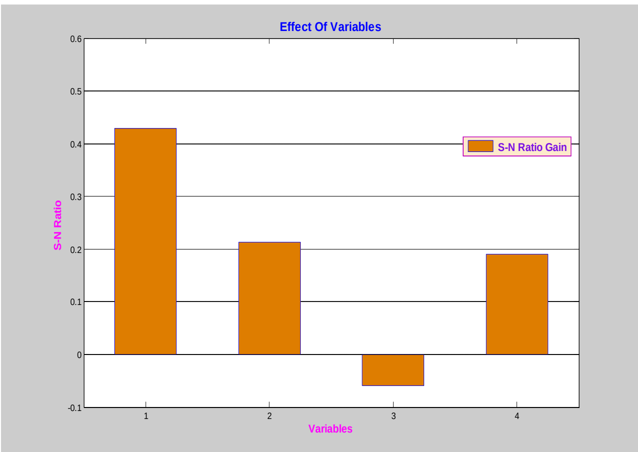

Figure-3: Factorial Effect of the Variables

Table-8: MDs range for "reduced model" training samples

Species of B-Schools	Species 1	Species 2	Species 3	Species 4
Samples size	100	100	100	100
MDs range	0.0066~ 2.5479	5.2926~ 46.5418	59.7420~ 135.6902	158.069~ 243.0365
Average	0.990004	22.32192	97.9015	198.1705

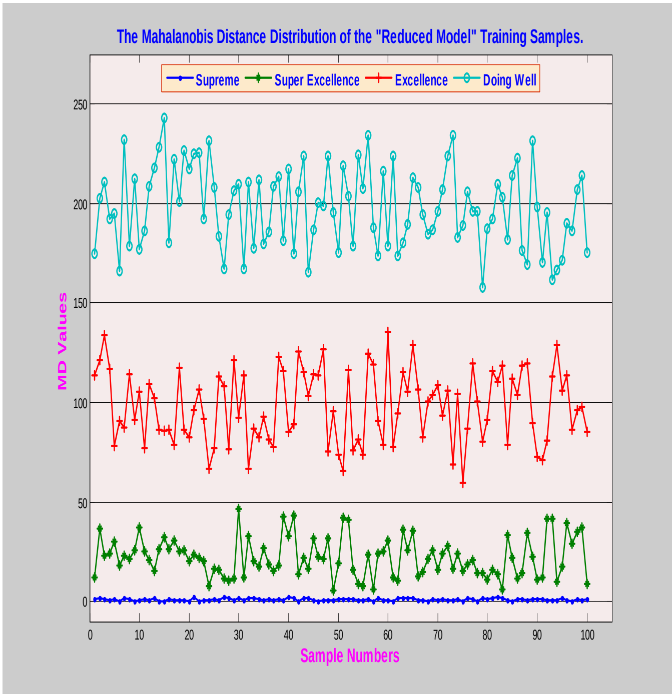

Fig-4: The Mahalanobis Distance Distribution of the "Reduced Model" Training Samples

Step3: Validate the Ability of the Measurement Scale

The test samples from Table2 are used to evaluate whether the MD constructed by variables X1, X2 and X4 has good prediction ability or not. Figure5 shows the MDs distribution of four species testing samples. And MDs ranges for each group in testing samples are also given in Table9. Hence the Measurement Scale constructed by variables X1, X2 and X4 is a good scale. According to Mahalanobis Taguchi System, the collected data on three variables (X1, X2, and X4) are enough to identify these four different species of B-Schools.

Table-9: MDs range for "reduced model" testing samples

Species	Species 1	Species 2	Species 3	Species 4
Samples size	50	50	50	50
MDs range	0.0294~ 2.0629	6.3853~ 50.3637	54.9364~ 141.7575	162.9317~ 235.8007

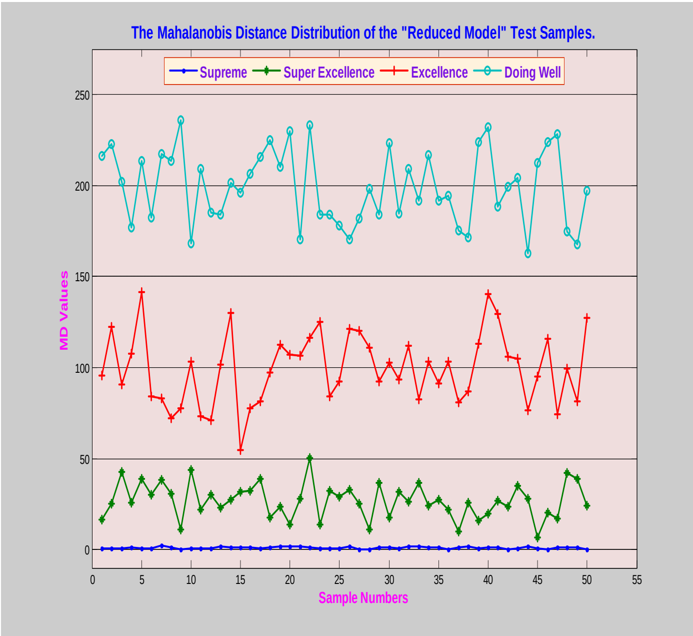

Fig-5: The Mahalanobis Distance Distribution of the "Reduced Model" Test Samples

Step4: Establish the Threshold

From Table8 and Table9, there is some gap between the scaled Mahalanobis Distances of the four groups. So that the threshold values for each group are established for increasing the prediction ability of B-Schools using the useful variables(X1, X2 and X4). The assumed threshold MD values for each group are given in Table10. Using the threshold MD values the given B-Schools are easily classified.

Table-10: Threshold MDs range for each group in "reduced model"

S. No	Group	MD Range
1	Species 1	0~2.9346
2	Species 2	2.9346~53.8639
3	Species 3	53.8639~152.0384
4	Species 4	152.0384~250.2844

4. CLASSIFICATION OF INDIAN B-SCHOOLS

The study used the B-Schools data from the Indian Business Schools, which is collected at the Competition Success Review Magazine [1] conducted by Global Human Resources Development Centre (GHRDC) B-Schools survey in India. The data about Indian B-schools are taken from the Competition Success Review Magazine [1] for the analysis of these performances using the proposed method. The data about 132 Indian B-Schools are taken for this analysis.

In this section, the Indian B-Schools MDs are calculated using the four variables considering with the mean, standard deviation, and correlation coefficient of species1 training data. Again calculate the Indian B-Schools MDs using the three variables(X1, X2, X4) considering with the mean, standard deviation, and correlation coefficient of species1 training data.

The sample calculated MD values using all variables and useful variables are tabulated in Table11. From the Table5 and Table10, the Indian B-Schools are classified into five groups according to their threshold MDs range for each group. If the calculated MD values for B-School using both methods have within their threshold MDs range, the B-School belong to that particular group. The comparison of Indian B-Schools MD values using both four variables and useful variables are shown in Table11.

Table-11: MDs comparison of Indian B-Schools using 4 and 3 variables (Sample Values)

College code	X1	X2	X3	X4	MD values before	MD values After	Remark
01	158.00	355.48	284.27	355.18	1.2921	1.6581	**Supreme**
02	139.71	302.10	245.75	350.80	7.3774	7.2173	**Super excellence**
08	109.70	252.53	227.17	300.73	40.468	47.3496	**Super excellence**
09	101.13	256.10	227.44	292.01	51.588	61.7606	**Excellence**
10	121.20	256.85	208.73	282.62	33.297	34.7091	**Super excellence**
12	113.27	216.25	213.51	288.09	45.449	51.5297	**Super excellence**
13	107.32	224.62	217.98	274.06	51.817	60.3656	**Excellence**
60	090.03	166.81	160.71	169.62	120.42	133.7772	**Excellence**
61	079.24	165.60	175.93	163.35	137.66	160.5357	**Doing well**
62	082.69	172.97	172.63	152.92	**133.39**	**153.8245**	**Wrong Detect**
63	066.99	174.47	170.90	160.39	162.67	191.3571	**Doing well**
64	074.88	163.72	177.43	153.67	148.97	175.5037	**Doing well**
65	081.95	152.35	159.23	173.17	**137.14**	**155.0393**	**Wrong Detect**

66	086.29	145.57	164.96	167.41	131.47	149.4942	**Excellence**
67	067.58	158.86	170.32	164.95	163.94	193.0139	**Doing well**
68	069.19	178.52	142.59	168.34	162.06	181.2436	**Doing well**
69	084.22	168.82	150.93	152.34	137.18	151.8421	**Excellence**
70	071.13	150.79	169.45	162.30	159.25	186.6722	**Doing well**
71	091.57	153.60	141.05	165.25	127.55	136.4993	**Excellence**
72	087.61	135.40	160.00	165.19	133.81	151.0458	**Excellence**
73	069.70	150.78	163.06	161.95	163.94	190.7310	**Doing well**
85	074.18	151.61	141.14	142.32	166.00	185.5100	**Doing well**
86	094.56	124.76	131.96	154.75	136.52	144.9478	**Excellence**
87	080.81	121.52	146.14	154.57	156.30	175.3608	**Doing well**
92	072.82	127.59	135.64	150.41	174.32	194.6186	**Doing well**
93	051.46	140.67	147.90	143.97	**219.24**	**257.0278**	**Wrong Detect**
94	073.57	117.34	143.55	147.37	174.42	197.6974	**Doing well**
108	061.85	106.81	141.58	121.82	211.85	244.9428	**Doing well**
109	049.82	107.07	121.72	146.95	240.16	274.3807	**Good**
110	064.86	108.78	119.57	127.34	209.19	232.9739	**Doing well**
111	044.85	111.95	124.59	135.14	254.94	294.3702	**Good**
112	062.31	091.57	134.90	125.29	216.41	248.5488	**Doing well**
113	051.19	120.65	117.30	122.88	241.32	273.2759	**Good**
114	070.59	106.23	125.23	105.34	203.35	227.3190	**Doing well**
115	049.88	088.92	117.81	147.51	246.83	281.6005	**Good**
122	035.27	125.61	118.76	098.53	292.87	340.0286	**Good**
123	066.97	086.53	136.61	085.40	221.39	254.9057	**Doing well**
124	055.63	092.26	103.65	121.87	243.55	270.4943	**Good**
132	045.99	070.08	106.71	110.87	279.13	317.8002	**Good**

4.1 Results

Table-12: Comparison the Results of Indian B-Schools Classification

Group / Method	Species 1	Species 2	Species 3	Species 4	Others	Total
4 Variables	1	10	56	45	20	132
3 Variables	1	10	54	46	21	132
Both4&3 Variables	1	10	54	44	20	129

Classification of Indian B-Schools using the full model, reduced model, and both methods are given in Table12.

From the Table12 the following results are observed. Using the two model methods the species1 and species2 B-Schools are correctly detected. So the assumed threshold MDs range for species1 and species2 are good. Using the 4 variables 56 B-Schools are detected as species3.

Using the 3 variables 54 B-Schools are detected as species3. And using the both methods 54 B-Schools are detected as species3 only. So the classification accuracy rate using the four variables is 96.30 % for the assumed threshold MD range. And the classification accuracy rate using the three variables is 96.30 % for the assumed threshold MD range.

Using the 4 variables 45 B-Schools are detected as species4. Using the 3 variables 46 B-Schools are detected as species4. And using the both methods 44 B-Schools are detected as species4. So the classification accuracy rate using the four variables is 97.73 % for the assumed threshold MD range. The classification accuracy rate using the three variables is 95.45% for the assumed threshold MD range.

Using the 4 variables 20 B-Schools are detected as the others. Using the 3 variables 21 B-Schools are detected as the others. And using the both methods 20 B-Schools are detected as others. So the classification accuracy rate using the four variables is 100 % for the assumed threshold MD range. The classification accuracy rate using the three variables is 95% for the assumed threshold MD range.

The overall classification accuracy rate in both the cases is 97.73%.

5. CONCLUSION

It is important to define objectively the current state of the institution in order to make any future improvements. In this study shows, the Mahalanobis distance can objectively measure the performance of the B-Schools. The Mahalanobis Distance is superior to the Euclidean distance because it takes the correlation of the data. The result shows that the using “all variables” and “useful variable” both have a same prediction ability of B-Schools. So the collected data on three variables (X1, X2, and X4) are enough for evaluating the performance of B-Schools in future.

Future work would include the collection of survey data directly from the Business Schools. The survey can be organized and collect the data on more variables in future work. In this study, we have used the MD metric to measure the overall performance of the B-Schools; this metric can be extended to measure the various departmental performances with in the B-Schools. In this study we assumed the threshold values for the given groups, we would establish the threshold values using the Taguchi's quadratic loss function in future work.

REFERENCES

[1]. Competition success review magazine, November& December 2009.
[2]. G.Taguchi and R. Jugulum, "The Mahalanobis-Taguchi Strategy – A Pattern Technology System", John Wiley & Sons, 2002.
[3]. Johnson, R. A., and Wichern, D. W. (1992) "Applied Multivariate Statistical Analysis", Prentice Hall.
[4]. Phillip j. Ross "Taguchi techniques for quality engineering", McGraw- hill, 1996.
[5]. R. B. Chinnam, B. Rai, N. Singh, "Tool-condition monitoring from Degradation Signals Using Mahalanobis-Taguchi System Analysis", ASI's 20th Annual Symposium of Robust Engineering, pp.343-351, 2004.
[6]. Deepak Mohan, Can Saygin, Jagannathan Sarangapani, "Real time detection of grip length deviation during pull-type fastening: a Mahalanobis Taguchi system (MTS) based approach", International Journal for Advanced Manufacturing Technology, volume 39, pp.995-1008, 2008.
[7]. H. Wang, C. Chiu, C. Su, "Data Classification using Mahalanobis Taguchi System", Journal of the Chinese Institute of Industrial Engineers, Volume 21, No. 6, pp. 606-618, January 2004.
[8]. J. Srinivasaraghavan, V. Allada, "Application of Mahalanobis Distance as a Lean Assessment Metric", International Journal for Advanced Manufacturing Technology, Volume 29, pp.1159–1168, 2004.
[9]. R. Jugulum and L. Monplaisir, "Comparison between Mahalanobis-Taguchi- System and Artificial Neural Networks", Journal of Quality Engineering Society, Vol. 10, No.1, pp.60-73, 2002.
[10]. Elizabeth A. Cudney, Jungeui Hong, Rajesh Jugulum, "An Evaluation of Mahalanobis-Taguchi System and Neural Network for Multivariate Pattern Recognition", Journal of Industrial and Systems Engineering, Vol. 1, No. 2, pp 139 - 150, 2007.

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