Applying the Mahalanobis Model to Predicting School Closures: An Example of Taipei City

FU-HSIANG. KUO
Department of Finance
National Yunlin University of Science and Technology
Yunlin City, Taiwan, R.O.C
s1185072@gamil.com

Abstract: In this study, we applied the Mahalanobis-Taguchi System (MTS) to assess the problem of school closure. Therefore, this study hopes, through risk assessment, to identify schools that may be suffering from poor management. We found that more than half of the private schools that we studied may face bankruptcy. This is a very serious discovery, so we further analyzed the findings. At present, only six of the 22 existing schools are operating normally; four schools are in the mild category (25%), six schools are moderate (50%), four schools are moderately severe (75%), and two schools are severe (100%), and have been closed. We also found that several things happen when private schools may face bankruptcy. First, the school will give priority to not hiring part-time teachers, followed by staff, thereby reducing expenditures and maintaining operations. When the above policies are implemented, the management is not good. It then becomes necessary to reduce the number of full-time teachers, and finally reduce the number of classes, creating a vicious cycle. Finally, the school will face bankruptcy.

Keywords: Mahalanobis-Taguchi System (MTS); Predicting School Closure; Mahalanobis Distance (MD), School Closures.

1. Introduction

In Taiwan, the transformation of the educational environment and the declining birth rate have severely affected the operation and development of private secondary schools. However, the private schools still have an important role to play in the education market.

According to its statistics, the Ministry of Education is in charge of 98 private high-level secondary schools; seven of these schools have applied for suspension or bankruptcy [[1]]. One of these schools applied in 2013, three in 2014, and two in 2015. No schools were closed in 2016 or in 2017. However, the impact of the declining birthrate has not yet bottomed out. In the next few years, therefore, the enrollment of high schools and colleges will be more seriously affected. The situation of private schools closing down is becoming increasingly serious.

The continuous decline in the number of students in private schools has been affecting school management. The number of students in a private secondary school is the most important indicator of said school's financial adequacy. If the school's financial resources are sufficient, the salary structure of its teachers is bound to be stable, and the teacher turnover rate will therefore be low. This stability in the school's teachers enables the management of students' learning and lives to be stabilized. If the students' learning environment is stable, this in turn allows their learning outcomes to be improved, developing the school's reputation and therefore attracting more student applications. This is a benign loop structure.

In other words, if the number of enrolled students in a private secondary school is greatly reduced, or is insufficient, the school's tuition income will be relatively reduced, and its fixed expenses will also be affected. For example, school staff, water, and electricity expenses. In a similar manner, the school in question may not have much surplus. Thus, the school cannot afford to update teaching equipment or improve its learning environments. This in turn increases the chances of the school having insufficient teachers, or losing the ability to hire enough qualified full-time teachers. Finally, this can result in the school choosing to close down [[2]].

At present, there are about 22 private high schools in Taipei. However, in recent years, these schools have been facing a shortage of students. Therefore, in the past two years, two of these schools have closed down, and have withdrawn from the education market in Taipei. Although the other schools are continuing to operate, across the overall educational environment, the number of students is still declining, and these schools may also face the problem of school closure. Therefore, the Ministry of Education has proposed school management counseling and assistance for poorly run schools. However, schools will not readily agree to a counseling mechanism, because this could lead to the school being labeled (i.e., suspension or bankruptcy), decreasing its reputation and accelerating its closure. An effective methodology is needed to handle this complex situation in a more realistic way, therefore. Thus, the methodology proposed here uses the MTS pattern recognition scheme to assess the problem of school closure. This study aims, through risk assessment, to use the MTS to find out which schools in Taipei city may face poor management. These results will then be used to recommend a prevention mechanism that the government could use to deal with schools that may face poor management.

This paper is structured as follows: Section 1 introduces the research background and the goals of this research. Section 2 reviews the conceptual framework and provides an overview of policy. Section 3 introduces the methodology of this study. Section 4 presents the empirical results. Finally, the last section provides the concluding remarks.

2. Literature Review

The influence of declining fertility will not only change the population structure of schools, but will also cause many industries to be affected. Among these, the education industry is focused upon here, because after the minority is reduced, school management will be greatly affected.

Student reductions will lead schools entering bankruptcy, leading to more unemployed teachers. Eventually, this will lead to a serious shortage of labor and human resources in the enterprise, leading to a decline in the overall productivity of the country [[3]].

Domestic scholars and experts have identified that the phenomenon of fertility decline will have several impacts on Taiwanese society, such as the imbalance of its gender ratio, the reduction of its school-age population, the impact of its education system, and the reduction of its working-age population [[4]].

This birth rate decrease will also impact education and will decrease the number of classes. This means that schools will face problems such as being abolished, or having serious imbalances between teachers' supply and demand [[5]]. The imbalanced population structure will have a sharp decline in economic growth, which will ultimately lead to heavy social welfare expenditures. Decreases in government finances have been shown to create social problems [[6]].

Therefore, scholars have highlighted that as schools' budget fees come from the number of students they have, if the number of students reduces, their relative expenditure will also reduce. Eventually, the school will choose to close down in this scenario [[7]; [8]; [9]].

De Witte and Van Klaveren [[10]] demonstrated that school closures create a social disturbance, such that educational outcomes may be negatively affected. Many studies have pointed out that population decline (i.e., declining student numbers) will lead to the closure of inefficient schools. Thus, when more schools close, the community will decline faster. As a result, school closings have been regarded as a sign of the death of local communities [[11]; [12]; [13]; [14]; [15]].

Furthermore, the more schools are closed, the more social problems there are. According to the school closure policy implemented by Chicago Public Schools in 2013, research shows that it will lead to increased social problems such as crime and poverty [[16]]. However, little attention has been given to this problem till date.

As mentioned above, risk assessment is very important for identifying school bankruptcy or school closures. Theoretically, a risk assessment is a thorough examination of a workplace, aimed to identify situations, processes, etc. that may cause harm, particularly to people. After an identification is made, the next step is to analyze and evaluate how likely and severe the risk is. Following this determination, appropriate measures should be put in place to effectively eliminate or mitigate the risk in question [[17]].

In the last few years, several articles have been devoted to the study of risk assessments. Asada [[18]], for example, used the MTS model to forecast the yield of wafers. Other studies have focused on known and unknown samples. The MTS has also been used for prediction and diagnosis, which illustrates the methodology's accuracy and effectiveness. For example, Jugulum and Monplaisir [[19]], and Wu [[19]] performed preliminary comparisons between the MTS and neural networks. The results of both studies indicated that the MTS performed better than neural networks for small sample sizes. Other studies have shown that the Mahalanobis model can be used for forecasting, and to predict the effects of parameters. In this regard, the MTS has been applied to vehicle ride [[21]], and pattern recognition has been used to diagnose human health [[22]]. Furthermore, some studies have used this model to assess personal credit [[23]], and financial projections [[24]; [25]]. It is apparent, therefore, that the MTS model is an appropriate method with which to assess the problem of school closure.

If schools are poorly run, closing it may not be a simple solution. Attention must be paid to the social problems behind its closure. Therefore, here we use the MTS model to perform a risk assessment of the school. We then analyze and evaluate how likely and severe the risk is. Finally, we determine what measures should be put in place to effectively eliminate or control the risk from happening, thereby letting the school maintain sustainable operation.

3. Research Methodology

The purpose of this study is to determine which schools may face problems due to bad management. Therefore, here we used the MTS model to perform a risk assessment of schools. We opted to use the MTS model here because its forecasting power matches our goal to unravel the problem of bad school

management. Furthermore, this study then assesses the opportunities to close the school.

3.1. The Mahalanobis-Taguchi System

Prasanta Chandra Mahalanobis introduced Mahalanobis distance (MD) in 1936 for the first time. The MTS was later developed by Genichi Taguchi as a diagnosis and forecasting method using multivariate data for robust engineering.

The MD is a distance measure that is based on correlations between variables and the different patterns that can be identified and analyzed with respect to a reference population.

Further, MD is a discriminant analysis tool [[26]], which will be used to predict changes in consumer satisfaction, or company early warning analysis. And to analysis process is not need a lot of samples.

Thus, the MD model is a measure based on correlations between variables and the different patterns that can be identified and analyzed with respect to a reference point. MD is very useful in determining the similarity of a set of values from an unknown by comparing a sample from the unknown group to a measured collection of known samples [[27]].

$$MD_J = D_j^2 = \frac{1}{K} Z_{ij}^T A^{-1} Z_{ij} \quad (1)$$

where,

•k = total number of variables

•i = number of variables (i = 1, 2,…, k)

•j = number of samples (j = 1, 2,…, n)

• Z_{ij} = standardized vector of normalized characteristics of x_{ij}

•Z_{ij} = $(x_{ij}-m_j)/s_i$

•x_{ij} = value of the ith characteristic in the jth observation

•m_j = mean of the ith characteristic

• s_i = standard deviation of the ith characteristic

• ^{T} = transpose of the vector

•A^{-I} = inverse of the correlation matrix

As can be seen from above, the MD is used to determine the similarity of a known set of values to that of an unknown set of values. Also, since the MD is measured in terms of standard deviations from the mean of the samples, it provides a statistical measure of how well an unknown sample matches a known sample set [[28]]. Thus, the MD is a discriminant analysis tool that is used in this research to and evaluate the school how likely and severe the risk is.

3.2. Model setup

This section describes of the four fundamental steps of the MTS methodology [[23]]:

Stage 1: Construction of measurement scale

For the construction of a measurement scale, collection of a homogeneous data set from normal observations is required in order to build a reference group, which is the normal group. This group is utilized as a base or reference point in the scale. Standardization needs to be performed on the collected normal datasets in order to obtain a dimensionless unit vector, which is followed by the MD computation. Practically, the MD for normal data group is generally divided into two groups, which are normal data and bad data.

Stage 2: Validation of the measurement

scale (to find the estimated coefficient)

In order evaluate the measurement scale, observations are performed outside of MS, or abnormal datasets are used. The same mathematical calculation is repeated in order to calculate the same goal (MD value) using the abnormal sample data. However, according to the two groups to find of the estimated coefficient.

Stage 3: Identification of significant variables

At this stage, the system is optimized by selecting particularly the features which are known to be significant or 'useful' for the system (MD value). Following that, to use of the unknown sample data which on the MD values for all samples is then computed.

Stage 4: Future deployment with significant variables

The optimized system is then re-evaluated using the abnormal samples in order to validate the effectiveness of assessing the discriminant power. Once confirmed, the optimized system is used for future application with the purpose of diagnosis, classification, or forecasting.

3.3. Calculation of estimate for an ordinal 5-point scale from normal to severe

We give different definitions based on the results of the estimated value coefficient range. Thus, we arranged the estimated values across a five-point ordinal scale. The scale presented in Table 1 represents the increasing severity of disease, where one is normal and five is severe.

Table 1. Weight value coefficient range definitions

Grading scale	Weight value	Definition
1	Above 0	Normal
2	(-0.9) - (-1.5)	Mild (25%)
3	(-1.6) - (-3)	Moderate (50%)
4	(-3.1) - (-4.5)	Moderately severe (75%)
5	Below (-4.6)	Severe (100%)

4. Empirical Results and Analysis

The empirical analysis conducted in this study mainly comprises two parts: First, this section details our adoption of the MTS model to calculate the MD variables and estimate the results. This was followed by an assessment of the rankings of opportunities for school closures.

4.1. Study Objects

This study is mainly applicable for private high school schools in Taipei city, as the

sample set did not include any public schools. The main reason for this is that private schools' budgets are determined by the number of students they have, unlike public schools, which receive government support. Therefore, when the number of students is reduced, this will inevitably affect school operations (by reducing tuition income). The sample set did include schools that are not well managed, however. Therefore, we will use this sample set to assess the risk of bankruptcy in private schools in Taipei City. We will then calculate the estimated value while differentiating it into two groups. The first group consists of normal schools. In this group we select the top five schools for each year. The second group consists of schools that have already undergone closure.

In addition, we exclude newly established schools and the high schools is transformational vocational high schools. At last, we listed the school names and attributes of the above schools are outlined in Table 2:

Table 2. School names and attributes

NO	School name	Attributes	City name	Situation
1	Jingwen High School	Private	Taipei	Normal
2	Taibei High School	Private	Taipei	Normal
3	Dongshan High School	Private	Taipei	Normal
4	Jinou Girls High School	Private	Taipei	Normal
5	Youde High School	Private	Taipei	Normal
6	Hujiang High School	Private	Taipei	Normal
7	Yanping High School	Private	Taipei	Normal
8	Qiangshu High School	Private	Taipei	Normal
9	Tatung High School	Private	Taipei	Normal
10	Wego High School	Private	Taipei	Normal
11	Blessed Imelda Girls High School	Private	Taipei	Normal
12	Tsai Hsing High School	Private	Taipei	Normal
13	Shixin High School	Private	Taipei	Normal
14	Wesley Girls High School	Private	Taipei	Normal
15	Dacheng High School	Private	Taipei	Normal
16	St. Francis High School	Private	Taipei	Normal
17	Taipei Fuhsing Private School	Private	Taipei	Normal
18	Daren Girls High School	Private	Taipei	Normal
19	St. Bonaventure Girls High School	Private	Taipei	Normal
20	Huaxing High School	Private	Taipei	Normal
21	Zhongxing High School	Private	Taipei	Close

22	Lih-Ren High School	Private	Taipei	Close

4.2. Selection of Variables for the MTS model

The advantage of using MD holds as long as the data arise from the model (1), and as long as we distinguish between two groups (Normal and Close), where the random vector c is a linear function of a hidden variable x. In this section, based on the study [[29]; [30]], we present an extension to the nonlinear case, i.e.:

$$MD_J = c = f(x) \quad (2)$$

Prior to the establishment of the empirical model, we must list as many preliminary assessment factors as possible for the units. Thus, after referring relevant literatures [[31]; [32]; [33]; 34] and statistical reports, we select the following seven operational variables: private vocational high schools, the total number of students, the teacher-student ratio, the number of full-time teachers, the number of part-time teachers, the number of staff, and the number of classes. Ultimately, data were collected on these seven variables across seven years (2011-2017). The basic factors may be described as follows:

$\boldsymbol{Z_{1_{it}}}$: Total number of school students (school size) of school $_i$.

$\boldsymbol{Z_{2_{it}}}$: Teacher-student ratio (average number of students per teacher) of school $_i$.

$\boldsymbol{Z_{3_{it}}}$: Total number of full-time teachers of school $_i$ (this represents the number of schools that are willing to hire).

$\boldsymbol{Z_{4_{it}}}$: Total number of part-time teachers of school $_i$ (this represents the number of schools that are willing to hire).

$\boldsymbol{Z_{5_{it}}}$: Total number of staff of school $_i$ (this represents the number of schools that are willing to hire).

$\boldsymbol{Z_{6_{it}}}$: Total number of classes of school $_i$.

4.3. Research Analysis in MTS model

4.3.1. Determine the Seven Operational Variables

We conducted MTS model analyses to address this issue. Finally, we preformed further MTS model analyses to determine the seven operational variables shown in Table 3. We then estimated the variable results as follows:

Table 3. The grey incidence order is shown.

$\boldsymbol{Z_1}$	$\boldsymbol{Z_2}$	$\boldsymbol{Z_3}$	$\boldsymbol{Z_4}$	$\boldsymbol{Z_5}$	$\boldsymbol{Z_6}$	C
-0.003	0.052	0.062	-0.012	-0.025	0.135	-6.475

Judging from the results shown in Table 2, we find the total numbers of school students, the total number of part-time teachers, and the total number of staff have been shown negatively related to MTS model, and that it can reduce the risk of school bankruptcy. In other words, we find that the teacher-student ratio, the total number of full-time teachers, and the total number of classes have been shown to be related to the MTS model, and that they will add to the risk of school bankruptcy.

4.3.2. Calculation of the Estimated Results (Normal or Close).

We estimate the school risk by substituting the above estimates into the model. Finally, we will estimate the risk in Table 4.

Table 4. Estimations of the risk degree of private secondary schools.

NO.	School name	MD	Degree of risk
1	Dongshan High School	2.936	Normal
2	Wego High School	1.803	Normal
3	Jingwen High School	1.253	Normal
4	Taibei High School	0.694	Normal
5	Yan Ping High School	0.558	Normal
6	Jin'ou Girls High School	0.322	Normal
7	Youde High School	-0.308	Mild (25%)
8	Blessed Imelda's School	-0.495	Mild (25%)
9	Taipei Shixin High School	-0.832	Mild (25%)
10	Hujiang Senior High School	-1.012	Mild (25%)
11	Taipei Fuhsing Private School	-1.912	Moderate (50%)
12	Wesley Girls High School	-2.165	Moderate (50%)
13	Qiangshu High School	-2.286	Moderate (50%)
14	Huaxing High School	-2.847	Moderate (50%)
15	Datong High School	-2.929	Moderate (50%)
16	Daren Girls High School	-3.015	Moderate (50%)
17	Shixin High School	-3.533	Moderately severe (75%)
18	Dacheng High School	-3.722	Moderately severe (75%)

19	St. Francis High School	-3.782	Moderately severe (75%)
20	St. Bonaventure Girls High School	-4.365	Moderately severe (75%)
21	Zhongxing High School	-5.075	Severe (100%)
22	Lih-Ren High School	-6.364	Severe (100%)

The data displayed in Table 3 reveal that more than half of the private schools in Taipei City may face bankruptcy. This is a very serious warning. We further analyze the findings. At present, only six of the 22 existing schools are operating normally; these are: Dongshan High School, Wego High School, Jingwen High School, Taibei High School, Yan Ping High School, and Jin'ou Girls High School.

There are four schools in the mild (25%) category: Youde High School, Blessed Imelda's School, Taipei Shixin High School, and Hujiang Senior High School. There are six schools in the moderate (50%) category: Taipei Fuhsing Private School, Wesley Girls High School, Qiangshu High School, Huaxing High School, Datong High School, and Daren Girls High School.

Furthermore, we found four schools in the moderately severe (75%) category: Shixin High School, Dacheng High School, St. Francis High School, and St. Bonaventure Girls High School. Lastly, two schools were in the severe category (100%), and had been closed. These were Zhongxing High School and Lih-Ren High School.

One explanation for our finding that more than half of these private schools may face bankruptcy is that when the number of students decreases, this will decrease relative school income. Therefore, the school will give priority to not hiring part-time teachers, followed by staff, thereby reducing expenditures and maintaining operations. The above policies represent poor management. It is necessary in this instance to reduce the number of full-time teachers, and then finally to reduce the number of classes. This constitutes a vicious cycle in which schools reduce the number of full-time teachers and the number of classes. Eventually, the school will face bankruptcy.

Overall, for a school facing a bankruptcy, the main key factors are reducing the number of full-time teachers and reducing the number of classes. Therefore, when the school reduces the number of full-time teachers and the number of classes, this will accelerate the risk of school bankruptcy. Conversely, it reduces risk of school bankruptcy.

5. Concluding Remarks

In this study, we used the MTS method to assess the problem of school closure. Therefore, this study hopes, through risk assessment, to find out which schools may face poor management. We then recommend prevention mechanisms that the government should pay attention to regarding schools that may face poor management.

We find more than half of private schools in Taipei City may face bankruptcy. This is a very serious warning. Further analysis of these findings reveal that at present, only six of the 22 existing schools are operating normally, four schools are in the mild (25%) category, six schools are in the moderate (50%) category schools, four schools are in the moderately severe (75%) category, and two schools were in the severe (100%) category; these schools have been closed.

Furthermore, we find that the total numbers of school students, the total number

of part-time teachers, and the total number of staff are all negatively related to the MTS model, and it can therefore reduce the risk of school bankruptcy. In other words, we find that the teacher-student ratio, the total number of full-time teachers, and the total number of classes are related to the MTS model and add to the risk of school bankruptcy.

Thus, when a private school may face bankruptcy, it may prioritize avoiding hiring part-time teachers, followed by staff, thereby reducing expenditures and maintaining operations. The implementation of these above policies represents poor management, however, making it necessary to reduce the number of full-time teachers, and finally reduce the number of classes. This cycle reduces the number of full-time teachers and number of classes, increasing the likelihood of bankruptcy.

Lastly, the conclusions and recommendations presented here are based on the models constructed, the sample data collected, and the research methodologies employed in this study. Hence, it is necessary to take into consideration the current situation and the changes in the environment that are impacting private high schools in a particular district of Taiwan, to further tailor any application of our findings so as to yield more accurate conclusions.

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