JOURNAL OF MODERN MANUFACTURING SYSTEMS AND TECHNOLOGY (JMMST)
e-ISSN: 2636-9575
VOL. 4, ISSUE 2, 84 – 97
DOI: https://doi.org/10.15282/jmmst.v4i1.7035

ORIGINAL ARTICLE

Application of Mahalanobis-Taguchi system in descending case of methadone flexi dispensing (MFlex) program

S.K.M. Saad[1], S.N.A.M. Zaini[1] and M.Y. Abu[1]

[1]Faculty of Manufacturing and Mechatronic Engineering Technology, Universiti Malaysia Pahang, 26600 Pekan Pahang, Malaysia.

ABSTRACT – Patient under methadone flexi dispensing (MFlex) program is subjected to do methadone dosage trends for descending case since no parameters were employed to identify the patient who has potential rate of recovery. Consequently, the existing system does not have a stable ecosystem towards classification and optimization due to inaccurate measurement methods and lack of justification of significant parameters which will influence the accuracy of diagnosis. The objective is to apply Mahalanobis-Taguchi system (MTS) in the MFlex program as it has never been done in the previous studies. The data is collected at Bandar Pekan clinic with 16 parameters. Two types of MTS methods are used like RT-Method and T-Method for classification and optimization respectively. In classification of descending case, the average Mahalanobis distance (MD) of healthy is 1.0000 and unhealthy is 11123.9730. In optimization of descending case, there are 9 parameters of positive degree of contribution. 6 unknown samples have been diagnosed using MTS with different number of positive and negative degree of contribution to achieve lower MD. Type 6 of 6 modifications has been selected as the best proposed solution. In conclusion, a pharmacist from Bandar Pekan clinic has confirmed that MTS is able to solve a problem in classification and optimization of MFlex program.

ARTICLE HISTORY
Received: 25th November 2021
Revised: 22nd December 2021
Accepted: 23rd December 2021

KEYWORDS
Mahalanobis-Taguchi system
Mahalanobis distance
descending case
methadone flexi dispensing program
classification
optimization

INTRODUCTION

Illegal drugs are used by an estimated 5.5% of the world's population. Cannabis is the most widely used illegal substance in the world, followed by opiates and amphetamines. Around 275 million individuals use illicit drugs globally, with 36.3 million classified as addicts or serious drug users. Drug addiction and misuse may have a detrimental influence on relationships, raise the risk of many illnesses, and eventually lead to death [1]. In addition, discrepancies with access to vital controlled medications throughout the world continue to prevent individuals in severe pain from finding relief from their suffering. In West and Central Africa, four standard doses of controlled pain medicine were accessible every day for every one million people in 2019, compared to 32,000 doses in North America [2].

Drug addiction is a complicated topic that has been a major public health concern in Malaysia. Study into the contributing causes of drug addiction is an ongoing attempt to combat this rising social menace, and previous research has revealed that familial influences and peer influence are two of the major contributory factors of drug addiction [3]. As a societal problem and a national security concern, Malaysia has designated the drug problem as nation's number one adversary since 1983. A thorough and balanced approach will be used in order for Malaysia to effectively deal with and battle the drug problem [4]. Thus, the prevention of recurrent addiction between drug treatment is an important component of recovery.

The MFlex program has been implemented with the aim of curbing HIV infection and other blood-borne diseases especially among injecting drug users, at the same time reducing opiate drug abuse and related side complications as well as improving the mental and physical health as well as socioeconomics of patients [5].

It is important to have a deep knowledge of certain variables that directly influence system output because not all variables have the same degree of effect [6]. Patient under MFlex program is subjected to do methadone dosage trends such as descending case involving 16 parameters to determine whether the patient has better recovery process or vice versa. To identify patient with the potential rate to recover, no specific parameters have been used. This proves that the existing system does not have an accurate method of measurement and lack of justification on the recovery rate.

The objective is to analyse the classification and optimization factors in the descending case, and to diagnose the unknown data of the MFlex program. Literature review describes related studies on MTS, where the research gap on MTS is the most significant in this chapter. Next, research methodology explains the methods and strategies used to meet the objectives of the research. Result and discussion elaborate all the evidence that has been possessed during data collection using the MTS method for classification and optimization. Lastly, the conclusion concludes the final findings after the measurements have been handled and provides some recommendations for the subsequent work.

*CORRESPONDING AUTHOR | S.N.A.M. Zaini | ✉ areena5582@gmail.com

LITERATURE REVIEW

Opioids were used by 0.73 to 1.55 percent of the worldwide population between 15 to 64 years old in the previous year, whereas amphetamines were used by 0.46 to 0.65 percent of the population. As of 2019, this statistic depicts the estimated proportion of the worldwide population who took illegal substances in the previous year by drug type [1]. The synthetic opioid epidemic in North America is still dominated by fentanyl and its variants, while tramadol, a different synthetic opioid, is causing havoc throughout West, Central, and North Africa. Worldwide seizures of tramadol increased dramatically from less than 10 kilos in 2010 to almost 9 tons in 2013 and 125 tons in 2017. Cannabis continues to be the most frequently used drug in the world, with an estimated 188 million individuals using it in 2017 [7].

The Narcotics Crime Investigations Department (NCID) of the Royal Malaysia Police (RMP) is the primary body in charge of enforcing drug legislation in Malaysia. The Narcotics Division of the Royal Malaysian Customs Department (RMCD) is in charge of enforcing drug regulations. Furthermore, the Ministry of Health's Pharmacy Enforcement Division (PED) enforces the Poisons Act 1952 and its rules, as well as the Hazardous Drugs Act 1952 and its rules, which govern the sale, import, and export of harmful drugs (narcotics), poisons (including psychotropic compounds), precursors, and vital chemicals [4]. The amount of arrests made under the Dangerous Drugs Act (DDA) of 1952 is shown in Table 1. In 2018, there were 6,884 arrests for drug trafficking under Section 39B, 3,997 for significant possession under Section 39A(2), and 14,691 for minor possession under Section 39A(1) [4].

Table 1. Amount of arrests made under Dangerous Drugs Act 1952 (DDA), 2014-2018.

Year/Section	2014	2015	2016	2017	2018
Sec. 39B – Trafficking	4,932	5,354	5,771	6,759	6,884
Sec. 39A(2) – Significant Possession	3,259	3,455	3,706	4,140	3,997
Sec. 39A(1) - Minor Possession	8,023	9,625	11,721	13,583	14,691
Other sec. (under DDA 1952) [Sec.6 /Sec. 6B/ Sec.9/Sec.12(2)]	34,172	38,299	47,002	52,979	56,640
Sec.15(1)(a) – self-administration	81,435	81,435	84,205	80,925	75,465
Total	131,812	140,938	153,204	158,386	157,677

The implementation of the MFlex program has generally proven to be effective in addressing the issue of HIV/AIDS and addiction. The program has successfully improved the quality of life of drug addicts. The prevalence of HIV among injecting drug users showed a similar pattern of decline from 22.1% in 2009 to 16.3% in 2014. Government investment in this program turned out to be very cost-effective. This program is proven to be able to prevent a total of 1,597 new HIV infections from 2000 to 2015 and saving a cost of RM 3.85 million [5]. MFlex patients typically take their methadone as prescribed by a pharmacist in a public clinic. Based on yearly dosage monitoring, pharmacists can anticipate critical patients based on large monthly dose increases [8].

MTS that has been developed by Genichi Taguchi is a multivariate application that uses Taguchi Methods ideas to create a multivariate scale of measures utilizing a data-analytical approach to aid in quantitative decision making [9]. Classification in MTS used for classifying data as healthy and unhealthy. In the classification of MTS, it has some formulas and the calculation itself to find MD values for healthy and unhealthy groups. It is a metric to define the difference between the data point and the mean of a multivariate population. The MD scale of the chosen component will then be used for diagnosis or estimation [10]. MTS results in the MD scale used to assess the abnormality of unhealthy groups relative to a set of healthy groups [11]. The orthogonal arrays (OA) and the signal-to-noise ratios (SNR) are then used to determine the contribution of every parameter and to pick a useful range of parameters [10].

PC Mahalanobis introduced MD for the first time in 1930. It is an effective technique for determining the similarities between an unknown and known data analysis. The distance between the MD and the Euclidian distance (ED) has two significant changes [12], as shown in Figure 1. MD is employed in classical approaches to determine the "nearness" of an unknown point to the group's middle point (s). An observation is split into a range of distances from the center of the range [13].

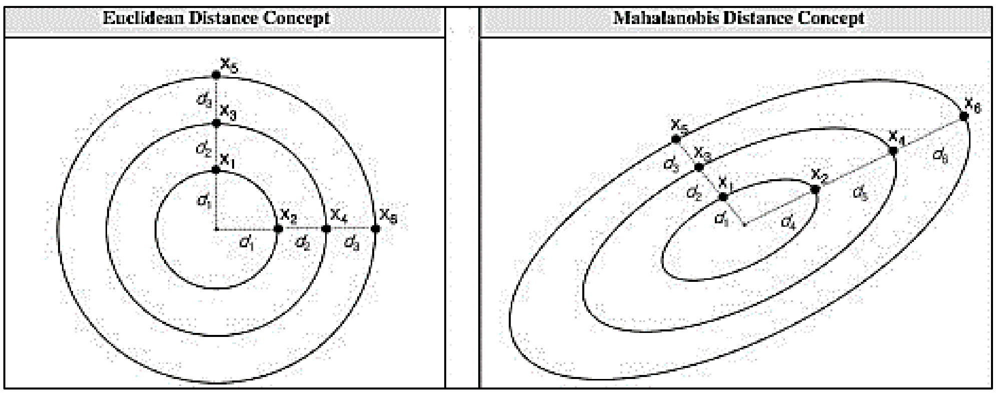

Figure 1. Comparison between MD and ED [14].

The multivariate control chart is a method that was created to compensate for the shortcomings of the traditional control chart. The RT-Method, on the other hand, is a technique that was originally developed for pattern recognition. As a result, the RT-Method explicitly covers fields such as surgical care, an inspection of features, image inspection, assessment of uncertain scenarios, the anticipation of potential conditions or changes, and so on. These are the things that the multivariate control chart does not answer. Table 2 shows the distinctions in concepts and organizational techniques between RT-Method and Multivariate Control Chart [15].

Table 2. distinctions in concepts and organizational techniques.

Concept and Organizational Technique	RT-Method	Multivariate Control Chart
Differences in the definition of normalcy	To provide reliable identification, Unit Space is established using homogeneity (normal state, state of consistency, state of high concentration) concerning the aim as the benchmark.	It considers the normal condition to be the standard and finds no relevance in the presence or absence of the homogeneity component.
Technique proposal for feature extraction	The effectiveness of feature extraction in pattern recognition impacts the outcome of the entire process.	No concept such as feature extraction is used, and the observed data is used in a nearly raw form.
Proposal for a recognition system evaluation criterion	- Includes a concept for quantifying success/failure in the recognition system. - The SN ratio can be used to assess the overall suitability of a recognition system.	NIL.
Item selection proposal	- Choose a variable that is efficient for detecting abnormalities. - Remove unneeded variables to increase the sensitivity of anomaly detection.	There are no such recommendations with the multivariate control chart.
Proposal for a diagnostic method for abnormality causes	- When an abnormality event happens, the causes can be identified. - When target data (unknown data) is found to be abnormal, it is feasible to establish which variable is generating the anomaly.	NIL.

T-Method is used in the MTS for optimization problem. A theory that predicts and estimates an outcome value (objective variable) dependent on a multivariate, and it serves the same function as multiple regression analysis. However, the analytical processes vary significantly [15]. In this section, we will look at what distinguished T-Method from multiple regression analysis. The differences between T-Method and multiple regression analysis are summarized in Table 3.

Table 3. Comparison of T-Method and multiple regression analysis.

	T-Method	Multiple
Unit Space	Selection is made from a homogenous, dense population with a median range output value.	The concept of “Unit Space” was not accepted. The total amount of data utilized to construct the regression formula.
Conditions restrictive	- The number of samples of Unit Space n ≥ 1. - The number of samples of Signal Data 1 ≥ 2. - (There is no multicollinearity.)	- The restriction is that the total number of items n > number of items k. - If multicollinearity exists, no solution is available. The removal of items may make it possible, but the effects of significant items may become hard to identify.
Correlation between elements	- Correlation between elements that were *not* used. - Signal Data outputs and items are subjected to a single regression (proportional equations with a reference point of zero). - If the correlation is near to “1”, the accuracy of the integrated estimate value may affect.	- Correlation between elements that were used. - If the correlation is near to “1”, partial regression coefficients and a single regression coefficient’s signs will not correspond.
The accepted evaluation function	SN ratio η integrated estimate	Multiple correlation coefficient, often known as multiple correlation coefficient corrected for degrees of freedom.

There are some advantages of MTS such as it classified normal and abnormal findings and optimized different criteria for the development of a higher-performing product at the workstation [16], it allowed to identify of abnormalities even though learning data were classified as ‘unlabelled’ [17], it used to create a continuous scale of measurement and to calculate the abnormality degree [18], it can define critical and non-critical variables [19] and it measures healthy retrospective observations and unhealthy retrospective observations [20]. On the other hand, MTS has a poorer statistical base relative to the classic multivariate processes [18], it can handle issues with binary classification only [21], characteristic factors may show the covariance matrix and multicollinearity is singular and irreversible which is MD cannot be calculated in this way [22], it can decide imperative features, but employments the difficult threshold to choose the features [21], and it lacks a strategy for evaluating an appropriate binary classification threshold [23].

According to Mota-Gutiérrez et al [24], the research of MTS is qualified into 7 categories which are, introduction to the method, case of study/application, comparison with other methods, construction of MS, integration, and development with other methods, dimensional reduction, and threshold establishment. This work is used these categories to summarize the research gap of the published work from the year 2011 to 2020 as shown in Figure 3.

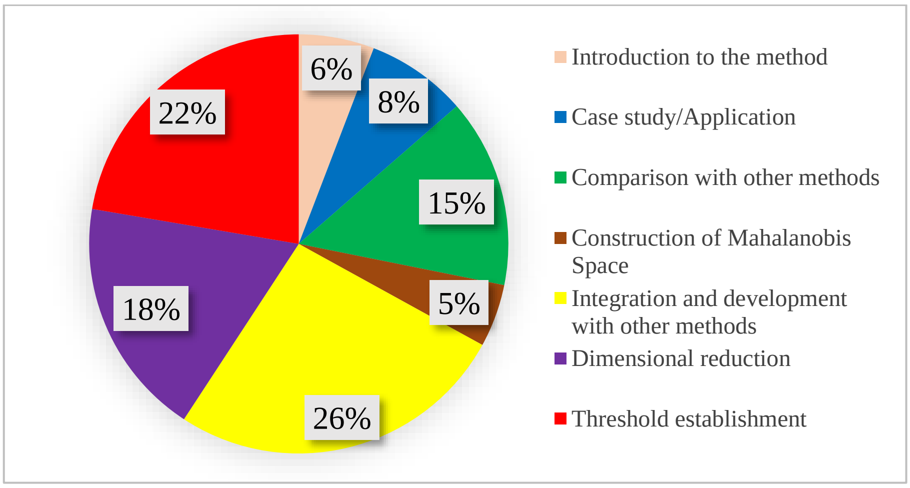

Figure 3. Variety of application field in MTS.

In case study/application which contribute 8%, MD calculated on the basis of the collection of descriptive variables for items used to distinguish between normal and abnormal items [25]. The predicted values can be used to study MD in high-dimensional environments [26]. The MTS increased the reliability of the detection of the quality characteristics of mechanical parts [27]. The MTS fields developed a multidimensional scaling method using the MD to calculate the abnormality level in “abnormal” items relative to a set of “normal” items [28]. MD is suggested as an alternate method for evaluating and choosing organizations and allows them to consider a potential flaw when aggregating individual results [29].

Abu et al [30] applied MTS to the big-end diameter of connecting rod to distinguish between two distinct ranges within the remanufacturability process spectrum. In 2014, Abu and Jamaludin [31] provided a systematic analysis of the data set on the main journal diameter of crankshaft. Abu et al [32] provided a systematic pattern recognition using MTS by constructing a scatter diagram which could support decision making of particular industry on 14 main journals of crankshaft belong to 7 engine models with different numbers of samples. Abu et al [33] classified crankshafts’ end life into recovery operations based on the Mahalanobis-Taguchi system. Nik Mohd Kamil and Abu [34] developed a distinctive pattern of crankshaft and identify the critical and non-critical parameter of crankshaft based on the MTS, then applied the Activity Based Costing (ABC) as a method of estimation for the remanufacturing cost of crankshaft. Abu et al [35] identified the critical and non-critical variables during remanufacturing process using MTS and simultaneously estimate the cost using ABC method. Abu et al [19] evaluated the criticality of parameters on the end of life crankshaft based on Taguchi’s orthogonal array. Then, estimate the cost using traditional cost accounting by considering the critical parameters. Azmi et al [36] measured the degree of abnormality using MTS and diagnosed the parameters that influence the system. Nik Mohd Kamil et al [37] proposed of MTS and Time-Driven Activity-Based Costing (TDABC) in electric and electronic industry to evaluate the significant parameters and develop time equation and capacity cost rate respectively. Nik Mohd Kamil et al [38] identified 4 insignificant and 11 significant parameters in the visual mechanical inspection workstation using MTS. Safeiee and Abu [16] found that positive gain through SNR indicates the quality of system still in good condition from February with 0.1244 until December with 0.4432 after insignificant variable has been removed using MTS. Kamil et al [39] concluded that MTS is a practical method for classification and optimization in the industry. Kamil et al [40] concluded that MTS and TDABC are a great tool and feasible to be implemented in the electronic industry. Saad et al [8] developed MTS based graphical user interface for analysing and classifying the normal and abnormal patient under MFlex service for better monitoring system. Ramlie et al [41] concluded that none of the four thresholding methods outperformed one over the others in (if it is not for all) most of the datasets. Harudin et al [42] proved that incorporating Bitwise Artificial Bee Colony (BitABC) techniques into Taguchi’s T-Method methodology effectively improved its prediction accuracy.

RESEARCH METHODOLOGY

To conduct a case study in the MFlex program at Bandar Pekan clinic, the procedures are shown in Figure 4.

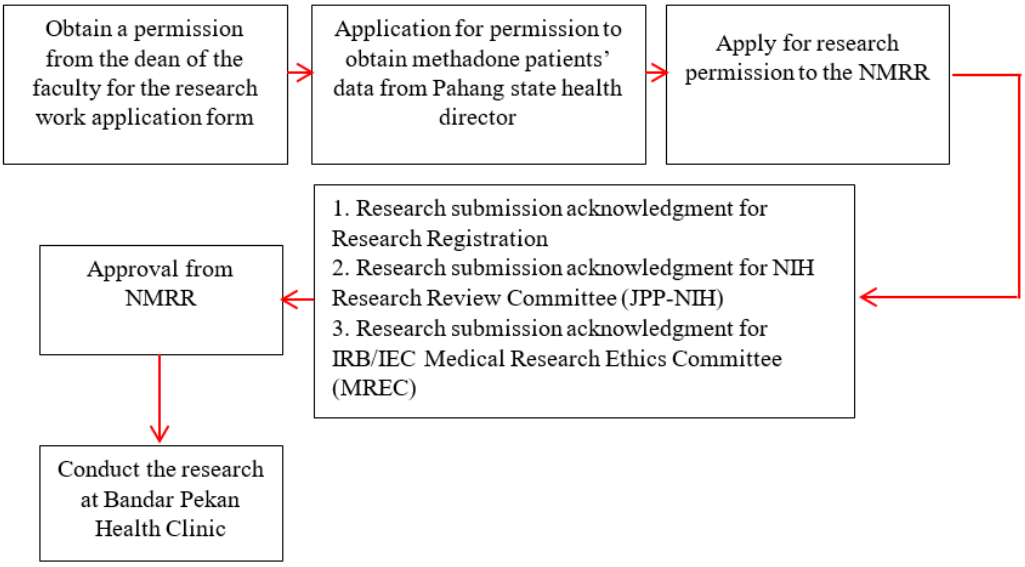

Figure 4. Sequence for research work.

This research work focused on MFlex program under Ministry of Health Malaysia in the methadone dosages. The 16 parameters of methadone dosage are created into four types of cases which are ascending, descending, up-down, and down-up. Thus, the classification of data and optimization of parameters can be analyzed between those types. To classify whether the patient tend to be healthy or require attention to restore the level of addiction, the methadone dosages contain 16 parameters where it is taken for four years start from 2017 until 2020. Each year are divided into four classes of methadone dosages. Table 4 shows the parameters of methadone dosages with reference range for each classes.

Table 4. Parameters in methadone dosages.

Parameters	Dosage duration	Unit	Reference range
1	Jan-Mar 2017	mg	(160-151)
2	Apr-Jun 2017	mg	(150-141)
3	Jul-Sep 2017	mg	(140-131)
4	Oct-Dec 2017	mg	(130-121)
5	Jan-Mar 2018	mg	(120-111)
6	Apr-Jun 2018	mg	(110-101)
7	Jul-Sep 2018	mg	(100-91)
8	Oct-Dec 2018	mg	(90-81)
9	Jan-Mar 2019	mg	(80-71)
10	Apr-Jun 2019	mg	(70-61)
11	Jul-Sep 2019	mg	(60-51)
12	Oct-Dec 2019	mg	(50-41)
13	Jan-Mar 2020	mg	(40-31)
14	Apr-Jun 2020	mg	(30-21)
15	Jul-Sep 2020	mg	(20-11)
16	Oct-Dec 2020	mg	(10-1)

The RT-Method could classify items into two categories which are within and outside the unit space. Unit data was chosen on the basis of the largest number of samples, among other samples. The RT-Method measured value of the output, but the category is clear when more than one unit spaces exist. The average value for each parameter is calculated as shown in Eq. (1), from n number of samples in healthy group.

$$\bar{x}_j = \frac{1}{n}\left(x_{1j} + x_{2j} + \cdots + x_{nj}\right) \ (j = 1, 2, \ldots k) \tag{1}$$

The sensitivity β, the linear formula L, and the effective divider r, are shown in Eq. (2), Eq. (3), and Eq. (4) respectively.

$$\text{Sensitivity}, \beta_1 = \frac{L_1}{r} \tag{2}$$

$$\text{Linear equation}, L_1 = \bar{x}_1 x_{11} + \bar{x}_2 x_{12} + \cdots + \bar{x}_k x_{1k} \tag{3}$$

$$\text{Effective divider}, r = \bar{x}_1^2 + \bar{x}_2^2 + \cdots + \bar{x}_k^2 \tag{4}$$

The total variations S_T, variation of proportional term S_β, error variation S_e, and error variance V_e, are shown in Eq. (5), Eq. (6), Eq. (7), and Eq. (8) respectively.

$$\text{Total variation}, S_{T1} = x_{11}^2 + x_{12}^2 + \cdots + x_{1k}^2 \tag{5}$$

$$\text{Variation of proportional term}, S_{\beta 1} = \frac{L_1^2}{r} \tag{6}$$

$$\text{Error variation}, S_{e1} = S_{T1} - S_{\beta 1} \tag{7}$$

$$\text{Error variance}, V_{e1} = \frac{S_{e1}}{k-1} \tag{8}$$

The standard SN ratio η is then calculated as stated in the Eq. (9). The greater the value of η, the stronger the relationship between the input and output.

$$\text{SN ratio}, \eta_1 = \frac{1}{V_{e1}} \tag{9}$$

The sensitivity β, and the standard SN ratio η, are then calculated in the healthy group, and the two variables Y_1 and Y_2 are calculated to generate a scatter diagram. The Eq. (10) and Eq. (11) show the value of Y_1 and Y_2 respectively.

$$Y_{i1} = \beta_i \tag{10}$$

$$Y_{i2} = \frac{1}{\sqrt{\eta_i}} = \sqrt{V_{ei}} \tag{11}$$

The prediction of origin is referred to the calculation of average for Y_1 and Y_2 in Eq. (12) and Eq. (13) respectively.

$$\bar{Y}_1 = \frac{1}{n}(Y_{11} + Y_{21} + \cdots + Y_{n1}) \tag{12}$$

$$\bar{Y}_2 = \frac{1}{n}(Y_{12} + Y_{22} + \cdots + Y_{n2}) \tag{13}$$

Finally, MD is calculated through Eq. (14).

$$\text{Mahalanobis distance}, D^2 = \frac{YA^{-1}Y^T}{k} \tag{14}$$

The methadone patients who are under monitoring was classified as unhealthy group. To calculate unhealthy group, the similar equation as healthy group is repeated, but the different between two groups is in normalization of unhealthy group. The linear equation L', and the effective divider r', are calculated as the same equation in healthy group which are Eq. (3) and Eq. (4) respectively. Note that the average values of samples and parameters $\bar{x}$, and the effective divider r', are the same values of the healthy group. Next, the value sensitivity β, for each unhealthy group can be calculated as stated in the Eq. (2).

After that, the total variations S_T, variation of proportional term S_β, error variation S_e, and error variance V_e, are calculated through Eq. (5), Eq. (6), Eq. (7), and Eq. (8) respectively. The value of sensitivity β, and the standard SN ratio η, from unhealthy group are used for the calculation of variables Y_1 and Y_2 as well. The value of sensitivity β is used for Y_1 as stated in Eq. (10), meanwhile the variable Y_2 is converted first as stated in the Eq. (11) for allowing the evaluation of any scattering from the normal conditions. The average value for Y_1 and Y_2 are same as shown in the Eq. (12) and Eq. (13) respectively for the prediction of healthy group origin. Lastly, the MD value can be found based on the Eq. (14).

The T-Method is utilized as evaluation to the parameters towards the output. The highest sample will be defined as a healthy group while remaining number of samples will be defined as unhealthy group. The average values for every parameter and the output average value from the number of samples in the healthy group are found as shown in Eq. (15) and Eq. (16) respectively.

$$\bar{x}_{\mathrm{j}} = \frac{1}{\mathrm{n}}\left(x_{1j} + x_{2j} + \cdots + x_{nj}\right) \tag{15}$$

$$\bar{\mathrm{y}} = \mathrm{m}_0 = \frac{1}{\mathrm{n}}\left(y_1 + y_2 + \cdots + y_n\right) \tag{16}$$

The balance samples that belong to healthy group are defined as unhealthy group. After that, the unhealthy group has been normalized using the average value of every parameter and output that belong to healthy group. The aim of normalization is to make the data more flexible by removing their redundancy. The calculation of normalized data for input and output are shown in the Eq. (17) and Eq. (18) respectively.

$$X_{ij} = \acute{x}_{ij} - \bar{x}_j \tag{17}$$

$$M_i = \acute{y}_i - m_0 \tag{18}$$

Proportional coefficient β and SN ratio η for each parameter are calculated as shown in Eq. (19), Eq. (20), Eq. (21), Eq. (22), Eq. (23), Eq. (24), and Eq. (25).

$$\text{Effective divider}, r = M_1^2 + M_2^2 + \cdots + M_l^2 \tag{19}$$

$$\text{Total variation}, S_{T1} = X_{11}^2 + X_{21}^2 + \cdots X_{l1}^2 \tag{20}$$

$$\text{Variation of proportional term}, S_{\beta 1} = \frac{(M_1 X_{11} + M_2 X_{21} + \cdots + M_l X_{l1})^2}{r} \tag{21}$$

$$\text{Error variation}, S_{e1} = S_{T1} - S_{\beta 1} \tag{22}$$

$$\text{Error variance}, V_{e1} = \frac{S_{e1}}{l-1} \tag{23}$$

$$\text{Proportional Coefficint}, \beta_1 = \frac{M_1 X_{11} + M_2 X_{21} + \cdots + M_l X_{l1}}{r} \tag{24}$$

$$\text{SN ratio}, \eta_1 = \begin{cases} \frac{\frac{1}{r}(S_{\beta 1} - V_{el})}{V_{el}} \\ 0 \end{cases} \left(when\ S_{\beta 1} > V_{el}\right) \left(when\ S_{\beta 1} \leq V_{el}\right) \tag{25}$$

A positive value of β means that the steepness is ascending to the right, while a negative value of β means that the steepness is descending to the right. The value of η should be in positive value, but if it turns out to be in negative value, it will be considered zero which means there is no longer a significant relationship between input and output.

The integrated estimate value of unhealthy group is computed by using the proportional coefficient β and SN ratio η for each parameter. The calculation of integrated estimate value is shown in Eq. (26). Note that, x_{j1}, x_{j2}, …, x_{j6} are the normalized value of each parameter.

$$\text{Integrated estimate value}, \widehat{M}_i = \frac{\eta_1 \times \frac{X_{i1}}{\beta_1} + \eta_2 \times \frac{X_{i2}}{\beta_2} + \ldots + \eta_k \times \frac{X_{i6}}{\beta_6}}{\eta_1 + \eta_2 + \cdots + \eta_6} \tag{26}$$

The step by step for calculating estimated SN ratio η are using the following Eq. (27), Eq. (28), Eq. (29), Eq. (30), Eq. (31), Eq. (32), and Eq. (33). In fact, the estimated SN ratio η is based on the suitability of OA.

$$\text{Linear equation}, L = M_1 \widehat{M}_1 + M_2 \widehat{M}_2 + \cdots + M_l \widehat{M}_l \tag{27}$$

$$\text{Effective divider}, r = M_1^2 + M_2^2 + \cdots + M_l^2 \tag{28}$$

$$\text{Total variation}, S_T = \widehat{M}_1^2 + \widehat{M}_2^2 + \cdots + \widehat{M}_l^2 \tag{29}$$

$$\text{Variation of proportional term}, S_\beta = \frac{L^2}{r} \tag{30}$$

$$\text{Error variation}, S_e = S_T - S_\beta \tag{31}$$

$$\text{Error variance}, V_e = \frac{S_e}{l-1} \tag{32}$$

$$\text{Estimated SN ratio}, \eta = 10 \log \left[\frac{\frac{1}{r}(S_\beta - V_e)}{V_e} \right] \tag{33}$$

The relative importance of parameter is evaluated in terms of the extent to which the estimated SN ratio deteriorates when the parameter is not used. Two-level OA which is level 1 and level 2 is used for an evaluation. The use of OA enables measurements to be made of the estimated SN ratio under various conditions. The two-level of OA means that level 1 is parameter will be used and level 2 is parameter will not be used. With respect to the estimated SN ratio, the difference between the averages of SN ratio for level 1 and level 2 for each parameter and on that basis determine the relative importance of the parameters. When the parameter is used with larger SN ratios and when the parameter is not used with smaller SN ratios, the degree of contribution turns to be positive. Otherwise, when the parameter is used with lower SN ratios and when the parameter is not used with higher SN ratios, the degree of contribution turns to be negative.

RESULT AND DISCUSSION

The scatter diagram of the methadone dosages between healthy groups and unhealthy groups are created. The samples of healthy and unhealthy groups are computed into two variables of Y_1 and Y_2. The horizontal line represents Y_1 and vertical line represents Y_2. The healthy group (blue dotted) has 50 samples while the unhealthy group (orange dotted) has 7 samples. In addition, the scatter diagrams consist of 16 parameters which have four years start from 2017 until 2020 with 4 classes of months for each of the year. Figure 5 shows a scatter diagram of descending case between healthy and unhealthy samples. The healthy and unhealthy samples form an aggregation of their own. From the scatter diagram, the unhealthy are scattered but still in group of its own. Both healthy and unhealthy do not overlap with each other due to the MD values for both samples are not identical. The MD value of maximum and minimum for healthy samples are 5.7535 and 0.0212 respectively while for unhealthy are 12830.7894 and 9247.7356 respectively. Moreover, the average value of MD for healthy is 1.0000 and for unhealthy is 11123.9730.

The value of correlation coefficient *r* for the unhealthy samples (orange dotted) is 0.3054. This is a positive correlation, which means the relationship between Y_1 and Y_2 variables are weak because the value is nearer to zero. Then, for the healthy samples (blue dotted) the value of *r* is -0.2901. It is a negative correlation with a weak relationship.

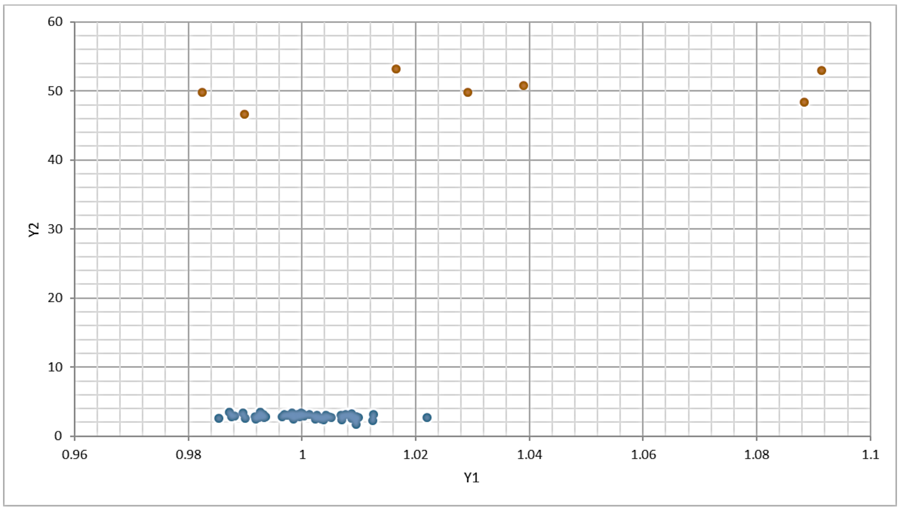

Figure 5. Scatter diagram of descending case between healthy and unhealthy.

In the descending case of methadone dosages, the number of healthy and unhealthy samples are 5 and 52 respectively with 16 parameters. The data is organized in the ascending order of output value, as shown in Figure 6. Sample number 4 turns out to be the smallest with 0.021 while sample number 55 turns out to be the largest with 12830.789. This means sample number 49, 6, 1, 30, and 16 are set to be the center point in blue and red dotted.

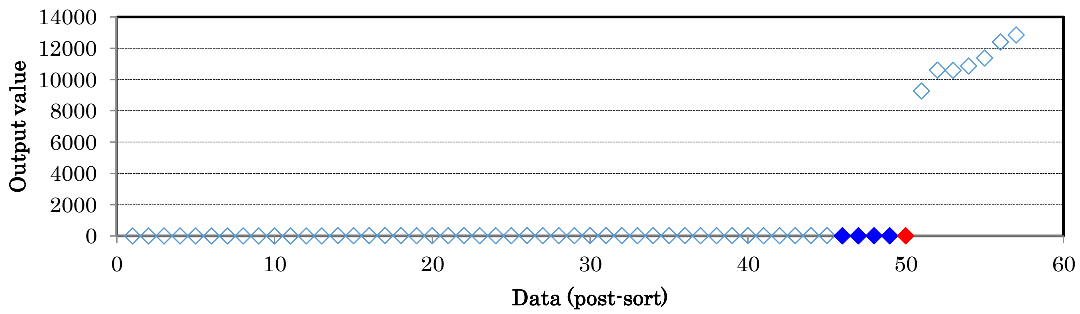

Figure 6. Data (post-sort) for descending case in methadone dosages.

The relationship between parameters and their output values is shown in Figure 7. The x-axis represents the normalized output values and the y-axis represents the normalized parameters values. To determine which of the parameters would be useful for evaluation, parameter by parameter computation of the proportional coefficient β and SN ratio η were carried out. The T-Method calculates SN ratios η and proportional coefficients β based on the relationship between the normalized output value and the normalized parameter value. According to [15], the greater the SN ratios η produces a stronger relationship or in the other words the distribution is closer to a blue line. Since Figure 7 (xvi) which represents the parameter 16 has $5\text{x}10^{-6}$ SN ratio η, so the distribution is approaching to the blue line whereas Figure 7 (v) and Figure 7 (vi), which represent the parameter of 5 and 6 has $1\text{x}10^{-8}$ SN ratio η, so the distribution is far away from a blue line. This proves that the greater value of SN ratio, the closer the distribution to a blue line in a graph.

Furthermore, [15] also stated that ascending the line from left to the right indicates the parameter has a positive value of proportional coefficients β whereas the descending the line indicates the parameter has a negative value of proportional coefficients β. This has been proven through Figure 7 (i) until Figure 7 (v) have negative value of proportional coefficient β whereas the remaining 11 parameters have positive value of proportional coefficient β. As a result, those parameters are well suited to the purpose of calculating integrated estimate value. This study would derive the value of integrated estimate value by using those proportional coefficient β and SN ratios η values. Therefore, the higher the SN ratios η, the greater the degree to which it contributes to the integrated estimates of MD value which is closer to the actual normalized MD value. Since none of those parameters has a negative SN ratio η value, subsequently all those parameters are considered in integrated estimate value.

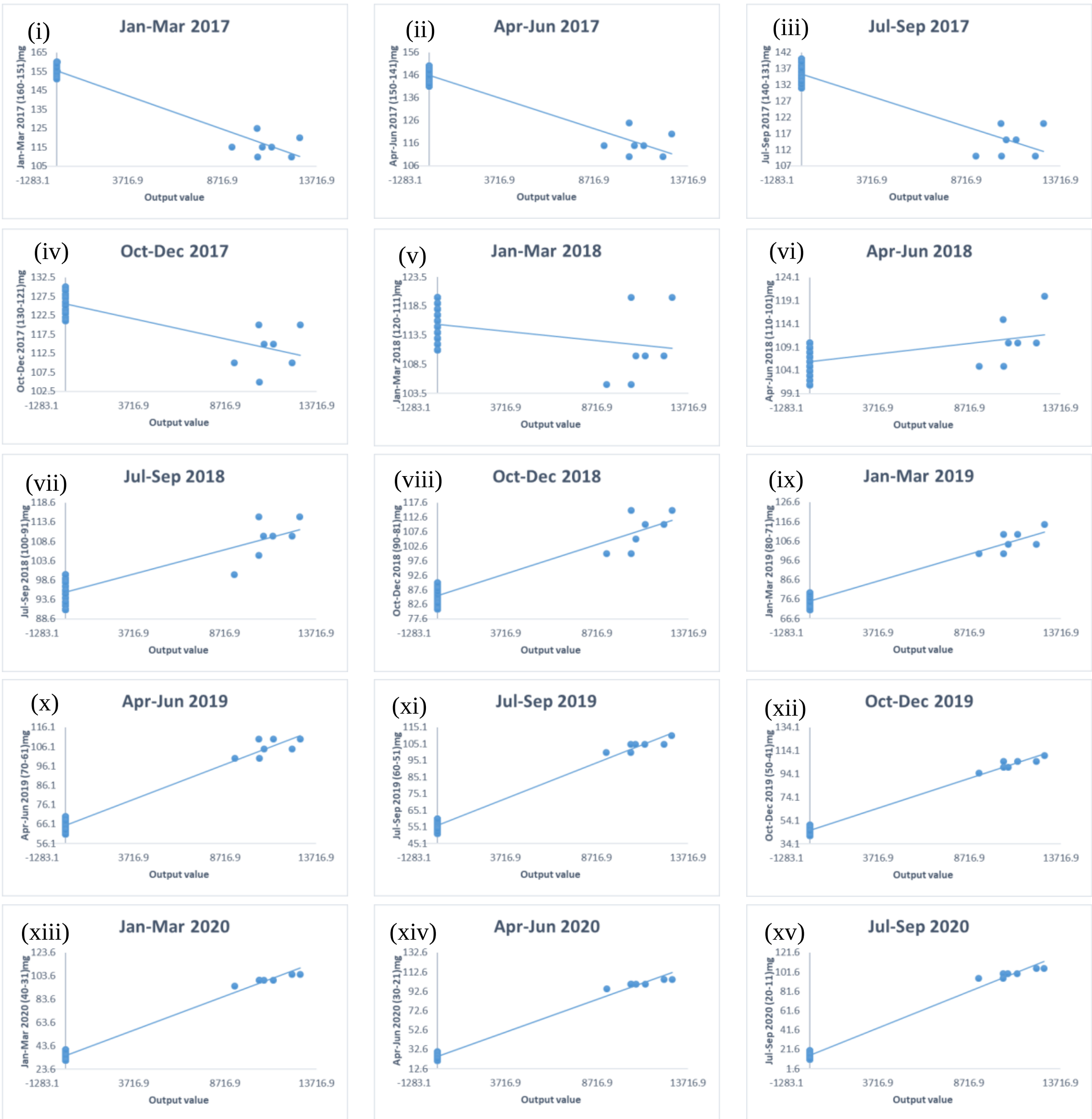

Figure 7. Scatter of normalized output and parameter values of descending case.

Figure 8 shows a scatter diagram reflecting of what happens when actual values are expressed in x-axis terms, and the estimated values in y-axis terms. If estimated values line up above a straight line, it indicates that a good estimation has been made. Furthermore, the graph will offer additional information regarding an approximate straight line and its attributes. The model contributes to 0.9937 of R^2 or -49.61 db of SN ratios η in general estimation. It means the correlation is high and the distribution is closer to the green line. The equation of the line is shown in Eq. (34).

$$y = x \tag{34}$$

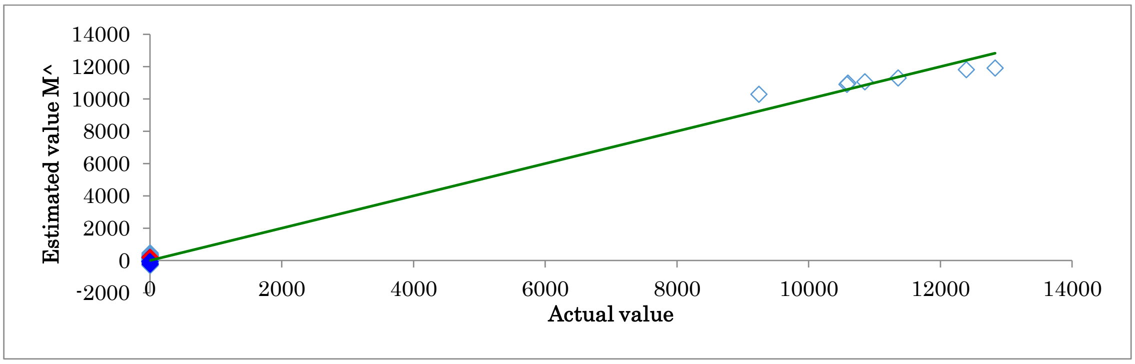

Figure 8. Distribution of actual and estimated signal data values of descending case.

Subsequently, the degree of contribution is translated into a bar graph as shown in Figure 10. From that, it shows how the parameters are significant to the output. When the parameter 13 has been used (level 1) with a greater relationship (SN ratio = -50.63 db) to the output and when the parameter has not been used (level 2) with a smaller relationship (SN ratio = -51.48 db) to the output, the parameter would obtain a higher degree of contribution (0.85 db) which is a positive contribution to the output. On the other hand, when the parameter 4 has been used (level 1) with a smaller relationship (SN ratio = -51.39 db) to the output and when the parameter has not been used (level 2) with a greater relationship (SN ratio = -50.72 db) to the output, the parameter would obtain a lower degree of contribution (-0.67 db) which is a negative contribution to the output.

Positive degree of contribution means that the use of parameter produces the effect of elevating the output of MD whereas negative degree of contribution means that the use of parameter produces the effect of lowering the output of MD. Consequently, parameter 1, 7, 9, 10, 12, 13, 14, 15, and 16 are positive degree of contribution whereas parameter 2, 3, 4, 5, 6, 8, and 11 are negative degree of contribution. This research work is suggested that in order to obtain lower MD, positive degree of contribution should be maintained while negative degree of contribution should be decreased.

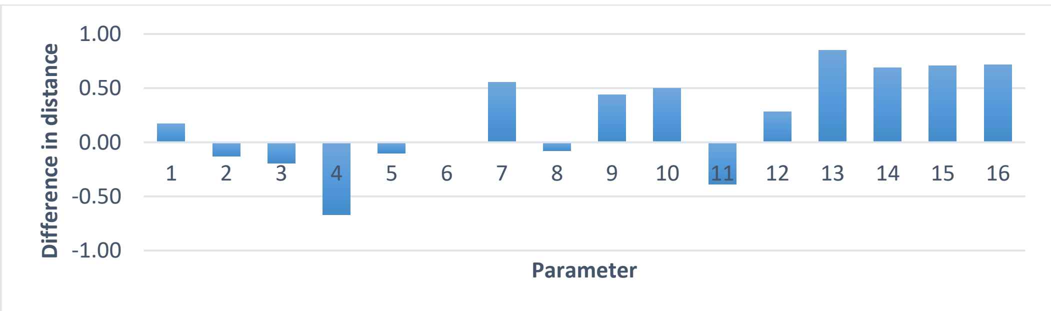

Figure 9. Degree of contribution of descending case.

The purpose of diagnosis of unknown data is to measure the MD and evaluate their parameters for each sample. The normalization is performed by subtracting from the average value of the parameters in the healthy group. The results of estimated value $M\hat{}$ or MD for unknown data are calculated through the Eq. (26) and can be seen in Table 5.

Table 5. The estimated value $M\hat{}$ (MD) for unknown data in descending case.

No. of sample	Estimated value $M\hat{}$ (MD)
1	174.6534
2	436.5083
3	11028.0519
4	11142.5671
5	8812.7234
6	7652.3142

Figure 10 shows a scatter diagram of the estimated values after subjected to the ecosystem which has been developed during optimization of descending case of methadone dosages. The x-axis represents the actual values of the output, M and the y-axis represents the estimated values of the output, $M\hat{}$. Since the actual values are unknown, the positions of unknown data on the x-axis use the same values as the estimated values. The position of 6 samples of unknown data are marked as green triangle in Figure 10. It can be concluded that 2 unknown samples are closely belong to the healthy group, 2 unknown samples are belonging to the unhealthy group, and another 2 unknown samples are belonging to the outlier.

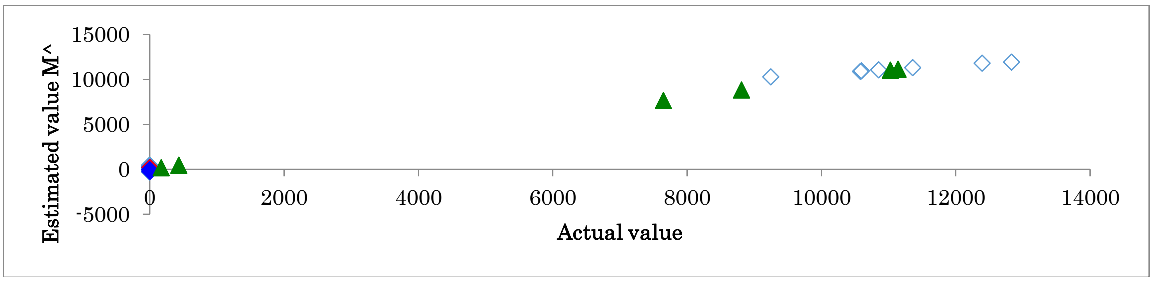

Figure 10. Interpretation of unknown data in descending case.

Figure 11 shows the degree of contribution in the first sample of unknown data in descending case. Consequently, parameter 3, 4, 5, 8, 11, 13, and 14 are positive degree of contribution whereas parameter 1, 2, 6, 7, 9, 10, 12, 15, and 16 are negative degree of contribution. This research work is suggested that in order to obtain lower MD, positive degree of contribution should be maintained while negative degree of contribution should be decreased.

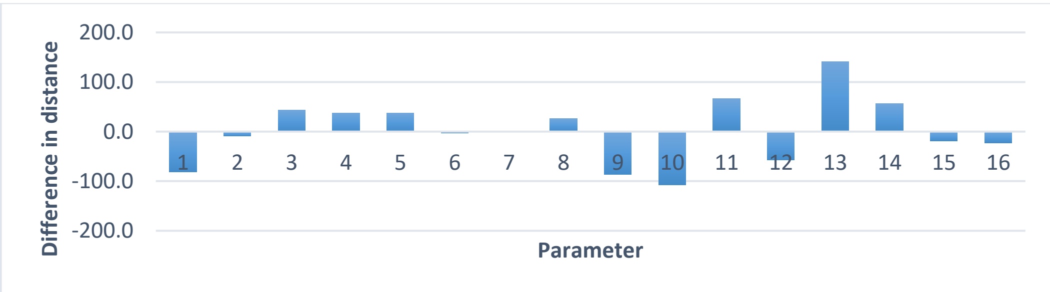

Figure 11. Degree of contribution in first sample of unknown data in descending case.

There are two types of degree of contribution. First is the positive degree of contribution indicating that the use of this parameter produces the effect of elevating the output. It means by increasing the value of this parameter, the MD value will be increased as well. Second is the negative degree of contribution indicates that the use of this parameter produces the effect of lowering the output. It means by decreasing the value of this parameter, the MD value will be decreased as well. The purpose of this section is to prove that the purpose solution to the Bandar Pekan clinic which is lowering degree of contribution is the best solution. Thus, this research work has selected methadone dosage (descending case) sample 1 as a subject matter as shown in Figure 11. The original output for sample 1 descending case is 174.65 as shown in Table 6. The value is compared with 6 types of modification.

Table 6. Comparison between original and types of modification.

Original	MD	Modification	MD
1	174.65	Type 1	210.32
		Type 2	138.99
		Type 3	101.40
		Type 4	-1857.10
		Type 5	308.05
		Type 6	76.92

The MD value for type 1 modification is 210.32 which is higher than the original sample. This modification means the higher positive degree of contribution is added with two points (parameter 11, 13, and 14) while lower positive degree of contribution is added with one point (parameter 3, 4, 5, and 8). On the other hand, the higher negative degree of contribution is subtracted with two points (parameter 1, 9, 10, and 12) while the lower negative degree of contribution is subtracted with one point (parameter 2, 6, 7, 15, and 16). Consequently, this modification as proposed solution has been rejected.

The MD value for type 2 modification is 138.99 which is smaller than original sample. This modification means the higher positive degree of contribution is subtracted with two points (parameter 11, 13, and 14) while lower positive degree of contribution is subtracted with one point (parameter 3, 4, 5, and 8). On the other hand, the higher negative degree of contribution is added with two points (parameter 1, 9, 10, and 12) while the lower negative degree of contribution is added with one point (parameter 2, 6, 7, 15, and 16). Consequently, this modification as proposed solution has been rejected.

The MD value for type 3 modification is 101.40 which is smaller than original sample. This modification means the higher positive degree of contribution is added with two points (parameter 11, 13, and 14) while lower positive degree of contribution is added with one point (parameter 3, 4, 5, and 8). On the other hand, the higher and lower negative degree of contribution is set as 0. Consequently, this modification as proposed solution has been rejected.

The MD value for type 4 modification is -1857.10 which is smaller than original sample. This modification means the higher and lower positive degree of contribution is set as 0. On the other hand, the higher negative degree of contribution is subtracted with two points (parameter 1, 9, 10, and 12) while the lower negative degree of contribution is subtracted with one point (parameter 2, 6, 7, 15, and 16). Consequently, this modification as proposed solution has been rejected.

The MD value for type 5 modification is 308.05 which is higher than original sample. This modification means the higher positive degree of contribution is added with two points (parameter 11, 13, and 14) while lower positive degree of contribution is added with one point (parameter 3, 4, 5, and 8). On the other hand, the higher and lower negative degree of contribution is maintained their value. Consequently, this modification as proposed solution has been rejected.

The MD value for type 6 modification is 76.92 which is smaller than original sample. This modification means the higher and lower positive degree of contribution is maintained their value. On the other hand, the higher negative degree of contribution is subtracted with two points (parameter 1, 9, 10, and 12) while the lower negative degree of contribution is subtracted with one point (parameter 2, 6, 7, 15, and 16). Consequently, this modification as proposed solution has been accepted.

Therefore, the best solution to the Bandar Pekan clinic is modification type 6 because it shows the lowest positive MD value compared to others. However, the proposed solution also might be influenced to the total number of positive and negative degree of contribution, and the total number of higher and lower degree of contribution. This research work shows the most important for types of modification is only a suggestion and not practically used in clinic. The interview session with the pharmacist at Bandar Pekan clinic is done to ask her opinions about the classification and optimization using MTS in MFlex program. The question was asked as follow:

Question: From the table results degree of contribution for unknown data blood screening tests, the parameter with red highlighted is a negative contribution to the output which means the patients need treatment for that parameter. In your opinion, does the T-Method help the health department in identifying the patients who needs treatment on a disease more easily and effectively?

Answer: Yes, it helps a lot because we can easily classify the healthy and unhealthy patients instead of need to go through for all the patients. Moreover, we can see only the red highlighted in the table and then can do the treatment for the patients.

CONCLUSION

From this research, MTS can classify between the healthy and unhealthy data. Besides, it can identify the significant parameters for descending case in the methadone dosages. In other words, it is proved that MTS can analyse the significant factors in the methadone dosages of the MFlex program. This research work is originally developed four types of cases which are ascending, descending, up-down, down-up, and 16 parameters as stated in Table 4. In descending case, the average MD of healthy is 1.0000 and unhealthy is 11123.9730. The positive degree of contribution is parameter 1, 7, 9, 10, 12, 13, 14, 15, and 16 whereas the negative degree of contribution is parameter 2, 3, 4, 5, 6, 8, and 11. 6 unknown samples in descending case methadone dosages of MFlex program have been diagnosed using MTS. All of them have different number of positive and negative degree of contribution to achieve lower MD. There are 6 types of modification to prove the proposed solution and type 6 modification has been selected as the best solution. A pharmacist from Bandar Pekan clinic has confirmed that MTS is able to solve a problem in classification and optimization in the MFlex program. The methods in MTS might be interesting if used to determine the medications, ascertainment of the methadone patients from previous clinic, and for system updates.

ACKNOWLEDGEMENT

This research is fully supported by PGRS2003154 and the authors fully acknowledge University Malaysia Pahang for the approved fund, and to the Ministry of Health Malaysia for the approval to do research work at Bandar Pekan clinic which makes this research effective.

REFERENCES

[1] J. Elflein, "Illegal drug use prevalence global population 2019," *Statista*, retrieved September 16, 2021, from https://www.statista.com/statistics/274690/population-prevalence-of-illegal-drugs-worldwide-since-1990/.

[2] G. Waly, "WDR 2021_booklet 1. United Nations : Office on Drugs and Crime," retrieved 2021, from https://www.unodc.org/unodc/en/data-and-analysis/wdr-2021_booklet-1.html.

[3] T. C. Lian, and F. Y. Chu, "A qualitative study on drug abuse relapse in Malaysia: Contributory factors and treatment effectiveness," *International Journal of Collaborative Research on Internal Medicine & Public Health*, vol. 5, no. 4, pp. 217 - 232, 2013.

[4] Ministry of Health of Malaysia, "Malaysia Country Report on Drug Issues 2019," *Alternative Development towards a Drug-Free ASEAN Community*, pp 1-27, 2019.

[5] F. Yuswan, and M. N. M. Dazali, "Policies and Standard Operating Procedures Methadone Treatment Program," pp 7-42, 2016.

[6] E. Reséndiz, L. A. Moncayo-Martínez, and G. Solís, "Binary ant colony optimization applied to variable screening in the Mahalanobis–Taguchi System," *Expert Systems With Applications*, vol. 4, no. 2, pp. 634-637, 2013, doi:10.1016/j.eswa.2012.07.058.

[7] World Drug Report, "World Drug Report 2019: 35 million people worldwide suffer from drug use disorders while only 1 in 7 people receive treatment," *United Nations : Office on Drugs and Crime*, retrieved September 16, 2021, from https://www.unodc.org/unodc/en/frontpage/2019/June/world-drug-report-2019_-35-million-people-worldwide-suffer-from-drug-use-disorders-while-only-1-in-7-people-receive-treatment.html.

[8] S. K. M. Saad et al., "Optimizing the MFlex monitoring system using Mahalanobis-Taguchi system," *IOP Conf. Series: Materials Science and Engineering*, vol. 1092, pp. 1-10, 2021, doi:10.1088/1757-899X/1092/1/012009.

[9] G. Taguchi, "Taguchi methods in LSI fabrication process," *6th International Workshop on Statistical Methodology*, pp. 1-6, 2001, doi:10.1109/iwstm.2001.933815.

[10] A. A. Jobi-Taiwo, "Data classification and forecasting using the Mahalanobis-Taguchi method," *Masters Theses*, pp. 1-56, 2012.

[11] W. H. Woodall, R. Koudelik, K. -L. Tsui, S. B. Kim, Z. G. Stoumbos, and C. P. C. MD, "A Review and Analysis of the Mahalanobis-Taguchi System," *Technometrics*, vol. 45, no. 1, pp. 1-15, 2012, doi:10.1198/004017002188618626.

[12] E. Ghasemi, A. Aaghaie, and E. A. Cudney, "Mahalanobis Taguchi system: a review," *International Journal of Quality & Reliability Management*, vol. 32, no. 3, pp. 291-307, 2015, doi:10.1108/ijqrm-02-2014-0024.

[13] G. Taguchi, and R. Jugulum, "The Mahalanobis-Taguchi Strategy: A Pattern Technology System", retrieved January 05, 2021, from https://books.google.com.my/books?hl=en.

[14] J. Ahn, M. Park, H. -S. Lee, S. J. Ahn, S. -H. Ji, K. Song, and B. -S. Son, "Covariance effect analysis of similarity measurement methods for early construction cost estimation using case-based reasoning," *Automation in Construction*, vol. 81, pp. 254-266, 2017, doi:10.1016/j.autcon.2017.04.009.

[15] S. Teshima, Y. Hasegawa, and K. Tatebayashi, "Quality Recognition and Prediction: Smarter Pattern Technology with the Mahalanobis-Taguchi System," *Momentum Press LLC*, pp. 1-220, 2012, doi10.5643/9781606503447.

[16] F. L. M. Safeiee, and M. Y. Abu, "Optimization using Mahalanobis-Taguchi System for inductor component," *Journal of Physics: Conference Series*, vol. 1529, pp. 1-7. 2020, doi:10.1088/1742-6596/1529/5/052045.

[17] M. Ohkubo, and Y. Nagata, "Anomaly detection for unlabelled unit space using the Mahalanobis Taguchi system," *Total Quality Management & Business Excellence*, pp. 1-15, 2019, doi:10.1080/14783363.2019.1616542.

[18] Z. P. Chang, Y. W. Li, and N. Fatima, "A theoretical survey on Mahalanobis-Taguchi system," *Measurement*, pp. 501-510, 2019, doi:10.1016/j.measurement.2018.12.090.

[19] M. Y. Abu, E. E. M. Nor, and M. S. A. Rahman, "Costing improvement of remanufacturing crankshaft by integrating Mahalanobis-Taguchi System and Activity based Costing," *IOP Conference Series: Materials Science and Engineering*, vol. 342, pp. 1-10, 2018, doi:10.1088/1757-899x/342/1/012006.

[20] B. Buenviaje, J. Bischoff, R. Roncace, and C. Willy, "Mahalanobis-Taguchi System to Identify Preindicators of Delirium in the ICU," *IEEE J Biomed Health Inform*, vol. 20, no. 4, pp. 1205-1213, 2016, doi:10.1109/JBHI.2015.2434949.

[21] N. Wang, Z. Wang, L. Jia, Y. Qin, X. Chen, and Y. Zuo, "Adaptive Multiclass Mahalanobis Taguchi System for Bearing Fault Diagnosis under Variable Conditions," *Sensors (Basel)*, vol. 19, no. 1, pp. 1-16, 2018, doi:10.3390/s19010026.

[22] J. Chen, L. Cheng, H. Yu, and S. Hu, "Rolling bearing fault diagnosis and health assessment using EEMD and the adjustment Mahalanobis–Taguchi system," *International Journal of Systems Science*, vol. 49, no. 1, pp. 147-159, 2018, doi:10.1080/00207721.2017.1397804.

[23] M. El-Banna, Modified Mahalanobis Taguchi System for Imbalance Data Classification," *Computational Intelligence and Neuroscience*, pp. 1-15, 2017, doi:10.1155/2017/5874896.

[24] C. G. Mota-Gutiérrez, E. O. Reséndiz-Flores, and Y. I. Reyes-Carlos, "Mahalanobis-Taguchi system: state of the art," *International Journal of Quality & Reliability Management*, vol. 35, no. 3, pp. 596-613, 2018, doi:10.1108/IJQRM-10-2016-0174.

[25] D. C. Montgomery, "The Mahalanobis-Taguchi Strategy," *Journal of Quality Technology*, vol. 35, no. 2, pp. 229-231, 2018, doi:10.1080/00224065.2003.11980211.

[26] D. Dai, T. Holgersson, and P. Karlsson, "Expected and unexpected values of individual Mahalanobis distances," *Communications in Statistics - Theory and Methods*, vol. 46, no. 18, pp. 1-14, 2017, doi:10.1080/03610926.2016.1200096.

[27] L. Ma, J. Mao, and H. Fan, "Key Quality Characteristics Identification Method for Mechanical Product," *International Conference on Digital Enterprise Technology*, vol. 56, pp. 50-54, 2016, doi:10.1016/j.procir.2016.10.015.

[28] W. Jiang, "The Mahalanobis–Taguchi Strategy," *Technometrics*, vol. 45, no. 3, pp. 266-267, 2012, doi:10.1198/tech.2003.s769.
[29] B. Beshah, "The effect of aggregating multivariate performance parameters in a quality award process," I*nternational Journal of Quality & Reliability Management*, vol. 31, no. 6, pp. 618-628, 2014, doi:10.1108/IJQRM-07-2012-0104.
[30] M. Y. Abu, K. R. Jamaludin, and F. Ramlie, "Pattern Recognition using Mahalanobis-Taguchi system on Connecting Rod through Remanufacturing Process: A Case Study," *1st International Materials, Industrial, and Manufacturing Conference*, vol. 845, pp. 584-589, 2014, doi:10.4028/www.scientific.net/AMR.845.584.
[31] M. Y. Abu, and K. R. Jamaludin, "Application of Mahalanobis-Taguchi System on Crankshaft as Remanufacturing Automotive Part: A Case Study," *1st International Materials, Industrial, and Manufacturing Conference*, vol. 845, pp. 883-888, 2014, doi:10.4028 / www.scientific.net/amr.845.883.
[32] M. Y. Abu, K.R. Jamaludin, A. M. Shaharoun, and E. Sari, "Pattern Recognition on Remanufacturing Automotive Component as Support Decision Making using Mahalanobis-Taguchi System," *12th Global Conference on Sustainable Manufacturing*, vol. 26, pp. 258-263, 2015, doi:10.1016/j.procir.2014.07.025.
[33] M. Y. Abu, K. R. Jamaluddin, and M. A. Zakaria, "Classification of crankshaft remanufacturing using Mahalanobis-Taguchi System International," *Journal of Automotive and Mechanical Engineering*, vol. 13, no. 2, pp. 3413-3422, 2017, doi:10.15282/ijame.13.2.2016.10.0282.
[34] N. N. N. M. Kamil, and M. Y. Abu, "Integration of Mahalanobis-Taguchi System and activity based costing for remanufacturing decision," *Journal of Modern Manufacturing Systems and Technology*, vol. 1, pp. 39-51, 2018, doi:10.15282/jmmst.v1i1.197.
[35] M. Y. Abu, N. S. Norizan, and M. S. A. Rahman, "Integration of Mahalanobis-Taguchi system and traditional cost accounting for remanufacturing crankshaft," *IOP Conference Series: Materials Science and Engineering*, vol. 342, pp. 1-9, 2018, doi:10.1088/1757-899X/342/1/012005.
[36] I. I. Azmi, S. N. A. M. Zaini, and M. Y. Abu, "Application of Mahalanobis-Taguchi System in Palm Oil Plantation," *Journal of Modern Manufacturing Systems and Technology*, vol. 3, pp. 1-8, 2019, doi:10.15282/jmmst.v2i2.2864.
[37] N. N. N. M. Kamil, M. Y. Abu, N. F. Zamrud, and F. L. M. Safeiee, "Proposing of Mahalanobis-Taguchi System and Time-Driven Activity-Based Costing on Magnetic Component of Electrical & Electronic Industry," *Proceedings of the International Manufacturing Engineering Conference & The Asia Pacific Conference on Manufacturing Systems 2019*, pp. 108-114, 2020, doi:10.1007/978-981-15-0950-6_17.
[38] N. N. N. M. Kamil, M. Y. Abu, M. Oktaviandri, N.F. Zamrud, and F. L. M. Safeiee, "Application of Mahalanobis-Taguchi System on Electrical and Electronic Industries," *Journal of Physics: 4th International Conference on Engineering Technology*, vol. 1532, pp. 1-10, 2020, doi:10.1088/1742-6596/1532/1/012004.
[39] N. N. N. M. Kamil, S. N. A. M. Zaini, and M. Y. Abu, "A case study on the application of Mahalanobis-Taguchi system for magnetic component," *International Journal of Engineering Technology and Science*, vol. 7, no. 2, pp. 1-12, 2021, doi:10.15282/ijets.7.2.2020.1001.
[40] N. N. N. M. Kamil, S. N. A. M. Zaini, and M. Y. Abu, "Feasibility study on the implementation of Mahalanobis Taguchi system and time driven activity-based costing in electronic industry," *International Journal of Industrial Management*, vol. 10, no. 1, pp. 160-172, 2021, doi:10.15282/ijim.10.1.2021.5982.
[41] F. Ramlie et al., "Classification performance of thresholding methods in the Mahalanobis–Taguchi system," *Applied Sciences*, vol. 11, no. 9, pp. 1-22, 2021, doi:10.3390/app11093906.
[42] N. Harudin et al., "Binary bitwise artificial bee colony as feature selection optimization approach within Taguchi's T-method," *Mathematical Problems in Engineering*, vol. 6, pp. 1-10, 2021, doi:10.1155/2021/5592132.