Deterioration Model for Sewer Network Asset Management in Baghdad City (case study Zeppelin line)

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ABSTRACT

Asset management involves efficient planning of economic and technical performance characteristics of infrastructure systems. Managing a sewer network requires various types of activities so the network can be able to achieve a certain level of performance. During the lifetime of the network various components will start to deteriorate leading to bad performance and can damage the infrastructure. The main objective of this research is to develop deterioration models to provide an assessment tool for determining the serviceability of the sewer networks in Baghdad city the Zeppelin line was selected as a case study, as well as to give top management authorities the appropriate decision making. Different modeling techniques were used based on statistical methods such as discriminant, and artificial neural network (ANN) which were used to build the deterioration models. The results of the discriminant model gave correct classification of 68.9% for the condition class of this line. The main significant influencing variables that play an important role in sewer networks were: sewer age, planning, performance and maintenance which is known as the Management function. From ANN model the confusion matrix gave correct classification of 76.7% and MSE 0.128.This study providing a good source of information for future planning.

Key words: asset management, deterioration, discriminant, artificial neural network, sewer condition.

نموذج ادارة تدهور شبكات المجاري لتطوير خدماتها في مدينة بغداد (خط زبلن حالة دراسية)

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الخلاصة

إدارة الشبكات تشمل التخطيط الفعال وقياس الاداء في كافة المجالات الاقتصادية والتقنية لأنظمة البنية التحتية. إدارة شبكة الصرف الصحي تتطلب أنواع مختلفة من الفعاليات وبالتالي فإن الشبكة يمكن أن تكون قادرة على تحقيق مستوى معين من الأداء. وخلال فترة عمل الشبكة ستبدأ المكونات المختلفة في التدهور مما يؤدي إلى سوء الأداء ويمكن أن تؤدي الى فشل في البنية التحتية. ان الهدف الرئيسي من هذا البحث هو بناء وتطوير نماذج تدهور لتوفير أداة تقييم وتحديد خدمية لشبكات الصرف الصحي في مدينة بغداد بالإضافة الى اعطاء الادارات العليا اتخاذ القرار المناسب. واستخدمت تقنيات نمذجة مختلفة استنادا إلى الأساليب الإحصائية مثل ألتمايز وتحليل

الشبكات العصبية الاصطناعية لبناء نموذج التدهور. وقد تم اختيار خط زبلن الرئيسي الناقل للصرف الصحي في مدينة بغداد كحالة دراسية. أعطت نتائج نموذج التمايز تصنيفا لحالة الصرف الصحي بنسبة 68.9%. وكانت المتغيرات الهامة الرئيسية التي تؤثر في الصرف الصحي لخط زبلن هي ألعمر ، التخطيط ,الأداء والصيانة وتسمى بدالة الادارة. ومن تحليل الشبكات العصبية الاصطناعية فان مصفوفة التداخل أعطت تصنيفا 76.7% ومربع خطا 0,128 .هذه الدراسة تعتبر مصدر مهم للبيانات والمعلومات تفيد في التخطيط المستقبلي.

الكلمات الرئيسية : ادارة الاصول ,التمايز ، التدهور , الشبكات العصبية ألاصطناعية حالة انبوب الصرف .

1- INTRODUCTION

The sewage network system is a key part of the urban infrastructure, which should work accurately and to maintain at a prudent, planned manner, sustainable and based on a scientific basis ,**Baik et al., 2006**. However, many cities suffer because of the infrastructure sewer deterioration that leaves the communities in a difficult psychological suit and disrupt not only sanitation services but other events which are related to people service **,Ana and Bauwens, 2007**. Large parts of sewer networks have already been replaced by newer materials, but in some cities there are still parts of the 19th century sewer in use. In Iraq and distinguish in Baghdad city most of the existing network was built in the second part of the 20th century. Many parts of the sewer networks have been deteriorated therefore they will need to be replaced, repaired or renovated in order to guarantee their required performance and to avoid possibility of failure. Deterioration models can make a significant contribution towards developing proactive management plans and to identify the significant factors that affect the condition of the sewer networks. These factors can be considered during different stages (design, construction and operation) of the project.

Dulcy et al., 2002 presented a description of improved methodology for careful analysis and interpretation of data in sewer systems. The proposed methodology allows fast and accurate assessment, which is important in building sewer asset management database.

Ana and Bauwens ,2007 presented a sewer asset management decision-support tools.. Each tool is qualified and its conforming information requirements are determined. They looked into cases of framing the use of the present available tools and presented a forestation on further research needs in the field.

Tran ,2007 developed hydraulic and structural deterioration models that can predict the conservation status of the sewerage with respect to population expectation. The output of the models may be used for long term annual budget and prioritizing maintenance.

Ana ,2009 studied the contribution of two important concepts in sewer network asset management. The research reported a significant grade in the progression and use of sewer construction deterioration models found on the regression Markov of semi, logistic analysis and multi criteria decision making (MCDM) in prioritizing sewer rehabilitation projects.

Sophie et al., 2013 a censored model (survival) was progressed to forecast total structural condition of a sewer by using camera examining outputs. The deterioration model was advanced to get the survival age. The e^x and Wiebul equations were used to stand for the division of ages in each deterioration condition.

Bouamrane and Bouziane 2014 developed a decision backup to deliver judgments to the problems of networks administration/ repairing, in order to help senior management. They stated that priority of interference may be by computation of three criteria (economic, environment and social) as well as the planning displayed should be well considered.

Even though the condition of Iraq sewer networks is not as good as those in other countries, large problems can be expected in the future if the current approach is not drastically changed. Allocated funds for sewer maintenance and operation are limited and not sufficient to keep the system in good condition.

1-1 Objective of the Study

The main objective of this research is to develop a performance based asset management program to provide an assessment tool for determining the serviceability of the sewer infrastructure system in Baghdad city by building deterioration models. These models are developed using discriminate analysis and artificial neural network. The predictive performance of these models is assessed by adaption of statistical tests and confusion matrix.

2- FACTORS AFFECTING SEWER DETERIORATION

The established knowledge on the mechanisms of sewer structural deterioration and failure along with the factors associated with deterioration should be identified and understood. The occurrence and propagation of defects and the rate of deterioration of pipes are affected by a number of factors.

2-1 Physical Factors

These factors refer to the physical attributes of the sewers:

2-1-1 Age

The construction year affects the sewer condition since it represents the sewer age and the quality of the construction work.

2-1-2 Shape

Among the different shapes in sewer networks, circular sewers are considered the strongest, **Baur and Herz, 2002**.

2-1-3 Diameter

The effect of pipe size on deterioration is rather contradictory across different studies. Some say that small diameter pipes are aging faster than bigger sizes.

2-1-4 Depth

Sewers at depths of less than 2m have higher than average failure rates **Fenner et al., 2000**. In addition **Anderson and Cullen ,1982** reported that 65% of the 4400 sewer failures that they studied occurred at a depth of 2m or less and 25% occurred at a depth from 2 to 4m.

2-1- 5 Length

Typically, long sewer (manhole-to-manhole length) results in higher deterioration rates. Defects in the connecting joints of the sewer pipes are one of the defects that cause the deterioration problems **Park and Lee, 1998.**

2-1-6 Material

There are many advantages and disadvantages using different types of materials in sewer networks. Typically, concrete pipes perform better than other pipes due to their high abrasion resistance, strength and cost **Ana, 2009**. Material types used in the construction of sewer pipes affect their reaction with the environmental **Salman, 2010.**

2-1-7 Slope

The sewers at medium slopes deteriorate slower than sewers with steep slopes where the corrosion rates are high **Ayuob et al., 2004**.

2-1-8 Type

The combined system deteriorates with slower rates compared with the separate network carrying sanitary sewage, **De Toffol et al., 2007.**

2-2 Environmental Factors

These factors refer to the characteristics of the surrounding environment of the sewer systems.

2-2-1 Presence of tree roots

The growth of roots inside the pipe affects the sewage transport. Furthermore roots inside the sewer exert more pressure on the pipe which may break it **Perera et al., 2007**.

2-2-2 Soil/backfill type

WRc ,1994. described fine, cohesive less soils (e.g. silt, fine sand) as highly susceptible to ground loss, where cohesive soils (e.g. coarse sand, gravel) and clay are the opposite,as well as to soil properties , trench side slop and execution methods .

2-2-3 Traffic and surface loadings

Studies have provided evidence that sewers under main roads (heavy traffic) suffer more defects (cracks, fractures) compared to minor roads (light traffic).

2-3 Operational Factors

These factors are related to how sewers operate and function.

2-3-1 Sewer function

One classification for the sewer networks is according to what kind of sewage it may carry. For the combined system the domestic sewage may be diluted with storm water and this could decrease the corrosion process, **Tran, 2007**.

2-3-2 Sewer maintenance

Appropriate maintenance strategies, like sediment removal, sewer cleaning and root cutting generally increase the service life of sewers. Nevertheless, cleaning techniques may accelerate sewer deterioration, **Davies et al., 2001**.

3- MONITORING AND ASSESSING PIPE CONDITIONS

Pipe condition (status) is often used to describe the overall serviceability, i.e. structural and hydraulic capacity of pipes at a point of time in their lifetime. Because of pipe deterioration, the task of monitoring and assessing the changes of pipe condition over time becomes extremely important as part of proactive management strategies. In the current management practice of sewers pipes, this task consists of two steps: 1- selection of inspection techniques and 2- grading conditions **Manu, 2010**. Laser profiling is used in conjunction with closed circuit television (CCTV) as it uses a ring of laser to assess the shape of the pipe wall or any change caused by deformation, sedimentation and corrosion, etc., **Van der Hoop, 2010**.

3-1 Rating Description of Condition

Scale which ranges from excellent to poor was used as the basis of all assessment sewer networks, **Wagga Guide, 2010**.

3-1-1-Excellent condition: Only planned maintenance is required, no defected is detected in the system.

3-1-2 Very good: It requires minor maintenance as well as programmed maintenance and rehabilitation can be scheduled for long term construction.
3-1-3 Good: Significant maintenance is required, rehabilitation is necessary for a medium –term within 3- 5 year.
3-1-4 Poor: Significant renewal/upgrade is required, rehabilitation is keen and must be completed in one - two years, necessary emergency has to be checked**.**
3-1-5 Very Poor: Complete breakdown of the pipe, rehabilitation stringent and short term to prevent collapse is necessary.

4- DETERIORATION MODELS

Many techniques for modeling the deterioration of sewer systems are available some are based on statistical methods such as, the discriminant analysis, and other based on artificial neural networks. The basic data required in the deterioration modeling are the factors mentioned in section 2.These requirements were gained from the data collected from Baghdad Mayoralty.

Table 1 shows the code identification that was used in the models to specify the different independent variables and dependent conditions.

4-1 Discriminant MODEL

Fisher's linear discriminate analysis (LDA) is a statistical method for classifying or predicting individuals or objects into mutually exclusive and exhaustive classes based on a set of independent variables or predictors, **Huberty, 1994**. The goal of this model is to get a linear transformation of independent variables which represent the maximum proportion amidst the within scatter class, **Laitinen, 2007**. Modeling needs to consider classification models that search for any exist or potential separation between groups centers of the variables of interest. Clear separation of the group's center indicates the goodness of the considered set of independent variables in the interpretation of the variability between groups of the variable condition. The classification models (Discriminant analysis) consider highly correlated sets of independent variables. The matrix of the correlation coefficients between the continuous variables was obtained by using SPSS program. The information gathered for this case study was subjected to statistical analysis in order to provide scientific evidences about modeling the variables of interest.

4-2 Artificial Neural Networks (ANN) Model.

In the case of sewer deterioration modeling, neural networks investigate the mathematical relationships between predictors (independent variables, i.e. deterioration factors) and responses (dependent variables, i.e. discrete sewer condition classes), **Kley et al., 2013**. Each connection between neurons has an associated weight that is determined by minimizing fault between the predicted output and the real output values.

5- CASE STUDY: ZEPPELIN SEWER TRANSPORTATION LINE

This line is one of the main sewers that collect sewage from Alrusafa side in Baghdad city. This sewer is about 25400 m in length and starts from the municipality of Al- Shaab and ends at Alrustamiya waste water treatment plant (3rd expansion) south of Baghdad. This sewer starts with diameters of 1800 to 2400 mm at depths of 3 to 7 m and ends at 3000 mm in diameter with 6 to 10 m in depth at the plant. This main line is clogged at rates ranging from 40% to 80% by oil, industrial wastes, trash, sediment and mud, knowing that this problem is one the most complex problems facing the drainage systems and requires fast and effective solutions.

5-1 Discriminant Model

The dependent variable (condition of the sewer) has only four rating conditions instead of five. The excellent condition was not recorded. **Table 2** shows the matrix of simple linear correlation coefficients for the set of variables in this region. With respect to the test of significant, the variables age, diameter, and length were found to be not significant linearly correlated, therefore will be considered in the Discriminant model. It is clear from the discriminant model shown in **Fig.1**, that the group centroids are well separated from each other but there is an over lapping of the category Good with cases of Very good and Poor categories. This is an indication that some of the remaining variables may help enhancing the classification and the total correct classification was found to be 68.9%. Different trials were made in order to decide on the set of categorical factors. The results revealed that all the variables are to be used as independent variables in the analysis and their contribution explains the dependent variable (condition). **Fig. 2** shows the merged groups centroids which reflect a better separation than that shown in **Fig.1**. This figure shows that cases of the Good category are still not well separated whereas all of the other three categories are very well separated.

The Box's M test, **Table 3** shows that the equalities of covariance matrices are significantly different and Table 4 shows the summary of the canonical correlations. In this situation the first function explains about 78.5% of the variance in the dependent variable that represent the square high correlation$(0.886)^2$.

Table 5 shows the output of the Wilks' test which also indicates that the condition categories are significantly different from each other.

The standardized canonical discriminates of the function coefficients are shown in **Table 6**. From this table, sewer age contributes to the maximum variance in the condition of the sewerage network. It can be used as a threshold to enhance the efficiency of the sewer pipe. Planning was found highly contributed to the dependent variable variance appeared by the second discriminant function. Moreover material was found also highly explained by the third function. According to the structure matrix **Table 7**, function 1 can be named as the age function since age has the largest absolute value among other independent variables. Function 2 can be named as the planning function and function 3 can be named as the material function.

Table 8 shows the group centroids which can be used as a reference when judging or predicting new cases. **Table 9** shows the unstandardized coefficients of the canonical discriminant functions which are used to build the actual prediction equation using new cases for classification. The classification matrix and Jack-Knife cross validation of this model ,**Table10** shows that condition 1 (Very good) has a 100% of correct classification. This is an indication that the discriminant function is very robust in detecting cases of this group. The condition categories Poor and Very poor are also well separated and they have percent of correct classification 83.3 and 93.5% respectively.

5-2 Artificial Neural Networks (ANN) Model.

Artificial neural network (ANN) was used here in order to enhance the results of the previous analysis of sewerage conditions. MATLAB programming environment provides very powerful procedures for implementation of such techniques. ANN is not always the procedure of choice in cases where there is no consistency between input and target sets of data. In order to compare the results of ANN to that of the Discriminant analysis, the MATLAB ANN was used. Out of the input and target sets of data, the MATLAB program will extract three samples of data called training, validation and testing. The most common activation function is the sigmoidal function which may be defined as follows:

$$Y = F(S) = \frac{1}{1 + e^{-S}} \quad (1)$$

In the back propagation learning occurs in the perceptron by changing connection weights after each piece of data is processed, based on the amount of error in the output compared to the expected result. In the case of supervised learning carried out through back propagation, error in output node is actually the difference between the target (TY) value and output value obtained by the net (Y). That is:

$$e=TY-Y \quad (2)$$

Accordingly, corrections to the weights of the nodes must be made in order to minimize the error in the entire output. This is a procedure that can be done by using different functions like gradient descent, gradient descent with momentum, and scaled conjugate gradient which is the case of this research work.

The scaled conjugate gradient algorithm (SCG), was designed to avoid the time-consuming line search. This algorithm is too complex to explain in a few lines, but the basic idea is to combine the model-trust region approach (used in the Levenberg-Marquardt algorithm described later), with the conjugate gradient approach. **Table 11** shows the default values of scaled conjugate gradient function. The default number of hidden neurons is set to 10. One might want to come back and increase this number if the network does not perform as well as he/she expect. The number of output neurons is set to the number of categories of the target data. In this context, **Fig. 3** shows the first diagram of the neural network used in this research for the data of Zeppelin line.

If the provided data is not large enough, then it is not expected that ANN will lead to meaningful or good results. Pattern recognition tool is also a classification procedure, was used to produce alternative classifications. Almost all confusion matrices revealed approximately the same percentages of correct classifications reaching 76.7% ,**Fig. 4**. The Mean Squared Error (MSE) is about 0.128 as shown **Fig. 5** and the error histogram ,**Fig. 6** is also well distributed around zero. The neural network analysis showed that the condition classes are overlapped and that they are not really five classes but maybe three or four classes.

6-CONCLUSIONS

Continuous inspection of any sewer network including pipes, manholes and pumping stations is necessary to provide the required maintenance as soon as possible. Training the technical staff will help in improving the ability of the workers for good management of technical problems. Deterioration models will help to predict the asset condition and a critical management decision can be made. In this study deterioration models were developed for the Zeppelin line in Baghdad city. The Discriminant and Artificial neural network models were used for the development of these models. The main conclusions achieved regarding these models are:

6-1 Discriminant Analysis

The condition variables were designed to have five distinguished classes; it appeared that these classes are actually four or sometimes three. Mostly these classes were Good, Poor and Very poor. Moreover, sewer age was the most significant variable in the evaluation process of the sewerage network condition. Planning (management function) appeared to have influence on judging the condition of this line where material also had some influence. The cross-validate grouped cases correctly classified was 68.9% .

6-2 Artificial Neural Network (ANN)

ANN has a remarkable ability to derive facts (target) from complicated or imprecise sets of data (inputs). Pattern recognition tool was used for classification of the condition classes. The percentage from the confusion matrix was 76.7% and MSE from the error histogram was 0.128 which indicates the goodness of the model in classifying new cases. Error histogram shows that the errors are distributed approximately equally around zero, this is indication of the goodness of fit for the ANN model. Continuous inspection and maintenance of this line, manholes and pumping stations are required as soon as possible for better performance.

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List of Abbreviations

ANN	Artificial Neural Network
LDA	Linear Discriminate Analysis -

GRP Glass Fiber Reinforced Plastic (GRP) Pipes

PVC Polyvinylchloride Pipes

CCTV Closed Circuit Television

MSE Mean Squared Error

Table 1. CODE Summary of the sewer network**.**

Data	**Measurement type**	**Codes**
Condition	Ordinal	excellent (condition1),very good (condition 2) , good (condition 3) , poor (condition 4) , very poor (condition 5)
Sewer type	Nominal	1-Gravity sewer, 2- pressure sewer
Sewer shape	Nominal	1-circular , 2- rectangular
Sewer function	Nominal	1-combined system ,2-separate system
Age	Scale (year)	
Diameter	Scale (mm)	
Depth	Scale (m)	
Length	Scale (m)	
Slope	Scale(m)	
Tree roots	Scale (number)	
Traffic	Ordinal	1-low , 2-medium , 3- high
Maintenance type	Nominal	1-rehabilitation , 2-major maintenance, 3-minor maintenance
Performance	Scale	90% (excellent performance), 75% (good performance) 65% (medium performance), 55% (poor performance)
Planning type	Nominal	1-planning long term, 2-planning medium term, 3-planning short term.
Material	Nominal	1-concrete pipe ,2-PVC polyvinylchloride pipe,3-GRP glass fiber reinforced pipe

Table 2. Simple linear correlation coefficient matrix.

		Age	Perform.	Diameter	Depth	Length	Slope
Age	Pearson Correlation	1	-.600**	.101	.092	-.090	-.101
	Sig. (2-tailed)		.000	.312	.355	.366	.311
	No.	103					
Perform.	Pearson Correlation	-.600**	1.0	.066	.040	.080	-.059
	Sig. (2-tailed)	0.000		.509	.686	.422	.552
	No.	103					
Diameter	Pearson Correlation	.101	.066	1.00	.837**	-.064	-.994**
	Sig. (2-tailed)	.312	.509		.0 00	.524	.00
	No.	103					
Depth	Pearson Correlation	.092	.040	.837**	1.0	.035	-.808**
	Sig. (2-tailed)	.355	.686	.000		.725	.0
	No.	103					
Length	Pearson Correlation	-.090	.080	-.064	.035	1 .00	.091
	Sig. (2-tailed)	.366	.422	.524	.725		.363
	No.	103					
Slope	Pearson Correlation	-.101	-.059	-.994**	-.808**	.091	1 .0
	Sig. (2-tailed)	.311	.552	.000	.000	.363	
	No.	103					

**. Correlation is significant at the 0.01 level (2-tailed).

Table 3. Equalities of covariance matrices.

Box M		74.188
F	Approximate	1.787
	d.f1	36
	d.f2	13554.221
	Significance.	.003

Table 4. Summary of the canonical correlation.

Functions.	Eigen. value	% of variance.	Cum. %	Canonical Correlation.
1	3.6390[a]	90.60	90.6	.886
2	.3009[a]	7.7	98.3	.486
3	.069[a]	1.7	100.	.254

a. First 3 canonical discriminant functions were used in the analysis.

Table 5. Wilk's, Lambda test.

Test Function (s)	Wilks' Lam.	chi-square	df	Sig.
1.0 through 3.0	.154	179.603	24	.000
2.0 through 3.0	.714	32.287	14	.004
3.0	.935	6.412	6	.379

Table 6. Standardized canonical discriminant coefficients.

	Function 1	Function 2	Function 3
Age	-1.004	.065	-.157
Dia.	.590	.322	.631
Length	-.013	.034	-.414
Traffic	.534	.028	-.179
Tree roots	.201	-.005	-.353
Maintenance	.110	-.248	.174
Planning	-.143	.885	-.116
Material	.297	.098	.968

Table 7. Structure matrix.

	Function 1	Function 2	Function 3
Age	-.883*	.191	-.033
Planning	.067	.963*	-.034
Diameter	.009	.634*	.167
Material	-.049	-.304	.545*
Tree roots	.091	.142	-.455*
Traffic	.208	.000	-.440*
Maintenance	.031	.136	.233*
Length	.062	-.151	-.190*

*. Largest absolute correlation between each variable and any discriminant function

Table 8. Functions at group cancroids.

Cond.	Function		
	1	2	3
1.00	3.573	.579	.548
2.00	1.407	.316	-.370
3.00	.071	-.738	.044
4.00	-2.416	.405	.082

Unstandardized canonical discriminant functions evaluated at group means
Unstandardized coefficients

Table 9. Coefficients of the discriminant functions.

	Function 1	Function 2	Function 3
Age	-.402	.026	-.063
Dia.	.001	.001	.001
Length	.000	.002	-.026
Traffic	.650	.035	-.217
Tree roots	.227	-.005	-.400
Maintenance	.174	-.393	.276
Planning	-.179	1.111	-.145
Material	.935	.307	3.042
(Constant)	8.610	-4.750	-2.136

Table 10 . Classification matrix and jack-knife cross validation [b,c].

		Cond.	Predicted Group Membership				Total
			1.0	2.0	3.0	4.0	
Originally	Count	1.00	10	0	0	0	10
		2.00	6	14	4	2	26
		3.00	0	5	30	1	36
		4.00	0	0	2	29	31
	%	1.00	100.0	.0	.0	.0	100.0
		2.00	23.1	53.8	15.4	7.7	100.0
		3.00	.0	13.9	83.3	2.8	100.0
		4.00	.0	.0	6.5	93.5	100.0
Cross-validation [a]	Count	1.00	7	3	0	0	10
		2.00	6	11	7	2	26
		3.00	0	7	26	3	36
		4.00	0	1	3	27	31
	%	1.00	70.0	30.0	.0	.0	100.0
		2.00	23.1	42.3	26.9	7.7	100.0
		3.00	.0	19.4	72.2	8.3	100.0
		4.00	.0	3.2	9.7	87.1	100.0

a. Cross validation is done only for those cases in the analysis
b.. 80.6% of origin group cases correctly classified.
c.. 68.9% cross-validated grouped cases correctly classified.

Table 11. Default values of the function trainscg.

Epochs	100	Maximum number of epochs to train
Show	25	Epochs between display (NaN for no displays)
Time	Inf	Maximum time to train in seconds
min_grad	1-e6	Minimum performance gradient
max_fail	5	Maximum validation failures
Sigma	5.0e-5	Determine change in weight for second derivative approximation
Lambda	5.0e-7	Parameter for regulating the indefiniteness of the Hessian

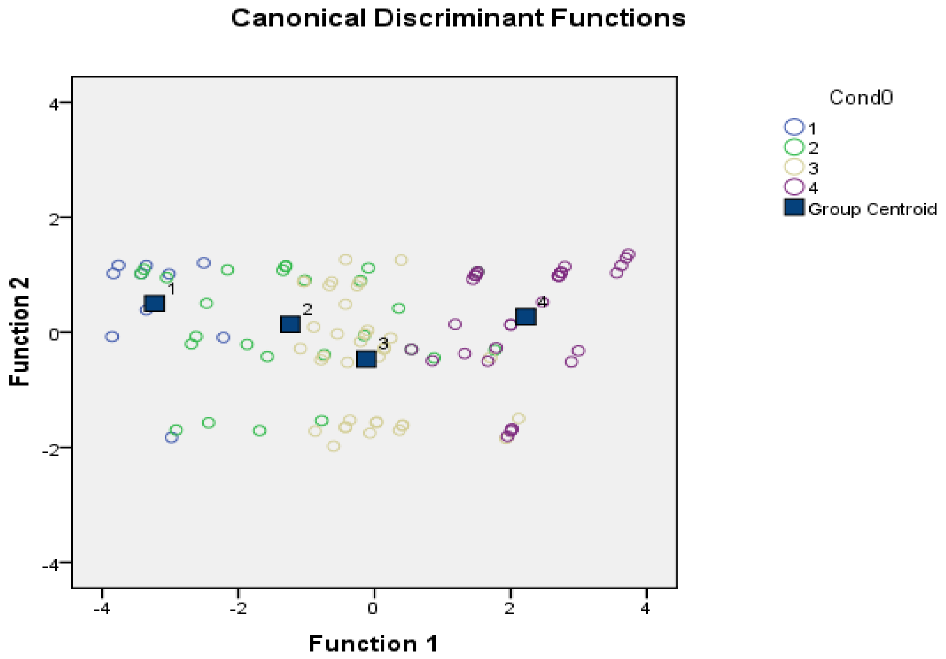

Figure1. Canonical discriminant functions applied to the data of region.

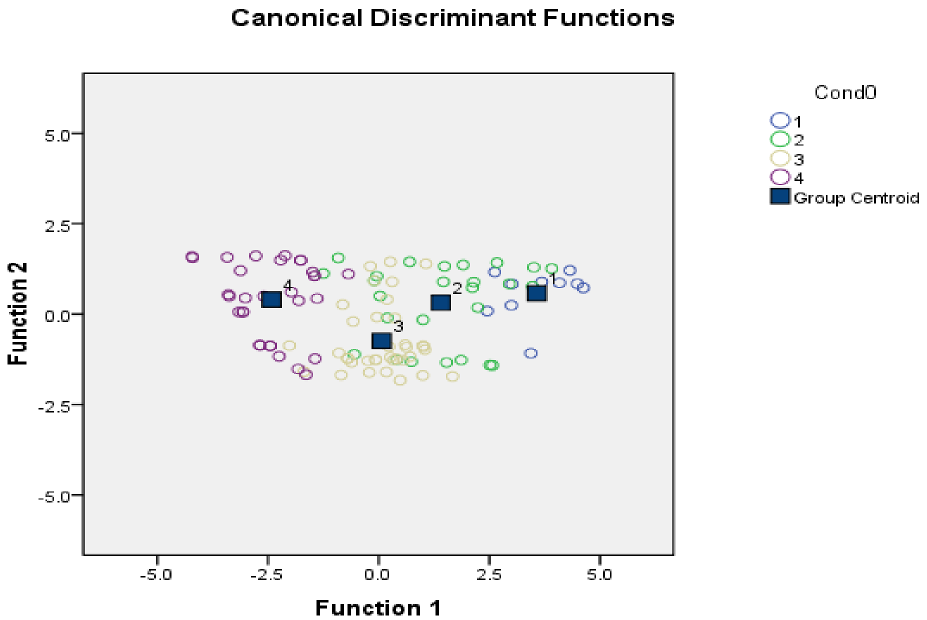

Figure 2. Canonical discriminant functions applied to the merged data of the region.

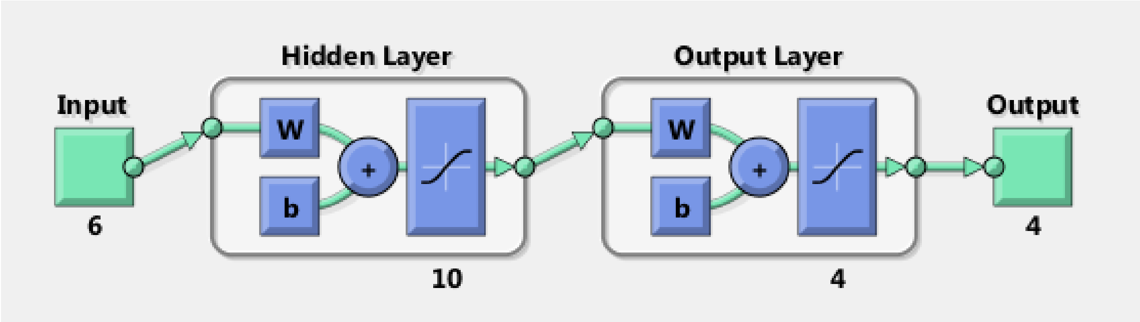

Figure 3. The first diagram of neural network.

Figure 4. Confusion matrices of the Zeppelin line.

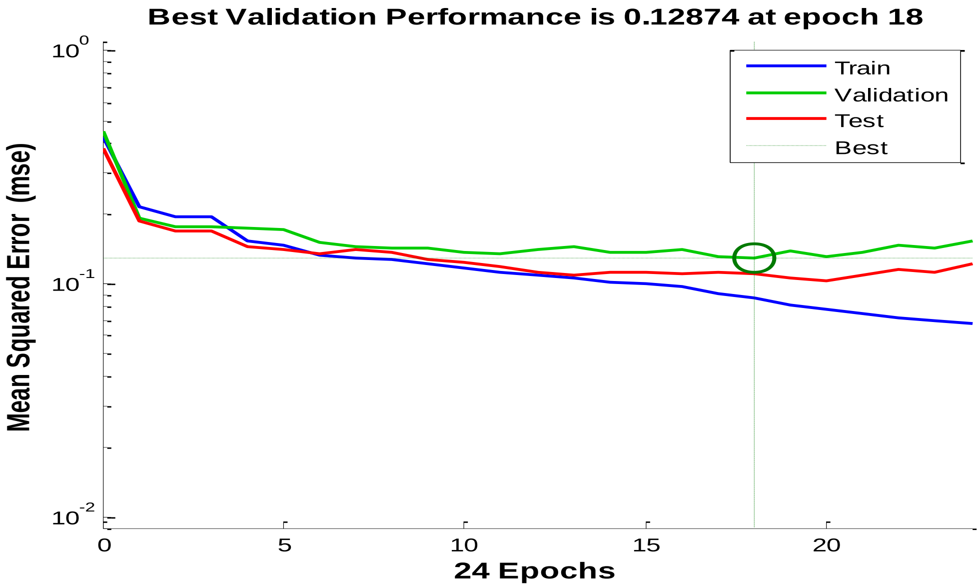

Figure 5. MSE of the ANN model for the Zeppelin line.

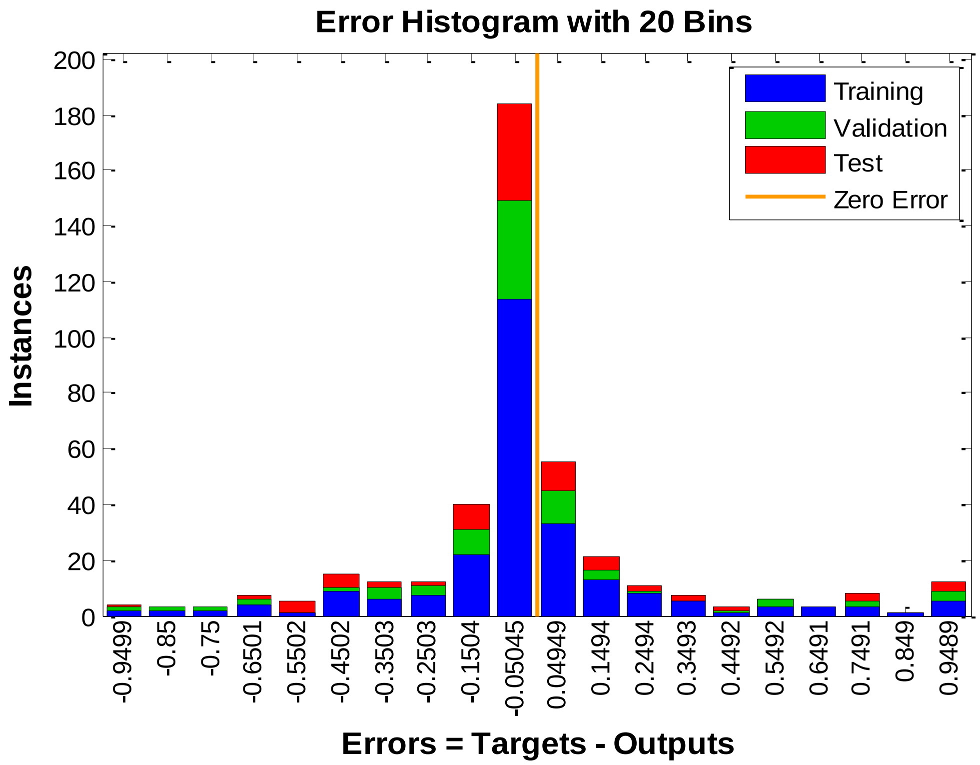

Figure 6. Error histogram of the outputs of ANN model.