CHAPTER I

INTRODUCTION

1.0 General

Bridges are among the most important structures in the highway network of any nation. A bridge provides the vital link to any transportation system. Bridges constitute a unique class of structures in the sense that they undergo such dynamic loads as truck weight that changes with time. Usually the reason for the changes is due to government regulations and the demand by the public to increase the legal truck weight. Aside from the truck load, bridges are also exposed to variety of environmental conditions that may cause a rapid deterioration on their components.

Due to the variety of loading situations, environmental conditions and continuous use, bridges are vulnerable to a more severe deterioration process than most other structures. Because of their vulnerability to a rapid deterioration, most transportation agencies have stringent requirements for bridge maintenance and repair. It is only through a rigorous inspection and repair program that the service life of a bridge can be extended and its safe operation maintained. As part of an effective maintenance and repair program for bridges, condition assessment of bridges ranges from simply a structural analysis combined with visual inspection to a more severe program involving non-destructive tests. Availability of new technologies such as advanced computerized life cycle cost analysis, stress analysis and Artificial Neural Network (ANN) analysis can help reduce the effort needed in bridge condition assessment. In particular, the ANN analysis can effectively be used to develop a scheme by which the condition of a bridge can be assessed using the information available for other bridges. More precisely, the data on past inspection records can be used in training an ANN system to predict the condition of a given bridge. Although the result from the ANN system may only be approximate, nevertheless such information may be helpful in determining what bridge or group if bridges need to be prioritized for immediate inspection and/or repair. This can reduce the cost associated with the management of a network of highway bridges.

1.1 Background

A significant issue in bridge maintenance today is the method of evaluating bridge conditions. The demand for the type of maintenance and repair depends on the outcome of the bridge condition assessment. An effective method, that has been used extensively, is based on visual inspections. Analytical methods using load rating has also been used either independently or along with a visual inspection process.

Usually, upon conducting a visual inspection, a rating value is assigned to individual components of the bridge. The rating assigned represents the bridge deterioration level normally known as bridge condition rating. Depending on the agencies responsible for the bridge, different rating schemes are used. For example, for highway bridges, most agencies use a scale of 0 to 9. A scale of 0 indicates that a bridge is an extremely critical situation and must be immediately replaced, whereas, a scale of 9 indicates that the bridge is in good condition and thus not required any action at least until the next inspection cycle. Table 1.1 presents a complete description of the ten scales used by most federal and state agencies in USA that are responsible for maintenance of highway bridges.

Most agencies responsible for railroad bridges use different rating scheme. This type of rating is either ranging between 1 to 5 or from 1 to 4. For example, the American Railway Engineering Association (AREA) uses a scale of 1 to 5 as summarized in Table 1.2.

Most highway and railway bridges are inspected every 2 years. The rating process if conducted by experienced inspector and on a systematic basis, provides an effective way of monitoring the deterioration trend in bridge components. In highway bridges, the individual component ratings are combined to arrive at an overall rating for bridge sub-systems such as the deck, superstructure and substructure. Those ratings and its change overtime are often used in constructing the bridge condition profile (Mohammadi, Guralnick and Yan, 1996).

As seen in Figure 1.1, any repair administered on the bridge improves the condition rating. However, the improved rating is never reaching the maximum value of 9. In fact, the improved rating after each repair is less than the previous one. After certain age, any repair done to the bridge will not improve the condition by any meaningful amount. This is when the bridge must be replaced. Information such as that in Figure 1.1 is of value for estimating the condition of bridges that are similar in geometry and traffic usage to those for which inspection rating results are available.

Table 1.1: Description of rating scale used by Federal Highway Engineering Administrations (FHWA).

Rating	Condition
9	**Excellent condition**
8	**Very good condition**, no problem noted
7	**Good condition**, some minor problems
6	**Satisfactory condition**, structural elements show some minor deterioration
5	**Fair condition**, all primary structural elements are sound but may have section loss, cracking, spalling or scour.
4	**Poor condition**, advance section loss, deterioration, spalling or scour.
3	**Serious condition**, loss of section, deterioration, spalling, scour have seriously affected primary structural members, local failures are possible; fatigue cracks in steel or shear cracks in concrete may be presented.
2	**Critical condition**, advance deterioration of primary structural members, fatigue cracks in steel or shear cracks in concrete may be presented or scour may have removed substructure support. Unless closely monitored, it may be necessary to close the bridge until corrective actions is taken.
1	**Imminent failure condition**, major deterioration or section loss present very critical structural components or affecting structural stability. Bridge is closed to traffic but corrective measures may put the bridge back in light service.
0	**Failed condition**, out of service, beyond corrective action.

Table 1.2: Description of rating scale for railway uses by American Railway Engineering Association (AREA)

Rating	Condition
5	**Good condition**, no visible defects, no repairs necessary
4	**Fair condition**, slightly defective or deteriorated member, no repair necessary, keep under observation
3	**Marginal condition**, moderate defective or deteriorated member that will progress to a serious defect, repair or rehabilitate within 3 years
2	**Poor condition**, heavily defective or deteriorate that will progress quickly to a severe and serious condition, repair or rehabilitate within 1 year
1	**Critical condition**, extensive and dangerous defects in need of immediate repair

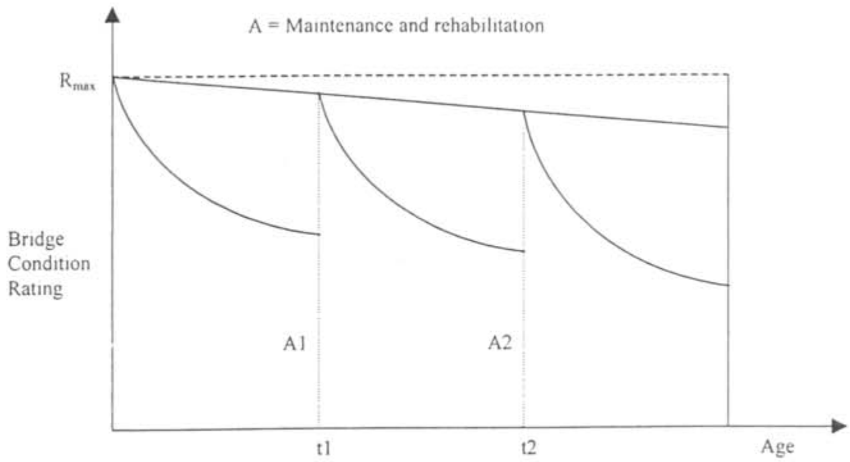

Figure 1.1: Bridge condition rating after two maintenance jobs (Mohammadi, Guralnick and Yan, 1996)

A different rating method used for bridges is the analytical rating. For highway bridges this method is known as Load rating. In this method, the analytical rating is primarily based on the results of a structural analysis. The rating can be done for any member and any type of load effect (such as the bending moment, shear force, etc.). In essence, the rating can be written in the following general form (ASSHTO, 1994):

$$Rating = \frac{Capacity - D_l}{L_L \times impact} \quad (1.1)$$

Where:

D_l = Dead load

L_l = Live load

Different versions of Equation 1.1 have been used by various organizations. The American Association of State Highway and Transportation Officials (ASSHTO) describes the rating process based on Equation 1.1 for various bridge components and for two levels of component capacities. These are: (1) the operating rating, and (2) the inventory rating (ASSHTO, 1994). The difference between the two ratings is in the capacity values used in Equation 1.1.

The American Railway Engineering Association (AREA) uses a slightly different version of Equation 1.1. The AREA uses a multiplier in the equation also (AREA, 1997). The AREA rating method is referred to as the Cooper rating.

Analytical rating methods have been intended as means to determine the safety level of bridges through calculations. For example, the Cooper Rating method (outlined in the American Railway Engineering Association specifications) is used in railroad bridges to determine the value that represents the condition of railroad bridge and its deficiency in carrying the bending moment and shear forces. Analytical rating method considers dead load, live load and impact load to produce the rating value for a bridge without directly considering the effect of component deterioration that may occur overtime. The calculated rating is unable to represent the actual condition of the bridge components, but it still can be used as a preliminary assessment tool especially in prioritizing bridges for further evaluations. The analytical rating on the other hand is less uncertain but it is unable to provide a reliable measure for a bridge actual condition.

As discussed earlier, subjective rating is conducted by assigning the rating value to individual bridge components. The rating assigned depends on the defects present. This method is conducted in the field by bridge inspectors and will be primary influenced by the inspector's individual experience. This will cause inconsistencies on the bridge rating values. This occurrence is due to the fact that only experienced inspectors are able to assign proper evaluation compared to an inexperienced inspector. This is to say that inspection results based on visual inspections are subject to uncertainties. The subjective rating method also requires inspection to every bridge, this is time and labor consuming.

However, it is obvious that subjective and analytical ratings both are needed in bridge condition assessment. One effective method to use the available rating results in estimating the condition of a bridge is through statistical analysis of data. Such analysis may include simple correlation analysis or more advanced techniques such as fuzzy logic and ANN methods.

There has been a growing interest in neural network computing technique in civil engineering in recent years for its capabilities in learning and generalizing from given examples, to produce a meaningful solution to problems even when input data contain errors and may be incomplete (Flood et al, 1994). The method can adapt solution overtime to compensate for changing situation (Shi, 2000).

Neural network will be the method of choice in this research to establish the relation between the bridge condition and subjective rating. An attempt to correlate the rating (in railway bridges) using conventional least square analysis and fuzzy logic resulted no specific relation between these two bridge assessment methods (Chen, 1991). Cattan and Mohammadi (1997) established the relationship between bridge parameters and Cooper rating with subjective rating for railroad bridge through a series of logical steps in neural network. The research results show that neural network has the capability in establishing the unknown relationships between a set of input and output values.

1.2 Problem Statement

Conventional methods in assessing the bridge condition are time and labor consuming. Both methods also have their own weakness in assessing the bridge condition. Attempts to utilize conventional least-squares analysis and fuzzy logic to establish relation between condition assessment and bridge parameter resulted unsuccessful to provide a solution for the problem mentioned. The technique based on an artificial neural network (ANN) is utilized to predict the subjective rating using analytical rating and bridge parameter data as the input data. If the ANN is successful to predict the subjective rating, then fewer inspections are needed because an overall estimate of a bridge condition can readily be made just through analytical determination. This can provide cost-effective method for screening those bridges, which are critical and need to be prioritized for inspection. Furthermore, when the rating can be predicted using ANN, approximation of maintenance cost also can be done.

1.3 Objectives

The objectives of this research are:

a) To predict the bridge deck condition rating using ANN
b) To evaluate the ANN performance in the assessment of bridge condition
c) To proposed improvement in ANN modelling for bridge condition assessment.

1.3.1 Scope of work/study

The study consist of two parts:

a) Designing the best ANN topology to predict the deck condition rating. ANN using Vanilla Backpropagation Algorithm will be utilized to train the network. The process also will involve the trial and error process to find out the suitable combination of input variables available in the data set to predict the deck condition rating. The data is obtained from California Department of Transportation (CALTRAN).

b) Two methods applied to improve the ANN prediction performance. Uniform distribution method will be applied to improve the distribution of the original data. Generalized delta rule algorithm will be used to speed up the training process to enhance the ANN performance. An attempt to apply the local data provided by Public Work Department of Johor will be conducted.

1.4 Thesis Organization

The thesis contains a total of 7 chapters and 2 appendices. In Chapter 2 a brief discussion of existing research and publications on artificial neural network in civil engineering is presented. In this chapter, the literature on bridge assessment is also discussed. Chapter 3 includes a discussion of the overview and review of the methodology used in application of artificial neural networks and bridge condition rating as recommended by transportation agencies. Chapter 4 explains the basic theoretical background for bridge assessment and neural network.

In Chapter 5, backpropagation artificial neural network is used to achieve the objective of the thesis work. In Chapter 6 attempts to improve the neural network performance are applied. The conclusions of the study and recommendations for future development are given in Chapter 7.