PREDICTION OF CASUALTIES AND DAMAGES OF INFRASTRUCTURE CAUSED BY CYCLONE USING NEURAL NETWORK.

BY

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A Project Thesis Submitted to the Department of Civil Engineering of Bangladesh University of Engineering and Technology, Dhaka in Partial Fulfillment of the Requirements for the Degree of

Masters of Engineering in Civil Engineering

July, 1998

DECLARATION

I hereby declare that the research reported in this project thesis was performed by me as a research project in partial fulfillment of the requirements for the degree of Master of Engineering in Civil Engineering from Bangladesh University of Engineering and Technology (BUET).

This thesis contains no material which has been accepted for the award of any other degree or diploma from any other institution. Further, to the best of my knowledge and belief, the thesis contains no material previously published or written by any other person, except when due reference is made in the text of the thesis.

July, 1998

(Lipika Khan)

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ABSTRACT

Natural disaster, especially cyclone, is a perennial problem for Bangladesh. Every year cyclones cause colossal damage to the people and economy of the country. With the increase of environmental degradation, it is expected to increase in the future. These natural disasters can not be prevented from occurring. Rather, with proper warning and precautionary measures, the casualties and damages caused by the cyclones can be reduced greatly.

Information about path and strength of the cyclone can be obtained from meteorological departments. Using this information, the casualties and damages caused by cyclone can be assessed through forecasting models. By assessing the damages, the relief and rehabilitation measures can be planned judiciously. In this study several models have been developed to forecast the damages caused by cyclones. 'Neural Network' technique has been found to be most applicable in this case. Data has been collected from various sources such as CARE Bangladesh Ltd., Cyclone Preparedness Program of Bangladesh Red Crescent Society and Bangladesh Bureau of Statistics. The variables considered in the modelling are wind speed of cyclone, height of water surge, distance from the path of cyclone, population, amount of livestock, numbers of permanent and temporary houses and length of paved and unpaved roads. Back-propagation technique has been used for calibration purpose.

The modelling approach has been found to be very successful. The model predictions are highly convergent with the observed results. It has been observed that the height of water surge has the most detrimental effect on the casualties. The neural network technique has been extended further to analyze the effect of noise in data using 'Monte-Carlo Simulation'. It is observed that the prediction remains fairly consistent for noise upto twenty percent above which the predictions become quite inconsistent.

The models developed in this study has a wide range of applications in disaster management planning, infrastructure planning and, relief and rehabilitation planning. The approach can be extended further to include other variables related to cyclone.

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CHAPTER - 1

INTRODUCTION

1.1 GENERAL

Cyclone and storm surges often hit the off-shore islands and the coastal areas of Bangladesh causing great economic losses to the country in general and immense sufferings to the local people in particular. It is predicted that both the intensity and the frequency of occurrence of such menace will increase over the years to come due to degradation of the environment and global warming because of greenhouse effect. Also statistical analysis show that in every thirty years a decade comes with high frequency of such cyclones. Such a decade occurred in 1960's with disastrous cyclones in 1961, 1963, 1965 and 1970. In this connection, the next decade beginning from 2001 is going to a very painful one.

The cyclone which hit the coastal areas of Bangladesh on the night between 29 and 30 April, 1991, is one of the most devastating natural disasters in living memory. Wind speeds upto 225 km/h, accompanied with storm surges, leading to water depths upto 6.1m over land, affected large areas in 89 upazilas of southern Bangladesh. A total of about 150,000 people are reported to have lost their lives. The cyclone and storm surge produced colossal damage to livestock, agriculture, power system, telecommunications, housing and other physical infrastructure facilities.

The intensity of damage was maximum at Sandwip in Chittagong, Cox's Bazar, Noakhali and Bhola. The estimated damage is around Tk. 3634 million. Storm surge was responsible for most of the damages.

Storm surge rolled sea water of over 1.5m depth up to a distance of 5 km inland from the coast line. The depth of water on land was not usually more than 4m on the coast line which diminished to a tolerable limit of 1.5m depth at a distance of 5 km inland, the rate of fall of height was about half a meter per km travel. The tidal inundation has lasted for 2 to 4 hours before the sea started receding.

The depth of inundation of Chittagong Airport was 2.5m while this was 1.5m in Patenga industrial belt including Export Processing Zone.

Some data on cyclones between 1822 and 1995 are shown in Table 1.1. It presents the data of the cyclones in a monthwise calendar year. The figure shows that the months of May and October are the most cyclone prone months in a year although cyclones have occurred from March through June and from September through December. Most of the devastated cyclones (50%) have hit the coastal areas of Chittagong, Teknaf and Cox's Bazar.

Disasters caused by nature cannot be stopped, but appropriate precautions and preventive measures can surely reduce the degree of losses and sufferings to a great extent. These measures can be taken if the casualties can be assessed beforehand. To predict the casualties forecasting models can be used.

1.2 BACKGROUND OF THE STUDY

Cyclones cause wide spread damage. It is not possible for a country like Bangladesh to escape from cyclone. Also it is not possible to construct buildings and other structures to be capable of withstanding cyclones of any strength for all the people. It is feasible to build only few structures (like cyclone shelters) in which people can be sheltered whenever required. But to provide the affected people with proper and adequate relief, medical services and rehabilitation facilities must be maintained. But it is not feasible to keep all these facilities at all the shelter all the time. To reduce the damages and casualties to a minimum in a economically feasible way, the relief materials and services should be sent to the affected areas whenever required. This must be done before the disaster hits area because after the disaster the affected areas may become inaccessible. For this purpose it is required to assess the damages about 24 hours before the cyclone hits.

In this way appropriate forecasting of damage caused by disasters may save human lives and reduce financial losses. A study on the damages caused by cyclones was done by "CARE/UNDP/CPP" for relief and rehabilitation purpose, in Bangladesh (CPP,1996). In that study, the damage prone areas have been identified. But the study did not attempt to analyze the relationship among the characteristics of the disaster (location, wind speed, height of water surge etc.), socio-economic and infra-structural characteristics of the areas, and the damages caused by the disasters. So, it is not possible to predict the amount of relief and rehabilitation works required for each area separately. Also, it does not consider the accessibility condition which is a very important parameter. This information is required to take necessary precautionary measures.

The technique used in the study is qualitative which may not be applicable if the socio-economic variables and the characteristics of the cyclone changes. In this regard, quantitative analysis using forecasting techniques and predictive models are required.

1.3 POTENTIAL OF THE SYSTEM

For a natural disaster like cyclone or tornado, it is not possible to prevent these from occurring by building infrastructures or by taking any other structural measures. It is also infeasible to build infrastructures which can withstand these natural disasters of high magnitude. Rather, it is better to build infrastructures capable of coping with the disasters upto moderate magnitude and in the case of disasters of high magnitude to take erasive action by providing shelters at strongly built cyclone shelters and reducing damages through improved relief and rehabilitation actions. Quick and prompt actions in this case may be economically more justified. To provide quick and prompt relief and rehabilitation, it is essential to assess the damages caused by natural disasters beforehand. For this purpose, it is required to forecast the damages caused by a specific cyclone. Using the information about the path and magnitude of a cyclone and models to forecast the damages, the number of casualties and amount of relief and rehabilitation works can be assessed. The information about the path and magnitude of a cyclone can be obtained from meteorological organizations (such as Bangladesh Meteorological Department, SPARSO etc.). Models to forecast the damages can be developed on the basis of data of previous cyclones. Using the expert system, proper arrangements and precautionary measures can be undertaken at every locations according to the requirement.

The need for these kind of expert systems may increase in the next decade. Although the country is hit by major cyclones frequently, historical data shows that a decade with high intensity of major cyclones hits the zone of Bay of Bengal with an interval of 30 years. The decade starting from 1960 to 1970 had been one such decade. It is expected that the next decade (i.e. from 2001 to 2010) will be another. Using the this kind of expert system damages can be reduced and many lives can be saved.

1.4 OBJECTIVES OF THE STUDY

The main objective of the research work is to develop a forecasting system to predict the damages caused by cyclones. In addition to the effect of the disasters on the human lives and their assets, its effect on accessibility situation is to be analyzed.

The uncertain nature of the input parameters must be included in the analysis to provide a useful tool for disaster management.

The specific objectives of the study are thus :

a) To examine characteristics of the damages caused by cyclone, i.e., the amount and types of casualties caused by cyclone and their relationships with the parameters of cyclone such as wind speed, height of water surge and distance from the center etc.

b) To examine the amount of damages caused by cyclone in relation to infrastructure facilities especially accessibility.

c) To develop a model to predict the damages caused by cyclone using Neural Network method.

1.5 ORGANIZATION OF THE THESIS

The remaining of the thesis has been organized into seven chapters.

Chapter 2 deals with relevant literature. It illustrates various disaster related studies done in Bangladesh and abroad.

Chapter 3 deals with study design and methodology of the prediction of casualties and damages caused by Cyclone using Neural Network.

Chapter 4 gives information on the collection of data, i.e. information casualties caused by Cyclone disasters and socio-economic variables.

Chapter 5 deals with computer modeling, calibration, validation etc.

Chapter 6 deals with model application and its result.

Chapter 7 contains the conclusions on the findings and recommendations for improvement, applications of model and directions for future studies.

1.6 SUMMARY

This chapter provided an introduction to the work presented in this thesis. Cyclone is a perennial problem for Bangladesh and cause enormous damages to human lives and economy of the country. These can be reduced if the damages can be assessed earlier and corresponding precautionary measures are taken. The assessment can be made through the development of forecasting models which is the principal objective of the research work presented in this thesis. In the following chapters the modeling techniques, data collection and analyzing methodologies and the results will be presented.

TABLE 1.1 : DETAILS OF MAJOR CYCLONE FROM 1822 TO 1995

Year	Month	Maximum wind speed mph	Storm wave in feet	Description of damage
1822	May	—	—	Many records swept away. 40,000 people killed, and 10,000 cattle lost.
1876	October	—	10-45	Dakhin Sahbajpur and some thanas of Patuakhali submerged to a depth of 10-45 ft. Inundation along Chittagong coast 3-6 miles in land. Hatiya lost more than half and Sandwip half of its population.
1897	October	—	—	Series of storm waves swept over islands of Kutubdia and villages on mainland near coast. Dikes along the sea were washed away. 14,000 people killed and 18,000 died subsequently in epidemic.
1961	May 9	92	—	Rail track between Noakhali and Harinarayanpur torn off. In Barisal BM college Hostel, Biology Lab and Gymnasium destroyed. Heavy loss of life in Char Alexander. 11,468 people died in cyclone.

1963	May 28-29	125	8-12	Chittagong, Noakhali and offshore islands badly affected. Inundation by storm wave along coast up to 30 miles north of Chittagong and neighboring offshore islands, death toll 11,520. Inundation of Patenga lower than October 31, 1960.
1965	May 11	100	12	Loss of life 19,279.
1966	October 1	90	20-22	Inundation of Chittagong town higher than October, 1960 cyclone. Area affected 2,727 sq.miles. loss of life 850.
1970	November 12-13	138	33	Entire belt from Khulna to Chittagong and offshore islands experienced hurricane winds for about 9 hours accompanied by storm surge of moderate to severe intensity to the order of 10-30 feet high. Patenga meteorological anemograph broke after recording a wind speed of 90 mph. A naval ship at Chittagong recorded 138 mph at peak of the storm. 200,000 people died. Many cattle and other animals killed.

1985	May 25	154	14	Chittagong, Noakhali, Bhola and offshore islands badly affected. Inundation by storm wave along 25 thanas of Sandwip and maximum affected in Urirchar. Loss of life 4,264.
1988	November 29	200	8-12	Khulna and mainly Sundarban offshore was badly affected. Cyclone intensity and its damages were more than 1970 cyclone. But its direction was diverted to the Sundarban so loss was minimum.
1991	April 29-30	225	20	Chittagong, Cox's bazar, Noakhali and Bhola were widely affected. Nineteen districts, 102 thanas and 9 unions were affected. Many structures and crops was destroyed. Loss of cattle 1061029 and loss of life 140107.
1995	May 15-16	60-70	7-8	Chittagong, Cox's bazar and Mongla Port were widely affected. Many crops, structures and people were affected. Loss of cattle 9103 and loss of life 23.

CHAPTER - 2

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter discusses about the various case studies of disaster and suitable method which would be applied for the analysis of disaster. In Bangladesh many organizations study about the cyclone disaster in different ways and for different purposes. These are discussed in this chapter thoroughly. This chapter also describes the study of various natural disasters in other countries. Different methods which may be used for the analysis of disaster and the comparison of neural network method with the these methods are discussed in this chapter. The application of neural network method in Bangladesh and abroad are also discussed in this chapter.

2.2 STUDIES REGARDING DAMAGES CAUSED BY CYCLONE IN BANGLADESH

Studies on cyclone disaster have been done by many organizations. The journal of Noami published a paper on *cyclone and storm surges in the coastal area of Bangladesh*. In this paper, Khalil and Monowar (1996) discussed about cyclone in the whole coastal belt of Bangladesh for the period of 1797 to 1995. They suggest some mitigating measures to avoid hazards or to reduce the impact. The mitigating measures suggested include coastal embankments, coastal afforestation, cyclone shelters and cyclone warning system.

CARE, Bangladesh has performed a study for identifying damage prone areas along coastal belt of Bangladesh in the case of cyclone (Cyclone Report 1991). CARE's role starts when a depression is formed in the Bay of Bengal. They have many field officers in districts, thanas and also in union level, who are working 24 hours to observe the cyclone characteristics and to inform the conditions in the head office in Dhaka by telephone or fax at one hour interval. After the cyclone hits, they survey the disaster zone and estimate the amount of disaster separately in zonewise and itemize form and inform the head office accordingly. In the head office, they assess the disaster and estimate the quantity of relief required. With full preparation of relief, they standby to distribute these relief and also to do rehabilitation work. But they can not start their work until they receive the order of Government. CARE performed their relief works in 1970 and 1991 cyclone and also others major floods. The study performed by CARE under the auspices of UNDP, was designed to expedite the relief work. The study is highly qualitative and can not assess the relief and rehabilitation requirement in relation to the condition of the infrastructures and strength of the cyclone.

Chowdhury (1996) describes the disaster of the countries which are vulnerable to natural hazards. It is also found that most victims of floods, cyclones, earthquakes that ravaged Asia and Africa are the poor of the developing world which are most vulnerable to natural disasters. According to an estimate of the Munich

Reinsurance (World's leading insurance company), in 1995 developing nations took the burnt of 30 out of the 50 worst natural disasters recorded worldwide and many of the victims were the poorest people in poor countries. Human Development Report (1995), maintains that disasters in developing countries are an integral part of their poverty cycle. Poverty causes disasters and disasters exacerbate poverty. According to FAO Report (1995), the Asia - Pacific region has become the most disaster - prone region in the world due to environmental degradation and a rapidly rising population. This paper mainly deals with the case of Bangladesh, which is very prone to natural disasters like floods, cyclones, storms surges, river erosion, etc.

Sirkin, A. (1995) published a paper on Hurricane Andrew which is the first major hurricane to attack south Florida. In this paper author describes the situation of cyclone and the damages and the casualties. Author also describes the critical position of the affected area after hitting the cyclone. He has been found that no plan was in place to provide a quick response for the victims. Workers and equipment needed to be repositioned and brought in from long distance. Hurricane - resistive building codes were found to be inadequate. Essential electrical power networks were lost. manufactured homes were devastated. He also suggests the preventive measures for future hurricane.

2.3 STUDIES RELATED TO PREDICTION OF DAMAGES CAUSED BY NATURAL DISASTER

Song et al. (1996) presents a study on damages caused by earthquake which have caused wide spread damage to newly developed urban areas. The patterns of the influences of earthquakes on citizens and society have been changing rapidly in Japan. In this purpose a comprehensive evaluation method on earthquake damage was developed by using fuzzy sets theory. In this study a comparison was made between the observed data and the evaluation results of damage during past earthquakes. For the damage of various buildings and structures from different distances to damage centers during the past nine(9) earthquakes in Japan, a comprehensive evaluation is made and the results are given as damage memberships. Further more, the 28 kinds of damage degrees of buildings and structures from different distances to damage centers are given in quantitative values. Also, damage grade classification is made based on this results.

After 1991 cyclone several studies were done to assess the damages. In one study (Cyclone damage 1991) the Consultants found that there was significant damage to the facilities of the health and education facilities, particularly to the basic kutcha construction buildings which were invariably demolished, the semi pucca (brick with corrugated iron roof) buildings suffered roof damages and pucca (full brick/concrete) construction were least affected. Damages to Bangladesh Railway and rolling stock was slight although there was significant damage to staff accommodation which was generally of lower standard of construction. Damages to road work and municipal services varied with the distance away from the coast line, however damages to bridges and culverts was uniform across the affected area due to heavy flows in waterways. There was widespread damage to the power generating and distribution system throughout the affected area.

Another study on relief and rehabilitation in the affected area (Operation Sheba, 1991) assessed the amount of relief and rehabilitation required for cyclone affected areas. The study also emphasized on the mobilization of all resources and services of all the agencies and departments (Armed Forces, Police, BDR, NGO's and Civil Bureau Cracy) to ensure smooth, effective and uninterrupted relief operation. The study also outlined the procedure emergency relief and rehabilitation phases in the case of future cyclones.

The study on cyclone protection measures (Cyclone Protection Project-II) also emphasized on the relief and rehabilitation measures. The study concluded that safe and endurable accessibility is required to allow people to escape from exposed areas before the cyclone hits and to provide the rescue teams with safest means of communication. It stated that as a part of early, the infrastructure should be planned beforehand so that local people know which route they follow to reach a safer place. Medical assistance, food, provisional shelters etc. can be dispatched rapidly on the roads to the hit areas and in particular to the existing cyclone shelters through roadways.

After cyclone of 1991, the Institute of Engineers, Bangladesh decided to form a Task Force to investigate causes of colossal damage, particularly from the engineering point of view and to suggest measures for mitigation of such damages in future cyclones. In this paper (IEB Report 1991) the Task Force decided to carry out investigations related to those tropics, such as, coastal embankments and related structures, bridges, culverts, roads, cyclone shelters, industry and environment, telecommunications, power systems, housing and building, water supply and sanitation, natural disaster management, ports and navigation, energy. In this paper they describe the amount of damages of the above tropics widely and find out the lack of the preventive measures for mitigation. They also given the technical suggestion for future cyclones.

Although these studies assessed the damages quite comprehensively, there was no scientific study relating the strength of the cyclone with the casualties. This kind of studies may help in the planning of relief and rehabilitation in the case of future cyclones.

2.4 OVERVIEW OF THE METHODS OF ANALYZING DAMAGES CAUSED BY NATURAL DISASTER

Several techniques are available for the prediction of damages caused by cyclone and other similar disasters. Among them the following are usually used.

I) Empirical Model

II) Mathematical Model

III) Simulation Model

IV) Neural Network Model

(I) Empirical Models : Among the approaches mentioned above 'Empirical Models' are the simplest and easiest. In this model the dependent variable explained by more independent (explanatory) variables. The selection of the variables and the functional form is arbitrary. Usually these are selected using experience in the study area. This kind of model is extensively used in economics, marketing research and social science. Because of arbitrary nature, mentioned above, this type of model suffer from specification error both in functional form and variable identification.

(II) Mathematical Model : This is an improved version of 'Empirical Models'. Here the dependent variable is related to the independent (explanatory) variables using theories and experimental results of the interaction among them. In this type of model, the functional relationship is derived from theory and validated by experimental results. These models are extensively used in Physical science and Engineering studies. The major problem in the application of this model is lack of theoretical knowledge. These models are as good as the theories are. For the problems where no such theories exist, this kind of models can not be developed.

(III) Simulation Model : Simulation models are in fact the smaller prototypes of the real world phenomena. In the simulation models, the actual situation is tried to be reconstructed in a controlled and much smaller scale. Using these models, the behaviour and effects of different variables can be studied and analyzed. They are widely used in engineering studies.

Simulation models can be classified into two groups, Physical simulation model and Computer simulation model. In the first type, physical prototype of smaller dimension is made. In the other type, the system is represented in computer by using relationships among different objects and sub-models.

(IV) Neural Network Models : A neural network model is an input output model represented by nodes and branches. Given an input vector (X_1, X_2---X_n), the network produces an output vector O. The relationship is determined by the network architecture. The 'knowledge' that the network going by training (calibration) is stored in the form of weights of the connection between nodes. Neural networks represent a class of nonlinear regression models. The basic difference between conventional regression model and neural network is that the later eliminates function specification error. Empirical study claim that the major characteristics of neural network are, self-learning, self-transformation, generalization and abstraction. Neural networks are well suited to problems in pattern recognition, classification, non-linear feature detection, non-linear forecasting.

For analyzing the damages caused by cyclone, there does not exist any theory for functional relationships and variable inclusion. In the case of simulation model, objects are to be defined at the micro-level and the mode of interaction among the objects must be exogenously provided. But, in the case of forecasting damages caused by cyclone, all the objects can not be defined at micro-level because of data limitation. Also, enough information is not available to develop theories or models of interactions among the objects.

Neural network model can overcome these problems because it does not need any pre-defined functional relationship. Also, the neural network model can deal with macro (aggregate) data which is available from secondary sources. It can handle variable identification problem endogenously. Considering all these, the neural network model can be selected as the analyzing technique for forecasting damages caused by cyclones.

2.5 SUMMARY

This chapter discussed about studies related to casualties caused by natural disasters both in Bangladesh and abroad. Most of these studies were in fact post-evaluation type. None of these studies were predictive type. This chapter also presented an overview of the techniques available for predictive model development. Among these techniques, Neural Network method seemed most appropriate for the prediction of damages caused by natural disasters. In the following chapter, the mathematical techniques for the development of neural network and analysis for its implementation will be presented.

CHAPTER 3

STUDY DESIGN AND METHODOLOGY

3.1 INTRODUCTION

This chapter describes in detail, the method of neural network. The overview of neural network method, its structure and configuration are discussed thoroughly in this chapter. Due to convenience of study the method of back-propagation of neural network calibration technique is presented here. The details of back-propagation methods including its the mathematical structure will be discussed here.

3.2 OVERVIEW OF NEURAL NETWORK (NN) METHOD

Neural Networks (NN) have received considerable interest during last few years largely due to their wide ranging of applications and ease with which they can handle problems involving imprecise, noisy and highly complex non linear data. The major advantage of most of neural network approaches over traditional curve fitting techniques is their learning and predicting capabilities with astounding accuracy. The traditional means of analyzing data needs the development of linear, non linear an multivariable regression models where as the neural nets have capacity to learn complex multiple input - multiple output relationships with ease and derive its own correlative patterns based on the data presented to the network.

Once the network has learned the pattern, it can predict the targeted outputs using the known inputs and its internal algorithms. Furthermore, the investigator does not have to decide which factors may be important in the model. The network itself will learn which inputs are important and which have no weight in the prediction of output. Once the neural net is generated, it can be used to make predictions for new input conditions. Figure 3.1 presents the taxonomy of neural network technique.

DECODING

ENCODING	FEEDFORWARD	FEEDBACK
SUPERVISED	**GRADIENT DESCENT** LMS BACKPROPAGATION REINFORCEMENT LEARNING	RECURRENT BACKPROPAGATION
UNSUPERVISED	**VECTOR QUANTIZATION** SELF - ORGANIZING MAPS COMPETITIVE LEARNING COUNTER - PROPAGATION	**RABAM** BROWNIAN ANNEALING BOLTZMANN LEARNING AB AM ART - 2 BAM = COHEN - GROSSBERG MODEL HOPFIELD CIRCUIT BRAIN - STATE - IN - A - BOX MASKING FIELD **ADAPTIVE RESONANCE** ART - 1 ART - 2

NEURAL NETWORK TAXONOMY

FIGURE 3.1 Neural - network models classified by how they encode or learn pattern information in their synaptic topologies, and by the cyclic or acyclic structure of the synaptic topology they use to decode or recall information.

3.3 THEORY AND STRUCTURE OF NEURAL NETWORK AND BACK - PROPAGATION

The structure of NN's forms the basis for information storage and governs the nets learning process. It is composed of a large number of single interconnected nonlinear computing elements or neurons, input nodes and output nodes connected by branches having adjustable weights. The computing elements may optionally have bias inputs. These NN's are built much like the human brain, where the computing element is similar to a human nucleus that acts as a central reaction unit and the inputs with different connection weights are analogous to dendrites with different bio-activities.

The flow of information is passed through the complete network by linear connection and linear or nonlinear transformations. A learning rule is to train the given data through adjustments of connecting weights by applying suitable algorithm. The optimal weighting factors are determined by training the neural net by back propagation algorithm. In general, neural nets are categorized, as supervised learning and unsupervised learning. Supervised learning means that the network has some information present during learning to tell what target answer it should meet with. Where as unsupervised neural nets operate analogously by learning with little or no information about the correct answer for an input information. The back propagation algorithm mainly comprises the two phases i.e. training phase & prediction phase of operation involving the minimization of the mean square error between the actual output of a multilayer feed forward perception and desired output.

Back-propagation technique is used for the calibration of the model. Sigmoidal function is used as transfer function of the nodes in the hidden and output layer. The inputs are normalized before being applied to the model. The weights are updated using the following procedure.

$$W^c_{ij} = W^c_{ij} + \alpha.\ \delta E/\delta E^c_{ij} \tag{3.1}$$

$$E = 1/2.(\text{observed}_i - S_i^{\ c+1})^2 \tag{3.2}$$

Where, W is the weight, E is the error, S is the output of a node and α is a parameter.

Considering the vagueness, complexity and indefiniteness of data and information in this kind of analysis, the concept of fuzzy mathematics is incorporated in the model.

Neural Networks consist of several elements :

a) The neuron, which is the heart of the network : this is a processing unit which is linked to its neighbours and which outputs a signal on the basis of the impulses which it receives.

b) The topology of the network : this is the way in which the neurons are interconnected - they may be completely or partially interconnected.

c) Network modification : this refers to the way in which the links between neurons or the connection weights are modified.

d) The connection weight : is a weighting which is applied to the link between two neurons.

e) The transfer function : expresses the output of a neuron according to the impulses it receives.

If i is the index of a neuron, e_i designates the weighted sum of the pulses it receives :

$$e_i = \sum_{j=1}^{n} W_{ij} \, . \, S_j$$

The output of neuron i is designated by S_i. This output depends on the impulses received by the neurons j which are weighted by the connections W_{ij}.

Most of the networks used in forecasting applications are organized in layers and are therefore known as layered networks, in Figure-3.2. Information transfer occurs by propagation from the input layer to the output layer. This means that the neurons in layer C receive data from the layer C-1 and transmit their pulses to the layer C+1. In terms of connections, this implies that layer C is connected only to layer C+1 and that there are no connections between the neurons in a particular layer.

The networks are calibrated by means of learning, which aims to determine the correct value for connections such that the response of a network to an input is as near as possible to the correct response. There are two modes of learning, supervised or unsupervised. In supervised learning, connections are updated from a cost function E when an input or a set of inputs are presented.

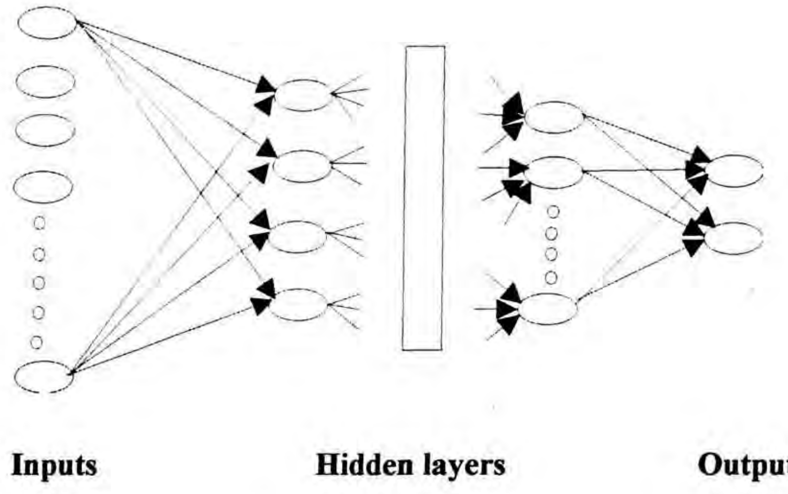

FIGURE 3.2(A Multilayer Network)

This type of learning is based on a penalty in the event of a large error and a reward when there is no error. In unsupervised learning the network is responsible for its own modification, and it is possible to talk of self-organization.

The first work on updating connections was performed using the delta rule, in which weightings were incremented from ΔW_{ij} ,

where $\Delta W_{ij} = \alpha.\ \delta_i.\ S_j = \alpha.\ (\text{observed}_i - S_i).\ S_j$.

There are several alternatives for generalization to multilayer networks. The most important are as follows :

___ stochastic gradient; this brings in random terms with regard to the transfer function or in the connection updating rule.

___ local gradient ; the connections are individually modified for each element in the learning set.

___ total gradient ; connections are updated after inputting all the cases in the learning set.

___ conjugate gradient ; updating is performed on the basis of the current gradient and that calculated for the preceding example in the learning set.

The potential of a neural network is assessed by means of a cost function which measures the disparity between the desired output and the real output (the error).

Back-propagation technique is used for the calibration of the model. Sigmoidal function is used as transfer function of the nodes in the hidden layer and output layer. The inputs are normalized before being applied to the model. The weights are updated using the following procedure.

$$W^{c}_{ij} = W^{c}_{ij} + \alpha.\ \delta E/\delta E^{c}_{ij} \quad (3.1)$$

$$E = 1/2.(\text{observed}_i - S_i^{\ c+1})^2 \quad (3.2)$$

Where, W is the weight, E is the error, S is the output of a node and α is a parameter.

Gradient backpropagation is computed differently depending on whether it is the weights on the last layer which are modified or the weights on the preceding layers. The term backpropagation is used because part of the error gradient for preceding layers is used when updating the connections in a layer.

For a neuron i which is in the last layer :

The cost function E consists of several functions (f, S, e). Thus the first step in order to express the gradient correctly is to expand $\delta E/\delta W^k_{ij}$ using e^{c+1}_i, which is an input computed with W^c_{ij}

$$\delta E / \delta W^c_{ij} = \delta E / \delta e^{c+1}_i . \delta e^{c+1}_i / \delta W^c_{ij} = \delta E / \delta e^{c+1}_i . \delta \sum_{l=1}^{nc+1} W^c_{il} . S^c_l / \delta W^c_{ij} \quad (3.3)$$

The expansion of (3.3) is expressed as follows :

$$\delta E / \delta W^c_{ij} = \delta E / \delta e^{c+1}_i . S^c_j \quad (3.4)$$

$\delta E / \delta e^{c+1}_i$ must be expanded once more as E is a function of S^{c+1}_i, which is itself derived from e^{c+1}_i.

$$\delta E / \delta e^{c+1}_i = \delta E / \delta S^{c+1}_i . \delta S^{c+1}_i / \delta e^{c+1}_i = (observed_i - S^{c+1}_i) . f(e^{c+1}_i) \quad (3.5)$$

Thus, finally, the updating rule for connections is :

$$W^c_{ij} = W^c_{ij} + \alpha . (observed_i - S^{c+1}_i) . f(e^{c+1}_i) . S^c_j$$

For a neuron i belonging to the other layers.

As in equation (3.3) the gradient $\delta E / \delta W^{c-1}_{ij}$ is expanded using the input e^c_i, computed from W^{c-1}_{ij}.

$$\delta E / \delta W^{c-1}_{ij} = \delta E / \delta e^c_i \,.\, \delta e^c_i / \delta W^{c-1}_{ij} = \delta E / \delta e^c_i \,.\, S^{c-1}_j \qquad (3.6)$$

The input e^c_i is used for the inputs to the higher layer, such that $\delta E / \delta e^c_i$ can be expressed using the gradients to the inputs $\delta E / \delta e^{c+1}_i$ which have already been computed by equation (3.5).

$$\delta E / \delta e^c_i = \sum_{l=1}^{nc+1} \delta E / \delta e^{c+1}_l \,.\, \delta e^{c+1}_l / \delta e^c_i \qquad (3.7)$$

The gradient $\delta e^{c+1}_i / \delta e^c_i$ is expanded using the output S^c_i in the calculation of e^{c+1}_i :

$$\delta e^{c+1}_l / \delta e^c_i = \delta e^{c+1}_l / \delta S^c_i \,.\, \delta S^c_i / \delta e^c_i = W^c_{li} \,.\, f(e^c_i) \qquad (3.8)$$

because $\delta e^{c+1}_l / \delta S^c_i = \delta \sum_{j=1}^{nc} W^c_{lj} \,.\, S^c_j / \delta S^c_i = W^c_{li}$

and $\delta S^c_i / \delta e^c_i = \delta f(e^c_i) / \delta e^c_i$

The gradient $\delta e^{c+1}_i / \delta e^c_i$ is applied to (3.7) :

$$\delta E / \delta e^c_i = \sum_{l=1}^{nc+1} \delta E / \delta e^{c+1}_l \,.\, W^c_{li} \,.\, f(e^c_i) \qquad (3.9)$$

Finally, the gradient $\delta E / \delta W^{c-1}_{ij}$ is expressed as follows :

$$\delta E / \delta W^{c-1}_{ij} = \sum_{l=1}^{nc+1} \left(\delta E / \delta e^{c+1}_l \,.\, W^c_{li} \right) \,.\, f(e^c_i) \,.\, S^{c-1}_j \qquad (3.10)$$

The updating rule for the connections of the neurons in other layers is therefore :

$$W^{c-1}_{ij} = W^{c-1}_{ij} + \alpha \, . \sum_{l=1}^{nc+1} \left(\delta E / \delta e^{c+1}_{l} \, . \, W^{c}_{li} \right) . \, f(e^{c}_{i}) \, . \, S^{c-1}_{j} \qquad (3.11)$$

The error formula is only expressed in the connections of the last but one layer. This means that it is possible to choose a specific cost function so as to maximize a particular criterion.

3.4 SUMMARY

This chapter described the method of neural network. The overall methodology of the neural network, its structure and back-propagation method had been explained in this chapter. The mathematical calculation of neural network had also been presented here. Using the methodology described in this chapter, the neural network model will be trained with a set of data of the casualties caused by cyclone. In the next chapters the data collection methods and its usage for calibrating neural network will be explained.

CHAPTER 4

DATA COLLECTION AND ANALYSIS

4.1 INTRODUCTION

This chapter discusses about the collection of various data on the casualties which caused by 1991 cyclone. Different data have been collected from different organizations. The types and characteristics of data, and analysis of data are also presented in this chapter.

4.2 BACKGROUND OF COLLECTION OF DATA

Cyclone disaster data have been collected mainly from CPP, i.e. Cyclone Preparedness Programme which is associated with BDRCS, i.e. Bangladesh Red Crescent Society. This CPP project was approved in 1973 by Bangladesh Government. Its study area contain the coastal belt from St. Martin in Teknaf to Patharghata in Barguna. .

After Cyclone, rehabilitation works are done by many organization. CARE is one of them. They study mainly on the amount of disaster for allocating rehabilitation works.

BMD i.e. Bangladesh Meteorological Department, observe the Cyclone position, movement or path, wind speed and date of Cyclone. This Department helps in supplying the accurate position and characteristics of Cyclone for forecasting.

As said earlier, the data on casualties are collected from CPP i.e. Cyclone Preparedness Programme. Data on casualties of human death, damaged livestock, damaged house and damaged roads are collected including some cyclone disaster photographs. They are highly cooperative to supply these materials for helping such type of study.

Two types of casualties i.e. wind speed and surge height are collected from BMD i.e. Bangladesh Meteorological Department They are also highly cooperative.

4.3 TYPES AND CHARACTERISTICS OF DATA

In 1991 cyclone, mainly 19 districts were affected very badly. But data were collected on disaster casualties only for 13 districts out of the 19 districts. Out of 13 district, 89 sets of data are collected for 89 thanas. Among this 89 thanas, 15 thanas belong to Chittagong, 7 thanas belong to Cox'sbazar, 6 thanas belong to Noakhali, 7 thanas belong to Bhola, 4 thanas belong to Lakshmipur, 5 thanas belong to Barguna, 5 thanas belong to Feni, 4 thanas belong to Jhalokhati, 6 thanas belong to Pirojpur, 3 thanas belong to Chandpur, 7 thanas belong to Bandarban, 10 thanas belong to Rangamati and 10 thanas belong to Barisal.

Data had been collected on the casualties of human being, livestock, houses and roads.

The data of wind speed have been collected from BMD (Bangladesh Meteorological Department). But these data of wind speed in district level. So that assumed the same wind speed in all thanas of a district where data are not available. From BMD also have been collected the data of the path of cyclone, from origin to first point of hitting land. The data of distances of each thanas have been calculated from the nearest point of the cyclone path.

Surge height are collected from cyclone shelter project (1992) and "Water Surge Model". From that model data of the surge height of water have been collected for all thanas. Existing data of population, houses, livestock and pavements would be collected from Bangladesh Census 1991 (BSS, 1991).

In Chittagong total loss of population was 78924, total damaged livestock was 111000, total fully damaged house was 327000, total partially damaged house was 204000, total damaged paved road was 180 km, total damaged unpaved road was 1023 km and average value of wind speed was 170 km/h, surge height was 6 m, distance was 24 km.

In Cox'sbazar total loss of population was 50013, total damaged livestock was 277114, total fully damaged house was 149297, total partially damaged house was 130706, total damaged paved road was 88 km, total damaged unpaved road was 74 km and average value of wind speed was 171 km/h, surge height was 9 m, distance was 84 km.

In Noakhali total loss of population was 8878, total damaged livestock was 6697, total fully damaged house was 173880, total partially damaged house was 160450, total damaged paved road was 10 km, total damaged unpaved road was 601 km and average value of wind speed was 150 km/h, surge height was 3 m, distance was 81 km.

In Bhola total loss of population was 221, total damaged livestock was 14593, total fully damaged house was 47218, total partially damaged house was 105001, total damaged paved road was 36 km, total damaged unpaved road was 292 km and average value of wind speed was 178 km/h, surge height was 4 m, distance was 84 km.

In Lakshmipur total loss of population was 10785, total damaged livestock was 556, total fully damaged house was 10785, total partially damaged house was 25665, total damaged paved road was 33 km, total damaged unpaved road was 210 km and average value of wind speed was 140 km/h, surge height was 4 m, distance was 112 km.

In Barguna total loss of population was 7, total damaged livestock was 2640, total fully damaged house was 10913, total partially damaged house was 44577, total damaged paved road was 16 km, total damaged unpaved road was 95 km and average value of wind speed was 195 km/h, surge height was 3m, distance was 116 km.

In Feni total loss of population was 5, total damaged livestock was 2233, total fully damaged house was 23602, total partially damaged house was 37173, total damaged paved road was 50 km, total damaged unpaved road was 563 km and average value of wind speed was 158 km/h, surge height was 3 m, distance was 77 km.

In Jhalokhathi total loss of population was 1, total damaged livestock was 2505, total fully damaged house was 4104, total partially damaged house was 14620, total damaged paved road was 25 km, total damaged unpaved road was 152 km and average value of wind speed was 150 km/h, surge height was 3 m, distance was 138 km.

In Pirojpur total loss of population was 1, total damaged livestock was 8, total fully damaged house was 417, total partially damaged house was 500, total damaged paved road was 29 km, total damaged unpaved road was 118 km and average value of wind speed was 148 km/h, surge height was 3 m, distance was 151 km.

In Chandpur total loss of population was 1, total damaged livestock was 165029, total fully damaged house was 532, total partially damaged house was 2063, total damaged paved road was 10 km, total damaged unpaved road was 73 km and average value of wind speed was 100 km/h, surge height was 2m, distance was 141 km.

In Bandarban total loss of population was 1, total damaged livestock was 1728, total fully damaged house was 13789, total partially damaged house was 20177, total damaged paved road was 32 km, total damaged unpaved road was 51 km and average value of wind speed was 160 km/h, surge height was 0 m, distance was 151 km.

In Rangamati total loss of population was 12, total damaged livestock was 389, total fully damaged house was 15998, total partially damaged house was 20197, total damaged paved road was 27 km, total damaged unpaved road was 68 km and average value of wind speed was 235 km/h, surge height was 0m, distance was 118 km.

In Barisal total loss of population was 0, total damaged livestock was 98, total fully damaged house was 1944, total partially damaged house was 10958, total damaged paved road was 33 km, total damaged unpaved road was 15 km and average value of wind speed was 160 km/h, surge height was 1 m, distance was 147 km.

Disaster data or casualties are plotted against the wind speed, distance and surge height separately for each type of casualties. But no linear or regular relationship had been obtained. Generally it seems that damage would be increased if wind speed and surge height increase and distance decrease. But these graphs do not give any concrete relationship and conclusion. All those graphs are shown in Figure 4.1a - 4.3f.

On the basis of this observation it can be concluded that conventional empirical or mathematical models can not be applied for forecasting of damages caused by cyclone and neural network technique is the only solution in this case.

4.4 SUMMARY

In this chapter the methods of collection of data and details of characteristics of data had been discussed. The relationships among the variables and their statistical properties have also been examined in this chapter. It is observed that the variables do not show any reasonable mathematical relationship among them. This implies that any mathematical relationship can not be developed in this case and emphasises on the use of 'Neural Network' type model to analyze this data. In the next chapter, this data set is applied to calibrate neural network models for forecasting damages caused by cyclones.

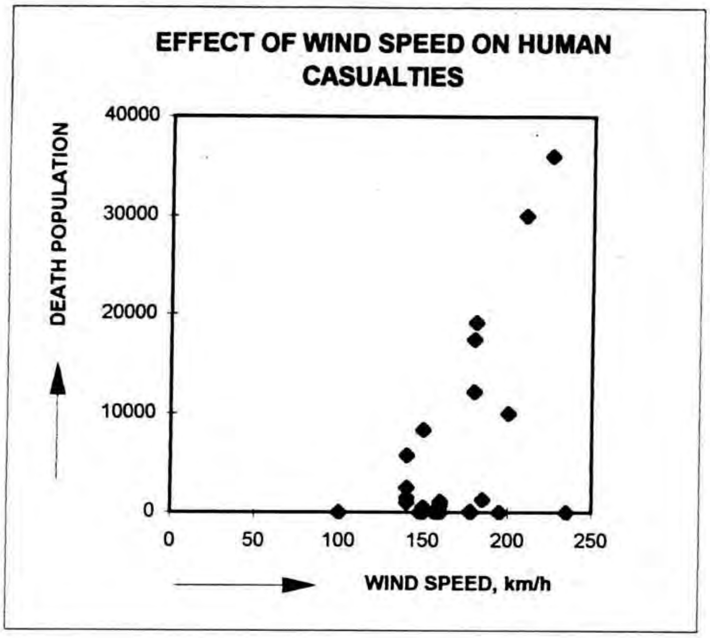

Figure 4.1a : Effect of Wind Speed on Human Casualties

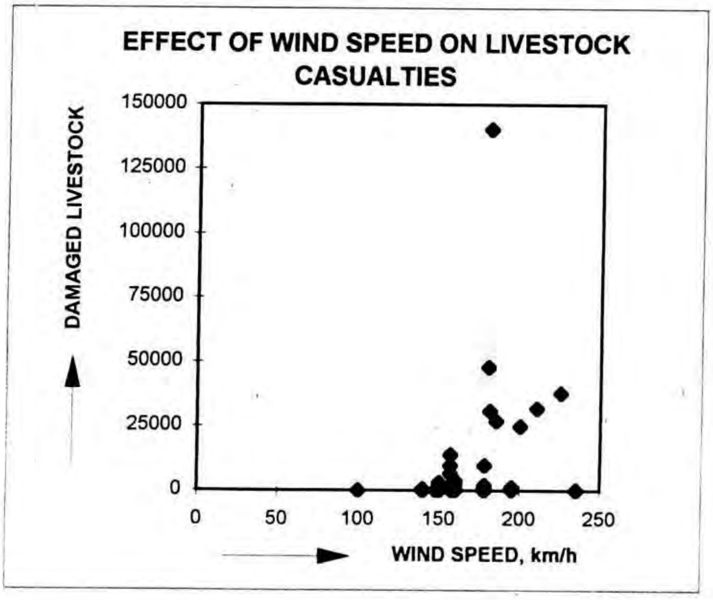

Figure 4.1b : Effect of Wind speed on Livestock Casualties

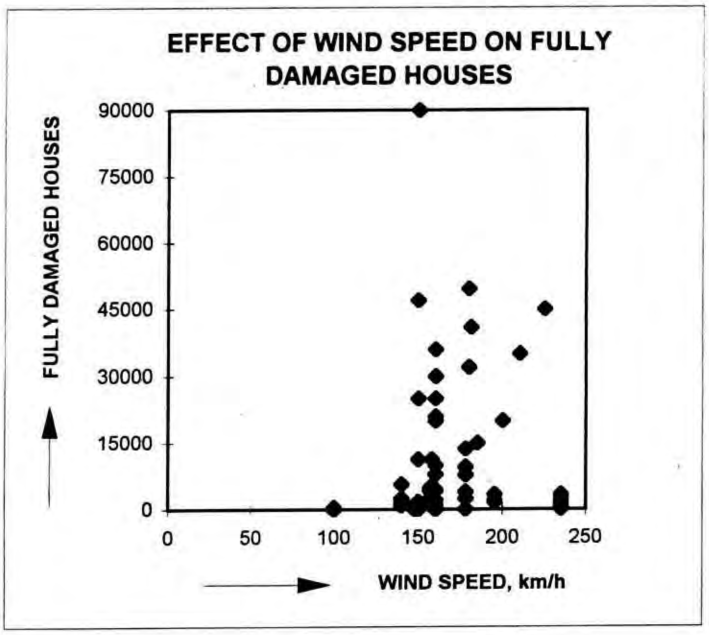

Figure 4.1c : Effect of Wind Speed on Fully Damaged Houses

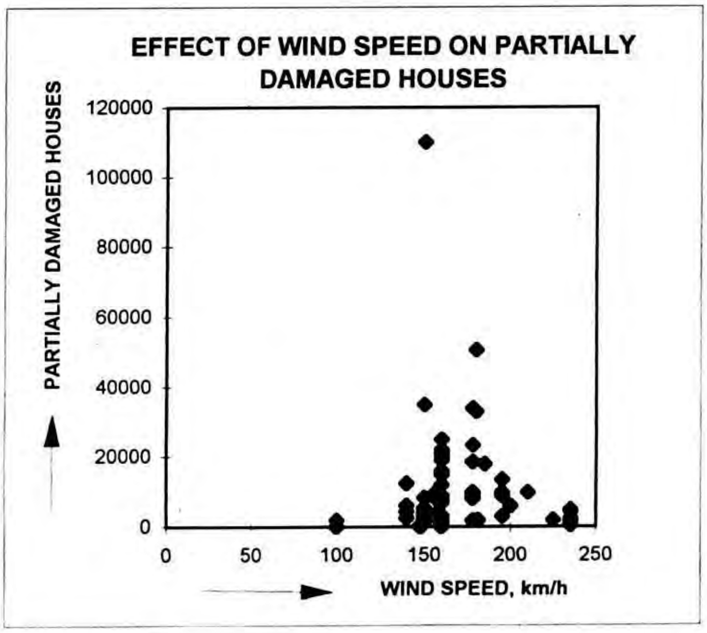

Figure 4.1d : Effect of Wind Speed on Partially Damaged Houses

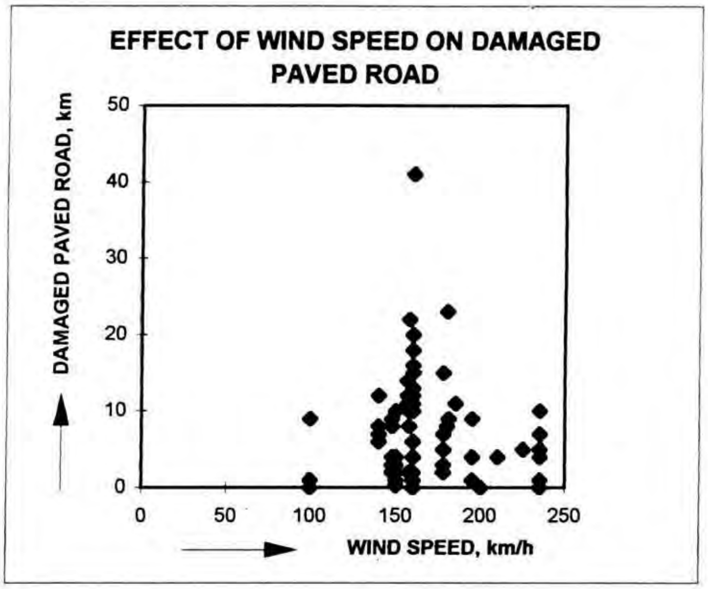

Figure 4.1e Effect of Wind speed on Damaged Paved Road

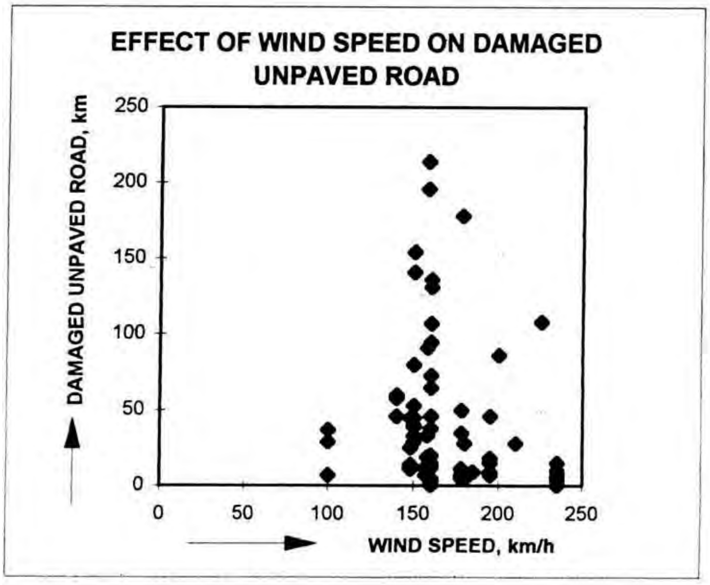

Figure 4.1f : Effect of Wind Speed on Damaged Unpaved Road

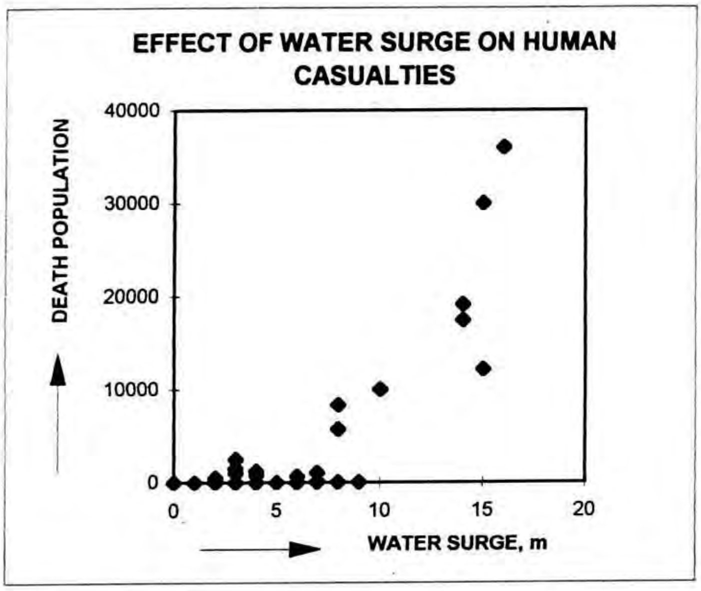

Figure 4.2a :Effect of Water Surge on Human Casualties

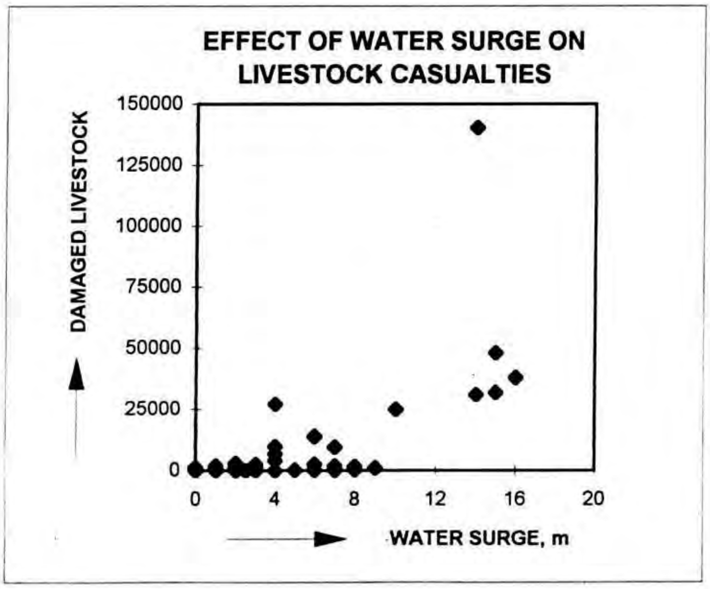

Figure 4.2b : Effect of Water Surge on Livestock Casualties

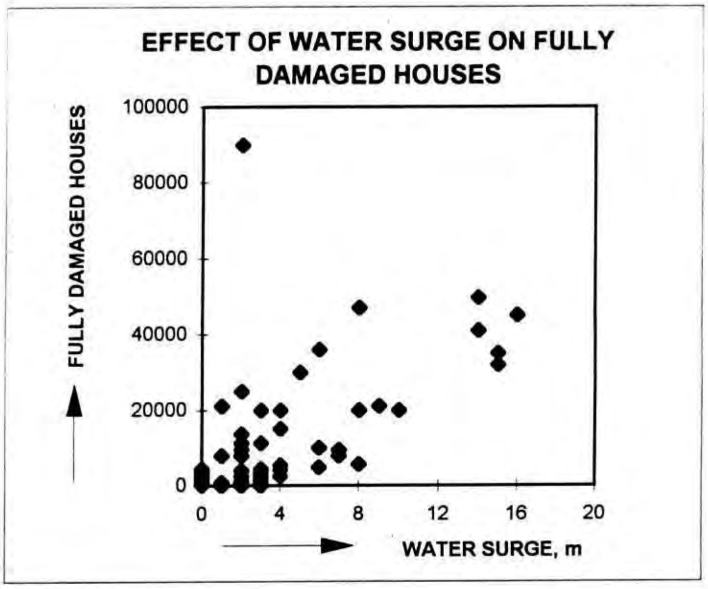

Figure 4.2c : Effect of Water Surge on Fully Damaged Houses

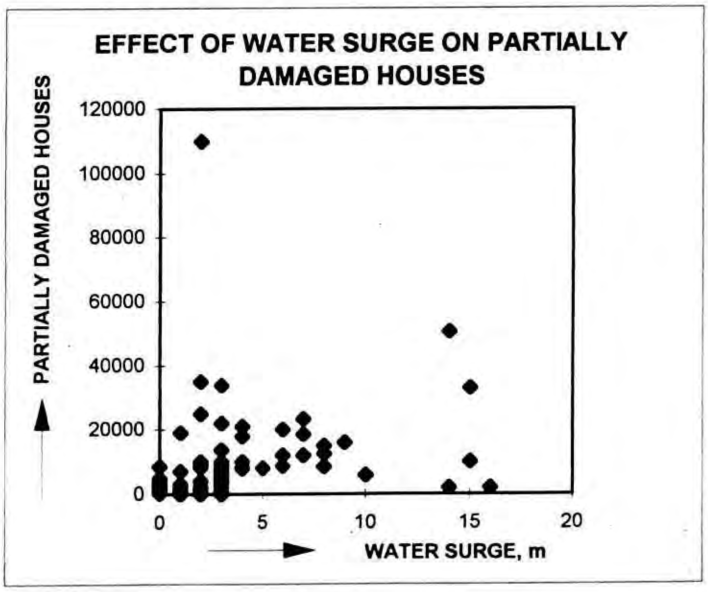

Figure 4.2d : Effect of Water Surge on Partially Damaged Houses

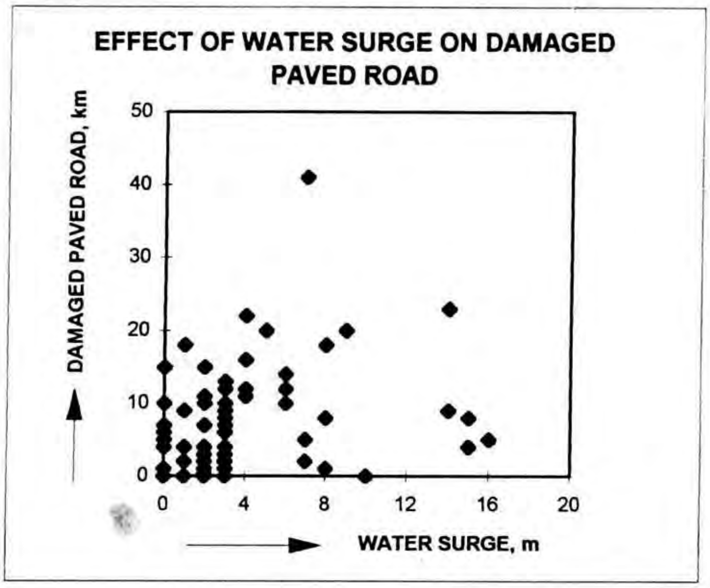

Figure 4.2e : Effect of Water Surge on Damaged Paved Road

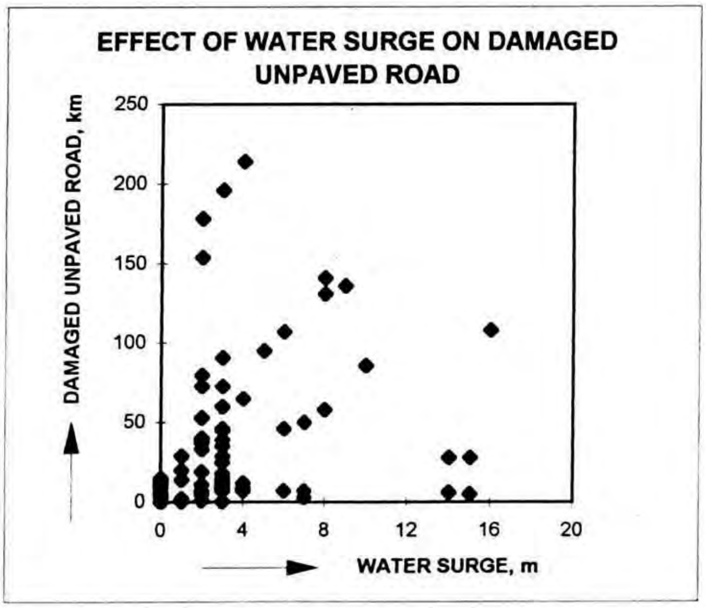

Figure 4.2f : Effect of Water Surge on Damaged Unpaved Road

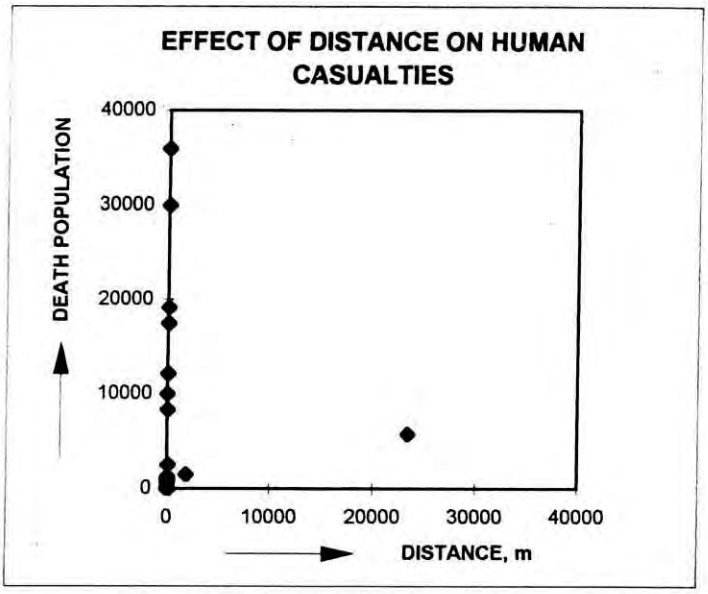

Figure 4.3a : Effect of Distance on Human Casualties

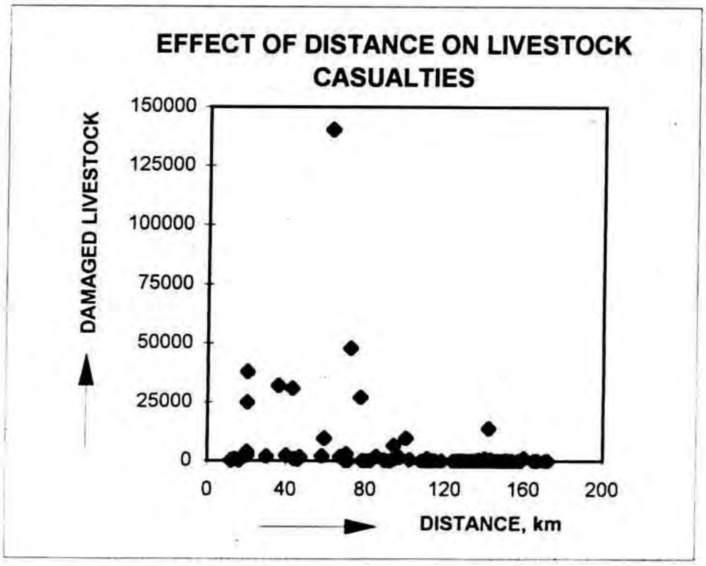

Figure 4.3b : Effect of Distance on Livestock Casualties

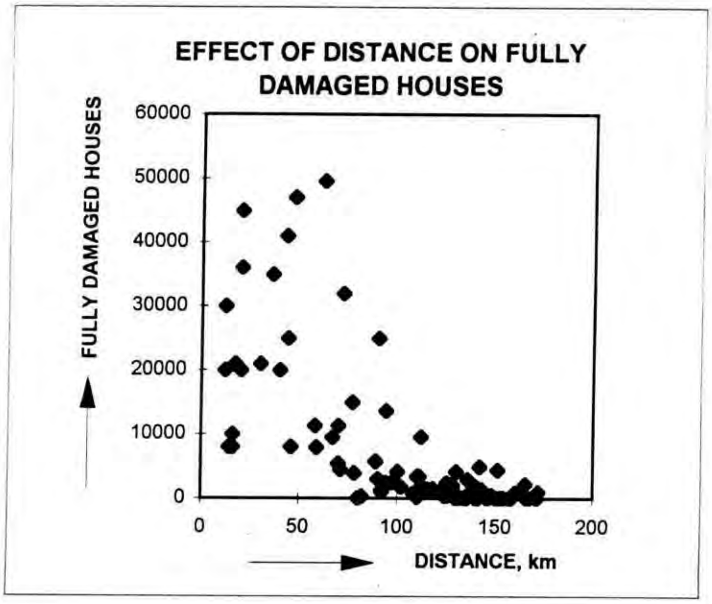

Figure 4.3c : Effect of Distance on Fully Damaged Houses

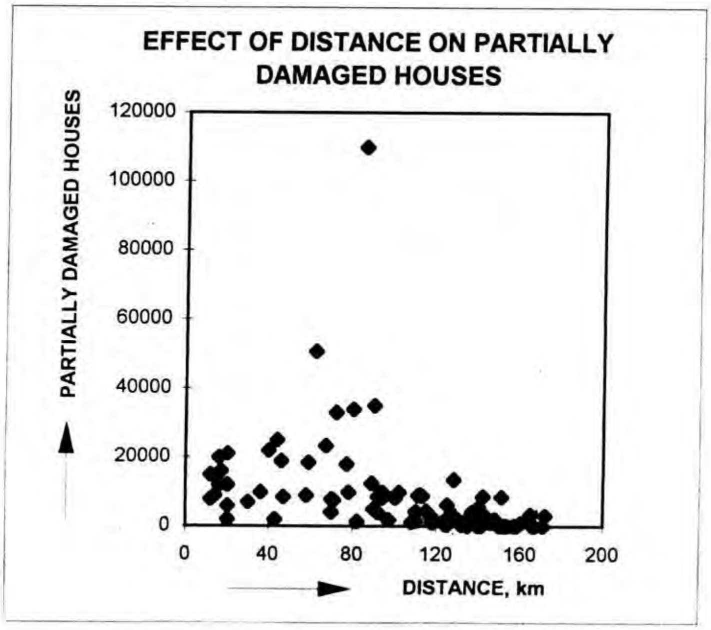

Figure 4.3d : Effect of Distance on Partially Damaged Houses

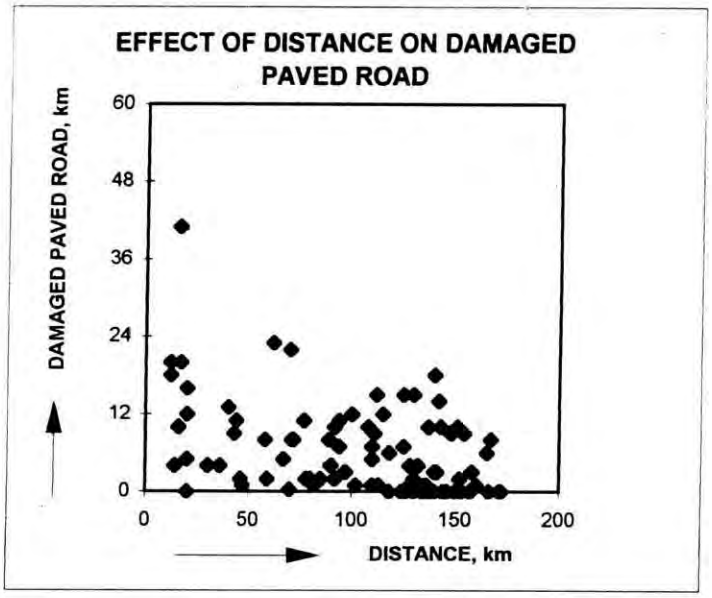

Figure 4.3e : Effect of Distance on Damaged Paved Road

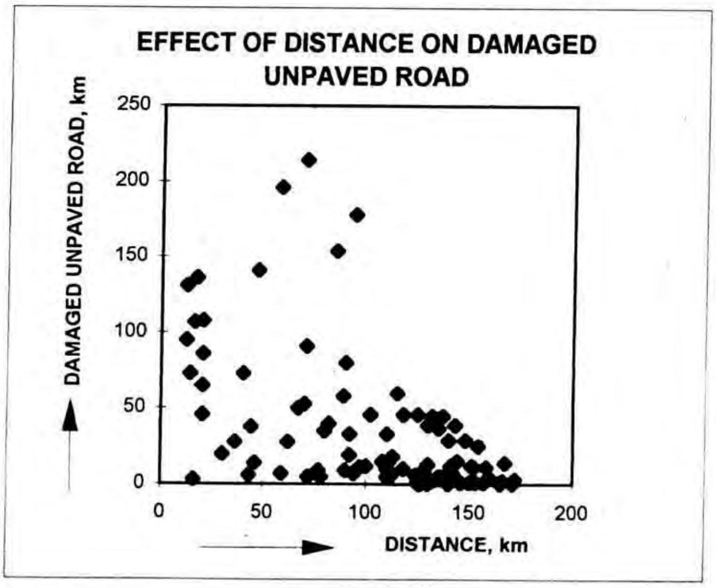

Figure 4.3f : Effect of Distance on Damaged Unpaved Road

CHAPTER 5

DEVELOPMENT AND CALIBRATION OF THE NEURAL NETWORK MODEL

5.1 INTRODUCTION

This chapter describes the development of the programme for the implementation of the neural network models for the analysis of the damages caused by cyclone. This chapter also describes the results of the calibration procedure of the models. The result of the calibration test are also presented in this chapter.

5.2 DEVELOPMENT OF THE MODEL

For the development of the model, the concepts described in Chapter 3 has been directly implemented. There are a number of softwares on neural network available in the market. The major problem with these softwares is that their source code is not available. So the changes in theories or techniques can not be experimented using these software. To assist in future development of neural network research, a software for neural network has been written using QBASIC programming language. There is nothing new and unique in the developed software. The results of the software have been compared with the results of other commercially available software. It is found that the results are highly consistent. In some cases, the commercially available software provide very lucrative presentations. Some of these presentations have been included here. The flow chart of the model is shown in Figure - 5.1. The neural network developed here has a 'Input layer', a 'Hidden layer' and a 'Output layer'.

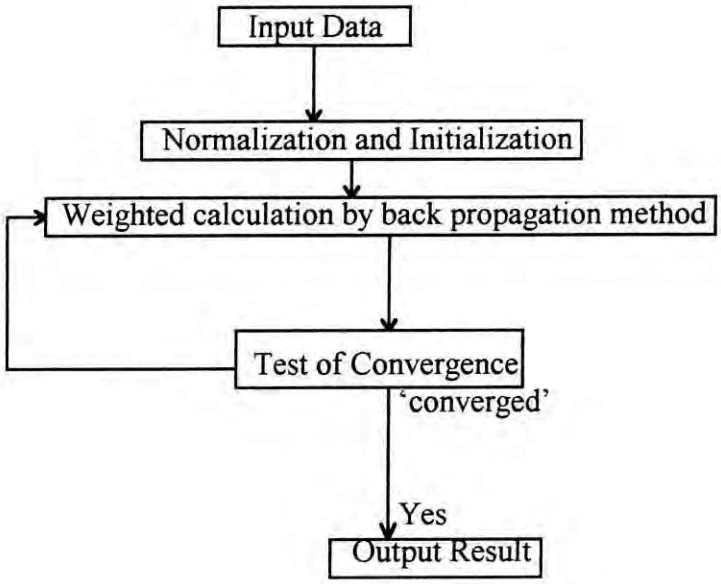

Figure - 5.1 Flow chart of the programme

At the initial stage of the programming all the variables have been incorporated in a single model. But it is found that the calibration process becomes extremely complex and sometimes numerical error results in. Later the output variables and related input variables have been separated in different models. It is observed that the resulting models are quite consistent and stable. The input variables related to the strength of the cyclone have been included in all the models.

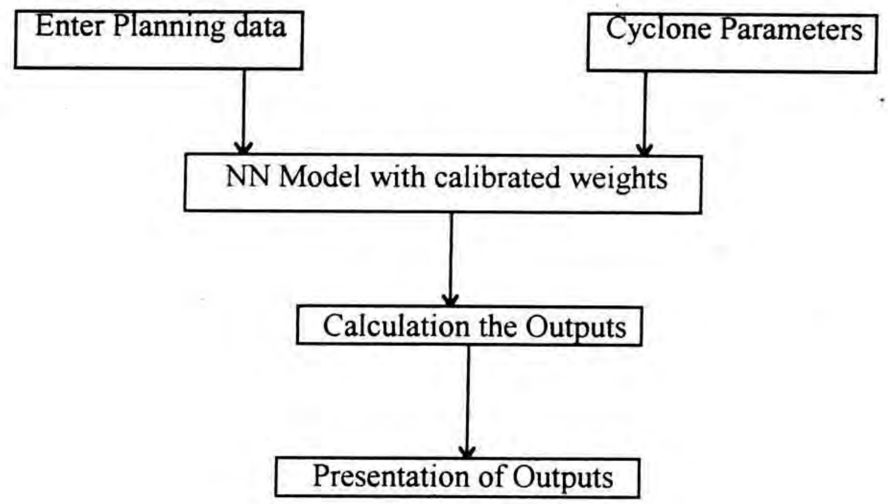

Figure - 5.2 Flow chart for forecasting

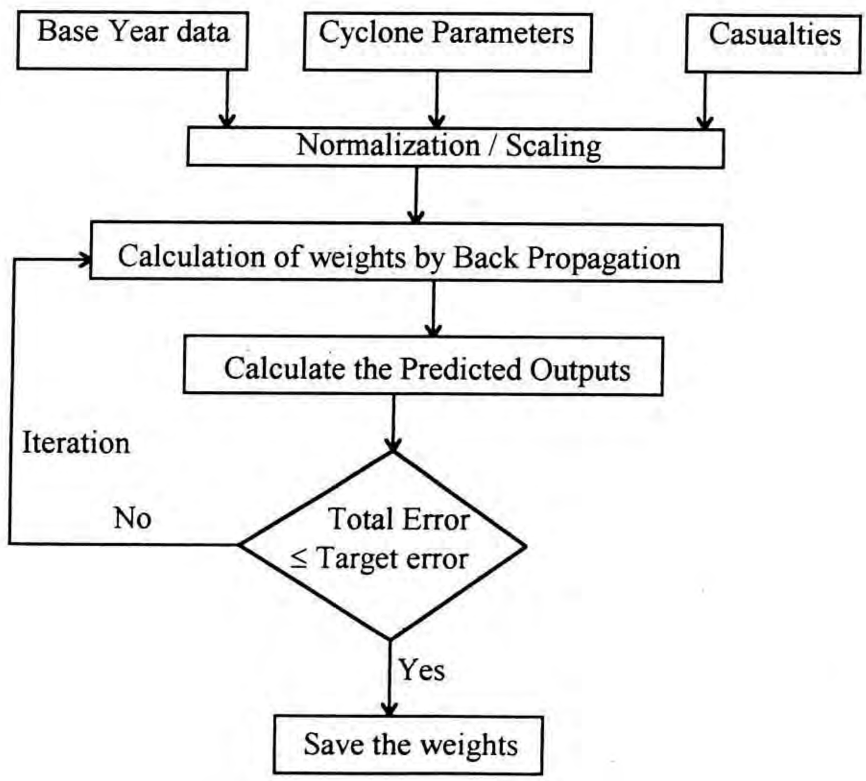

Figure - 5.3 Flow chart of programme for calibration

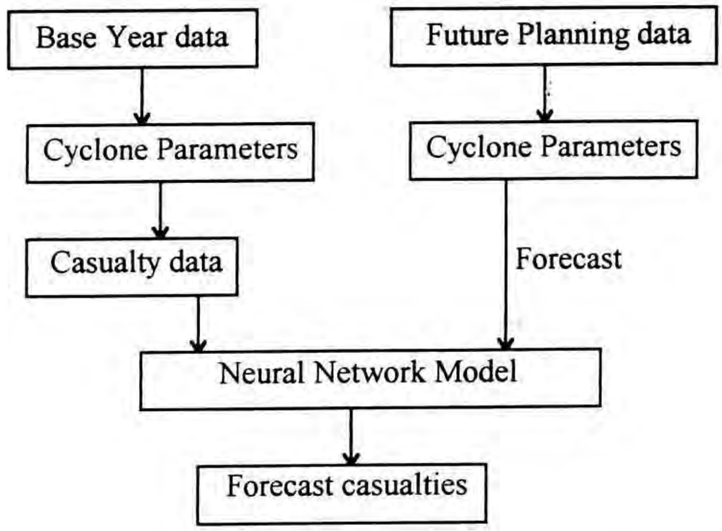

Figure - 5.4 Data flow of the Model

5.3 DEFINITION OF THE VARIABLES

In this section, the variables considered in the model are presented. The variables included in the model can broadly be divided into two categories - Input variables and Output variables. Input variables can again be divided into two groups. A set of input variables describe the characteristics of cyclone. The other set describe the demographic and socio - economic characteristics. The variables explaining cyclone include wind speed, height of water surge and the distance of the study area from the path of cyclone. This distance is measured perpendicularly from the path of cyclone if the study area is in the ocean and for other areas it is measured from the point at which the cyclone hits the land. The demographic and socio - economic data include population, amount of livestock, length of paved and unpaved roads and number of kutcha houses in the study area. The output variables include human casualties, livestock casualties, damage of paved and unpaved roads as well as partially and fully damaged houses.

5.4 DESIGN OF NEURAL NETWORK

The design of neural network can be divided into three steps - (i) Selection of variables, (ii) Selection of number of hidden layers, (iii) Selection of number of nodes in the hidden layer. In the following section each of these steps is explained in detail.

(i) Selection of the variables in the models

At first it was tried to incorporate all the variables in a single model. In this case, it was found that the calibration process can not proceed smoothly due to very small variations in error surface. Later, the variables had been separated into four categories each of which incorporated a specific type of concerned variables. Each of the categories included parameters related to cyclone as common variables. In this case, it was found that the training could be done successfully.

(ii) Selection of the number of hidden layers

A vigourous review of literature suggests that for calculation purpose it will be better to minimize the number of hidden layers. The selection of number of hidden layers is closely related to the number of output variables and number of nodes in the hidden layer. Although total computational difficulty is proportional to the total number of nodes in the hidden layer (summation of nodes in hidden layers), it is the number of hidden layers which affect the computational complexity most. In this context, it is tried to minimize the number of hidden layers. Also, too many hidden layers may induce diverging effect on the model. After examine several options, it is found that for the models in this study only one hidden layer is well enough to provide satisfactory result.

(iii) Selection of number of nodes in the hidden layers

As the number of hidden layer has been fixed at one, the role of number of nodes in hidden layer has become vitally important. In this regard, it has been tried again not to increase the computational difficulty unnecessarily. The criteria for the selection of the number of nodes in the hidden layer has been stated as " the number of nodes which minimizes the total error at optimum with minimum (or reasonable) number of iterations". The following figure illustrates selection procedure for human casualties model.

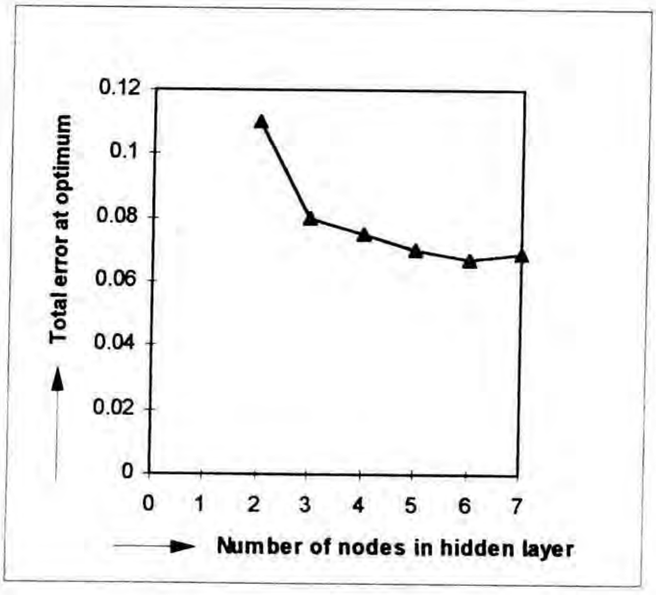

Figure - 5.4a Selection procedure for Human Casualties Model

5.5 RESULT OF CALIBRATION

In this section, the results of calibration are presented for each model. The first model deals with human casualties. The second, third and forth models deal with livestock casualties, damages to houses and damages to roads respectively. The inputs and outputs of the models are shown in Tables 5.1 a to 5.1 d.

Table 5.1a Variables of Human Casualty Model

Input	Output
• Population • Wind Speed • Height of Surge • Distance	• Human Casualties

Table 5.1b Variables of livestock Casualty Model

Input	Output
• livestock • Wind Speed • Height of Surge • Distance	• Livestock Casualties

Table 5.1c Variables of House Damage Model

Input	Output
• Houses • Wind Speed • Height of Surge • Distance	• Fully Damaged Houses • Partially Damaged Houses

Table 5.1d Variables of Road Damage Model

Input	Output
• Paved Roads • Unpaved Roads • Wind Speed • Height of Surge • Distance	• Paved Road Damaged • Unpaved Road Damaged

5.5.1 Calibration Result of Human Casualty Model

Table 5.2a presents the weight neural network model developed for forecasting human casualties. Value of last row represents the bias data.

Table 5.2a weights of human casualties NN model

		Hidden layer				
		1	2	3	4	5
Input	1	0.196342	-0.877137	1.301578	-0.344591	3.160982
	2	3.333496	-2.457053	-0.73589	2.514579	1.868707
	3	-1.728076	1.367499	1.188271	1.769453	-2.417634
	4	-3.762312	2.226486	-3.615928	6.05176	-3.747268
	5	0.270591	-1.851425	1.377853	2.077148	-2.773374

		Output
Hidden	1	-7.792332
	2	5.333333
	3	-1.482545
	4	-8.190393
	5	-1.623968
	6	1.251706

Target error on the normalized data = 0.07

Nos. of Iteration = 2340

RMS value = 0.01628243

5.5.2 Calibration Result of Livestock Casualty Model

Table 5.2b presents the weight neural network model developed for forecasting livestock casualties. Value of last two rows represents the bias data.

Table 5.2b weights of livestock casualties NN model

		Hidden layer				
		1	2	3	4	5
Input	1	-5.439213	0.979244	-5.511141	-2.2846	-0.909884
	2	-2.201383	-2.244537	-6.866039	2.029252	4.214265
	3	-1.307662	-2.473796	-1.514476	-2.528503	2.959378
	4	4.402561	1.622431	-3.838399	-1.32177	2.196399
	5	2.6597	4.734667	-2.572916	2.831068	-2.330932
	6	1.854374	5.657179	2.710545	-1.683068	-3.346393

		Output
Hidden	1	-6.551372
	2	6.493378
	3	-3.518351
	4	0.831583
	5	-1.362345
	6	4.808715
	7	-2.005418

Target error on the normalized data = 0.07

Nos. of Iteration = 20280

RMS value = 0.0166243

5.5.3 Calibration Result of House Damage Model

Table 5.2c presents the weight neural network model developed for forecasting houses damage. Value of last row represents the bias data.

Table 5.2c weights of houses damage NN model

		Hidden layer				
		1	2	3	4	5
Input	1	-13.00607	3.421956	-5.417477	2.871871	-3.236096
	2	-9.145556	1.238232	-9.832023	3.01175	-8.667592
	3	0.52501	0.894902	-3.90445	0.56169	0.851459
	4	0.229304	-0.786936	8.24885	1.260939	6.558613
	5	0.68223	1.887808	1.362005	-2.01191	4.245272

		Output	
Hidden	1	-2.686276	2.43747
	2	0.874634	-1.098482
	3	0.969809	11.18282
	4	-1.621277	8.280256
	5	-8.398708	0.554425
	6	7.22118	-14.83669

Target error on the normalized data = 0.15

Nos. of Iteration = 37610

RMS value = 0.05390899

5.5.4 Calibration Result of Road Damage Model

Table 5.2d presents the weight neural network model developed for forecasting roads damage. Value of last row represents the bias data.

Table 5.2d weights of roads damage NN model

		Hidden layer					
		1	2	3	4	5	6
Input	1	0.632373	-2.046532	-1.299196	0.39568	-4.319603	-12.1555
	2	1.158261	-0.746521	-1.45124	-3.109131	1.175272	2.086955
	3	-6.722982	6.092703	9.741474	11.22022	0.517547	-6.000582
	4	1.028109	-1.761486	-1.189245	-0.719872	2.88101	5.244998
	5	-3.630806	4.996361	1.623627	7.333965	-5.948925	1.347702
	6	2.899225	9.432088	10.69519	-7.391203	3.837843	11.84873

		Output	
Hidden	1	2.391174	-4.170473
	2	-5.434109	-1.986269
	3	-3.514304	-2.986633
	4	2.490126	4.632595
	5	2.653003	1.430571
	6	1.650118	-2.378164
	7	-1.786066	0.337397

Target error on the normalized data = 0.4

Nos. of Iteration = 43425

RMS value = 0.1160722

5.6 RESULT OF VALIDATION TEST

The calibrated results were validated by examining the explanatory power of the models. For this purpose, the predicted values have been regressed over the observed value. It is found that the outputs of the developed models are highly consistent with the observed values. This is also demonstrated by high values of the correlation coefficients. The observed and the predicted values of the output variables are shown in Figures 5.5a - 5.5f. The validation tests have been performed both for the whole data set as well as hold out data sets.

5.7 MODELS INCORPORATING ACCESSIBILITY

In the models developed earlier, the effects of accessibility on the damages, especially human and livestock casualties, have been ignored. It is expected that the better the accessibility the smaller will be the casualties. To incorporate the accessibility measure in the models, the amounts of paved and unpaved roads have been incorporated in the models as inputs. The results of the models are presented in this section.

Table 5.3a Variables of Human Casualty Model

Input	Output
• Wind Speed • Height of Water Surge • Distance • Population • Amount of Paved Road • Amount of Unpaved Road	• Human Casualties

Table 5.3b Variables of livestock Casualty Model

Input	Output
• Wind Speed • Height of Water Surge • Distance • Amount of Livestock • Amount of Paved Road • Amount of Unpaved Road	• Livestock Casualties

5.7.1 Calibration Result of Human Casualty Model

Table 5.3c presents the weight neural network model developed for forecasting human casualties. Value of last row represents the bias data.

Table 5.3c weights of human casualties NN model

		Hidden layer						
		1	2	3	4	5	6	7
Input	1	3.616684	-1.866244	-0.712175	1.277035	-0.115607	-1.736329	-2.369142
	2	0.086854	-2.759413	1.135442	-1.515115	-1.082727	-3.616804	-1.269264
	3	-3.27653	-2.799869	1.394477	0.654894	-0.843198	-3.208795	0.957738
	4	-1.296705	2.920667	-1.767521	1.368922	0.469088	2.263161	-2.446051
	5	3.709369	-0.007847	-2.79556	-1.041795	-0.994639	-0.983942	1.294513
	6	-1.682373	1.239263	-1.060683	1.804592	2.83315	2.038716	-1.389114
	7	0.795914	-2.357965	0.075328	1.35743	-1.51679	0.617862	-2.09915

		Output
Hidden	1	2.427906
	2	-2.293664
	3	-4.866185
	4	0.251161
	5	0.68373
	6	0.238842
	7	1.863611
	8	0.820706

Target error on the normalized data = 0.06

Nos. of Iteration = 2930

RMS value = 0.016792950

5.7.2 Calibration Result of Livestock Casualty Model

Table 5.3d presents the weight neural network model developed for forecasting livestock casualties. Value of last row represents the bias data.

Table 5.3d weights of livestock casualties NN model

		Hidden layer						
		1	2	3	4	5	6	7
Input	1	3.676176	2.351063	0.618649	0.552429	-0.771064	2.335073	1.328034
	2	-2.153505	-1.227595	-3.293657	-1.23262	0.89425	-3.034779	-2.65184
	3	-4.759297	-0.135577	-0.928501	-3.683709	-2.89567	-0.341597	-0.459056
	4	-0.200814	-3.119905	-1.778077	1.526083	-0.503541	-0.02944	0.943191
	5	1.495647	3.124929	-1.03501	2.248839	-0.354255	2.518537	-0.863374
	6	-5.458554	-0.109224	1.46639	1.762802	-0.452302	1.867357	-2.117244
	7	2.115947	-2.4505	1.098177	2.602824	3.015579	0.762884	-2.933794

		Output
Hidden	1	1.2994
	2	3.811098
	3	-5.89456
	4	-2.740084
	5	-1.157007
	6	-3.67111
	7	2.113894
	8	0.329284

Target error on the normalized data = 0.06

Nos. of Iteration = 24285

RMS value = 0.11737810

5.7.3 Result of Validation Test

It is observed that the outputs of the models agree quite satisfactorily with the observed data. The performance of the models are marginally better than the models which ignored accessibility with respect to RMS value at optimality and number of iteration required to reach optimality. The observed and the predicted values of the output variables are shown in figures 5.6a and 5.6b

5.8 SUMMARY

This chapter described the development of the neural network model for the analysis of casualties and damages caused by cyclone. This chapter also presented the results of calibration and validation of the models. It is observed that the models are consistent and stable. The validation tests prove that the explanatory power of the developed models are also very good. In the next chapter the application of the models will be discussed.

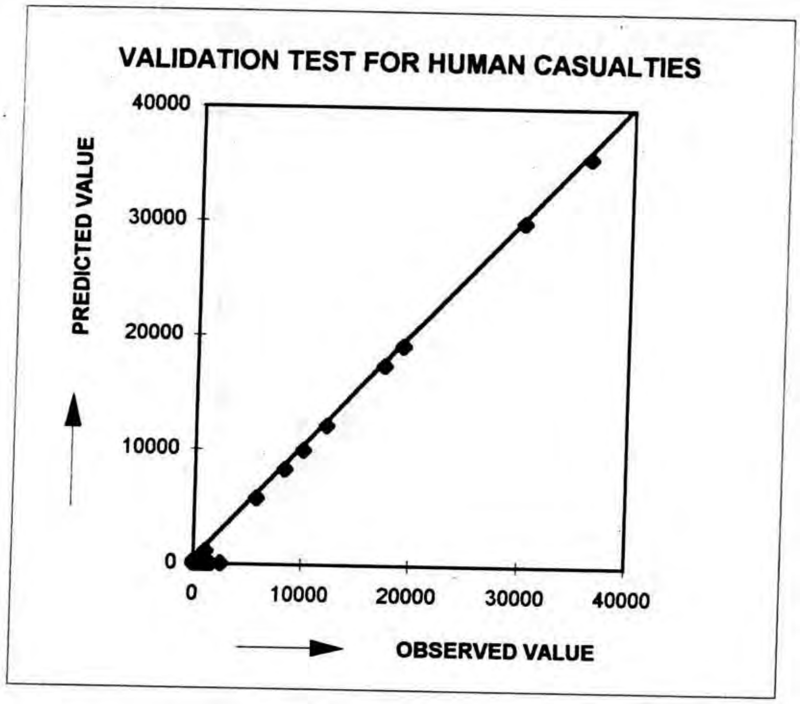

Figure 5.5a : Validation Test for Human Casualties

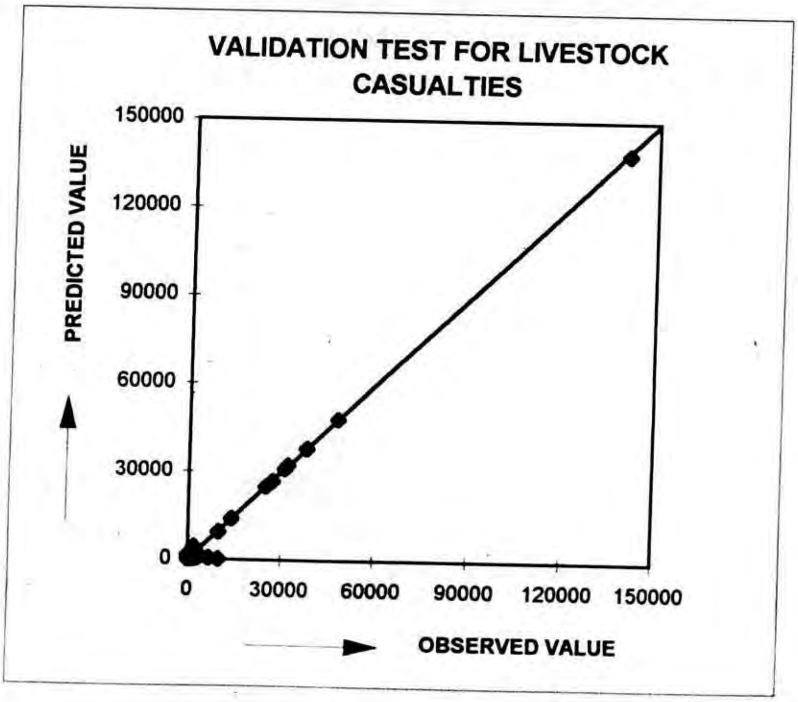

Figure 5.5b : Validation Test for Livestock Casualties

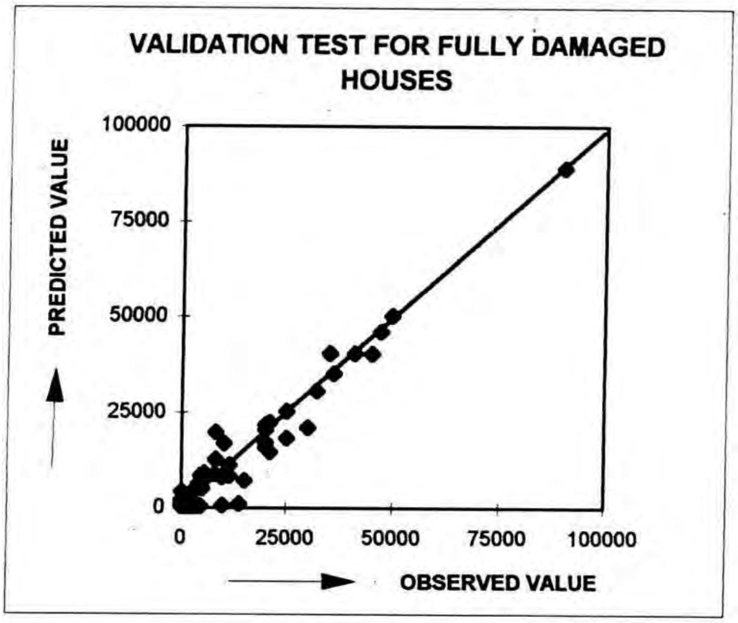

Figure 5.5c : Validation Test for Fully Damaged Houses

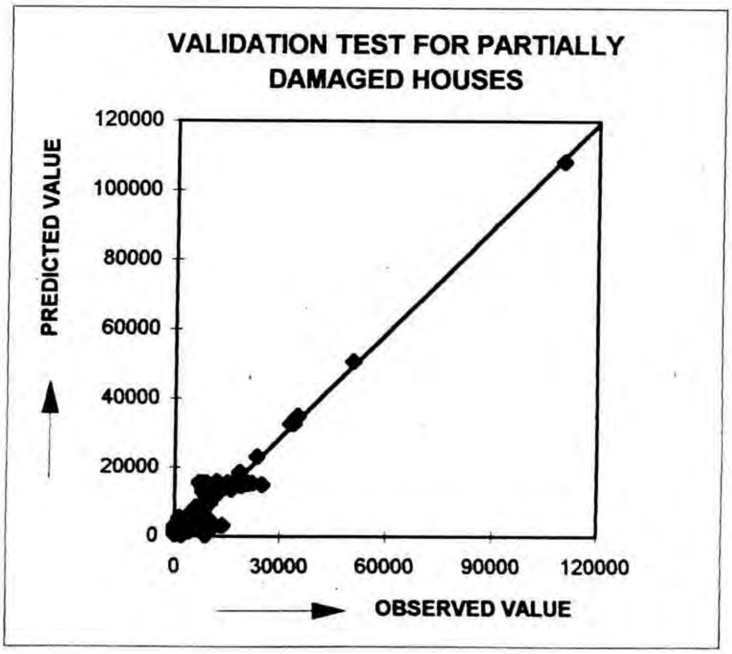

Figure 5.5d : Validation Test for Partially Damaged Houses

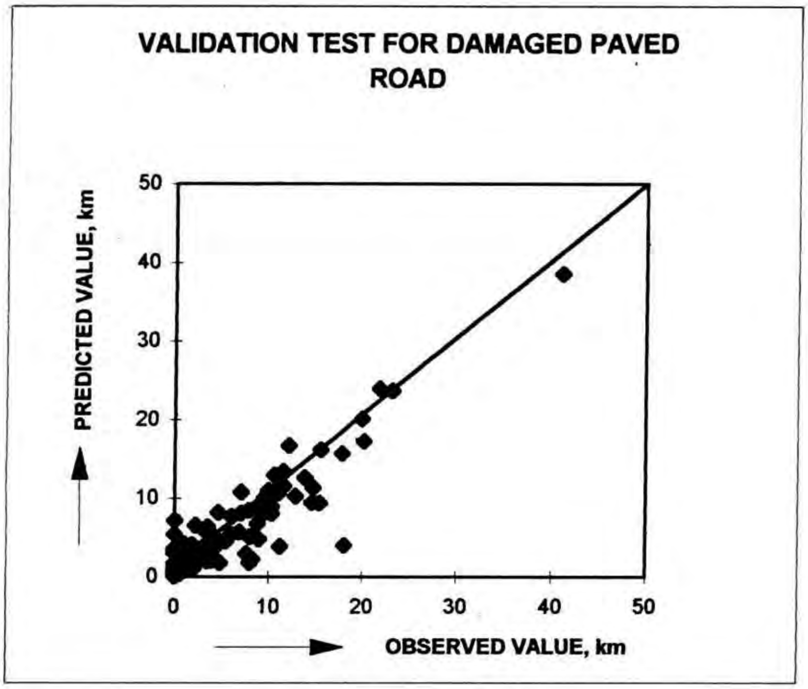

Figure 5.5e : Validation Test for Damaged Paved Road

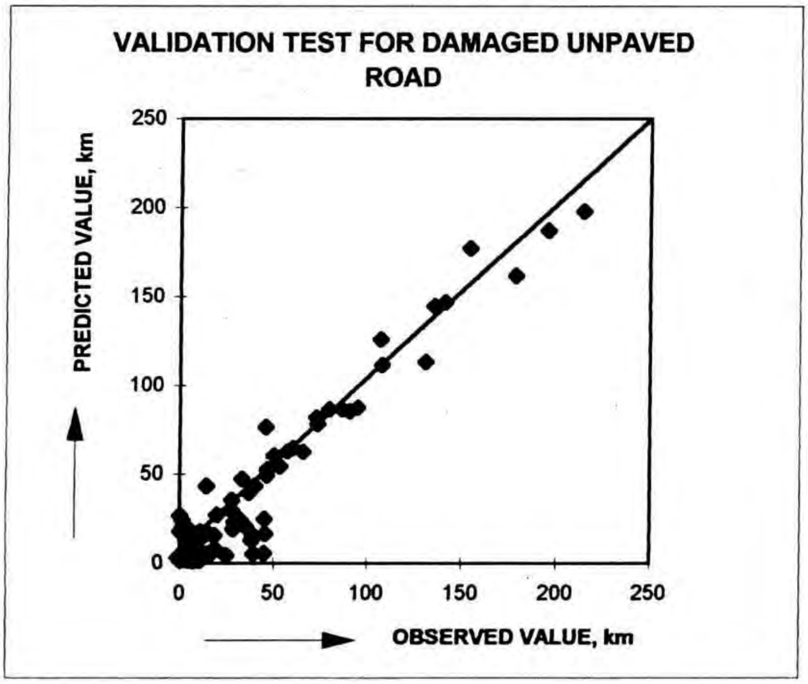

Figure 5.5f : Validation Test for Damaged Unpaved Road

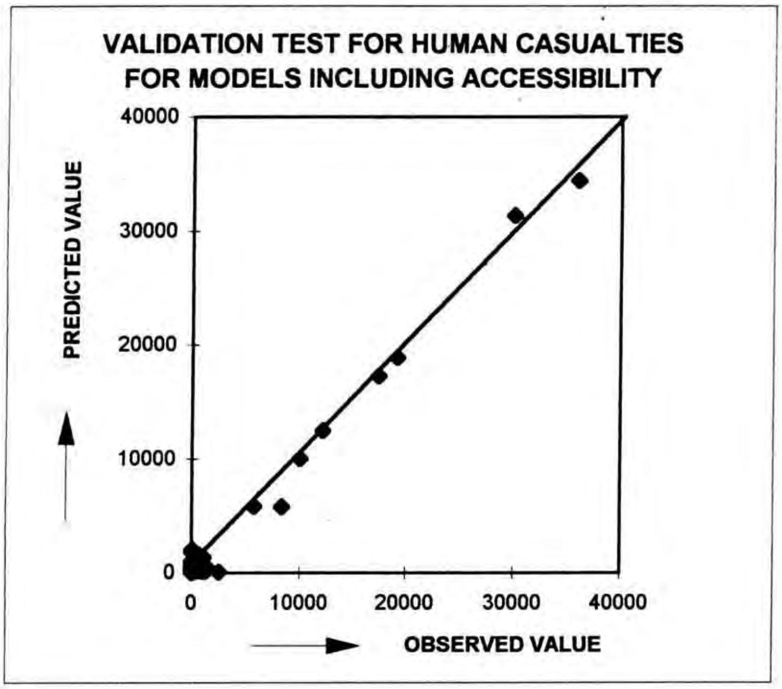

Figure 5.6a : Validation Test for Human Casualties for Models Including Accessibility

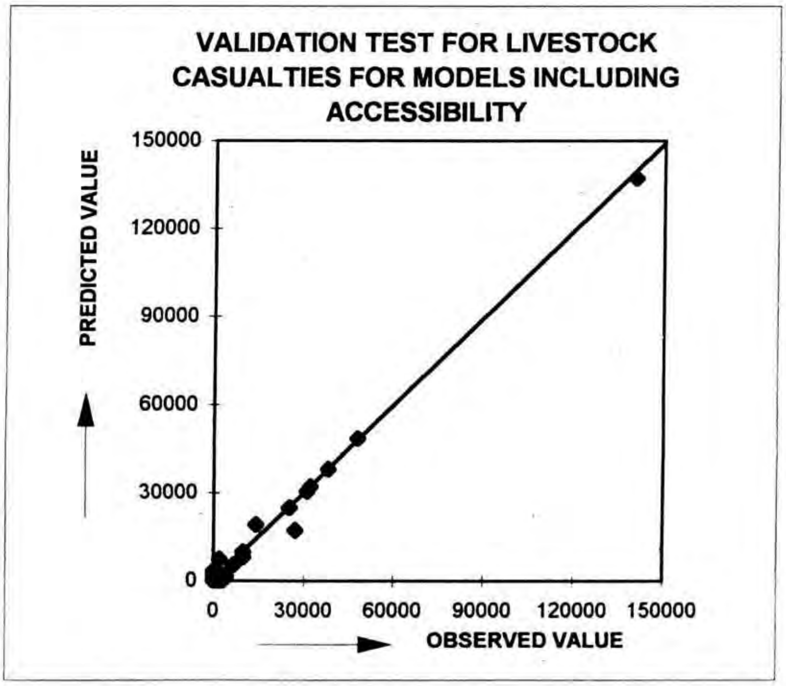

Figure 5.6b : Validation Test for Livestock Casualties for Models Including Accessibility

CHAPTER 6

MODEL APPLICATION AND RESULT

6.1 INTRODUCTION

In this chapter the application of the neural network model, developed in the earlier chapter, is described. The models developed have a wide range of application. Primarily the models can be applied to forecast the damages caused by cyclones of various strength. For this purpose, the variables related to the strength of cyclone are varied and their effects are examined. This chapter also investigates the effects of noise in the data. This initial model have been calibrated assuming that the data collected from various organizations is correct. But, the reported data may be incorrect which is the fact with this kind of data. It is impossible to know the exact amount of error in the data. By using 'Monte Carlo Simulation' the effect of noise in the data is analyzed and presented in this chapter.

6.2 EFFECT OF CYCLONE PARAMETERS

This section presents the analysis of the effect of different parameters related to cyclone. In the 'neural network model' developed in the earlier chapter the parameters describing the strength of cyclone are - wind speed, height of water surge and distance from the line of cyclone.

6.2.1 Effect of wind speed

Figures 6.1a - 6.1f show the effects of change of wind speed on all 6 types of casualties. Here all the variables other than wind speed have been assumed to be constant.

6.2.2 Effect of height of water surge

Figures 6.2a - 6.2f show the effects of change of height of water surge on different types of casualties. Here all the variables other than height of water surge have been assumed to be constant.

6.2.3 Effect of distance

Figures 6.3a - 6.3f show the effects of change of distance on different types of casualties. Here all the variables other than distance speed have been assumed to be constant.

Considering all these effects, it is observed that water surge is the most prominent destructive element among the three variables considered. Casualties decrease with the increase of distance from the line of cyclone.

6.3 ANALYSIS OF NOISE IN DATA

Data on different parameters from various organizations have been collected for the analysis. The neural network model has been calibrated using this data. But it is acknowledged that this data may be incorrect due to error in measurement, error in reporting and tendencies of various organizations to over and under estimates the amounts of casualties. This factor is well recognized in this kind of modeling practices. It is impossible to estimate the amount of error in the data.

To analyze the effect of error in the data, 'Monte Carlo Simulation' approach has been used.

6.3.1 Outline of 'Monte Carlo Simulation'

For the analysis of the effects of error in the data, it is assumed that the reported data is the mean value of the input variables. Using random number generation capability of computer, the values of the input variables have been generated randomly taking the reported data as the mean value and various standard deviations. The standard deviations have been changed by varying the coefficient of variance (Standard deviation divided by mean). The coefficient of variance when expressed in percentage provides the percentage of error in the data. The model has been run for several times with the same percentage of error. The maximum and minimum values of the predicted casualties at the locations of seven casualties are shown in figures 6.4a - 6.4f. It is assumed that the maximum percentage of error is ±25%.

6.4 SUMMARY

In this section the neural network models, developed in earlier chapter, have been applied to analyze the effects of different variables. It is found that height of water surge is the most destructive element among the variables considered. The amount of casualties decreases rapidly with the increase of distance from the time of cyclone. This chapter also presents the effects of error (or noise) in data. It is observed that for low noise of reported data the models remain fairly consistent. But with the increase of noise, the range of forecasts also increases very rapidly which has been demonstrated by 'Monte Carlo Simulation'. It implied that the models can forecast quite accurately if the error in the input data remain within the tolerable limit (20% in this case). With the increase in the error in input data the accuracy may decrease.

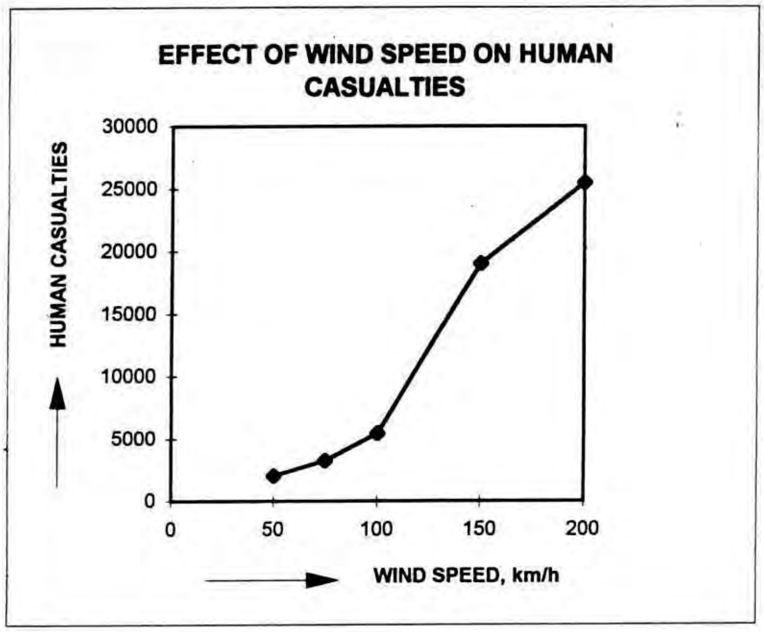

Figure 6.1a : Effect of Wind Speed on Human Casualties

[Assumed other variables distance = 16 km, height of water surge = 12 m, human casualties = 281076]

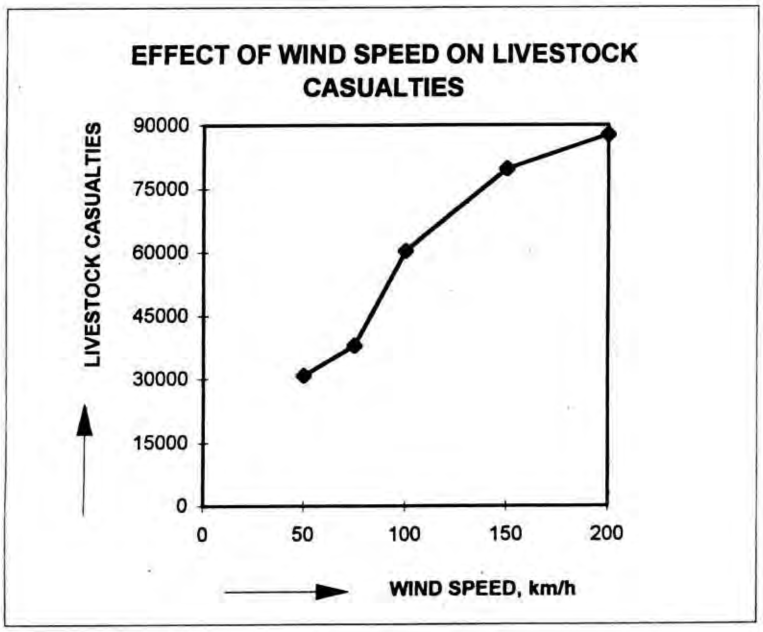

Figure 6.1b : Effect of Wind Speed on Livestock Casualties

[Assumed other variables distance = 16 km, height of water surge = 12 m, livestock casualties = 88378]

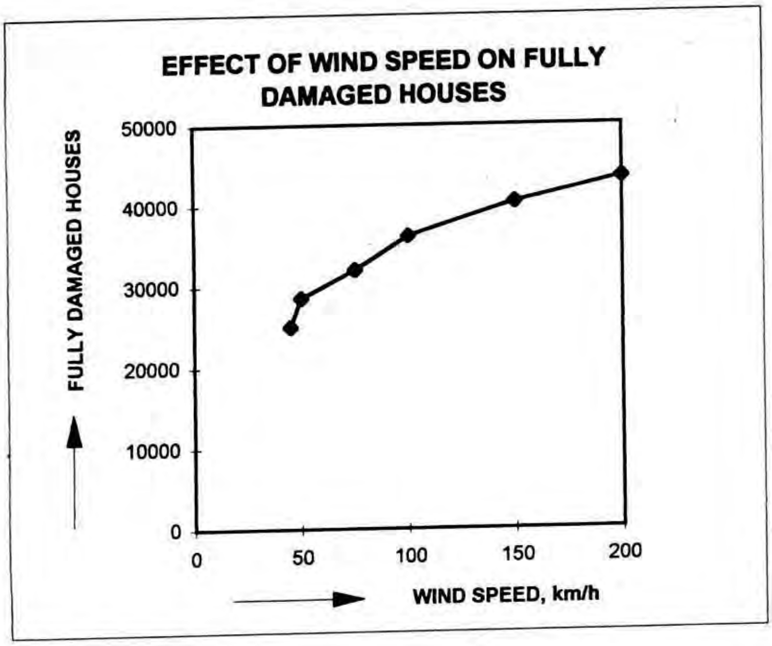

Figure 6.1c : Effect of Wind Speed on Fully Damaged Houses

[Assumed other variables distance = 16 km, height of water surge = 12 m, fully damaged houses = 47863]

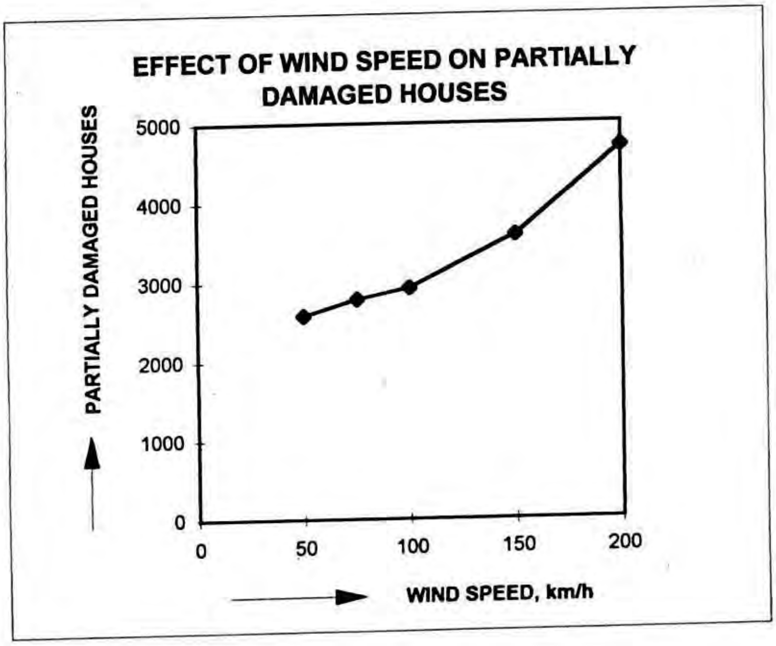

Figure 6.1d : Effect of Wind Speed on Partially Damaged Houses

[Assumed other variables distance = 16 km, height of water surge = 12 m, partially damaged houses = 45000]

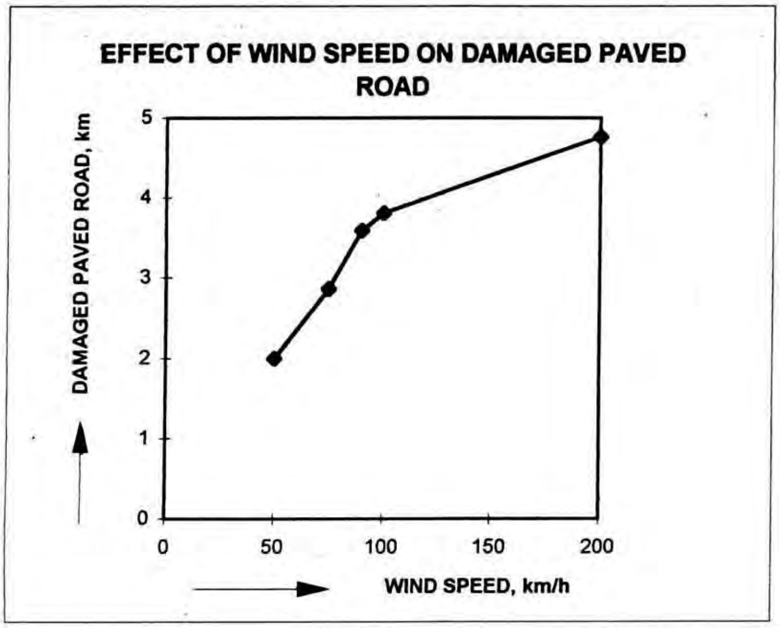

Figure 6.1e : Effect of Wind Speed on Damaged Paved Road

[Assumed other variables distance = 16 km, height of water surge = 12 m, damaged paved road = 4.83 km]

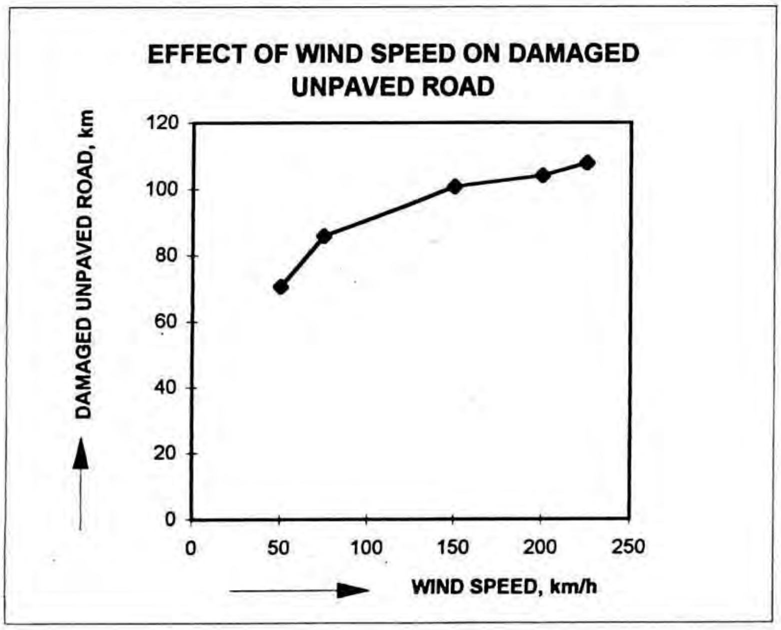

Figure 6.1f : Effect of Wind Speed on Damaged Unpaved Road

[Assumed other variables distance = 16 km, height of water surge = 12 m, damaged unpaved road = 107.96 km]

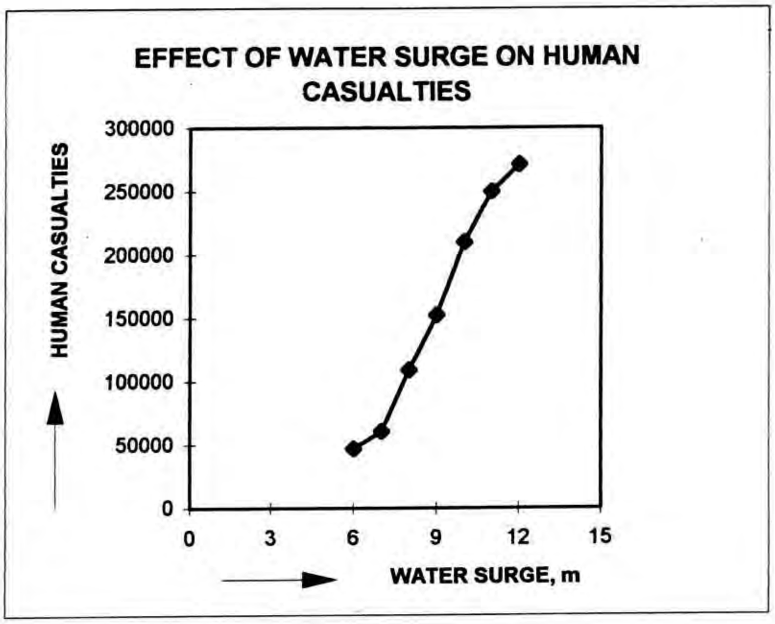

Figure 6.2a : Effect of Water Surge on Human Casualties
[Assumed other variables wind speed = 225 km/h, distance = 16 km, human casualties = 281076]

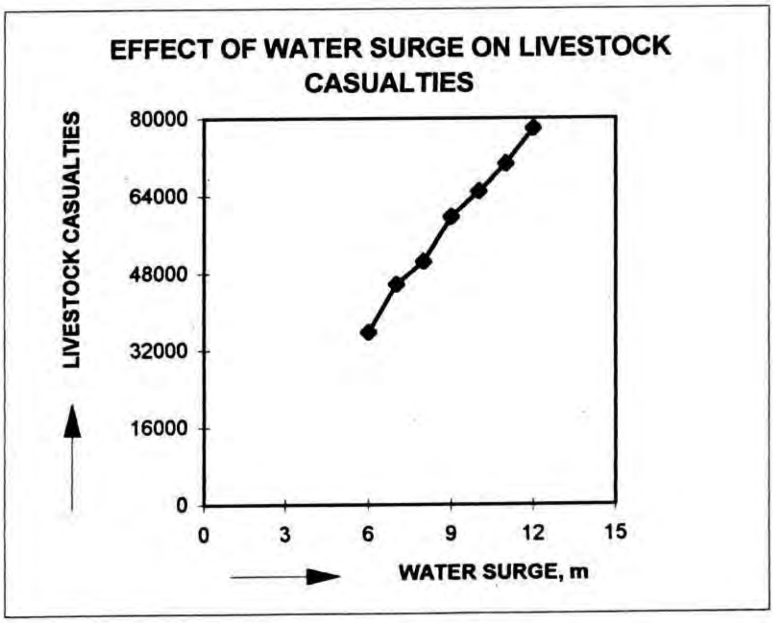

Figure 6.2b : Effect of Water Surge on Livestock Casualties
[Assumed other variables wind speed = 225 km/h, distance = 16 km, livestock casualties = 88378]

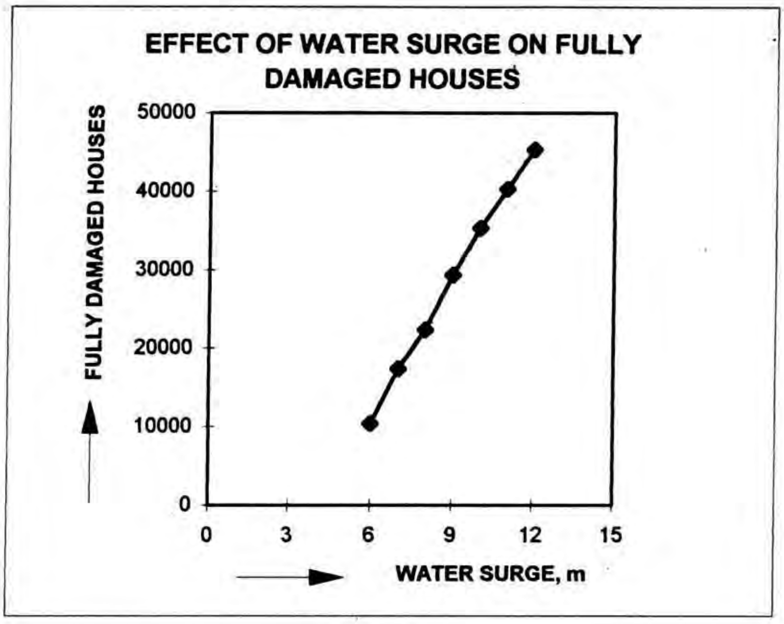

Figure 6.2c : Effect of Water Surge on Fully Damaged Houses
[Assumed other variables wind speed = 225 km/h, distance = 16 km, fully damaged houses = 47863]

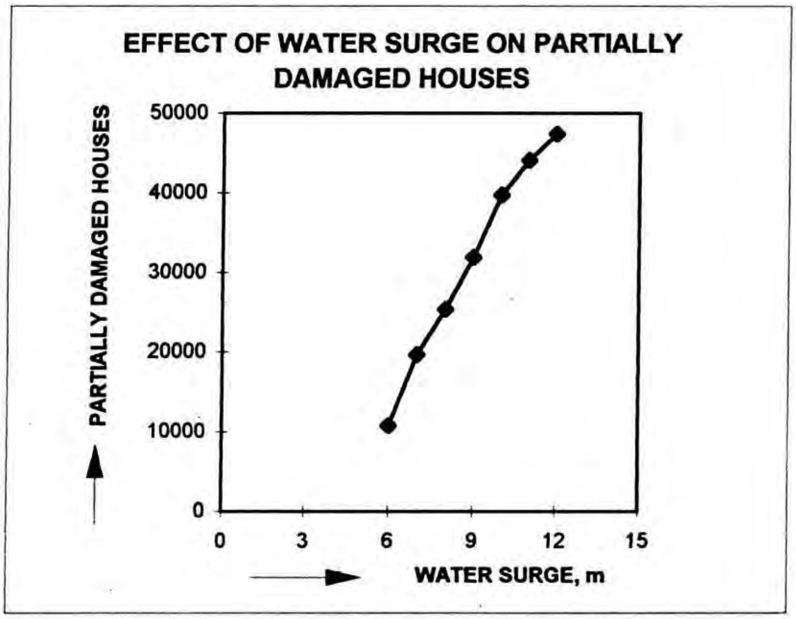

Figure 6.2d : Effect of Water Surge on Partially Damaged Houses
[Assumed other variables wind speed = 225 km/h, distance = 16 km, partially damaged houses = 45000]

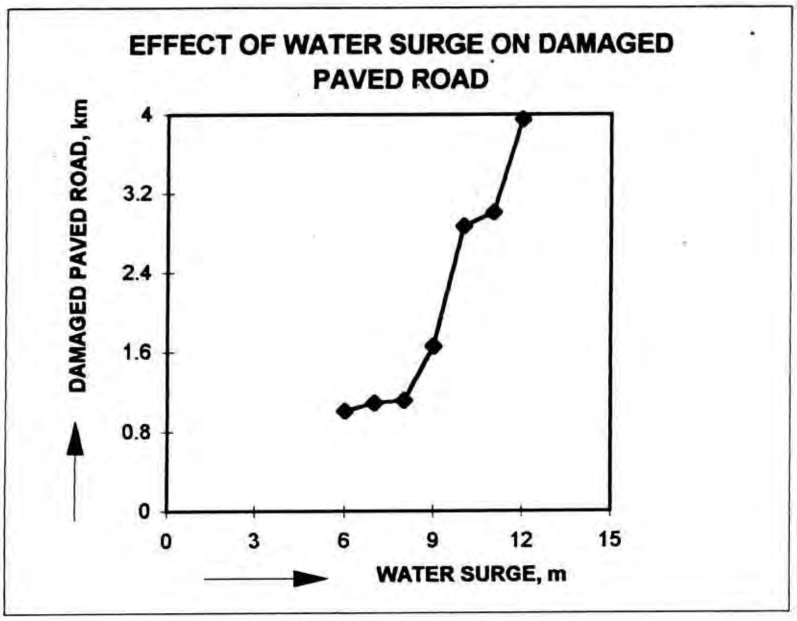

Figure 6.2e : Effect of Water Surge on Damaged Paved Road
[Assumed other variables wind speed = 225 km/h, distance = 16 km, damaged paved road = 4.83 km]

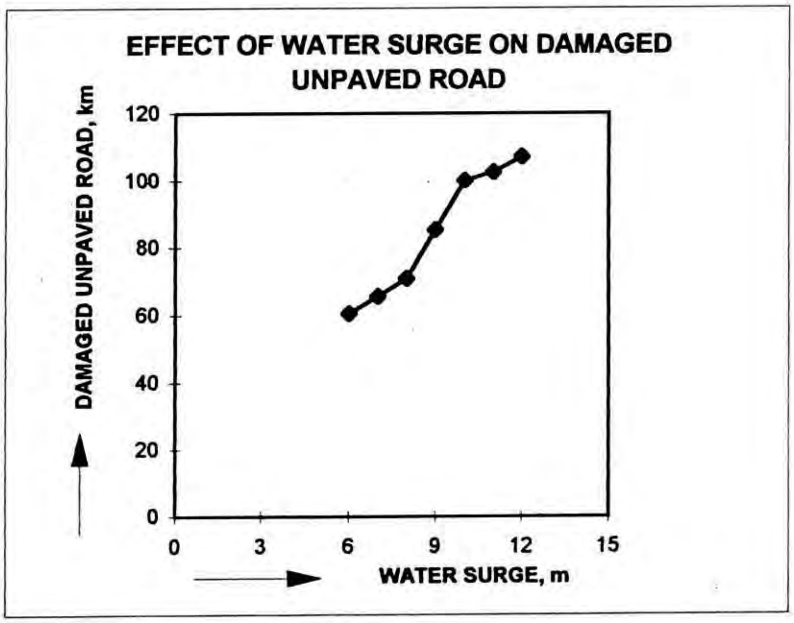

Figure 6.2f : Effect of Water Surge on Damaged Unpaved Road
[Assumed other variables wind speed = 225 km/h, distance = 16 km, damaged unpaved road = 107.96 km]

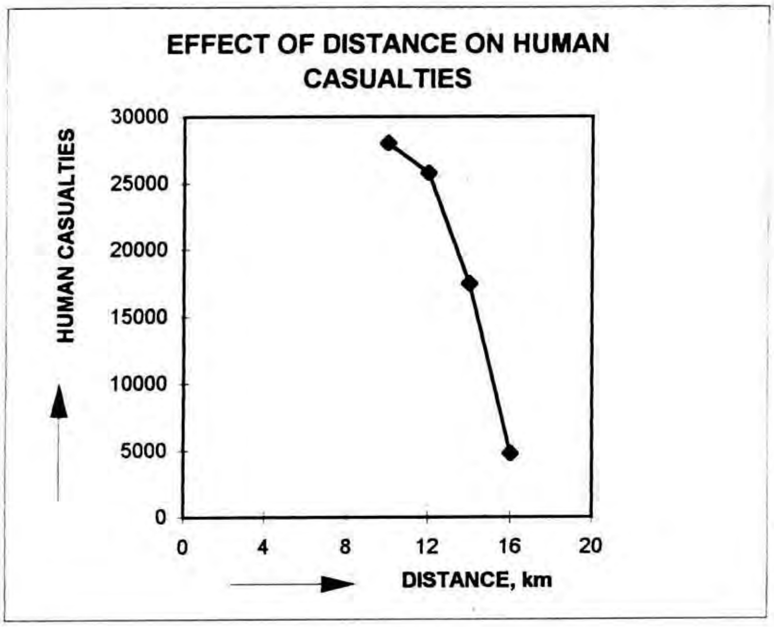

Figure 6.3a : Effect of Distance on Human Casualties
[Assumed other variables wind speed = 225 km/h, height of water surge = 16 m, human casualties = 281076]

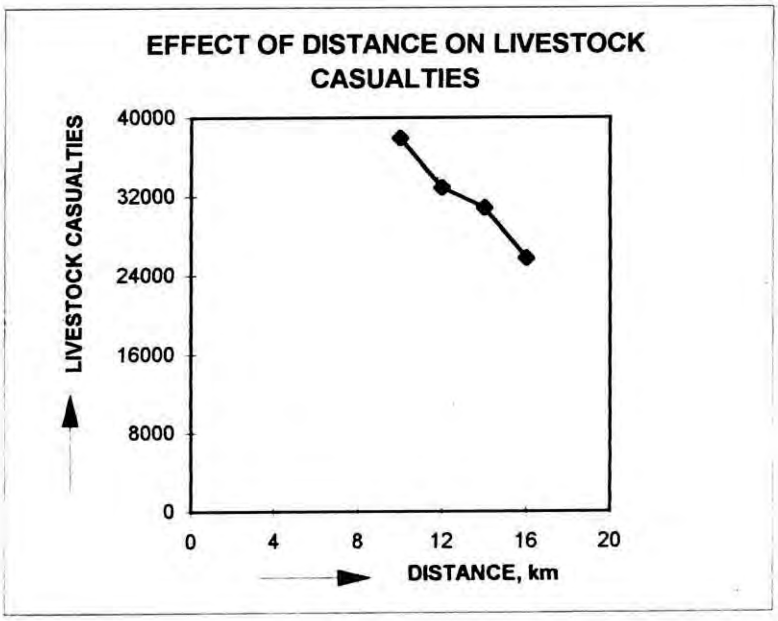

Figure 6.3b : Effect of Distance on Livestock Casualties
[Assumed other variables wind speed = 225 km/h, height of water surge = 16 m, livestock casualties = 88378]

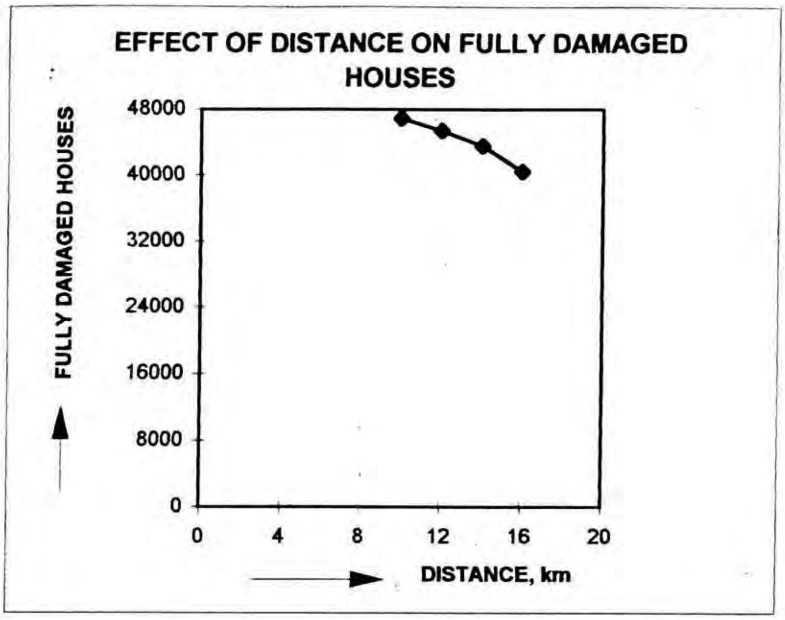

Figure 6.3c : Effect of Distance on Fully Damaged Houses
[Assumed other variables wind speed = 225 km/h, height of water surge = 16 m, fully damaged houses = 47863]

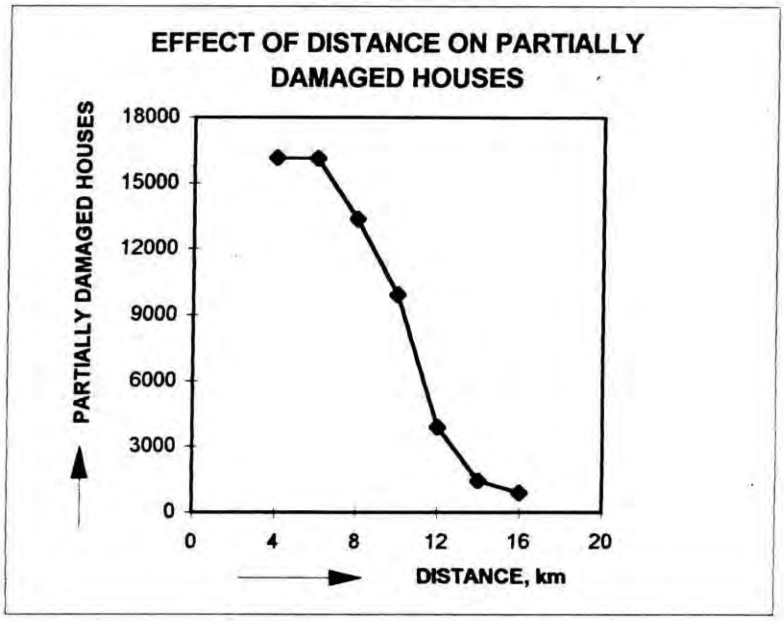

Figure 6.3d : Effect of Distance on Partially Damaged Houses
[Assumed other variables wind speed = 225 km/h, height of water surge = 16 m, partially damaged houses = 45000]

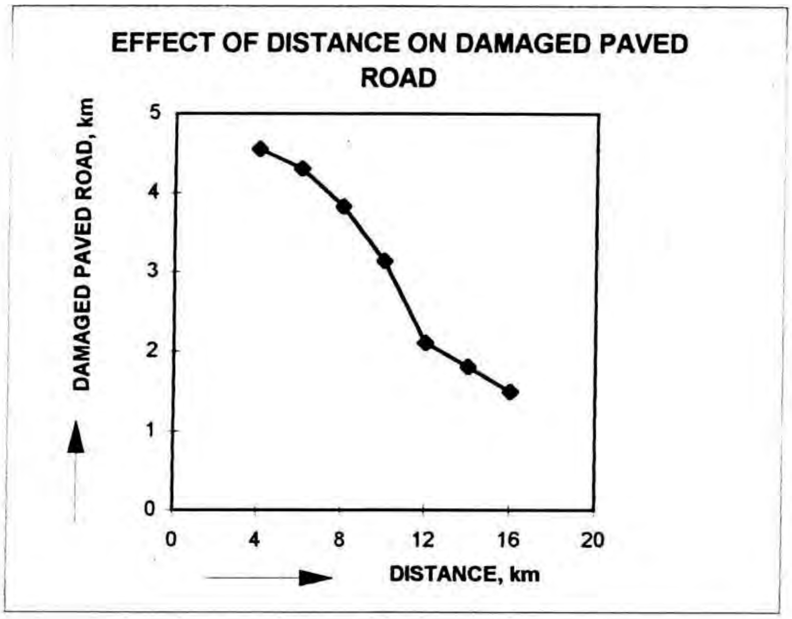

Figure 6.3e : Effect of Distance on Damaged Paved Road
[Assumed other variables wind speed = 225 km/h, height of water surge = 16 m, damaged paved road = 4.83 km]

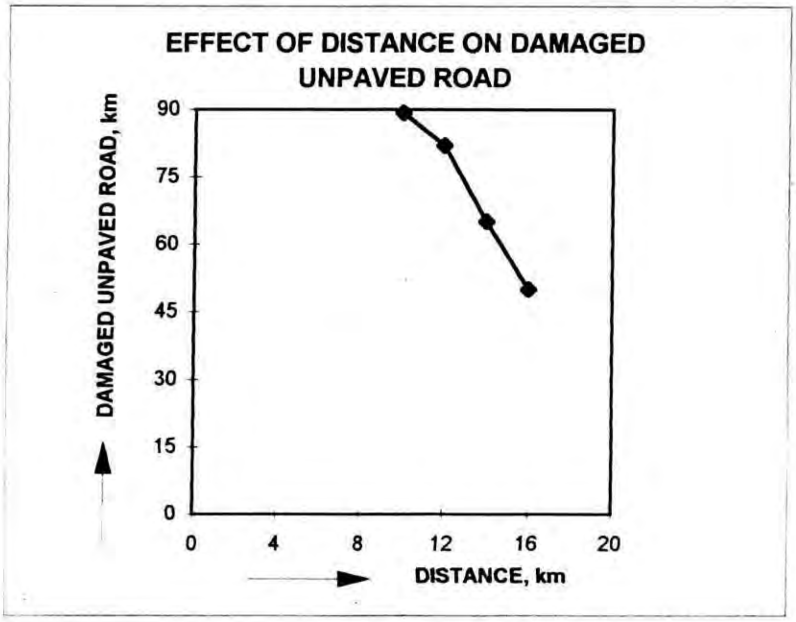

Figure 6.3f : Effect of Distance on Damaged Unpaved Road
[Assumed other variables wind speed = 225 km/h, height of water surge = 16 m, damaged unpaved road = 107.96 km]

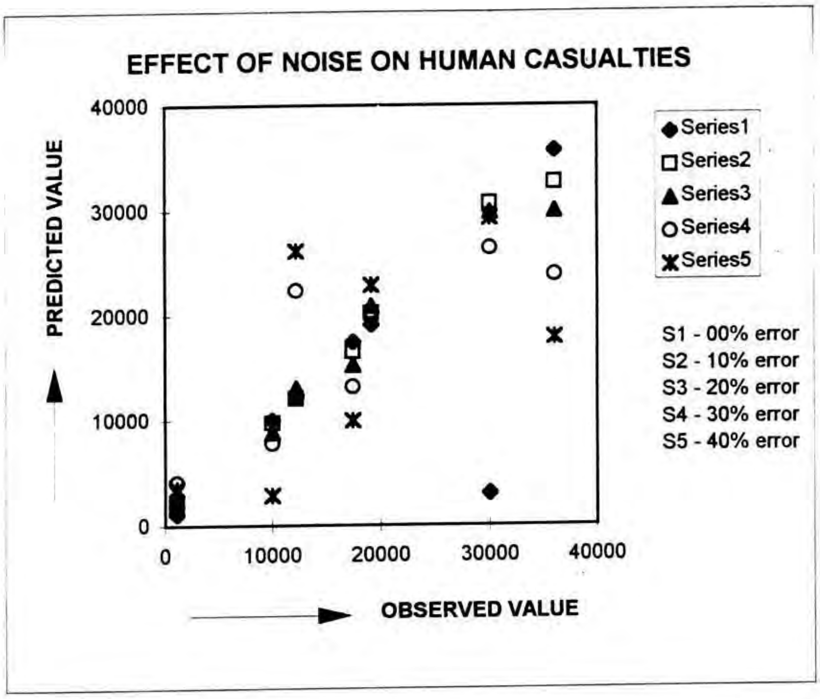

Figure 6.4a : Effect of Noise on Human Casualties

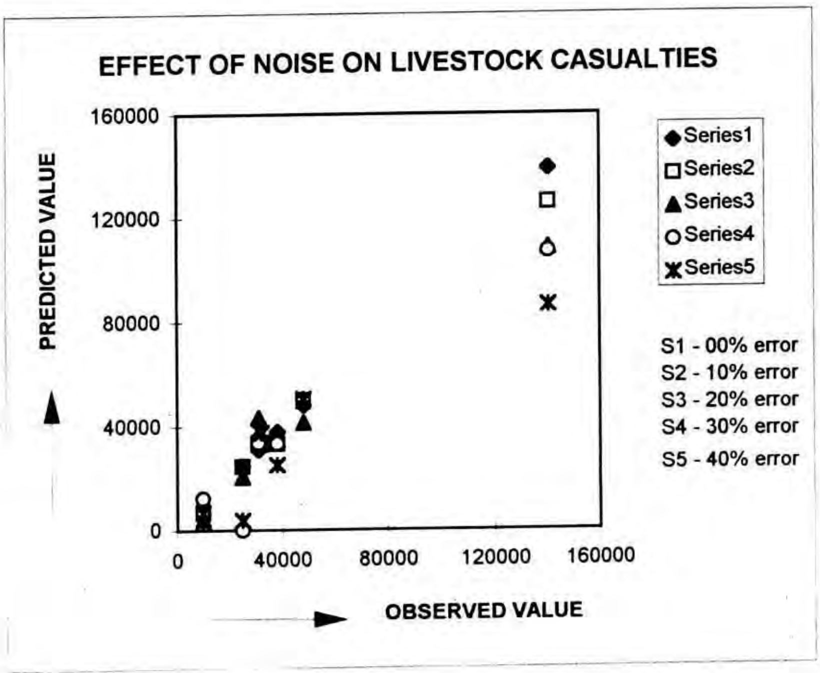

Figure 6.4b : Effect of Noise on Livestock Casualties

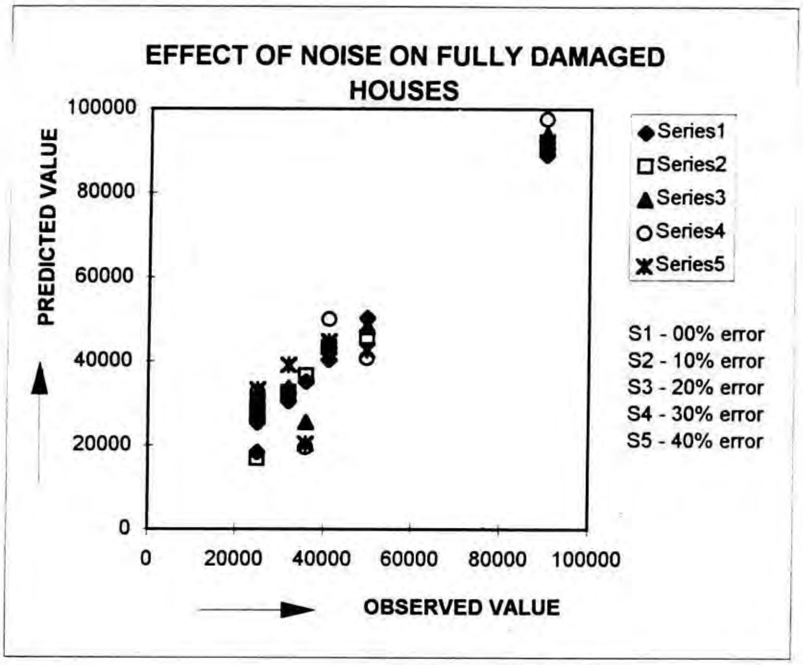

Figure 6.4c : Effect of Noise on Fully Damaged Houses

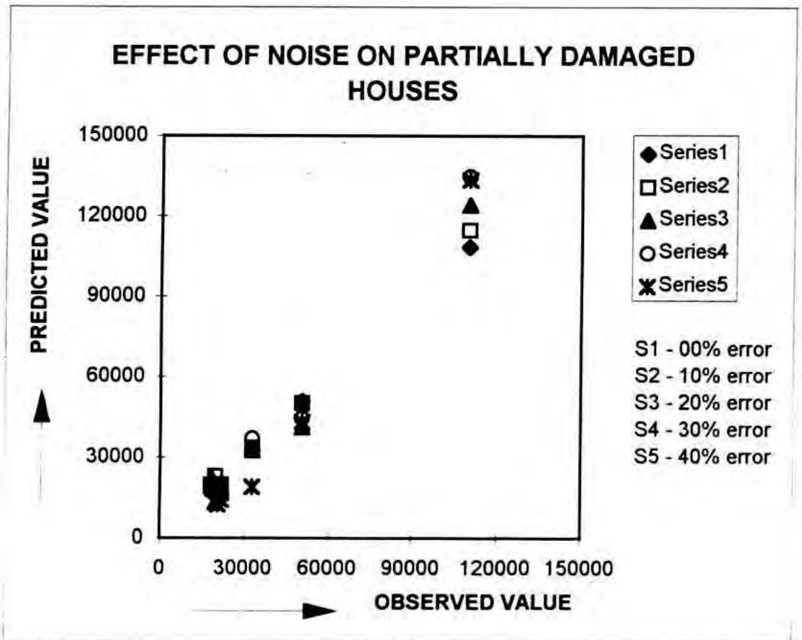

Figure 6.4d : Effect of Noise on Partially Damaged Houses

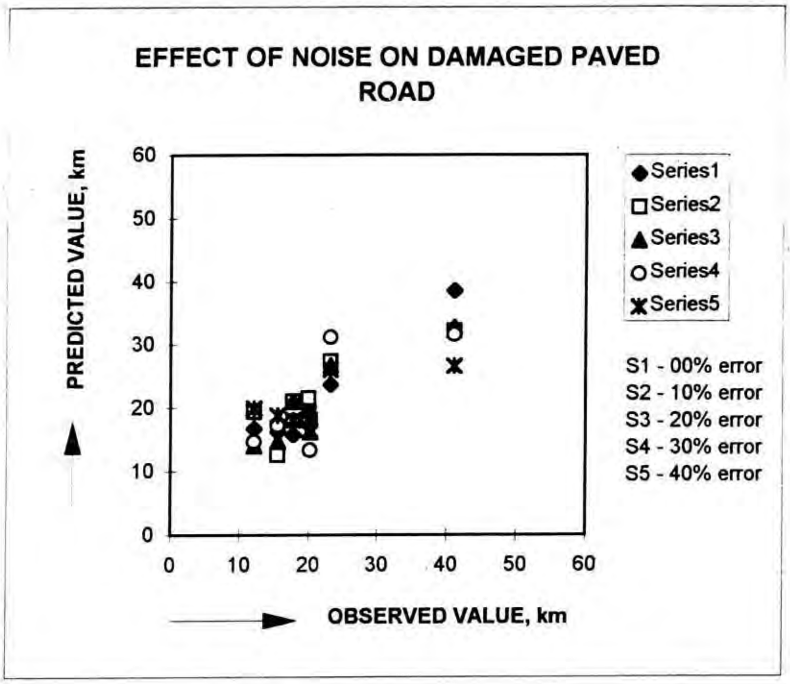

Figure 6.4e : Effect of Noise on Damaged Paved Road

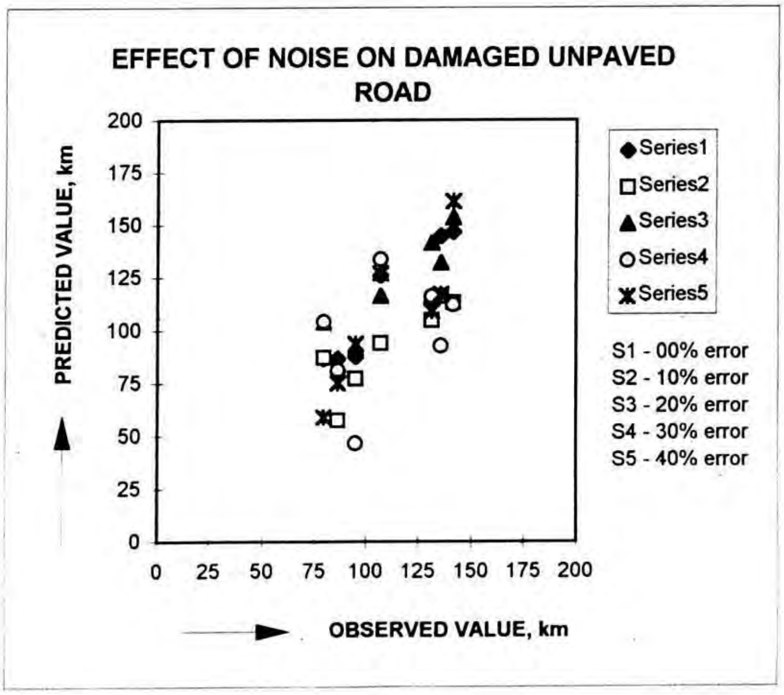

Figure 6.4f : Effect of Noise on Damaged Unpaved Road

CHAPTER - 7

CONCLUSION AND FUTURE RESEARCH DIRECTION

7.1 CONCLUSION

Bangladesh is a cyclone prone area. Major cyclones accompanied by very high wind speed and water surge hit the coastal areas of the country regularly. It is neither possible to prevent the cyclones from occurring nor feasible to build strong infrastructures for all the people which is capable of handling cyclones of any magnitude. Rather, it is plausible to arrange adequate relief and rehabilitation works beforehand to reduce the damages. To make arrangements of relief before the cyclone hits and within 24 hours after the cyclone hits, it is imperative to assess the damages which can be done by forecasting models. In this study several models have been developed to forecast the damages caused by cyclones. In the following sections the major aspects of the modelling process are summarized.

7.1.1 The Modelling Technique

Examining the structure of the problem and the characteristics of data, it was observed that conventional mathematical and empirical modelling techniques were not applicable in this case. The 'Neural Network' modelling technique was found to be the most appropriate one for forecasting the damages caused by cyclones. Back - propagation technique had been used for calibration purpose.

7.1.2 The Variables and Data

The variables included in the input side of the model were the characteristics of the cyclone defined by wind speed, height of water surge and distance from the path of cyclone as well as the socio - economic variables which include population, livestock, number of houses and amount of paved and unpaved roads.

Data had been collected from various sources such as Cyclone Preparedness Programme of Bangladesh Red Crescent Society, Bangladesh Meteorological Department and CARE, Bangladesh.

7.1.3 The Models and Their Application

Using the data and technique described above, the neural network models had been calibrated very successfully. The explanatory power of the models had been validated through regressing the outputs against the observed values. It was found that the predicted values are highly consistent with the observed values. The models were then applied to forecast the casualties in some hypothetical scenarios. The effects of noise of input data on the results of models had also been examined by using 'Monte Carlo Simulation'. It was observed that the output of the models remain fairly consistent for error upto twenty percent.

7.2 LIMITATIONS OF THE MODELS

The accuracy of the outputs of the models are fully dependent on the accuracy of the inputs. Among the input variables, the parameters related to cyclone influences the model outputs most significantly. For forecasting damages caused by cyclone using the models developed in the study, forecasts of cyclone parameters are required. If this forecast contain error, the outputs of the model will be erroneous. Therefore, wind speed and path of cyclone and height of water surge should be forecasted accurately.

Also, the damages will depend on the accuracy of cyclone warning system and people's awareness. An accurate warning system may increase the confidence and awareness of the people, and reduce damages. On the contrary, inaccurate warnings may reduce the confidence and awareness, and increase damages.

In this context, the models should be calibrated continuously and examined against the accuracy of the warning system.

7.3 FUTURE RESEARCH DIRECTION

The methodology and application developed in this study can extended in several directions. Firstly, the scope of application of the approach can be extended to incorporate other of variables and casualties to develop a comprehensive expert system. It can also be expanded to identify the damage prone zones qualitatively. Secondly, the approach can be extended to incorporate the effect of warning system, information system and improved awareness of the people.

The approaches developed in the study can be integrated into Geographic Information System (GIS) framework to develop an integrated system of data collection, analysis and presentation system.

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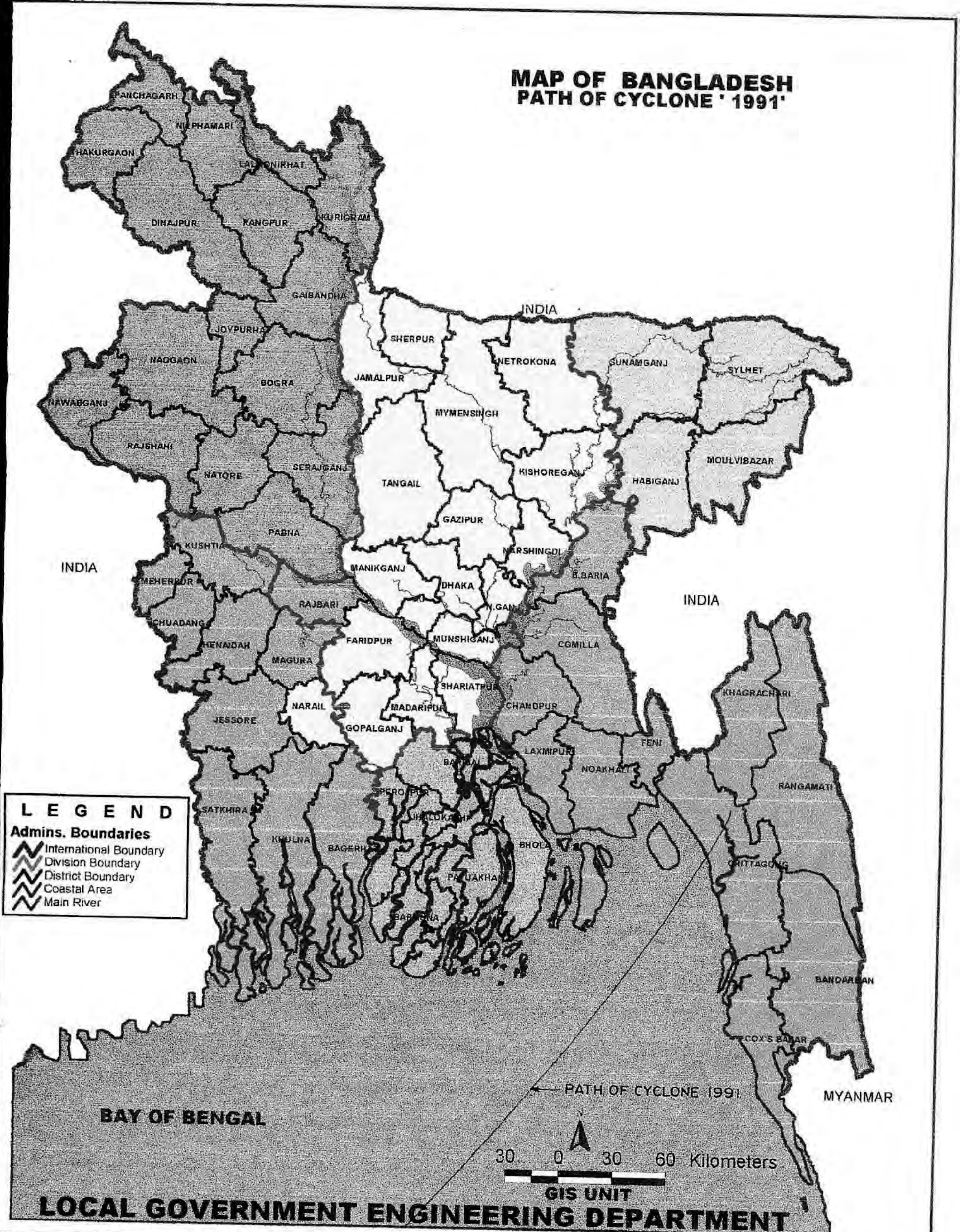
APPENDIX I

FIGURES AND PHOTOS OF CYCLONE 1991


MAP OF BANGLADESH
PATH OF CYCLONE ' 1991'
INDIA
INDIA
INDIA
MYANMAR
BAY OF BENGAL
PATH OF CYCLONE 1991
LEGEND
Admins. Boundaries
International Boundary
Division Boundary
District Boundary
Coastal Area
Main River
30 0 30 60 Kilometers
GIS UNIT
LOCAL GOVERNMENT ENGINEERING DEPARTMENT
DINAJPUR
RANGPUR
KURIGRAM
GAIBANDHA
NAOGAON
BOGRA
RAJSHAHI
NATORE
SERAJGANJ
PABNA
SHERPUR
JAMALPUR
NETROKONA
SUNAMGANJ
SYLHET
MYMENSINGH
MOULVIBAZAR
HABIGANJ
TANGAIL
GAZIPUR
MANIKGANJ
DHAKA
RAJBARI
FARIDPUR
MUNSHIGANJ
MAGURA
COMILLA
JESSORE
NARAIL
GOPALGANJ
CHANDPUR
FENI
NOAKHALI
RANGAMATI
KHULNA
BHOLA
BANDARBAN
KHAGRACHARI
B.BARIA

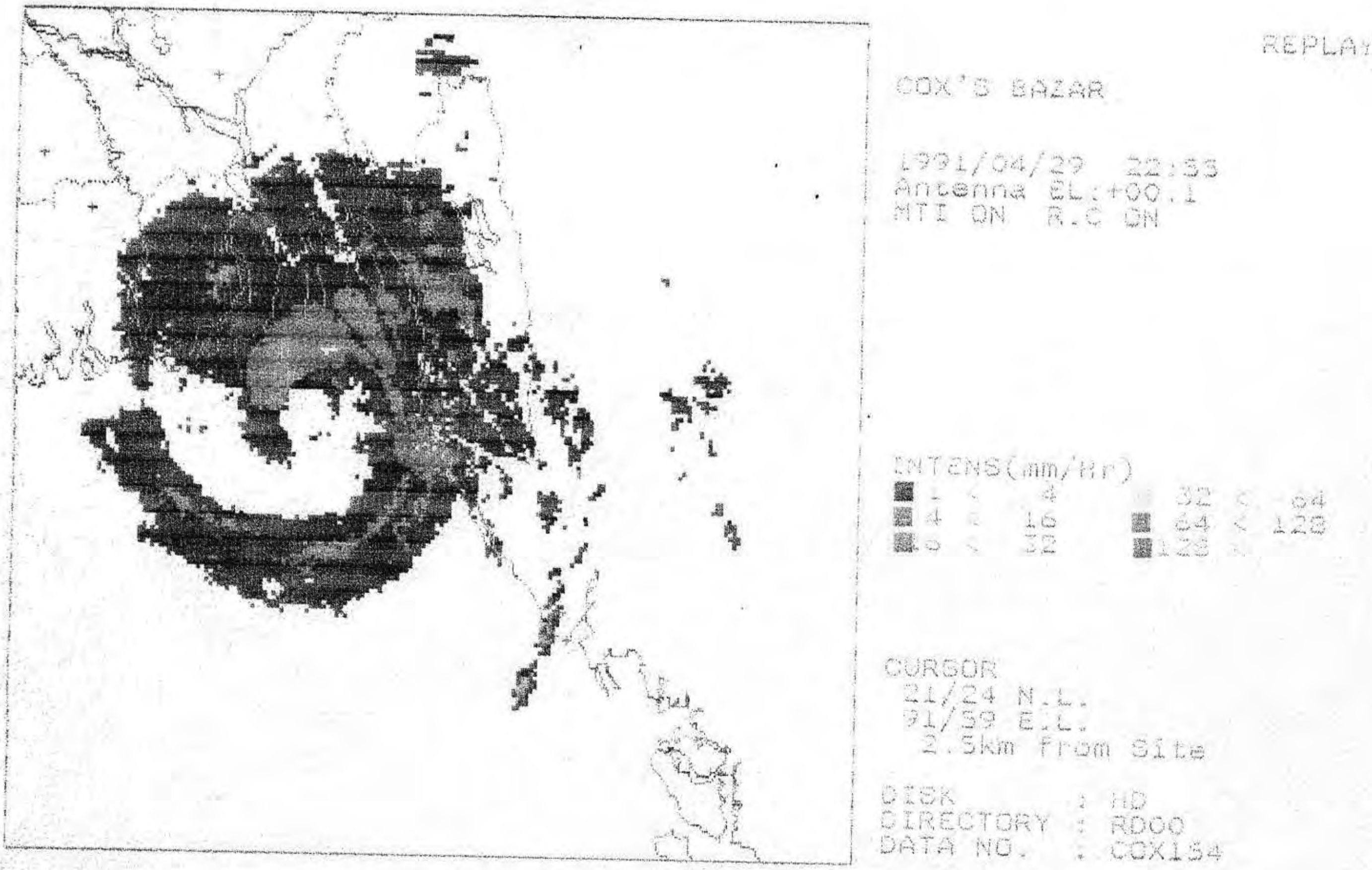


Figure : Photo of Cyclone before hitting the land at April 29 – 30 in 1991
(collected from BMD)

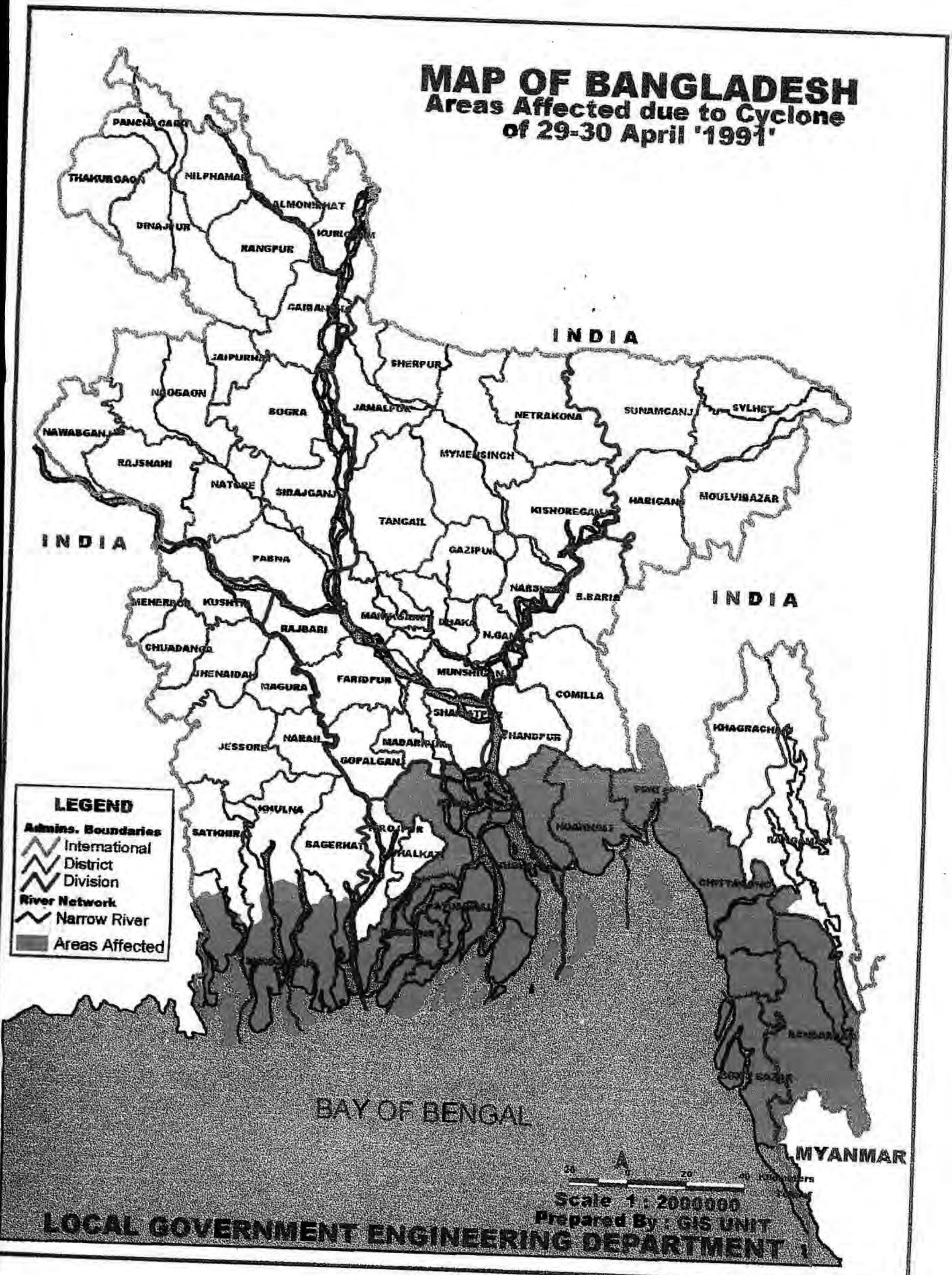

MAP OF BANGLADESH
Areas Affected due to Cyclone
of 29-30 April '1991'
INDIA
INDIA
INDIA
MYANMAR
BAY OF BENGAL
THAKURGAON
NILPHAMARI
DINAJPUR
RANGPUR
SHERPUR
NAOGAON
BOGRA
JAMALPUR
NETRAKONA
SUNAMGANJ
SYLHET
NAWABGANJ
RAJSHAHI
MYMENSINGH
SIRAJGANJ
HABIGANJ
MOULVIBAZAR
KISHOREGANJ
TANGAIL
PABNA
GAZIPUR
B.BARIA
KUSHTIA
RAJBARI
CHUADANGA
FARIDPUR
MAGURA
COMILLA
JESSORE
NARAIL
GOPALGANJ
KHAGRACHARI
KHULNA
SATKHIRA
BAGERHAT
LEGEND
Admins. Boundaries
International
District
Division
River Network
Narrow River
Areas Affected
Scale 1 : 2000000
Prepared By : GIS UNIT
LOCAL GOVERNMENT ENGINEERING DEPARTMENT

Photo of Damage Human Casualty

Photo of Damage House Casualty

Photo of Damage Livestock Casualty

Photo of Damage Road Casualty

Photo of Damage Human Casualty

Photo of Damage Human Casualty

Photo of Damage House Casualty

Photo of Damage House Casualty

Photo of Damages of Cyclone 1991

Photo of Damages of Cyclone 1991

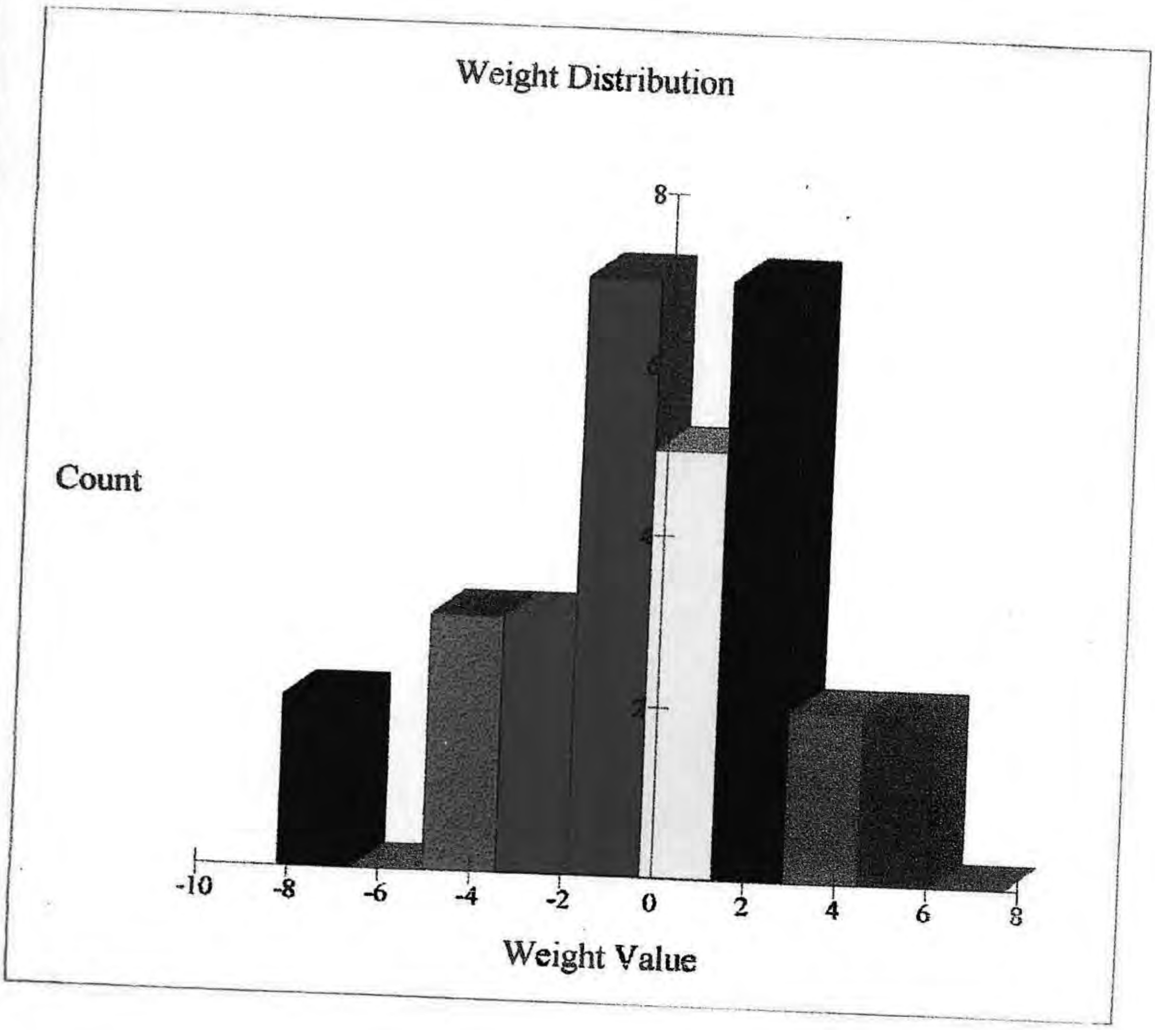
Photo of Damages of Cyclone 1991

Photo of Damages of Cyclone 1991

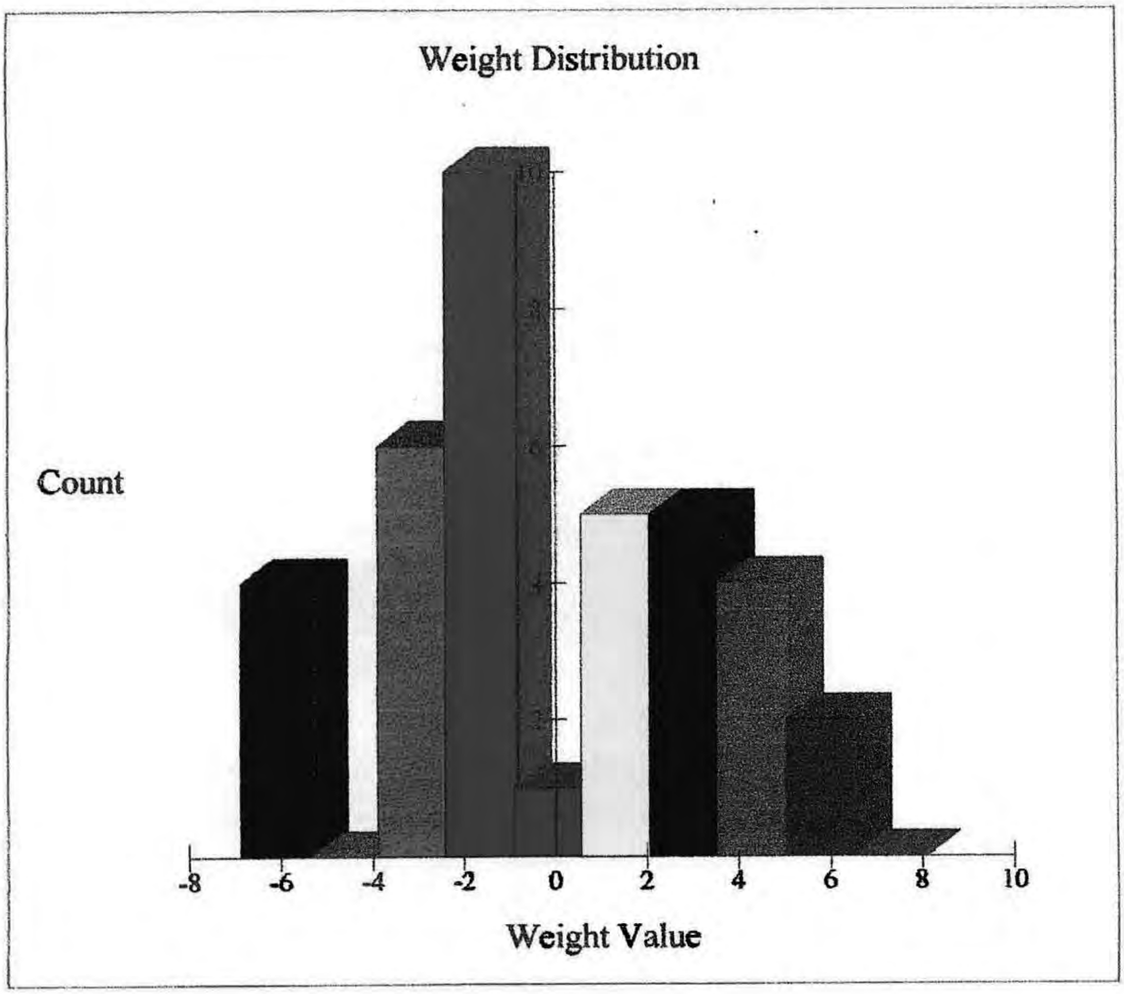
APPENDIX II

FIGURES OF NEURAL NETWORK MODEL

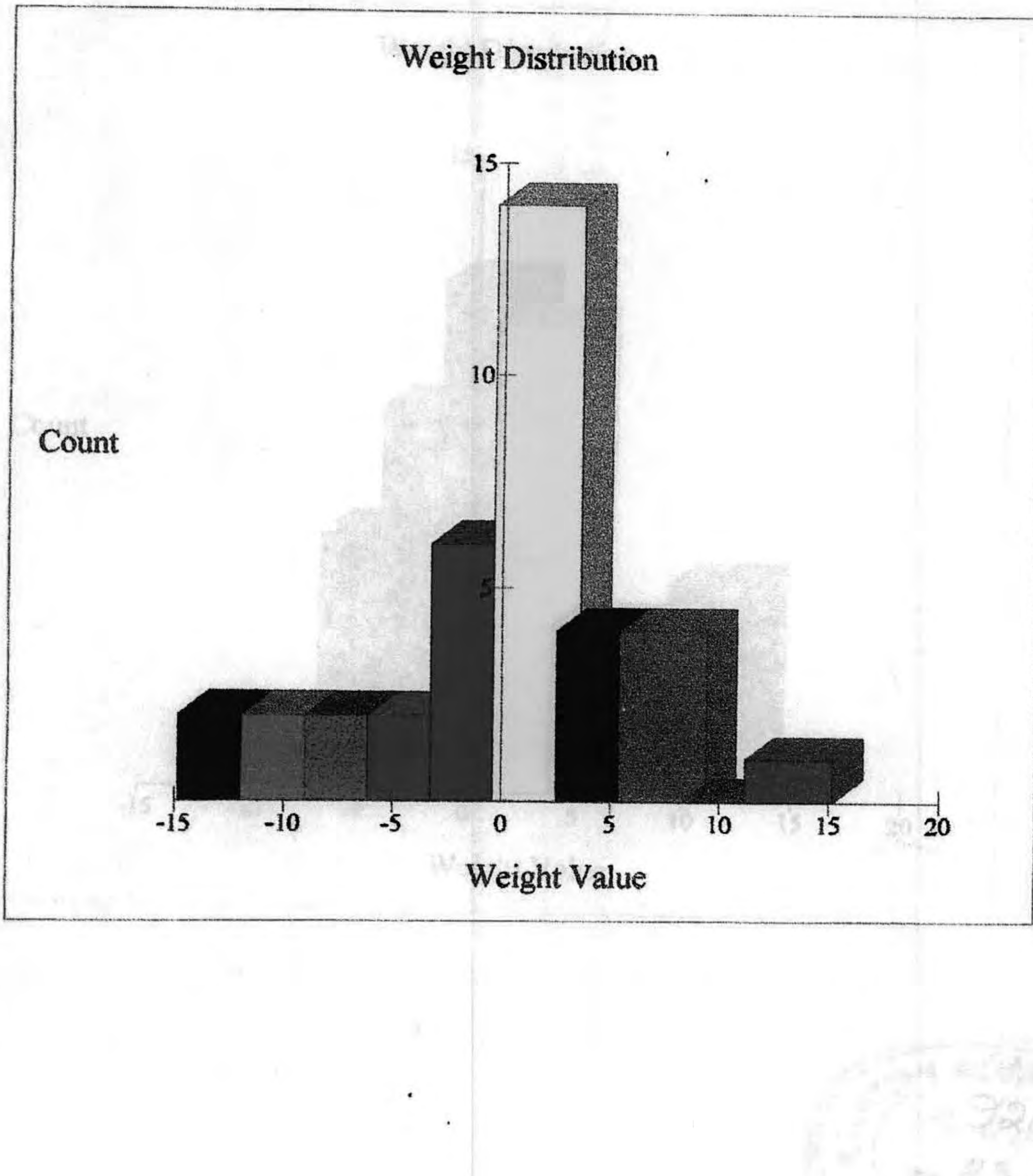
GRAPHICAL REPRESENTATION OF HUMAN NN NET - WEIGHT DISTRIBUTION



GRAPHICAL REPRESENTATION OF LIVESTOCK NN NET - WEIGHT DISTRIBUTION



GRAPHICAL REPRESENTATION OF HOUSE NN NET - WEIGHT DISTRIBUTION



GRAPHICAL REPRESENTATION OF ROAD NN NET - WEIGHT DISTRIBUTION