Estimation of environmental risks in construction projects in Puebla (Mexico): a neural network approach

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Abstract

In Mexico there is an urgent necessity to develop new ways for evaluating environmental risks, mainly based on new modelling techniques. This necessity is a critical problem for the Mexican government, due to the high development of the urban areas in Puebla. In addition, there is an absence of knowledge on this topic within many government agencies. The aim of this paper is to develop a neural network approach to assess the impact of environmental risks in construction projects in Puebla (Mexico). The objectives are: to create a human-intuition approach to advise government agencies towards the impacts of environmental risks, to store knowledge about risks in a single tool, to forecast the possible values of risks for developing appropriate contingence measures, to develop a flexible tool for use as an expert's opinion for similar future projects and to examine the feasibility of neural networks for pattern recognition. The data used for creating, training and testing the neural network was obtained from private contractors who are constantly involved with environmental risks. It was possible to demonstrate with the results, the pattern recognition of this neural approach, whilst testing the network with unknown data. In conclusion, this new approach for evaluating environmental risks in construction projects is an alternative tool that can be simulated for obtaining the probable risks impacts for a specific project. The methodology has a potential in modelling environmental risks, providing valuable outcomes for project managers working in government agencies.
Keywords: environmental risks, neural networks, project managers, construction management.

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1 Introduction

In developing countries, as is the case of Mexico, several problems arise due to the development of construction projects, especially in dense urban areas where the infrastructure has a very poor quality or is not sufficient to provide an acceptable level of service. The aim of this paper is to develop a neural network approach to assess the impact of environmental risks in construction projects in Puebla (Mexico). Risk management is not a new topic anymore in construction projects; however, it is important to formalise its use not only within projects, but also to involve the company. In this paper, the description and then the application of risk management is oriented to establish, at a company level, a risk management system. The system demonstrates the possibility to classify and evaluate environmental risks in a qualitative and quantitative manner. In addition, neural networks are introduced into the system in order to provide a new way of assessing environmental risks. Neural networks, as part of artificial intelligence, exhibit the feasibility for being used as a simulation technique for forecasting the possible values risks. The final part of the paper uses real data obtained from 50 different projects from diverse contractors. The system demonstrates, with the results, its reliability and workability.

2 Current problem and situation

The principal problem present in relation to the analysis and evaluation of environmental risks in construction projects in Mexico, is the absence of experts in both public and private agencies. It is, indeed, a critical problem because the country's infrastructure requires a considerable amount of investments to be improved, causing this boom of massive construction projects in urban areas. This situation is more critical when infrastructure projects are required in areas that are surrounded by natural eco-systems, industrial and inhabitant's zones. It is not enough only to import "state of the art" techniques designed in developed countries, because the necessities, as well as the government and contractors resources, are different and more limited than those of a developed country. Actually, is not possible to provide feasible solutions for many environmental problems existing in Puebla (Mexico), causing the necessity to search for alternative methods for satisfying these problems.

3 System definition

The system can be used as a methodical approach for quantifying, in terms of money, the environmental risks involved in construction projects. The system can be considered a human-intuition approach, which integrates the tools of Neural Network and Risk Management for the use and benefits of the contractor. The main aim of the system is: "to provide assistance to construction contractors in predicting the extra project cost caused by environmental risks". This will assist the contractor in keeping capital expenditure and delivery time to predetermined values and takes necessary managerial action to avoid a shortage

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of cash, bankruptcy, and gives early warning of cost overruns”. In other words, the system will provide more realistic project costs because the total environmental risk value will be calculated based on past experience and on 10 predefined environmental risks. The system is a flexible tool that can be used within different types of construction projects and also within a variety of evaluation areas.

4 System objectives

- To offer to the contractor a practical and useful environmental risk management tool, ready to be used at the bidding phase of a construction project.
- To develop a practical neuronal model for predicting the total environmental risk cost in construction projects.
- Refine, write-up and disseminate the results of the study and develop further the innovative findings and strategies.

5 Neural networks

Also referred to as connectionist architectures, parallel distributed processing, and neuromorphic systems, an artificial neural network (ANN) is an information processing paradigm inspired by the way the densely interconnected, parallel structure of the mammalian brain processes information. Artificial neural networks are collections of mathematical models that emulate some of the observed properties of biological nervous systems and draw on the analogies of adaptive biological learning. The key element of the ANN paradigm is the novel structure of the information processing system. It is composed of a large number of highly interconnected processing elements that are analogous to neurons and are tied together with weighted connections that are analogous to synapses Battelle Memorial Institute [1]. Today ANNs are being applied to an increasing number of real-world problems of considerable complexity (for example: in quality control, financial forecasting, economic forecasting, process modelling and management). They are good pattern recognition engines and robust classifiers, with the ability to generalize in making decisions about imprecise input data. They offer ideal solutions to a variety of classification problems such as speech, character and signal recognition, as well as functional prediction and system modelling where the physical processes are not understood or are highly complex.

6 System structure

The structure of the system is divided into three different sub-structures; each one describes the system from a general to a specific representation of its workability. The sub-structures are:

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- General system approach
- Neural structure
- System structure

It is possible to see in these substructures, the workability of the system. As can be observed, the three substructures are interrelated. The general system approach (Figure 1) shows the background of the system; the Neural structure (Figure 2) shows the specific configuration of the network. Finally, the System structure (Figure 3) shows the work-flow steps of the system. The graphical representations of the sub-structures are:

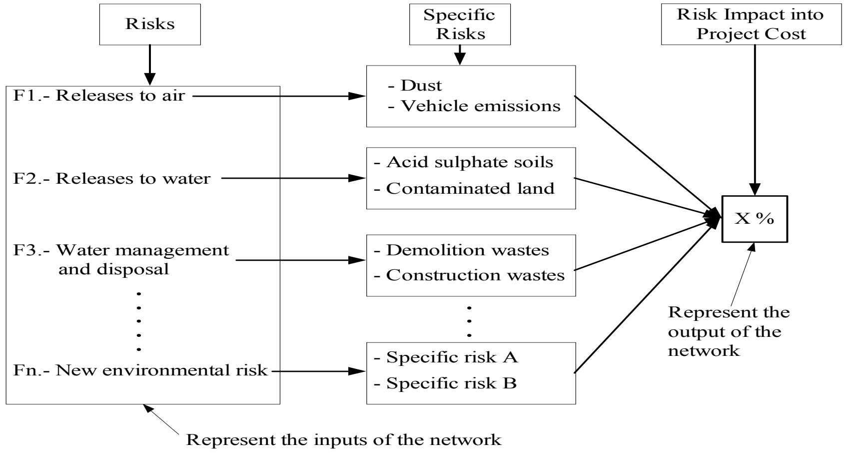

Figure 1: General system approach.

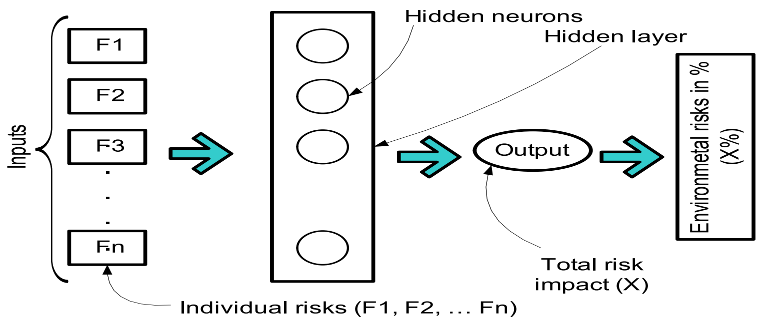

Figure 2: Neural structure.

While analysing Figure 4, the complete idea of the system can be followed. From the first step until the presentation of the project cost to the client

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(Step 12). All the procedures of the system follow a logical path in all the phases; this is of great help for understanding the mechanism of the system.

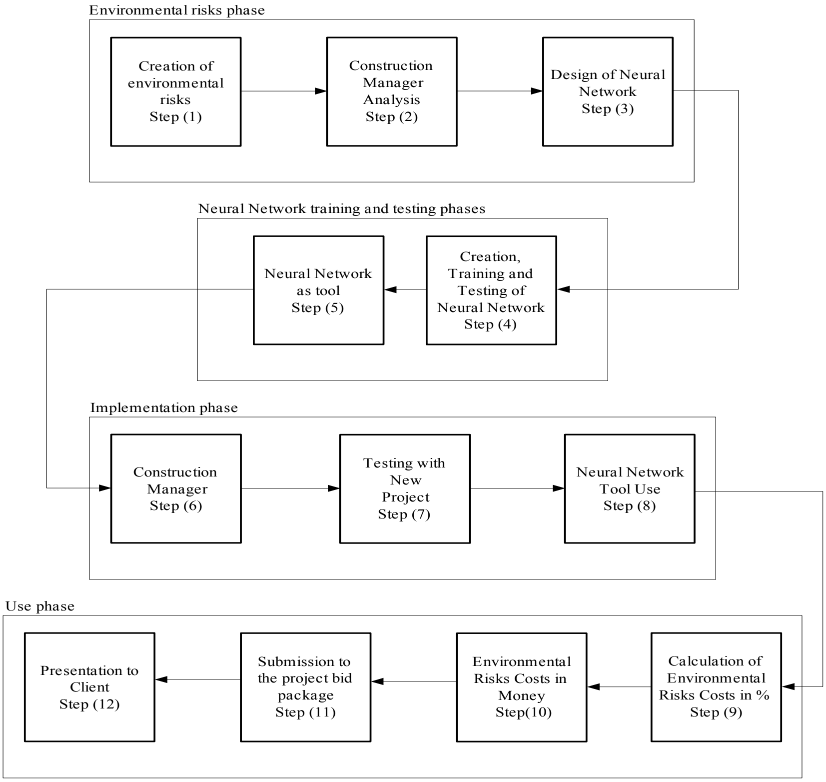

Figure 3: System structure.

7 Environmental risks

For the purpose of this work, a risk check-list was designed in order to obtain the input and output data from the contractors related to environmental risks. The list shown on Table 1 is only a representative list, nevertheless, it encloses the most common environmental risks present in this case in Puebla. Ten main risks where found to be the ones that affect the project more. In addition, specific risks, which are derived from the main risks, are included in the list below.

It is true that for some experts, the list of risks shown in Table 1 is limited by only 10 main environmental risks. The reality is, that for designing a list that can include all the environmental risks existing in construction projects will cause the system not to offer practical results. For that reason, specific environmental risks were included in the list (Table 1), as a matter for covering details which are not possible to model or include in the present system.

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Table 1: Environmental risks.

Risk Number	Risk Description	Specific Risks
F1	Releases to air	Ozone-depleting substances, Greenhouse gases, Dust, Vehicle emissions, Fumes from burning, Volatiles from solvents, paints and glues
F2	Releases to water	Discharge from sedimentation basins, Spillages from storage depots, Soil erosion and generation of sediment in run-off, Pollution sources (oils, fuels, wastewater, drilling fluids, concrete washings and residues), Acid sulphate soils (surface runoff), Contaminated land (surface runoff and groundwater pollution), Stormwater drainage and flooding, Sewage collection and domestic wastewater (construction sites).
F3	Waste management and disposal	Demolition wastes, Construction wastes, Packaging wastes, Litter/garbage, Contaminated waste handling and disposal.
F4	Contamination of land	Runoff from areas of contaminated land, Encapsulation and remediation design, Chemical storage, Fuel installations.
F5	Impact on local communities	Level of community participation, Access and traffic disruptions, Noise, Construction noise, Dust
F6	Use of raw materials and natural resources	Energy usage (construction requirements), Construction materials, Life cycle impacts of construction materials
F7	Ecological conservation	Identification and protection of ecosystems, Noise impacts on conservation areas, Impacts on threatened species, Disturbance of flora and fauna
F8	Heritage conservation	Identification and protection of features of heritage significance
F9	Emergencies	Environmental incident (eg. a spill), Spill prevention control and counter measures plan, Emergency response plan, Evacuation plan, Firefighting procedures, Bomb threat procedures
F10	Ecologically sustainable development (ESD)	Level of incorporation of ESD into architecture, Degree of meeting the guidelines and strategy, Financial viability, Fit for purpose considerations

8 Data analysis and model

The data collected from the contractors, was separated into data for being use as inputs and outputs. Developing with this the vectors necessary for designing, training and testing the network. It was possible to collect data from 50 finished projects, 40 projects were used for training the neural network and 10 for testing it. The environmental risks which represent the input data (input neurons) can be observed in Table 1 (column 2). The values related to the output data (output neurons), were obtained directly from the contractors.

In order to clarify the idea of relating the inputs and outputs used with the system a representative model was created; its graphical and mathematical description is as follow:

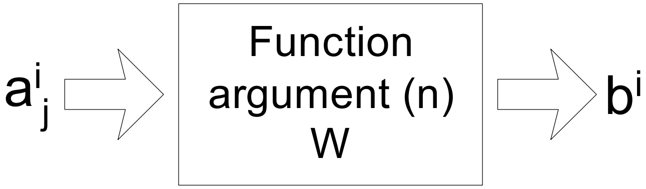

Figure 4: Input-output relation.

Where:

a = is the input vector, where i represents the project number and j represents the risk number; a is the value of the risk.

b = is the output vector, where i represents the project number and b the total value of risk for each project.

n = is the argument of the transfer function.

W = are the scalar weights

The presentation of the input and output vectors is as follows:

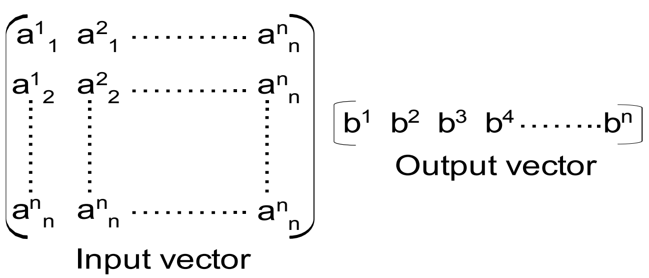

Figure 5: System vectors.

9 Results

A number of five different networks (Tn1, Tn3, Tn6, Tn9 and Tn11) where trained. The difference between the networks is the number of neurons in the hidden neuron. For example, Tn1 is a network that has only 1 neuron at the hidden layer, in the case of Tn6, there are 6 neurons at the hidden layer. The other parameters (transfer function, training algorithm and number of inputs and

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outputs) used to perform the training of the networks were the same. The next figure shows the results obtained for each network during their training.

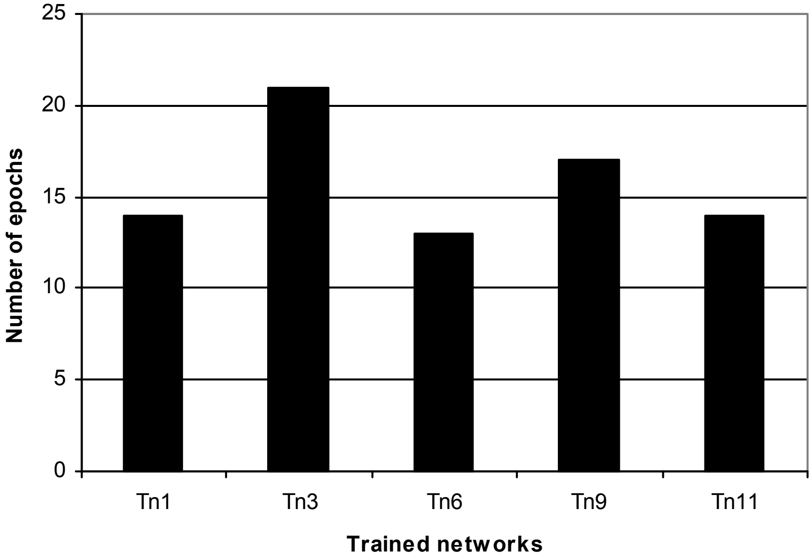

Figure 6: Networks training performance.

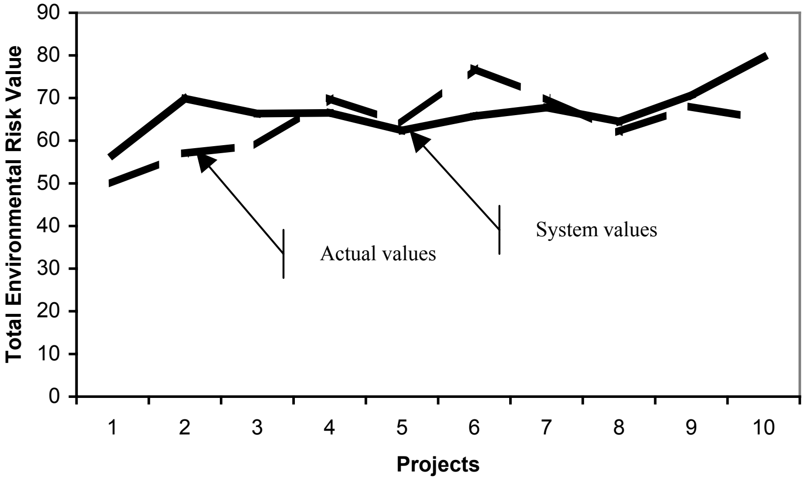

Figure 7: Testing results.

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As can be observed in Figure 6, all five networks did not require to perform a considerable number of epochs to obtain a good performance (small error). For this case, all the networks obtain the same value of the error at this training phase (0.00552135). The difference is that, for example, it took the Tn3 network around 21 epochs to obtain this error, and in the case for the Tn6 network it took only 13 epochs.

In the case of the testing phase, ten finished projects were used for obtaining the simulation results from the chosen network. The results of the simulation are shown in Figure 7 and Table 2, the Tn1 network was selected to perform the simulation. Naturally, the values between the system and the ones from the contractors are not identical; nevertheless, it is noticeable that the systems forecast some acceptable values of the total environmental risks. During the first three projects the values of the system are under the actual values, then along projects 4, 5, 6 and 7 the system values are above the actual values, and finally the values of the system are above the actual values for projects 8, 9 and 10.

Table 2 shows the difference in % between the actual values and the system values of the total environmental risk.

Table 2: Comparison of results.

Project (1)	Current Total Environmental Risk in % (2)	Total Environmental Risk (with ANN) in % (3)	Difference in % 4 (2-3)
1	50	56.63	6.83
2	57	69.83	12.83
3	59	66.36	9.36
4	70	66.49	3.51
5	64	62.40	1.60
6	77	65.74	11.26
7	70	67.63	2.37
8	62	64.51	2.51
9	68	70.65	2.65
10	65	79.62	4.62

While observing the results in Table 2, is possible to see that in only three projects the difference between the current values and the system values is considerable (projects 2, 6 and 3). In one project (project 3) the difference was not so marked. Finally with the last 6 projects (projects 4, 5, 7, 8, 9 and 10), the difference was acceptable. Within the network it was possible to recognise the patterns of the 10 projects used for testing.

It is extremely important to define in the construction contracts, clear rules for managing environmental risks. In other words, it is very important for the “good relation” between construction parties, to define how the possible environmental risks will be tackled, transfer, share or mitigate.

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Contracting parties should note that the relative distribution of assumed risks will vary according to the compensation method chosen by the parties. For example, under a limp sum basis of compensation, where the contractor agrees to furnish all labor and materials and to perform all work necessary to complete the contract for a fixed-price, the contractor will assume more project risks than under a cost of the work plus a fee basis, where the contractor is reimbursed for the cost of the work plus receives a fixed fee or a percentage of the total cost as a fee McCallum 2000 [2].

10 Conclusions

The system offers to the contractor a considerable advantage in predicting the possible value of the total environmental risk. With this value, the contractor has the possibility to include this extra cost into the project cost, or even to discuss this additional cost with the client. With the neural system it was possible to evaluate the environmental risks in two ways: qualitative because the risks were classified in extreme high, very high, etc); and quantitative because it was possible to evaluate risks from 0 (Extreme low) until 100 (Extreme high). This is a great advantage because two different types of results can be obtained with a single tool. The neural system is a very flexible technique; it can be use with different types of projects because the risks are adjustable. The complete process to implement the neural system is simple and practical. In the other side, it is necessary for the project manager to have knowledge of neural networks, which can be covered with the use of some of the commercial software tools available. The objective was to show an alternative way of assessing environmental risks due the critical situation of having an absence of experts.

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