NEURAL NETWORK APPLICATION FOR BUILDING PROJECTS COST ESTIMATION

Ass. Prof. Dr. Zouhair Al-Daoud **Ali Mohamed Humod**
University of Baghdad, College of Engineering, Mechanical Engineering Department

ABSTRACT

This work presents a neural network based cost estimating method, developed for the generation of conceptual cost estimates for total building and electromechanical systems in building project, by using eight parameters available at the early design phase. This model establishes a methodology that can provide an economical and rapid means of cost estimating. Eighteen High rise building projects, built between 1996 and 2009 in Middle East countries used in this study. The performance of developed cost models was tested against costs incurred by projects not used in training of those models. Results show the mean absolute percentage errors (MAPE) are between 1.51% and 4.771% for the five networks, and the maximum/minimum deviation of the cost estimation is 10.2/0.17. These figures considered good cost estimation at the early design stage.

الخلاصة

تقدم هذه الرسالة نموذجا عمليا لتخمين الكلفة اعتمادا على تقنية غير تقليدية و هي الشبكات العصبية الاصطناعية. التي تتضمن الكلفة الكلية لبناء الأبراج السكنية و الفندقية بالإضافة لكلف المنظومات الميكانيكية و الكهربائية، و بالإعتماد على ثمانية عناصر تصف حجم المشروع و خصائصه متوفرة في أوائل مراحل التصميم، و قد أستخدم لغرض تدريب و اختبار هذه الشبكات ثمانية عشر مشروعا حقيقيا مبنية كلها في دول الشرق الأوسط في الفترة ما بين 1996و 2009. تعتبر الشبكات العصبية الاصطناعية فرع من الذكاء الصناعي و تطبيقات علوم الحاسبات الحديثة، وقد استخدمت في هذا البحث لكفاءتها في إدارة الكلف و المعلومات للتطبيقات الهندسية و لإنها تعتمد في بنائها و تدريبها على معلومات واقعية لمشاريع حقيقية، مما أعطاها إمكانية تعميمها لتخمين كلف مشاريع جديدة. و من المعلوم إن تخمين كلف المشاريع في الأطوار الابتدائية (التخطيط و التصميم) أصبح هو العنصر المحدد و الأساسي في اتخاذ القرارات الحاسمة في الوقت المناسب و خصوصا في ظل التنافس العالمي بين الشركات و المؤسسات العالمية و المحلية و كذلك تقليل من نسب الأرباح المجتبة من هذه المشاريع. إن كفاءة النموذج المقدم اختبرت من خلال تطبيق معلومات لمشاريع لم تدخل في عملية تدريب الشبكات، و قد أظهرت نتائج الاختبارات للشبكات الخمسة ما بين (1.51 - 4.77)% كمعدل المطلق للنسبة المئوية للخطأ ، كما إن أعلى و أقل خطأ لكل حالة على إنفراد كان (10.2 و 0.17)% على التوالي، و هي تعتبر نتائج جيدة إذا ما قورنت بالطرق التقليدية.

KEYWORDS: **Neural Network, Cost Estimation, Project Managem ent, Functional Analysis, Artificial Intelligence.**

INTRODUCTION

Cost is one of the major criteria in decision making at the early stages of a project design process. In today's globally competitive world, diminishing profit margins and decreasing market shares, cost control plays a major role for being competitive while maintaining high quality levels. The cost of a project has a significant effects by decisions made at the design phase. While this influence decreases through all phases of the building project, the committed costs increase. Increasing project costs render effective and efficient decision making on cost issues a necessary for designers. To this end, designers use a number of cost estimating techniques and intuitive judgments by utilizing both their experience and data from previous projects [**Duncan, 1996**], [**US. Department of Defense,1995**] & [**CII,1998**].

The most important thing you can do to enhance a project's value is to include the right professionals for a project as early in the design process as possible. If you look at the following Cost Influence Curve **Fig.1**, you will notice that the time to achieve significant cost savings is before construction begins [**Kellogg & Kimsey,2008**].

Several cost estimating methods for the different phases of a project like; Preliminary cost estimate, Elemental (functional analysis) estimate, Unit price estimate, Detailed cost estimate, Parametric cost estimates and others [**R.S. Means,1997**], [**Ayed,1997**] & [**Evans1,2007**].

Traditional cost estimating procedures follow a quantity take off, while comparative cost estimating relies on parameters such as type, size, and capacity of project. While traditional cost estimating makes use of plans and specifications, comparative cost estimating assumes a relationship between the final cost and the basic design variables of the project [**Evans1,2007**].

Developments in computer and software technology have facilitated novel approaches for cost estimation. By the emergence of Artificial Intelligence (AI) tools (i.e., neural networks), possible multi- and non-linear relationships can now be investigated. Methods involving the new technology yield results that are both more realistic and accurate vis-à-vis real life conditions.

ARTIFICIAL NEURAL NETWORK

Neural network is an artificial intelligence model originally designed to replicate the human brain's learning process. The model consists of three main layers: input data layer (example the property attributes), hidden layer(s) (commonly referred as "black box"), and output layer (results), see **Fig.2** Neural network is an interconnected network of artificial neurons with a rule to adjust the strength or weight of the connections between the units in response to externally supplied data [**Flood,1994**].

Fig. 3 and eq. (1) show the neural network structure and training equation of the feed-forward neural network.

$$Y_k = g\left(\sum_{j=1}^{m} w_{jk} f_j\left(\sum_{i=1}^{n} w_{ij} * x_i - Si\right) - Sj\right) \quad (1)$$

Where Y_k : network output
f& g: transfer function of the hidden and output layer, respectively.
X_i: network input
i: input layer
j: hidden layer — w_{ij}: weight to layer j from layer I
k: output layer — w_{jk}: weight to layer k from layer j
S_i: bias from layer i to layer j
S_j: bias form layer j to layer k

NEURAL NETWORK MODEL

Current practice indicates the generation of five types of cost estimates:

- Total cost of the project;
- Cost of plumbing system;
- Cost of heating, ventilation and air conditioning system (HVAC);
- Cost of fire protection system;
- Cost of electrical system.

Accordingly, five neural network models were developed. Each network has the same inputs shown in table (1).

APPLICATIONS

a) Data

Eighteen High-rise building projects, built between 1996 and 2009, were collected over a four-month period, from Dar Al-Handasah – Shair and partners- for consultant engineering, the second rated international design firms in hotels and general building in 2006 according to ENR [**ENR,2006**]. Sample of projects data shown in table (2).

b) Training and testing of the neural network model

The data sample (eighteen projects) divided into two subsets: training, and test. These sets contained, respectively, 78%, and 22%, of the project cases considered in the data sample. The data extraction performed randomly. The training set used for training of each network. The test set used to check the performance of the learning process, during the network's training.

The network had not seen those cases during its training. Performance primarily measured against the accuracy observed in the production set. Once the networks were performing with an acceptable percentage of error, they considered trained and ready to assist the user in generating cost estimates.

For the problem at hand, Matlab-NN tool box employed for its ease of use, Speed of training, and for its host of Neural Network architectures including back propagation, with flexible user-optimization of training parameters. NN tool box includes a simplified set of procedures for building and executing a complete, powerful Neural Networks application. The user has the flexibility to specify own learning rate, activation functions, and initial weight range on a layer basis in the design module, **Fig. 4** show the flow chart for developing new network, this procedure was applied for the five networks.

c) Application Results

Data from four projects used for testing purposes. Results of the five networks shown in table (3):

The accuracy of the cost estimates can be close to an expert system developed by Mohamed and Celik [**Mohamed,2002**], where estimated total costs were found to be between the range of 2% and 4% of the actual cost. While the FIDIC (international federation of consultant engineer), where the bidding of any contract in infrastructure not to exceed 13% of the estimated value, and the bidding of contract in building not to exceed 6% of the estimated value [**FIDIC,2007**].

These results compare favorably with past research that has shown that traditional methods of cost estimation are less accurate, as evidenced by reported values of MAPE between 20.8% [Skitmore,1 990] and 27.9% [**Lowe,1996**].

DISCUSSION OF THE RESULTS

In present work, neural networks used to model the relationship between inputs (location, date and design variables) and outputs (cost of total building and electromechanical systems).

Performance of the training many algorithms were tested and the Scaled conjugate gradient backpropagation (trainscg), showed the best accuracy results.

The simulated annealing technique used to capture the best solution (weights and biases) among several local minima.
One of methods for improving network generalization is to use a network that is just large enough (number of hidden layers and number of neurons in each) to provide an adequate fit. The larger the network, the more complex the functions the network can create. If we use a small network, it will not have enough power over fit the data.
Unfortunately, it is difficult to know beforehand how large a network should be for a specific application.
Therefore, change architecture by raising the no. of neuron in hidden layer is used starting from 8 neurons to optimize network architecture and to improve the generalization. Adding more hidden layers is tried but it increased the error in test set.

CONCLUSIONS

- The using a neural network for cost estimation shown to be capable of providing accurate estimates of building and electromechanical systems cost per square meter by using eight parameters available at the early design phase. This model establishes a methodology that can provide an economical and rapid means of cost estimating for the total building and electromechanical systems of future building design processes.
- When increase the number of neuron in hidden layer, it is not always increase the result accuracy, because when the number of hidden neurons is too large the network overfit the training data, in which the network perform well for training data only and cannot generalize its knowledge to unseen (new) operating conditions and when the number of hidden neurons is too small, the network suffers underfitting problem, in which the network cannot learn the relationship distributed among training data set.

REFERENCES

- Amr S. Ayed "Parametric Cost Estimating of Highway Projects using Neural Networks". M.Sc. Thesis, Newfoundland, Canada. 1997
- CII. "Improving Early Estimates". Construction industry Institute. University of Texas at Austin. Austin, TX, USA. 1998
- D.K. Evans1, Dr J.D. Lanham1, Dr R. Marsh "Cost estimation method selection: matching user requirement and knowledge availability to methods". University of West of England, Bristol, UK. 2007
- ENR Engineering News-Record. "2006 global construction sourcebook." 2006.
- FIDIC (international federation of consultant engineer), www.fidic.org/ ,2007.
- Flood, I., and Kartam N. "Neural networks in civil engineering. I: Principles and Understanding, and II: Systems and application." Journal of Computing in Civil Engineering. ASCE. 8(Z). 131 -162. 1994
- Kellogg & Kimsey, Inc website, www.kelloggkimsey.com/.2008.
- Lowe, D. J. Experiential learning in design cost estimating. Ph.D. thesis, UMIST. 1996

- Mohamed A, Celik T. "Knowledge based-system for alternative design cost estimating and scheduling." Knowledge Based Systems, USA. 2002

- R.S. Means "Building Construction Cost Data". R.S. Means Company Inc., Kingston, MA. 1997

- Skitmore, M., Stradling, S., Tuohy, A. and Mkwezalamba, H. "The Accuracy of Construction Price Forecasts," University of Salford, Manchester. 1990

- US. Department of Defense. "Parametric Cost Estimating Handbook." Department of Defense, United States of America. Arlington, VA, USA. 1995

- William R. Duncan. "A guide to the project management body of knowledge", Project Management Institution, USA. 1996

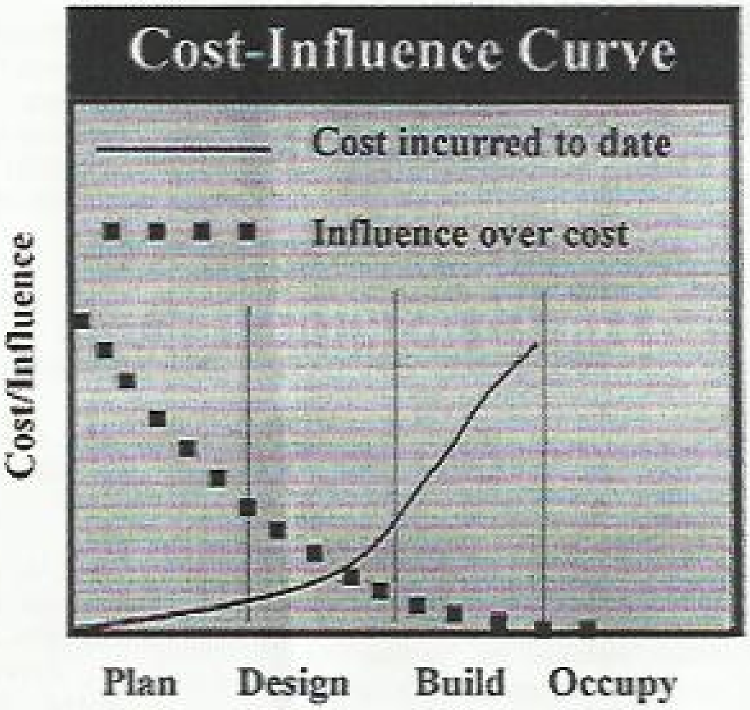

Fig. 1: Cost-Influence Curve

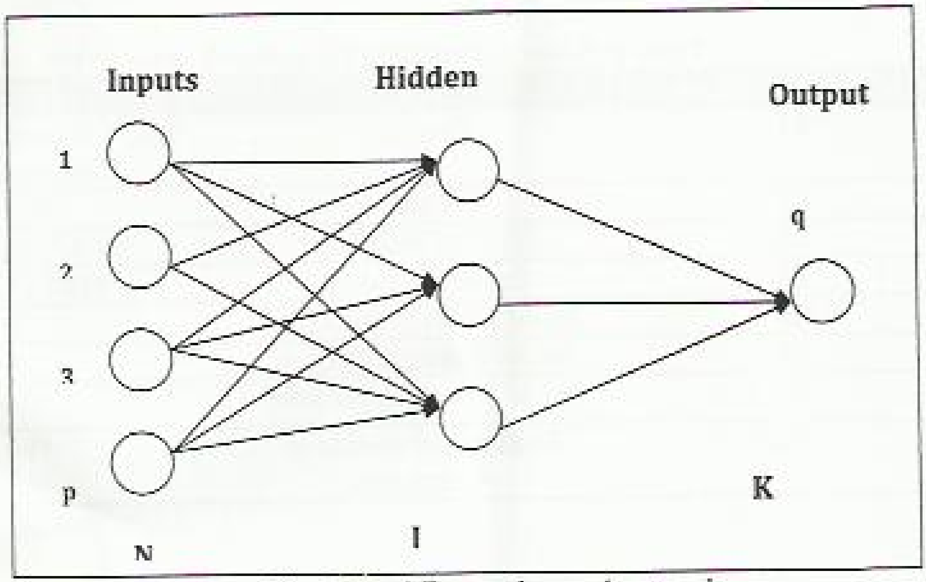

Fig. 2: Feed-Forward neural network

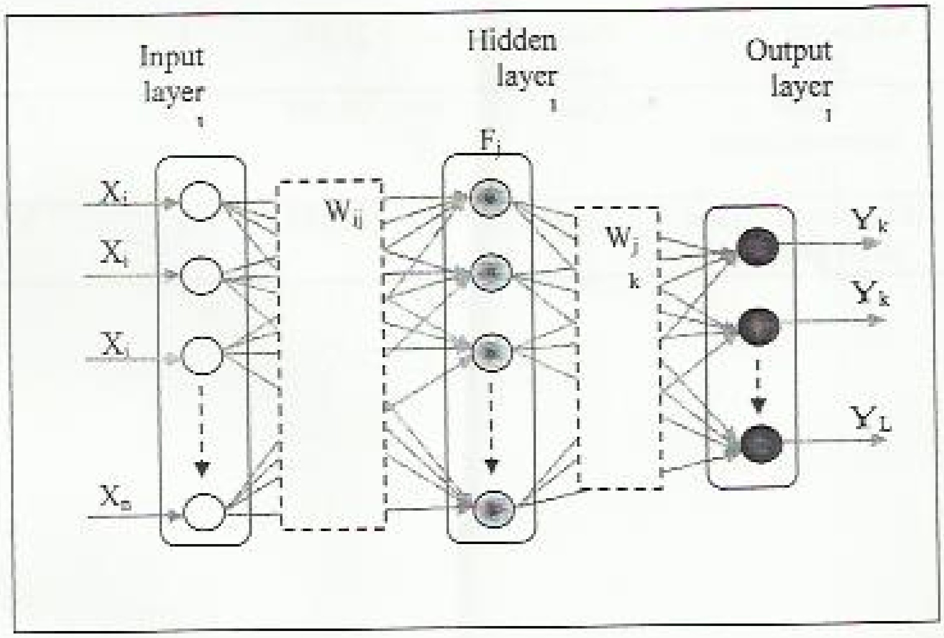

Fig. 3: Neural network structure

Table 1: 8-key parameters for network input layer

Design Parameter	Definition	Range
X1	Country	Iraq, Lebanon, KSA, Egypt, Qatar and Others
X2	Date	1996-2016
X3	Type of Building	HRAP (0), Hotel (1)
X4	Gross Floor Area	8500-113000 m^2
X5	No. of Floors in Basement	1-5
X6	No. of Floors in Podium	1-3
X7	No. of Floors Upper level	5-40
X8	Total No. of Rooms or Apartments	24-1735

Table: 2 Sample of projects data

	Project Name	Location	Date	GFA m2	Basement floors	Podium Floors	Tower Floors	No. of Rooms
1	Grand Hyatt Hotel Beirut	Lebanon	2009	54,541	5	3	8	402
2	Al Khojah Tower Jaddah	Saudi Arabia	2001	21,741	1	2	12	24
3	Doha Intercontinental Hotel	Qatar	1999	27,000	2	3	6	300
4	Hilton International Hotel Hurghada	Egypt	1996	22,152	2	3	12	225

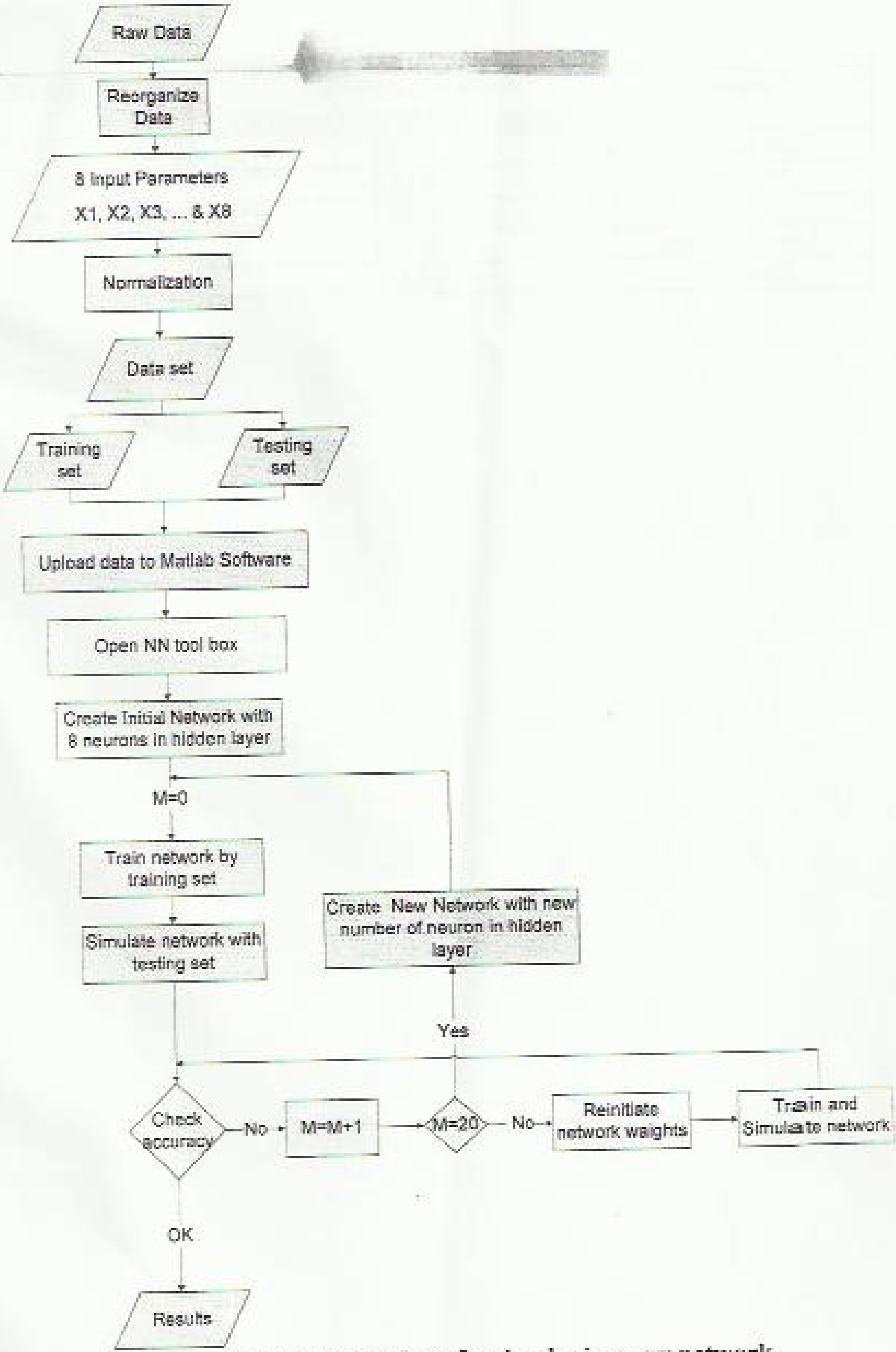

Fig. (4): Flow chart for developing new network

Table 3: Results of the five network

Network	No. of neuron in Input(N): Hidden(J): Output(K)	MAPE %
Total building	8:14:1	1.51
Plumbing	8:18:1	4.627
Hvac	8:10:1	3.604
Fire protection	8:12:1	4.771
Electrical	8:8:1	2.99