UNIVERSITI PUTRA MALAYSIA

DEVELOPMENT OF AN INNOVATIVE NEURO-FUZZY ASSESSMENT SYSTEM FOR THE EUROPEAN FOUNDATION FOR QUALITY MANAGEMENT

JAVAD DODANGEH

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By

JAVAD DODANGEH

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfillment of the Requirement for the Degree of Doctor of Philosophy

February 2013

DEDICATION

I dedicate this thesis to the memory of my grandfather, Younesali Dodangeh, who passed away in June 2007. He played a vital role in my successions and studies. And to my parents whose love and encouragement are the most wonderful of the many blessings that god has granted me.

Finally, this thesis is dedicated to all those who believe in the richness of learning.

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirements for degree of Doctor of Philosophy

DEVELOPMENT OF AN INNOVATIVE NEURO-FUZZY ASSESSMENT SYSTEM FOR THE EUROPEAN FOUNDATION FOR QUALITY MANAGEMENT

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Chairman: Professor Rosnah bt. Mohd. Yusuff, PhD

Faculty: Engineering

In growingly competitive business environment, numerous organizations adopt the total quality management (TQM) approach to achieve business excellence. To monitor the progress towards business excellence, thousands of organizations across the world use self-assessment on a regular basis. The European Foundation for Quality Management (EFQM) is among the most popular ones. However, the current self-assessment methods in EFQM model have some drawbacks and problems. Critical review of self-assessment models from literature showed that the majority of the assessment and self-assessment models developed were ambiguous, assumed assessment is only limited to certain and precise data and inability to consider the empirical investigation and expert knowledge in scoring and lack of a non-linear methodology for assessment system. Besides, none of the examined models developed consider simultaneous knowledge and experience of experts and historical behavior of variables.

Therefore, this research aims to develop a comprehensive intelligent assessment system using Neuro-Fuzzy system (Hybrid System) to overcome the uncertainties and complexities in the EFQM model and design fuzzy decision making model for best selection and ranking of Area for Improvement (AFI) in EFQM model.

A new assessment system based on Neuro-fuzzy is introduced and developed incrementally to address the deficiency in the existing models. Three different models have been introduced in this work: The first model is an assessment system based on the fuzzy inference system (FIS) in EFQM business excellence framework under conditions of imprecise (uncertain) data and nonlinear relations. The second model considers simultaneous knowledge and experience of experts and historical behavior of variables in EFQM and this model is a hybrid assessment system (Neuro-Fuzzy) which includes fuzzy inference system and adaptive neuro-fuzzy inference system (ANFIS). The third model is based on fuzzy multi criteria decision making (FMCDM) for selecting AFI in EFQM.

The models were tested and verified under real condition and were implemented in Rahyab Rayaneh Alborz Company. The case had been assessed by assessors and experts of an EFQM business excellence organization and internal assessors of the companies. Then the models were analyzed using the MATLAB software. Also by comparison of classic and new model, assessors and experts agreed with outputs of the developed (new) models.

The contribution of this research is modeling a new comprehensive assessment system in EFQM considering simultaneous knowledge and experience of experts and historical

behavior of variables (EFQM Criteria) using ANFIS. Moreover, organizational assessment and extraction of final Score for EFQM model under conditions of imprecise (uncertain) data and in nonlinear relations using FIS and employing FMCDM for priority of AFI in EFQM model would be considered as contributions for this study. The performances of the innovative assessment system proposed in this research include 1) considering the relation between variables as a nonlinear function, 2) ability to be implemented for any number of inputs and outputs, 3) providing more informative and reliable analytical results, 4) facilitating rapid assessment and decision making for managers, experts and assessors of organizations, 5) improving the FIS model efficiency by considering historical data and knowledge and experiences of experts through using hybrid assessment system (ANFIS), 6) being valid based on the hybrid system (ANFIS), due to the mean error between assessment of assessors and the output of model which was 0.000981517, 7) using FMCDM model for ranking and selecting AFIs in EFQM in practice and 8) being verified under real conditions and implemented in Rahyab Rayaneh Alborz Co. By comparison of classic and new model, assessors and experts agreed with the outputs of the developed (new) models.

Abstrak tesis yang dikemukakan kepada Senat Universiti Pura Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

PEMBANGUNAN NEURO-SAMAR INOVATIF SISTEM PENILAIAN UNTUK YAYASAN EROPAH UNTUK PENGURUSAN KUALITI

Oleh

JAVAD DODANGEH

Februari 2013

Pengerusi: Professor Rosnah bt. Mohd. Yusuff, PhD

Fakulti: Kejuruteraan

Dalam persekitaran perniagaan yang semakin berdaya saing, pelbagai organisasi mengguna pakai pendekatan pengurusan kualiti menyeluruh (TQM) untuk mencapai kecemerlangan perniagaan. Bagi memantau kemajuan ke arah kecemerlangan perniagaan, beribu-ribu organisasi di seluruh dunia menggunakan penilaian kendiri secara berkala. Yayasan Eropah bagi Pengurusan Kualiti (EFQM) adalah antara yang paling popular. Walau bagaimanapun, kaedah semasa penilaian kendiri dalam model EFQM mempunyai beberapa kelemahan dan masalah. Kajian semula kritikal model penilaian sendiri dari kesusasteraan menunjukkan bahawa majoriti model taksiran dan penilaian sendiri yang dibangunkan adalah kabur. Benilaian dianggap hanya terhad dun tepat kepada data tertentu dan ketidakupayaan untuk mempertimbang penyiasatan empirik dan pengetahuan pakar dalam pemarkahan disamping kekurangan mempunyai metodologi bukan linear untuk sistem penilaian. Selain itu, tiada model yang dikaji

mengambilkira pengetahuan dan pengalaman serentak duri pakar dan tingkah laku sejarah pembolehubah.

Oleh itu, kajian ini telah membangunkan satu penilaian komprehensif pintar yang menggunakan sistem Fuzzy Neuro (Sistem Hybrid) untuk mengatasi ketidakpastian dan kerumitan dalam model EFQM dan juga me reka bentuk model membuat keputusan kabur untuk pemilihan terbaik dan kedudukan Kawasan untuk Penambahbaikan (AFI) dalam model EFQM.

Sistem penilaian baru yang berdasarkan Neuro kabur diperkenalkan dan dibangunkan secara berperingkat untuk menangani kekurangan pada model yang sedia ada. Tiga model yang berbeza telah diperkenalkan dalam kajian ini: Model pertama ialah satu sistem penilaian yang berdasarkan sistem inferens logik kabur (FIS) di rangka kerja kecemerlangan perniagaan di EFQM bawah syarat-syarat data (pasti) tidak tepat dan hubungan tak linear. Model kedua menganggap pengetahuan dan pengalaman serentak pakar dan tingkah laku sejarah pembolehubah dalam EFQM di mana model ini adalah satu sistem penilaian hibrid (Fuzzy Neuro) yang termasuk dalam sistem inferens kabur dan penyesuaian neuro-kabur sistem inferens (ANFIS). Model ketiga adalah berdasarkan kabur kriteria membuat keputusan berbilang (FMCDM) untuk memilih AFI dalam EFQM.

Model telah dan disahkan di bawah keadaan sebenar dan telah dilaksanakan di sebuah syarikat pengeluar kereta mega serta syarikat elektrik serantau. Kes-kes ini telah dinilai oleh penilai dan pakar-pakar perniagaan organisasi EFQM kecemerlangan dan penilai dalaman syarikat. Kemudian model dianalisis dengan menggunakan perisian

MATLAB. Selain itu perbandingan model yang klasik dan baru, penilai dan pakar-pakar yang bersetuju dengan output model yang baru.

Sumbangan penyelidikan ini memodelkan sistem penilaian baru yang komprehensif di EFQM mengingati pengetahuan serentak dan pengalaman pakar dan tingkah laku sejarah pembolehubah (Kriteria EFQM) ANFIS menggunakan. Selain itu, penilaian organisasi dan pengekstrakan Skor akhir untuk model EFQM bawah keadaan data (tidak pasti) tidak tepat dan dalam hubungan tak linear menggunakan FIS dan FMCDM menggunakan untuk keutamaan tumbuh dalam model EFQM akan dipertimbangkan sebagai sumbangan untuk kajian ini. Prestasi sistem penilaian inovatif yang dicadangkan dalam kajian ini termasuk 1) mempertimbangkan hubungan antara pembolehubah sebagai fungsi linear, 2) keupayaan untuk dilaksanakan bagi apa-apa bilangan input dan output, 3) memberikan hasil yang lebih bermaklumat dan boleh dipercayai analitikal, 4)memudahkan penilaian pantas dan membuat keputusan untuk pengurus, pakar-pakar dan penilai organisasi, 5) meningkatkan kecekapan model FIS dengan mempertimbangkan data sejarah dan pengetahuan dan pengalaman pakar melalui menggunakan sistem taksiran hibrid (ANFIS), 6) menjadi sah berdasarkan sistem hibrid(ANFIS), disebabkan kesilapan min antara penilaian penilai dan output model yang 0,000981517, 7) menggunakan model FMCDM untuk kedudukan dan memilih AFIs dalam EFQM dalam amalan dan 8) yang disahkan di bawah syarat-syarat yang sebenar dan dilaksanakan di Rahyab Rayaneh Alborz Co. Mengikut perbandingan model klasik dan baru, penaksir dan pakar-pakar bersetuju dengan output model (baru) maju.

ACKNOWLEDGEMENTS

I would like to express my deepest appreciation to my supervisor Professor Dr. Rosnah bt. Mohd. Yusuff for her constant help and guidance. She has been helping me out and supported me throughout the course of this work and on several occasions. I am also extremely grateful to my thesis committee members Professor Dr.Napsiah bt. Ismail, Professor Dr. Mohd. Yusof Ismail, Dr.Mohammad Reza Beik Zadeh and Associate Professor Dr. Javad Jassbi for their attention, cooperation, comments and constructive criticism. Acknowledgment is due to the Director of Research Management Centre of UPM for granting financial support for this research.

I would like to express my sincere gratitude to the memory of my grandfather, Younesali Dodangeh, who encouraged and supported me for education until postgraduate studies, without his encouragement I could not have been achieve successful.

I would like to express my sincere thanks to Dr.Morteza Mousakhani as a president of QIAU, Dr.Vahid Nasehifar and Mohammad Reza Mosadegh as a managing director of Selseleyeh Hamgam Company for their support and encouragement.

I would like to express my sincere thanks to Mr.Farzad Ahmadzadeh managing director of Rahyab Rayaneh Alborz Company and assessors of the Company; I really appreciate their support and assistance during data collection of this study.

Finally, for those people who are not listed above but have given me a hand or advice, I would also like to say a word of thanks for their support.

I certify that a Thesis Examination Committee has met on 22th February 2013 to conduct the final examination of Javad Dodangeh on his thesis entitled "Development of an Innovative Neuro-Fuzzy Assessment System for the European Foundation for Quality Management" in accordance with the Universities and University Colleges Act 1971 and the constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Doctor of Philosophy.

Members of Thesis Examination Committee were as follows:

Mohd Sapuan Salit, PhD
Professor
Faculty of Engineering
Universiti Putra Malaysia
(Chairman)

Khairol Anuar Mohd Ariffin, PhD
Associate Professor
Faculty of Engineering
Universiti Putra Malaysia
(Internal Examiner)

Tang Sai Hong, PhD
Associate Professor
Faculty of Engineering
Universiti Putra Malaysia
(Internal Examiner)

Mohammed Saleem J Hashmi, PhD
Professor
School of Mechanical and Manufacturing Engineering
Dublin City University
(External Examiner)

SEOW HENG FONG, PhD
Professor and Deputy Dean
School of Graduate Studies
Universiti Putra Malaysia

Date:

This thesis submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirements for the degree of Doctor of Philosophy. The members of the Supervisory Committee were as follows:

Rosnah bt. Mohd. Yusuff, PhD
Professor
Faculty of Engineering
Universiti Putra Malaysia
(Chairman)

Napsiah bt Ismail, PhD
Professor
Faculty of Engineering
Universiti Putra Malaysia
(Member)

Mohd Yusof Ismail, PhD
Professor
School of Manufacturing
University Malaysia Perlis
(Member)

Mohammad Reza Beikzadeh, PhD
Senior Staff Researcher
Artificial Intelligence Center
MIMOS Berhad
(Member)

BUJANG BIN KIM HUAT, PhD
Professor and Dean
School of Graduate Studies
Universiti Putra Malaysia

Date:

DECLARATION

I declare that the thesis is my original work except for quotations and citations, which have been duly acknowledged. I also declare that it has not been previously and is not concurrently, submitted for any other degree at Universiti Putra Malaysia or other institutions.

JAVAD DODANGEH

Date: 22 February 2013

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