INTEGRATION AND FUZZY-BASED AUTOMIZATION OF MANAGEMENT SYSTEMS TOWARDS SUSTAINABILITY IN CONSTRUCTION PROJECTS

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INTEGRASI DAN AUTOMASI BERASAS KABUR SISTEM PENGURUSAN KE ARAH KEMAPANAN PROJEK-PROJEK PEMBINAAN

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DECLARATION

I hereby declare that the work in this thesis is my own except for quotations and summaries which have been duly acknowledged.

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ABSTRACT

Implementation of management systems in accordance with standards such as ISO 9001 for quality, ISO 10006 guide for quality in projects, ISO 14001 for environmental management, OHSAS 18001 for occupational health and safety usually done with minimum considerations for the integration opportunity within construction organizations. Consequently, organizations often develop or implement management systems that suffer not only from isolation, but also from great difficulty in evaluating performance in light of the multiplicity of management systems, conflict of priorities and duplication of most auditing activities. The research first aim to identify the need and discuses the procedures for a conceptual framework to integrate isolated management systems, including a model for integration of selected management system standard requirements and a supporting methodological approach to enable such integration. The concepts applied included Quality Function Deployment (QFD) technique to determine the Integrated Management System (IMS) requirements of stakeholders, system approach and process-oriented approach for the IMS designing and implementation. The second aim to develop a framework for integrating the appropriate modelling techniques in order to evaluate the IMS performance. The proposed framework takes advantage of the information and knowledge elicited from construction organizations to model variables involved in the IMS system and risks that influence performance of construction organizations. Correlation analyses were use to identify the risk factors contribute to negative influence and their interactions. The correlation results then used to derive logical model to calculate the probabilistic impact of different risks. The framework utilizes fuzzy-logic and discrete event simulation to simulate the models developed for the IMS performance. Each part of the IMS system have three main variables namely significance, availability and probability of fail. Fuzzy logic and fuzzy set theory used to define variables and quantify the different components and elements of the sub-system and subsequently evaluate the total IMS performance using triangular translation model of fuzzy membership. Then, Expert System for Integrated Management System (ES-IMS) was design based on two models; IMS performance model that uses all components, elements and sub-elements to perform the evaluation process, and evaluation model evaluates the effect of different risks in construction sector that could negatively affect IMS performance and subsequently influence the organization behaviour. ES-IMS includes checklists that enable construction firms to check the rules and standards against their management system evaluation and perform self-inspections. The system considers user's experience level, to include expert mode and beginner mode. Construction engineers and managers in realistic case studies then evaluated the ES-IMS. The evaluation result verifies validity and efficiency of using ES-IMS in construction sector. ES-IMS has the potential for implementing a variety of standardized management codes in the construction industry and helps construction firms to evaluate and assess their management system and their performance.

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ABSTRAK

Pelaksanaan sistem-sistem pengurusan mengikut piawaian seperti ISO 9001 untuk kualiti, panduan ISO 10006 untuk kualiti dalam projek-projek, ISO 14001 untuk pengurusan persekitaran, OHSAS 18001 untuk keselamatan dan kesihatan pekerjaan lazimnya, peluang untuk penyepaduan dilakukan dengan pertimbangan yang minimum oleh sebuah organisasi pembinaan. Akibatnya, organisasi sering membangunkan atau menjalankan sistem-sistem pengurusan yang terjejas bukan sahaja dari segi pengasingan, tetapi amat sukar untuk menilai prestasi yang berkait dengan pelbagai sistem pengurusan, konflik keutamaan dan mengulangi hampir seluruh aktiviti-aktiviti pengauditan. Tujuan pertama penyelidikan ini ialah mengenal pasti keperluan dan membincangkan prosedur-prosedur dalam kerangka konsep untuk menyepadukan sistem-sistem pengurusan yang berasingan, termasuk model bersepadu bagi keperluan sistem pengurusan piawaian terpilih dan suatu pendekatan kaedah yang menyokong penyepaduan ini. Konsep yang digunakan termasuklah teknik Penggunaan Fungsi Kualiti (QFD) untuk menentukan keperluan Sistem Pengurusan Bersepadu (IMS) bagi pemegang amanah, pendekatan sistem dan orientasi proses untuk menyokong reka bentuk kerangka kerja IMS dan pelaksanaannya. Tujuan kedua, membangunkan kerangka kerja yang memadukan teknik pemodelan yang sesuai bagi menilai prestasi IMS. Cadangan kerangka kerja mengutamakan maklumat dan pengetahuan yang diperolehi daripada organisasi pembinaan bagi memodelkan pemboleh ubah-pemboleh ubah yang terlibat dalam sistem IMS dan risiko-risiko yang mempengaruhi prestasi organisasi pembinaan. Analisis korelasi digunakan untuk mengenal pasti faktor-faktor risiko yang menyumbang kepada pengaruh negatif dan interaksinya. Seterusnya, keputusan korelasi digunakan bagi menerbitkan model logik untuk mengira impak kebarangkalian bagi risiko-risiko yang berbeza. Kerangka kerja menggunakan logik kabur dan penyelakuan peristiwa diskrit untuk menyelakukan model-model yang dibangunkan untuk prestasi IMS. Setiap bahagian sistem IMS mempunyai tiga pemboleh ubah utama iaitu keberertian, ketersediaan dan kebarangkalian gagal. Logik kabur dan teori set kabur telah digunakan untuk mentakrifkan pemboleh ubah-pemboleh ubah itu dan menjumlahkan komponen-komponen dan unsur-unsur yang berbeza dalam sub-sistem dan kemudiannya menilai jumlah prestasi IMS menggunakan model terjemahan segitiga dalam keahlian kabur. Kemudian, Sistem Pakar bagi Sistem Pengurusan Bersepadu (ES-IMS) telah direka bentuk berasaskan dua model; model prestasi IMS yang menggunakan semua komponen, unsur-unsur dan sub-unsur untuk menjalankan proses penilaian dan model penilai yang menilai kesan perbezaan risiko-risiko dalam sektor pembinaan yang boleh secara negatif menjejaskan prestasi IMS dan kemudiannya mempengaruhi kelakuan organisasi. ES-IMS menyediakan senarai semak yang membolehkan firma pembinaan memeriksa peraturan dan piawaian sistem pengurusan mereka dan melaksanakan pemeriksaan kendiri. Sistem ini mengambil kira tahap pengalaman pengguna, lantas menyediakan mod pakar dan mod orang biasa. Jurutera dan pengurus pembinaan telah menilai ES-IMS ini melalui kajian kes realistik. Keputusannya mengesahkan kesahihan dan kecekapan kegunaan sistem ini dalam sektor pembinaan. ES-IMS mempunyai potensi untuk melaksanakan kepelbagaian kod-kod pengurusan piawai dalam industri pembinaan dan membantu firma-firma pembinaan menimbang dan menilai sistem pengurusan dan prestasi mereka.

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LIST OF ABBREVIATIONS

AIHA-OHSMS	Occupational Health and Safety Management System of the American Industrial Hygiene Association
CCD	Crystal Correlation Diagram
CRs	Customer Requirements
CSA	Construction Safety Advisor
CSA	Construction Safety Advisor
CSO	Case Study Organization
DES	Discrete Event Simulation
Doc	Documentation
DRs	Design requirements
EMS	Environmental Management System
ES-IMS	Expert System for the Integrated Management System
FBES	Fuzzy-Based Expert System
HOQ	House of Quality
HSE	Health and Safety Executive, United Kingdom
IEC	Institute Electro-technical
ILO	International Labour Organization
ILO-OSH	Guidance on Occupational Safety and Health Management Systems of the International Labour Organization
IMS	Integrated Management System
ISO	International Organization for Standardization
MF	The membership functions
MS	Management System
MSs	Management Systems
OHS, H&S	Occupational Health and Safety
OHSAS	Occupational Health and Safety Management System

OR	Organization
OSHA	Occupational Safety and Health Administration
PDCA	Plan-Do-Check-Act
PMS	Quality Management System for Projects
PQMAF	Project Quality Management Assessment Framework
PR	Product Realization
QFD	Quality Function Deployment Model
QMS	Quality Management System
R&D	Research and Development
RM	Resources Management
SIM	The Separate Input-Process Method
SIRIM	Standards and Industrial Research Institute of Malaysia
TQM	Total Quality Management
UAE	United Arab Emirates
UKAS	United Kingdom Accreditation Service
I/O’s	Inputs / Outputs

LIST OF SYMBOLS

Ai	Availability of a particular component (*i*)
AIj	Absolute importance for element (j)
f	The frequency of an element
FS	Fuzzy Set
L	Risk relation to Requirement (it is either 1 if there is a relation, or Zero if there is no relation, refer to Appendix C3)
MF	Membership function
PE_i	Performance of sub-element($E_{i)}$
Pi	Probability occurrence (for risks) or Probability of fail for a particular component (*i*)
RCi	The Reduction Coefficient
RFi	Significance for risk factor (*i*)
RFSij	Relative value of fuzzy set (*ij*)
Rij	Relationship rating representing the strength of the relationship between Customer Requirements (CR) and Design Requirements (DR)
RIj	Relative Impact rating
Si	Significance of a particular component (*i*)
$\mu_A(x)$	The membership function that represent the value to which any element *x* in the fuzzy set *A* belongs to the fuzzy set *A*
Wi	Relative weight refer to priority of category (i.e., relative importance weight)
X-Value	Intermediate relation for any risk factor using to identify the impact on IMS performance