DEVELOPMENT OF AN EXPERT SYSTEM FOR THE ANALYSIS OF TECHNOLOGICAL DISASTERS IN MALAYSIA

IBRAHIM MOHAMED SHALUF

DOCTOR OF PHILOSOPHY
UNIVERSITI PUTRA MALAYSIA

2004
DEDICATION

I DEDICATE THIS THESIS TO MY PARENTS
Abstract of thesis presented to the Senate of Universiti Putra Malaysia in Fulfilment of the requirement for the degree of Doctor of Philosophy

DEVELOPMENT OF AN EXPERT SYSTEM FOR THE ANALYSIS OF TECHNOLOGICAL DISASTERS IN MALAYSIA

By

IBRAHIM MOHAMED SHALUF

August 2004

Chairman:  Associate Professor Fakhru'l-Razi Ahmadun, Ph.D.
Faculty:  Engineering

Malaysia has experienced several technological disasters in the last decade due to the operation of Major Hazard Installations (MHIs). Currently Malaysia operates 177 MHIs and Malaysia is witnessing continuous growth in MHIs. The number of MHIs increases at an average rate of 19 installations per year.

This study reviews and analyses technological disasters (TD), which has occurred in Malaysia. The objectives of this study were to identify factors responsibel of technological disasters, a combination of which triggered the technological disasters, to develop a model describing the pre-technological disaster stage, and an Expert System that could be used to aid the management of MHIs to control their installation. To achieve these objectives, a review of previous studies on disaster management in Malaysia was carried out together with an analysis of the technological disaster inquiry reports. A field survey and interview of the domain experts was also done.
Information research accidents, which occurred in Malaysia, was obtained from several sources. It has been found that Malaysia has experienced 28 disasters during the period 1968 to 2002. The disasters have resulted in 1,635 fatalities, 1,929 injuries, and caused severe damage to properties. Seven technological disasters have resulted in 104 fatalities and 201 injuries.

Four technological disaster inquiry reports have been reviewed in detail. This study shows that the factors, which contributed to the technological disasters in Malaysia, were mainly due to Social, Technical, Organizational, Operational, Investigational and Defences errors. It has been found from international experience that there are only a few models describing the disaster precondition stage. This study has produced a pre-technological disaster model. The model is called the Ibrahim-Razi model for technological disasters. This model describes the sequence of development of the pre-disaster stage in eight phases.

A field survey was carried out through a questionnaire. The targeted respondents were the Safety, Health and Environment Managers at the MHI. Domain experts interviews were also conducted. Descriptive analysis, Pearson correlation, and regression analysis were used for the data analysis.

CLIPS (C Language Integrated Production System) was used as a medium for the development of Technological Emergencies Expert System (TEES). The TEES is versatile, portable, reliable, and applicable to other emergencies applications. This study provides a tool as an aid for the Safety Managers, as well as the DOSH in decision making and to assess the state of the MHI.
Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia
Sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

PEMBANGUNAN SISTEM PAKAR UNTUK TUJUAN ANALISIS BENCANA-BENCANA TEKNOLOGI DI MALAYSIA

Oleh
IBRAHIM MOHAMED SHALUF

Ogos 2004

Pengerusi: Associate Professor Fakhru’l-Razi Ahmadun, Ph.D.

Fakulti: Kejuruteraan

Dalam tempoh sepuluh dekad yang lalu, sejak beroperasinya Pemasangan Berbahaya Besar atau ‘Major Hazard Installations’ (MHIs), Malaysia telah beberapa kali mengalami bencana teknologi. Pada masa ini 177 MHIs telah beroperasi dan Malaysia menunjukkan pertumbuhan MHIs yang berterusan. Bilangan MHIs meningkat pada kadar purata 19 pemasangan setahun.

Penyelidikan ini berkait dengan ulasan dan analisis bencana teknologi yang berlaku di Malaysia. Objetif kajian bertujuan untuk mengemukakan faktor-faktor bencana yang bergabung dan mencetuskan bencana teknologi, membangunkan model yang menerangkan tahap-tahap pra-bencana teknologi, dan Sistem Pakar yang boleh digunakan bagi membantu pengurusan MHIs mengawal pemasangan. Bagi mencapai objektif ini, ulasan tentang kajian-kajian terdahulu tentang pengurusan bencana di Malaysia telah dijalankan bersama analisis laporan penyiasatan bencana teknologi.

Tinjauan lapangan dan temu bual dengan pakar-pakar bidang juga dijalankan.


CLIPS telah digunakan sebagai alat untuk membangunkan Sistem Pakar Kecemasan Teknologi (TEES). TEES bersifat versatil, mudah alih dan boleh disesuaikan dengan aplikasi-aplikasi kecemasan. Kajian ini menyediakan alat bantuan untuk Pengurus-pengurus Keselamatan dan juga kepada DOSH dalam membuat keputusan dan untuk menilai keadaan MHIs.
ACKNOWLEDGEMENTS

Most of all, Praise be to Almighty Allah who makes this work approaches to its final stage. I would not have been able to make it without His help.

I would like to acknowledge my sincere and grateful thanks to the supervisory committee Dr. Fakhru’l-Razi Ahmadun, Dr. Sa’ari Mustafa, Dr. Abdul Rashid Shariff for their supervision and guidance of this research, and their continuous support throughout my studying in Univeristi Putra Malaysia (UPM). My gratitude and thanks to Puan Aini Mat Said for her useful discussion and advices to this research.

I acknowledge the co-operation of the technicians, secretariats and the staff at the Department of Chemical and Environmental Engineering. I also acknowledge the contribution of the staff and experts of the Department of Occupational Safety and Health (DOSH) Malaysia.

Last but not least, thanks to my brothers, sisters, and my wife for their continuous inspiration and encouragement.
I certify that an Examination Committee met on 29 of August 2004 to conduct the final examination of Ibrahim Mohamed Shaluf on his Doctor of Philosophy thesis entitled “Development of an Expert System for the Analysis of Technological Disasters in Malaysia” in accordance with the Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

**Mohamed Daud, Ph.D.**  
Professor  
Faculty of Engineering  
Universiti Putra Malaysia  
(Chairman)

**Chuah Teong Guan, Ph.D.**  
Lecturer  
Faculty of Engineering  
Universiti Putra Malaysia  
(Member)

**Medyan Riza, Ph.D**  
Lecturer  
Faculty of Engineering  
Univeristi Putra Malaysia  
(Member)

**Ir. Mohd. Azraai Kassim, Ph.D.**  
Professor  
School of Professional and Continuing Education (Space)  
Univesiti Teknologi Malaysia  
(Independent Examiner)

---

**GULAM RUSUL RAHMAT ALI, Ph.D.**  
Professor/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 requirement for the degree of Doctor of Philosophy. The members of the Supervisory Committee are as follows:

**Fakhru’l-Razi Ahmadun, Ph.D.**  
Associate Professor  
Faculty of Engineering  
Universiti Putra Malaysia  
(Chairman)

**Sa’ari Mustapha, Ph.D.**  
Associate Professor  
Faculty of Engineering  
Universiti Putra Malaysia  
(Member)

**Abdul Rashid Shariff, Ph.D**  
Associate Professor  
Faculty of Engineering  
Universiti Putra Malaysia  
(Member)

____________________

**AINI IDERIS, Ph.D.**  
Professor/Dean  
School of Graduate Studies  
Universiti Putra Malaysia

Date:
DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations that have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or any other institution.

__________________________

IBRAHIM MOHAMED SHALUF

Date: December 2003
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>DEDICATION</td>
<td>ii</td>
</tr>
<tr>
<td>ABSTRACT</td>
<td>iii</td>
</tr>
<tr>
<td>ABSTRAK</td>
<td>v</td>
</tr>
<tr>
<td>ACKNOWLEDGEMENTS</td>
<td>vii</td>
</tr>
<tr>
<td>APPROVAL</td>
<td>viii</td>
</tr>
<tr>
<td>DECLARATION</td>
<td>x</td>
</tr>
<tr>
<td>LIST OF TABLES</td>
<td>xiv</td>
</tr>
<tr>
<td>LIST OF FIGURES</td>
<td>xviii</td>
</tr>
<tr>
<td>LIST OF ABBREVIATIONS</td>
<td>xx</td>
</tr>
</tbody>
</table>

## CHAPTER

1 **INTRODUCTION**

1.1 Introduction 1
1.2 Problem Statement 3
1.3 Research Objectives 5
1.4 Significance of the Study 5
1.5 Scope and Limitation of the Study 7

2 **LITERATURE REVIEW**

2.1 Introduction 8
2.2 Organization 9
2.3 International Regulations and Guidelines 11
  2.3.1 International Regulations 11
  2.3.2 International Guidelines 14
2.4 Regulations of Malaysia 16
  2.4.1 OSHA 17
  2.4.2 CIMAH 17
2.5 Malaysian Disaster Management Guidelines 20
2.6 Major Hazard Installations 23
  2.6.1 Definition 23
  2.6.2 Criteria 23
  2.6.3 Classifications 25
2.7 Major Hazards Installations in Malaysia 25
2.8 Organization Theory and Accidents 28
2.9 Disaster 28
  2.9.1 Disaster Types 28
  2.9.2 Disaster Criteria 32
  2.9.3 Disaster Stages 36
  2.9.4 Man-made Disaster Models 38
2.10 Technological Disasters 41
2.11 Technological Disaster Factors 42
  2.11.1 Human Factor 42
  2.11.2 Organizational Factor 45
  2.11.3 Technological Factor 46
2.12 Disasters in Malaysia 47
2.13 Regression Analysis 52
2.14 Expert System 55
  2.14.1 Applications of Expert System 56
  2.14.2 Elements of Expert System 61
  2.14.3 CLIPS 62
  2.14.4 wxClips 64
2.15 Summary 65

3 RESEARCH METHODOLOGY 67
  3.1 Introduction 67
  3.2 Research Framework 68
  3.3 Review and Analysis of Technological Disasters 70
  3.4 Surveys 71
    3.4.1 Field Survey 71
    3.4.2 Domain Expert Interview Questionnaire 79
  3.5 TEES Development 80
    3.5.1 Assessment 81
    3.5.2 Knowledge Acquisition 81
    3.5.3 Design 83
    3.5.4 Testing 84
    3.5.5 Implementation 84
    3.5.6 Maintenance and Development 85
  3.6 Summary 86

4 RESULTS AND DISCUSSION 87
  4.1 Introduction 87
  4.2 Technological Disaster Criteria 88
  4.3 Classification of the Disasters in Malaysia 89
  4.4 Technological Disasters in Malaysia 90
    4.4.1 Classification of the Technological Disasters in Malaysia 91
    4.4.2 Document Analysis 94
    4.4.3 Summary of Analysis of the Disasters 117
    4.4.4 Technological Disaster Factors 121
    4.4.5 Disaster Incubation Periods 128
  4.5 Ibrahim-Razi’s Model 129
    4.5.1 Phase 1 – Inception of Errors 129
    4.5.2 Phase 2 – Accumulation of Errors 130
    4.5.3 Phase 3 – Warnings 130
    4.5.4 Phase 4 – Failure of Corrections 131
    4.5.5 Phase 5 – Disaster Impending Stage 131
    4.5.6 Phase 6 – Triggering Event 131