

EXECUTIVE INFORMATION SYSTEM FOR MONITORING BUILDING
CONSTRUCTION WORK PROGRESS

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To my beloved mother and father

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ABSTRACT

Progress monitoring and control is one of the most important tasks when managing a project. Basically, construction works produce a lot of information and it is the responsibility of the top management to track the work progress at project site. A recent issue highlights inefficiency in obtaining information from site on time. Hence, the focus of this research is to establish a computerized information system which can be utilized by the top management in order to evaluate the construction progress. The aim of this research is to propose a model and develop a computerized project progress monitoring system, known as Executive Information Site Monitoring System (EISMS). Before developing EISMS, current problems faced by the top management in monitoring work progress and various models for construction monitoring in Malaysia Construction Industry were investigated through a questionnaire survey. It was found that manual data collection, time consuming report making, and no on-time corrective actions are current problems incurred by the top management in Malaysia. Indeed, monitoring of work progress depends on a combination of three methods; taking pictures from construction processes, having a database, and using planning software such as Microsoft Project (MS Project). EISMS was developed based on the Waterfall Model and the process began by identifying system requirements, system analysis, system designs, coding, integration and finally system testing and implementation. The system requires three primary data which include; planned work schedule, 3DCAD drawing, and actual work completion at site. From these three parameters, the system is able to compute scheduled and actual work progress and hence schedule variance at any selected evaluation date. In conclusion, EISMS was successfully implemented during construction phase allowing the top management of construction organizations to monitor the construction site progress more efficiently, which helps them in decision making and taking timely appropriate action.

ABSTRAK

Pemantauan kemajuan serta kawalan selia kerja merupakan salah satu tugas yang paling penting apabila menguruskan satu projek. Pada dasarnya, kerja-kerja pembinaan menghasilkan banyak maklumat dan ia adalah tanggungjawab pengurusan atasan untuk mengesan kemajuan kerja di tapak projek. Isu baru-baru ini menonjolkan ketidakcekapan dalam mendapatkan maklumat dari tapak pembinaan pada masa yang ditetapkan. Oleh itu, tumpuan penyelidikan ini adalah untuk mewujudkan satu sistem maklumat berkomputer yang boleh digunakan oleh pihak pengurusan atasan bagi menilai kemajuan pembinaan. Tujuan kajian ini adalah untuk mencadangkan model dan seterusnya membangunkan sistem pemantauan projek kemajuan berkomputer, yang dikenali sebagai Sistem Maklumat Eksekutif Pemantauan Tapak (EISMS). Sebelum EISMS dibangunkan, masalah semasa pengurusan atasan dalam pemantauan kemajuan kerja-kerja dan model-model pemantauan pembinaan dalam industri pembinaan di Malaysia telah disiasat melalui kajian soal selidik. Hasil soal selidik mendapati bahawa pengumpulan data secara manual, masa yang panjang untuk membuat laporan, dan tiada tindakan susulan pembetulan yang cepat adalah masalah semasa yang di hadapi pengurusan atasan di Malaysia. Kerja-kerja pemantauan kemajuan kerja bergantung kepada gabungan tiga kaedah; gambar proses pembinaan, mempunyai pangkalan data, dan penggunaan perisian perancangan seperti Microsoft Project (Projek MS). Proses pembangunan EISMS berasaskan model 'Waterfall' dan ia bermula dengan mengenal pasti keperluan sistem, analisis sistem, reka bentuk sistem, pengaturcaraan, integrasi dan akhirnya ujian dan pelaksanaan sistem. Sistem ini memerlukan tiga data utama iaitu perancangan jadual kerja, lukisan 3DCAD, dan kerja siap sebenar di tapak. Daripada tiga parameter ini, sistem tersebut berupaya memproses pengiraan kemajuan kerja jadual yang di rancang dan kemajuan kerja sebenar; dan seterusnya jadual varian pada mana-mana tarikh penilaian yang dipilih. Kesimpulannya, EISMS telah berjaya dilaksanakan membolehkan pengurusan atasan organisasi pembinaan untuk memantau kemajuan pembinaan di tapak dengan lebih cekap serta membantu mereka didalam membuat keputusan serta mengambil tindakan susulan awal.

TABLE OF CONTENTS

CHAPTER	TITLE	PAGE
	DECLARATION	ii
	DEDICATION	iii
	ACKNOWLEDGEMENT	iv
	ABSTRACT	v
	ABSTRAK	vi
	TABLE OF CONTENTS	vii
	LIST OF TABLES	xvii
	LIST OF FIGURES	xx
	LIST OF ABBREVIATIONS	xxv
	LIST OF SYMBOLS	xxviii
1	INTRODUCTION	1
	1.1 Introduction	1
	1.2 Background of study	2
	1.3 Problem statement	3
	1.4 Aims and Objectives of the Study	4
	1.5 Scope and Limitation of Study	6
	1.6 Significance of the Research	6
	1.7 Research Methodology Framework	7

1.8	The organization of the thesis	9
2	CONSTRUCTION MONITORING PROBLEM AND ITS PERFORMANCE MEASUREMENT	11
2.1	Introduction	11
2.2	Monitoring	12
2.2.1	Project Progress Monitoring Practice	12
2.2.2	Four main categories that need to be monitored during construction projects	15
2.2.3	Project Monitoring Problems	
2.2.4	Review on Project Monitoring	19
2.3	Level of Management in a Construction Organization	19
2.3.1	Top-management	21
2.3.2	Middle-management	22
2.3.3	First-level-management	23
2.3.4	Management Level and Managerial Functions Relationship	24
2.3.5	Review on Management Level	24
2.4	Organizational Structure in a Construction Company	25
2.4.1	Small Size Construction Firms	27
2.4.2	Medium Size Construction Firms	29
2.4.3	Large Construction Firms	31
2.4.4	Review on Hierarchy Organization in Construction Company	33
2.5	Problems for Top Management in Construction Monitoring	34
2.5.1	Summarization of Problem Faced by Top Management	37
2.6	Performance Measurement and Its Measurement Method	38
2.6.1	Concept Related to Performance Measurement	39

2.6.2	Productivity and Performance Measurements	40
2.6.3	Performance Measurement in the Construction Industry	41
2.7	Key Performance Indicator	42
2.7.1	Quantitative Performance Indicators	43
2.7.2	Qualitative Performance Indicator	46
2.7.3	Summary of key performance indicator	48
2.7.4	Review on Key Performance Indicator	49
2.8	Earned Value Concept	49
2.8.1	Appraisal of the EVM Standards	50
2.8.2	Earned Value Management Cost-related Terms	51
2.8.3	Implementing EVM System	55
2.8.3.1	Define The Work	55
2.8.3.2	Schedule and Budget	55
2.8.3.3	Bill of Quantity (BQ)	56
2.8.4	Review on EVM Application	58
2.9	Chapter Summary	58
3	CONSTRUCTION MONITORING SYSTEM AND FEATURES FOR SYSTEM DEVELOPMENT	60
3.1	Introduction	60
3.2	Advances in Information Technology	61
3.2.1	Type of Computer Based Information System	61
3.2.2	Access of Shared Information	63
3.3	Executive Information Systems (EIS)	64
3.3.1	Components of EIS	68
3.3.2	Application of Executive Information System	69
3.3.3	Future Trends of EIS	70

3.3.4	Review on EIS	70
3.4	Existing Computerized Construction Monitoring Models	71
3.4.1	Photographic Synchronization	76
3.4.2	Summarization of Computerized Construction Monitoring System	78
3.4.3	Review on Computerized Monitoring Systems	81
3.5	Database	82
3.5.1	Basic Type of Database Modelling	83
3.5.2	Comparison of Database	84
3.5.3	Common Database Software	85
3.5.4	Using Database Software	86
3.5.4.1	Query Languages	86
3.5.4.2	Application Programs	88
3.5.5	Review on Database	88
3.6	The Need for Networks In Business Organization	89
3.6.1	Network Architecture	89
3.6.2	Network Operating System	90
3.6.3	Client / Server Network Architecture	94
3.6.3.1	Web Based Application	94
3.6.3.2	Web Base Structure	94
3.6.4	Review on Network Architecture	95
3.7	CADD System	96
3.7.1	Different Types of CAD	97
3.7.2	CAD Applications	98

3.7.3	Review on CADD System	99
3.8	Software Development Modelling	100
3.8.1	Evolution of Software Process Model	100
3.8.1.1	Code-and fix model	101
3.8.1.2	Stagewise Models	102
3.8.1.3	Waterfall Models	102
3.8.1.4	V Model	104
3.8.1.5	Evolutionary Development Model	105
3.8.1.6	The Transform Model	106
3.8.1.7	The Spiral Model	108
3.9	Software Architecture	111
3.9.1	Software Quality Attributes	112
3.9.2	Architectural Style	114
3.9.2.1	Data Centred Architectures	115
3.9.2.2	Data-Flow Architectures	116
3.9.2.3	Call-and-Return Architectures	118
3.9.2.4	Independent Component Architectures	120
3.9.3	Heterogeneous Styles	122
3.9.4	Analysis of Software Architecture	124
3.10	Chapter Summary	124
4	RESEARCH METHODOLOGY	127
4.1	Introduction	127
4.2	Research Methodology	127
4.3	Expert Panel Interview	128
4.4	Literature Review	128

4.5	Questionnaire Survey	129
4.5.1	Design of the Questionnaire	129
4.5.2	Data Sampling and Collection	131
4.5.3	Data Analysis	131
4.5.4	Likert Scales, Cronbach and Mann Whitney Analysis	133
4.5.5	Results and Discussion	134
4.6	EISMS Development	135
4.6.1	System Requirement for EISMS	135
4.6.2	System Proposal	136
4.6.3	System Design	136
4.6.4	Implementation (Coding)	137
4.7	Validation and Verification of EISMS	138
4.7.1	Identify suitable project	139
4.7.2	Preparation of Basic Data 1 (D1)	139
4.7.3	Preparation of Basic Data 2 (D2)	140
4.7.4	Validation of Month 1	140
4.7.5	Verification of EISMS as EIS	141
4.7.6	Verification of EISMS System Requirement	141
4.7.7	Validation of Month 2-5	141
4.8	Chapter Summary	142
5	ANALYSIS AND FINDINGS	144
5.1	Introduction	144
5.2	Findings	145
5.2.1	Part A: Background Information of the Respondents and Firms	145
5.2.1.1	Respondents' Qualification	145

5.2.1.2	Respondent's Experience in Construction Industry	146
5.2.1.3	Respondents' Designation	147
5.2.1.4	Company Specialization	148
5.2.1.5	Experience of Companies in Construction Industry	148
5.2.1.6	Highest Contract Amount Involved by Respondent's Company	149
5.2.1.7	Conclusion of Section A	149
5.2.2	Part B: State of the Art of Work Progress Monitoring in Malaysian Construction Industry	151
5.2.2.1	The Basic Technique Used by Top Management to Monitor Work Progress	151
5.2.2.2	Likert Scales, Cronbach and Mann Whitney Analysis	152
5.2.2.3	Current Means Used by Top Management to Monitor Work Progress	153
5.2.2.4	Current Computerized Monitoring Systems in Malaysian Construction Industry	156
5.2.2.5	Conclusion of Part B	159
5.2.3	Part C: Issues Related to Current Monitoring Systems in MCI	161
5.2.3.1	Main Problems of Current Computerized Monitoring Systems	161
5.2.3.2	Main Problems of Current Monitoring Systems from Perspective of Top Management	163
5.2.3.3	Main Problems of Current Monitoring Systems with Regards to Information Management	164
5.2.3.4	Conclusion of Part C	167
5.2.4	Part D: Required Features of a Computerized Executive Information System	168

5.2.4.1	The Most Important Key Performance Indicator for Development of Computerized Executive Information System	168
5.2.4.2	The Most Important Features for Development of Computerized Executive Information System	170
5.2.4.3	The Most common Construction Drawing Software	173
5.2.5	Conclusion of Part D	174
5.3	Chapter Summary	174
6	EISMS DEVELOPMENT	177
6.1	Introduction	177
6.2	System Requirements	177
6.2.1	Current Business Process in Construction Companies	178
6.2.2	Problem Identification	180
6.2.3	Summary of the System Requirements	181
6.3	EISMS Proposal	182
6.3.1	Proposed Data Structure of the EISMS	183
6.3.2	Proposed Data Flow of the EISMS	188
6.3.3	Proposed System Architecture of the EISMS	191
6.3.4	Proposed Modules and Functionalities of the EISMS	192
6.4	EISMS Design	193
6.4.1	EISMS Concept	193
6.4.2	The EISMS Hardware Requirement	196
6.4.3	Database Design	196
6.4.4	EISMS Computation Models	197
6.4.4.1	Schedule Work Progress Information	198

	Flow Model for EISMS	
	6.4.4.2 Actual Work Progress Information Flow Model for the EISMS	202
	6.4.4.3 Schedule Variance for the EISMS	204
	6.4.4.4 3D View of Work Progress Information Flow Model for the EISMS	207
	6.4.5 EISMS User Identification	215
	6.4.6 System Access Design	216
6.5	EISMS Implementation	217
	6.5.1 Coding	219
	6.5.2 Data Sample Output	221
6.6	Chapter Summary	226
7	EISMS VALIDATION AND VERIFICATION	228
	7.1 Introduction	228
	7.2 Validation and verification of data sample	229
	7.3 Validation and verification of an actual project	230
	7.4 The identified project	
	7.5 Preparation of Basic Data 1	233
	7.6 Preparation of Basic Data 2	237
	7.7 Validation and verification of EISMS results	237
	7.7.1 Validation of Month 1	239
	7.7.2 Validation of Subsequent month	
	7.7.3 Comparison of Project pictures to EISMS 3D drawing	241
	7.7.4 Verification of the EISMS as EIS	242
	7.7.5 Verification of EISMS System Requirement	244

7.8	Chapter Summary	245
8	CONCLUSIONS AND RECOMMENDATIONS	248
8.1	Introduction	248
8.2	Conclusions	249
8.2.1	Conclusion on first Objective	250
8.2.2	Conclusion on second Objective	250
8.2.3	Conclusion on third Objective	252
8.2.4	Conclusion on fourth Objective	253
8.2.5	Conclusion on fifth Objective	255
8.2.6	Conclusion on sixth Objective	256
8.3	Research Achievements	257
8.4	Recommendations for the Organization and Future Research	258
	REFERENCES	259
	APPENDICES A-D	268-295

LIST OF TABLES

TABLE NO.	TITLE	PAGE
2.1	KPI for Construction Firms (CBPP-KPI 2002)	42
2.2	Type of Performance Indicator	48
2.3	Earned Value Management Formula and Interpretation	54
3.1	Characteristic of EISs (Young and Watson, 1995)	66
3.2	Advantages of EISs (Young and Watson, 1995)	66
3.3	Features of EISs (Young and Watson, 1995)	67
3.4	Summarization of Database Application for Computerized Construction Monitoring Model, 1990 – 1999	79
3.5	Summarization of Database Application for Computerized Construction Monitoring Model, 2000 - 2010	80
3.6	Summarization of Photographic Application for Computerized Construction Monitoring Model, 2000 – 2006	81
3.7	Advantages/Disadvantages of Peer-to-Peer and Client/Server Networks	93
3.8	Summarization of Software Model	110
5.1	Respondents' Experience in Construction Industry Versus Highest Contract Amount Involved.	150
5.2	Grouping of Top Management and Lower Level Management	150
5.3	Reliability Coefficient	152
5.4	Means Used to Monitor Work progress	154
5.5	Mann Whitney test for Top Management versus Lower Level Management for Type of Traditional Method of Monitoring	156

	Work Progress	
5.6	Computerized Construction Monitoring System	157
5.7	EIS Characteristic of Computerized Construction Monitoring System	157
5.8	Output of Computerized Construction Monitoring System	158
5.9	Different Systems for Monitoring Construction Work Progress	160
5.10	Reason for Contractor not favouring The Computerized method to Monitor Work Progress	162
5.11	Mann Whitney Test for Reason of not using computerized system	162
5.12	Main problem faced by top management to monitor site progress	164
5.13	Mann Whitney Test for Top Management versus Lower Level Management for Site Progress Monitoring	164
5.14	Type of project information that contributes to ineffective approach for evaluating the construction progress	166
5.15	Mann Whitney test for Top Management versus Lower Level Management for Type of Project Information Received	166
5.16	Key Performance Indicator Need by Top Management to Monitor Work Progress	169
5.17	Mann Whitney Test of Top Management versus Lower Level Management for KPI	169
5.18	Important Features to be incorporated in the Proposed System Development	171
5.19	Mann Whitney Test of Important Features for the Proposed System Development	172
5.20	Common Software Used to Produce Construction Drawing	173
5.21	Mann Whitney for Construction Drawing Software	173
6.1	EISMS System Requirements	181
6.2	EISMS Schedule Sample	185
6.3	EISMS Data Structure	187
6.4	Hardware Requirement for EISMS	196
6.5	Example of Evaluation of Schedule Work Progress as at end	205

	of February 2009	
6.6	Example of Evaluation of Actual Work Progress as at end of February 2009	206
6.7	Example of Colour Scheme evaluation for Scenario 1	212
6.8	Example of Colour Scheme evaluation for Scenario 2	213
6.9	Example of Colour Scheme evaluation for Scenario 3	214
6.10	A Summary of Users and Their Current Responsibilities	216
6.11	System Access Design	217
7.1	Comparison of Schedule and Actual Work Progress between Manual Calculation and EISMS output for Data Sample	229
7.2	Project Profile	232
7.3	EISMS result versus Manual Computation	240
7.4	EISMS versus Manual Computation	240
7.5	Verification of EISMS as EIS	243
7.6	Verification of the EISMS System Requirement	244

LIST OF FIGURES

FIGURE NO.	TITLE	PAGE
1.1	Role of EISMS	7
1.2	Research Methodology Frameworks	8
2.1	Traditional Project Progress Monitoring Process (Memon, et al., 2006)	14
2.2	Summary of the result of literature review on problems of project monitoring.	18
2.3	Levels of Management (adopted from Jones and George, 2003)	21
2.4	Organization Structure of a Small Construction Firm (Adopted from Abdullah <i>et al.</i> , 2005)	28
2.5	Project Organization in a Typical Medium Size Firm (Adopted from Abdullah <i>et al.</i> , 2005)	30
2.6	Organization Structure of a Typical Medium Size Firm (Adopted from Abdullah <i>et al.</i> , 2005)	31
2.7	Organization Structure for a Large Firm (Adopted from Abdullah <i>et al.</i> , 2005)	32
2.8	Information Flow Chart	33
2.9	Performance Measurement Supports Effective Delivery of Services (Osborne & Gaebler, 1992)	39
3.1	Types of Information Systems Based on the Levels of Hierarchy in an Organization (Jones and George, 2003)	62
3.2	Executing an SQL command (Nickerson and Muthaiyah, 2004)	87
3.3	Peer-to-Peer Architecture (Adopted from Abdullah <i>et al.</i> , 2005)	91

3.4	Client / Server Network (Adopted from Abdullah <i>et al.</i> , 2005)	92
3.5	The code-and-fix model (Boehm, 1988)	101
3.6	The waterfall model of the software life cycle (Boehm, 1988)	103
3.7	V Model (Adopted from Sudhakar 2010)	104
3.8	Spiral Model (Adopted from Boehm, 1988)	109
3.9	Data Centered Architecture (Kaisler, 2005)	115
3.10	Batch Sequential Style Architecture (Kaisler, 2005)	116
3.11	Pipe and Filter Style Architecture (Kaisler, 2005)	117
3.12	Main-Program-and-Subroutine Architecture (Kaisler, 2005)	118
3.13	Object-Oriented Style Architecture (Kaisler, 2005)	119
3.14	Layered Style Architecture (Kaisler, 2005)	120
3.15	Independent Component Architectures (Kaisler, 2005)	120
3.16	Client server system Architecture (Kaisler, 2005)	121
3.17	Event Style Architecture (Kaisler, 2005)	121
3.18	Locationally Heterogeneous Architecture (Kaisler, 2005)	123
3.19	Hierarchically Heterogeneous Architecture (Kaisler, 2005)	123
4.1	Methodology for Validation and Verification of EISMS	138
4.2	Methodology for Preparation Basic Data 1	139
4.3	Methodology for Preparation Basic Data 2	140
5.1	Four Parts of the Questionnaire Survey	144
5.2	Percentage of Respondents' Qualification	146
5.3	Percentage of Respondents' Experience in Construction Industry	146
5.4	Percentage of Respondent's Designation	147
5.5	Percentage of Company Specialization	148
5.6	Percentage of Company Experience in Construction Industry	148

5.7	Percentage of Highest Contract Amount	149
5.8	Techniques used by top management to monitor work progress	152
5.9	Average Index for Means Used to Monitor Work Progress in Traditional Way	154
5.10	Average index for reason of not having computerized system	161
5.11	Average index for main problem faced by top management to monitor site progress	163
5.12	Average index for type of project information received by top management that contributes to ineffective approach for evaluating the construction progress	165
5.13	Average index of key performance indicator	168
5.14	Average index for important features for development of the Proposed System	171
5.15	Average index for software that is used to produce construction drawings	173
6.1	Process of Developing EISMS based on Waterfall Model	177
6.2	Organizational Hierarchy System	179
6.3	Role of EISMS	182
6.4	EISMS DFD – LEVEL 0	188
6.5	EISMS DFD_ Process 1.0 (Pre Construction Stage) – Level 1	189
6.6	EISMS DFD_ Process 2.0 (Construction Stage) – Level 2	190
6.7	EISMS System Architecture	192
6.8	EISMS Full Environment Model	194
6.9	HQ Environment Model	195
6.10	Site Environment Model	195
6.11	EISMS Database Relationship	197
6.12	EISMS computation model	198
6.13	Activity of element j of construction task i	200

6.14	Schedule Work Progress Information Flow Model of EISMS	201
6.15	Actual Work Progress Information Flow Model of EISMS	203
6.16	Scenario 1- Work has no Actual Start and Completion Dates	208
6.17	Scenario 2_Work has only Actual Start Date (No Completion Date)	210
6.18	Scenario 3_Work has both Actual Start Date and Completion Date	212
6.19	Frame Work Model of EISMS	219
6.20	3D CAD Drawing for Data Sample	221
6.21	Construction Progress Screen	222
6.22	3D Screen	222
6.23	S-curve Screen	223
6.24	Progress Table Screen	224
6.25	Element of main task 'Work Below Lower Floor Finish	224
6.26	Component of pad footings	224
6.27	Gantt chart screen	225
6.28	Claim status screen	225
7.1	Methodology of Validation and Verification	232
7.2	Preparation of Basic Data 1	233
7.3	Sample of Tender Price to EISMS Schedule Table	234
7.4	Sample of Construction Master Work Program	235
7.5	EISMS Schedule Input	236
7.6	3D AutoCAD drawing in EISMS	237
7.7	Digital Form for Site Input Data 3	238
7.8	Progress Evaluation Screen	238
7.9	EISMS Schedule and Actual Work Progress	239
7.10	Stump and footing under evaluation no. 4	241

7.11	Sub-basement ground beam after completion under evaluation no.10	241
7.12	S-Curve	245
7.13	Gantt Chart	245

LIST OF ABBREVIATIONS

AC	-	Actual Cost
ACAD	-	AutoCAD
ACWP	-	Actual Cost of Work Performed
AEC	-	Architect, Engineering, Construction
ARM	-	Activity Relationship Matrix
BAC	-	Budget at Completion
BCSW	-	Budgeted Cost of Work Scheduled
BCWP	-	Budgeted Cost of Work Performed
BQ	-	Bill of Quantity
Brep	-	Boundary Representation
CSG	-	Solid Geometry
CAD	-	Computer-Aided Design
CADD	-	Computer-Aided Design And Drafting
CIC	-	Computer-integrated Construction
CIDB	-	Construction Industrial Development Board
CPI	-	Cost Performance Index
CPM	-	critical path method
CPU	-	central processing unit
C/SCSC	-	Cost/Schedule Control Criteria
DBMS	-	Data Base Management System
DoD	-	Department of Defense
DSS	-	Decision Support System
EAC	-	Estimate at Complete
EIS	-	Executive information system
EISMS	-	Executive Information Site Management System

ETC	-	Estimate to Complete
EV	-	Earn Value
EVM	-	Earned Value Method
HAN	-	Home Area Network
HOPT	-	Head of Project Team
IDE	-	Integrated Development Environment
ISDN	-	Integrated Services Digital Network
ISO	-	International Organisation for Standardisation
IT	-	Information Technology
JIF	-	Java Inspection Framework
KBMS	-	Knowledge Base Management System
KPI	-	Key Performance Indicator
LAN	-	Local Area Network
MAN	-	Metropolitan Area Network
MCI	-	Malaysian Construction Industry
MIS	-	Management Information System
NSIA	-	National Security Industrial Association
PC	-	Personal Computer
PKK	-	Pusat Khidmat Kontarktor
PMB	-	Performance Measurement Baseline
PPMS	-	Project Performance Monitoring System
PV	-	Plan Value
QBE	-	Query-by-example
RDBMS	-	Relational Database Management System
RI	-	Relative Index
RM	-	Ringgit Malaysia
SAGE	-	Semi Automated Ground Environment
SMM2	-	Standard Method of Measurement
SQL	-	Structure Query Language
STEP	-	Standard for the Exchange of Product Model
SVM	-	Support Vector Machine
S.O	-	Superintending Officer
TPS	-	Transaction-Processing Systems

VAC	-	Variance at Completion
VB	-	Visual Basic
VIRCON	-	Virtual Construction
WAN	-	Wide Area Network
WBS	-	Work Breakdown Structure
XML	-	Extended Markup Language
2D	-	Two-dimensional
3D	-	Three-dimensional

LIST OF SYMBOLS

\$	-	Dollar value /USD (Refers to the cost)
£	-	British pound(Refers to the cost)
U	-	Mann Whitney U

LIST OF APPENDICES

APPENDIX	TITLE	PAGE
A	Sample of Survey Questionnaire Form	268
B	SPSS Output of Mann Witney Test	274
C	Sample of Validation and verification Questionnaire Form	281
D	Validation and verification of EISMS using Data Sample	295

CHAPTER 1

INTRODUCTION

1.1 Introduction

It is widely recognized that construction is an information intensive and complex industry. Effective and systematic monitoring and control of information flow is a critical ingredient throughout the life-cycle of construction projects. Harris and McCaffer (2001) described monitoring as an act of checking actual progress, actual resource usage and taking decisions to alter the likely future outcome, while control is completing the project on schedule. Hinze (1998) described monitoring as recording the actual start and finish dates for activities while the project is underway, and control relates to the analysis of the impact of any schedule deviations and evaluation of what remedial actions should be taken.

To effectively monitor a project, an organization should have a system that is able to provide critical information whenever it is required and share the information from a single source within the organization to support its daily operations and decision making. Development of Information Computer Technology (ICT) has enabled the construction industry to increase the efficiency and effectiveness of information exchange between head office and site office. Lock (1993) highlighted that the purpose of computer based information systems in the construction industry

is to integrate the collection, processing and transmission of information so that engineering professionals can gain additional insight into the operations they are managing.

A different class of computer applications for monitoring and evaluating construction projects have been developed including ‘Visual Inspection’ model by Silva *et al.*, (2009), DCM by Memon (2006), PPMS by Cheung *et al.*, (2004), PHOTO-NET II by Abeid *et al.* (2003), VIRCON by Dawood *et al.* (2002), ESCAAD by Wang (2001), DIPAP by Streilein (1996) and CADCIMS by Stumpf (1995) which replace traditional monitoring methods. In traditional monitoring method, the project progress is reported based on project manager’s diaries, daily site records and other documents that transmit paper-based data, contributing to errors and the inefficiency of site information communication and exchange.

1.2 Background of Study

The invention of Information Technology (IT) in this century is responsible for developing the concept of Management Information System (MIS) in organization management. MIS manages information flow allowing individuals to complete their daily work duties. At the Executive management level, making decisions is a daily duty, and these management decisions affect the organization’s performance. Thus, as a key component of decision making, reliable information must be provided to Executive management in a proper manner, and acceptable quality, if it is to enhance organizational performance. Executive Information System (EIS), as Decision Support Systems (DSS) were introduced in the early 80’s. In general, EISs are enterprise-wide decision support systems (DSS) that help top-level executives to analyze, compare, and highlight trends on important variables so that they can monitor performance and identify opportunities and problems. EIS and data warehousing technologies are converging in the marketplace. Turban and Aronson (2001) described an EIS as “computer-based system that serves the information

requirements of top executives. It provides rapid access to timely information and direct access to management reports. Apart from being user friendly, EIS can be supported by user graphics providing exceptional reporting and drilldown capabilities. It can also be connected to the Internet, Intranet and Extranets”.

Several studies conducted on EIS have highlighted various keys issues. Kaniclides and Kimble (1995) carried out a research on “A Framework for the Development and Use of Executive Information Systems”. They concluded that clear knowledge in EIS is essential before developing the system. Other research done by Young and Watson (1995) on “Determinates of EIS acceptance” proved that EIS is difficult to use and may fail but ease of use alone does not ensure acceptance. Ong *et al.* (2005) published “Revitalizing Executive Information System Design and Development” proving that EISs have uncertain characteristics that are impractical for individual executives. Jirachiefpattana (1997) studied “The impacts of Thai Culture on Executive Information Systems Development” and found that EIS should be created only if the users want to be involved in its development process to avoid failures.

1.3 Problem Statement

Top management of a growing organization can become separated from the mainstream of the organization to such a degree that the indicators of trouble become invisible to them. Contractors take so much workload and have very little time to manage well and no time to plan or review progress or performance. They never step back to see how the company is doing, and to get an overall picture of the project. Other contractors are unaware of trouble signs because their middle managers do not report to them, and top managers of large companies cannot observe all details at all times. They are great at putting construction in place but not skilled at overseeing the business and being alert to subtle changes that can affect it (Schleifer 1990).

Top management also has to make important decisions that can have a significant impact on the company. At project level, matters that concern top management amongst others are rate of productivity of work progress, work completion, certified works and paid works. Top management monitors work completion because it directly affects profit, where delay causes losses to the company. Schleifer (1990) stated that rate of productivity of work on the other hand can identify potential problems that may exist on site while certified works and paid works have a bearing on cash flow and tax structure of the company. All the above information needs to be supplied to top management in the quickest and simplest possible form.

Therefore, there is a need for contractors to be aware of work progress on site. It is also important that the vast amount of information from site is presented in the simplest possible form at head office so that the busy top management can digest and understand this information easily and effortlessly. This can be achieved by having an information system which can ultimately produce a 3D visual presentation model of the work progress on site together with analysis of its performance.

This system will be a tool for the top management, allowing them to have an independent information system. Knowing that the top management has an independent tool to verify their reports, project managers will work more diligently. This system will be expected to help top management make better decisions. At the end of this study, the system developed will be able to assist top management to easily monitor and evaluate the project performance, and to quickly and accurately pursue for successful completion of construction work according to clients' demands.

1.4 Aims and Objectives of Study

The aim of the research is to develop an Executive Information System for monitoring construction work progress (named 'Executive Information Site

Monitoring System'-EISMS). The system shall be able to analyse data obtained directly from site and to provide information to top management. It provides customised information required by top management to make decision. The system shall also serves as a checking or validating tool for top management when reviewing reports from project managers at site or from projects department at head office. By having such a system, top management is able to digest the status of work progress at site almost instantaneously. The system shall avoid using complicated integrated software system because it requires different skills to handle which in turn will involve many different departments. It should be a user friendly system, easy to install and to maintain. Thus, to achieve the final outcome of this research, the following step related objectives have been identified;

Objective1: To identify problems faced by top management to monitor construction work progress.

Objective2: To identify key performance indicators needed by top management to monitor construction work progress.

Objective3: To investigate and identify various models for construction monitoring in Malaysia Construction Industry (MCI).

Objective4: To investigate and identify Executive Information System feature requirements for development of Executive Information System.

Objective5: To develop an Executive Information System to monitor construction work progress.

Objective6: To validate and verify the developed Executive Information System.

1.5 Scope and Limitation of the Study

For the development of this new information system so called EISMS, the performance measurements to be analyzed in this study shall focus solely on the physical work completion at site. Other performance measurements, like resource productivity and which includes such things as material on site, labour, machinery and plants are not within this scope of study. The research is to improve efficiency in performance monitoring and not other scopes like improvement in scheduling, workers satisfaction and data acquisition.

The sponsor of the research has involved in many building projects and has interest in improving building construction. In line with that the research has focus more on developing a system for a building construction.

The research limits its scope to produce a software prototype to illustrate the workability of the system proposed and not a product up to commercial level. As such the case study selected for testing the prototype shall be limited to a simple and small building project with a construction price of not more than RM5 million.

1.6 Significance of the Research

Basically, construction works produce a lot of information that is required by the top management to track the work progress at site. The executive information system can improve top management's ability to monitor, coordinate and control the operation of an organization efficiently and to streamline the process of accurate decision making. This is because the system provides top management with high quality, timely, relevant, and relatively complete information. Apart from acting as a

validating tool, EISMS can also play the role of a second source of information to top management. This role can be depicted in the flow chart as shown below:

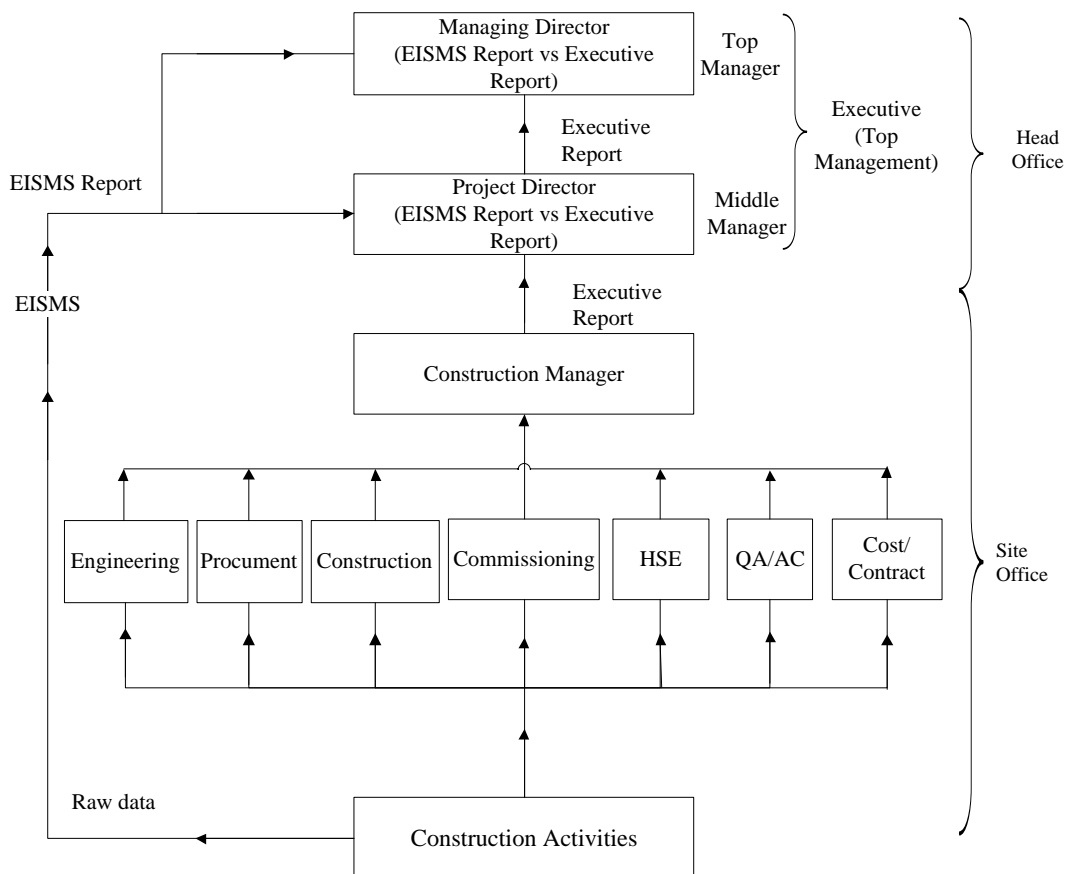


Figure 1.1: Role of EISMS

1.7 Research Methodology Framework

Preliminary understanding of the research subject was obtained through several discussions with personnel whose have more than fifteen years in

construction work followed by intensive literature review on various topics. A close-end questionnaire was designed for this research. The questionnaire was divided into five different sections corresponding to objectives of the research. Likert Scale method was selected to measure the variable data. The final developed questionnaire survey then was sent to contractor companies selected randomly from a list provided by the Construction Industry Development Board (CIDB) Malaysia; these companies were registered under building contractor of Grade VII (PKK Class A Contractor). Apart from the questionnaire survey, several face to face interviews were also carried out. The data collected from the survey were then analyzed using average index method for result and discussion.

From the discussions with the experience personnel, an intensive literature review and questionnaire survey, the system requirements for EISMS were established and from there, EISMS was developed based on Waterfall Model. To validate and test the EISMS, the complete developed prototype was used to monitor an actual construction building work in Selangor, Malaysia. Upon successful validation and verification of EISMS prototype, the research was concluded. A flow chart showing the process of the research methodology is presented in Figure 1.2.

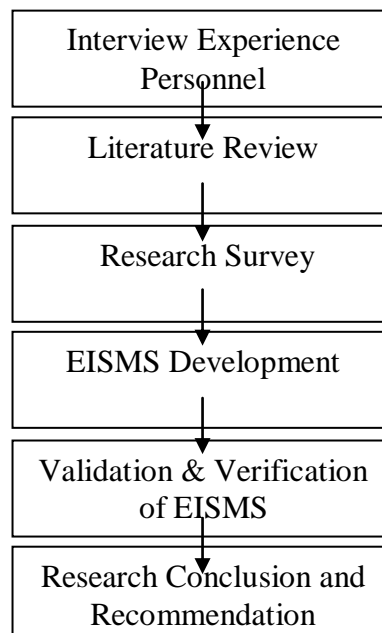


Figure 1.2 Research Methodology Frameworks

1.8. The Organization of Thesis

This research is presented into eight chapters as follows:

Chapter 1: Introduction; This chapter briefly discussed the introduction to the research topic, which is the development of an Executive Information System (EIS) to monitor construction work progress. This chapter furthermore outlined the background of the study, problem statement, aim and objectives, scope and limitations of the study, significance of the research, research methodology framework and the organization of the thesis.

Chapter 2: Construction Monitoring Problem and Its Performance Measurement; This chapter reviews the main subjects related to the research topic namely monitoring in construction, advances in information technology, an executive information system and level of management in a construction organization. This chapter also reviews various topics related to the first two objectives of the research study which are construction work performance, key performance indicator, method to measure performance and performance measurement methods by EISMS. It reviews the previous works by other researchers published in journals, books and proceedings.

Chapter 3: Construction Monitoring Systems and Features for System Development; This chapter reviews various topics related to the last four objectives of the research study which are current model of computerized construction monitoring system, system development, software architecture and finally network architecture. It reviews the previous work by other researchers published in journals, books and proceedings.

Chapter 4: Research Methodology; For this chapter, the process of the research methodology is presented in chronological order. These are literature review, research survey, EISMS development and EISMS validation and verification.

Chapter 5: Research Survey; This chapter deals with conducting research's survey including design of the questionnaire, method of sampling and data collection, data analysis, results and discussion, and finally survey conclusion

Chapter 6: EISM Development; In this chapter, the process of developing EISM is presented. The process of EISMS development is based on Waterfall Model starting from identification of the system requirement, followed by product design, detail design and coding, unit integration and system implementation/system testing.

Chapter 7: Validation and Verification of the EISMS; An actual case study was carried out to validate and verify the effectiveness of the EISMS. This chapter explains the flow of methodology for validation and verification of EISMS including identifying a suitable project, preparation of basic data 1, and preparation of basic data 2, validation of month 1, verification of EISMS as EIS, verification of EISMS system requirement, validation of month 2-5 and conclusion of validation and verification of EISMS.

Chapter 8: Conclusion and Recommendation; This chapter discussed the conclusion for the whole research, the problems encountered during the research, recommendations for the result and some ideas and suggestions to further extend the development of the EISMS to the next level.

REFERENCES

- Abd. Majid, M.Z., and McCaffer, R. (1997). *Assessment of performance of maintenance contractors in Saudi Arabia*, Journal of management in engineering, ASCE, 13,91.
- Abd. Majid, M.Z., Memon, Z.A., and Mustaffar, M. (2004). Conceptual digital Monitoring model for evaluating the progress of work. *The proceeding of 4th Conference of Construction Application of Virtual Reality (CONVR) 2004*, 13-15 September 2004, ADETTI/ISCTE, Lisbon, Portugal. 161-166.
- Abdullah, A., Marsono, A.K. and Ramli, M.Z. (2005). *Construction Management Information System*. 2nd ed., Information Technology Unit of Civil Engineering (ITUCE): Universiti Teknologi Malaysia.
- Abeid, J. N., Allouche, E., Arditi, D. and Hayman, M. (2003). *PHOTO-NET-II: A Computer-based Monitoring System Applied to a Project Management*. Journal of Automation in Construction. 12(5):603-616.
- Aldrich, H. E. (1979). *Organizations and Environments* (Englewood Cliffs, NJ: Prentice-Hall, 1979).
- Alfeld, L. E. (1988). *Construction productivity, on-site measurement and management*, McGraw-Hill, New York.
- Al-harthy, A.S.H. (2006). *The consultancy Fee for structural Design Changes of Reinforced Concrete Building in Oman*. Faculty of Civil Engineering, Universiti Teknologi Malaysia, Skudai, Johore, Malaysia:Ph.D. Thesis.
- Bassioni H.A., Price A.D.F and Hassan T.M. (2004). Performance Measurement in Construction, *Journal of Management in Engineering, ASCE* April
- Belcher L. and Watson H., (1993). *Assessing the Value of Conoco's EIS*. MIS Quarterly Vol. 17,No.3, September 1993.
- Blackburn. S. (2002). *The project manager and the project network*, International Journal of Project Management 20 (2002) 199-204.
- Boehm, B.W. (1988). A Spiral Model of Software Development and Enhancement. *IEEE*, May, 61-72.

- Bowler, C.E. (1994). Database use in Engineering Office. Computing in Civil Engineering, Proceeding of the first Congress, Washington, D.C., June 20-22, American Society of Civil Engineers, Vol. 2, pp. 1874-1879.
- Construction Best Practice Program-Key Performance Indicators (CBPP-KPI)*.(2002). (<http://www.cbpp.org.uk/cbpp.org.uk/cbplthemes/bm/KPIs/>)
- Chan, Y.C. (2003). *Pre-Qualification Structured Learning (PQSLs) Series - Schedule of Rates vs. Bills of Quantities*. <http://www.hkis.org.hk> viewed 03/06/05 The Hong Kong Institute of Surveyors
- Cheung, S.O., Sue, H.C.H., And Cheung, K.K.W. (2004). PPMS: a web based construction Project Performance Monitoring System, *Automation in construction* 13, 361-376
- Chin, S., Suwon Y., Kim. Y.S., Jeongwon Ryu, J., Choi. C., and Cho, C.Y. (2005). Realtime 4d Cad + Rfid For Project Progress Management. *Construction Research Congress 2005*
- Cox, R. F., Issa, R.R.A. and Ahrens, D. (2003). Management's perception of key performance Indicator of Construction, *Journal of Construction Engineering and Management*, March/April.
- Davis, P.R. and Baccharini, D. (2004). *The Use of Bills of Quantities in Construction Projects - An Australian Survey*. <http://www.rics-foundation.org/publish>, viewed 03/06/05
- Davis, R.C. (1951). *The Fundamentals of Top management*. New York: Harper, 1951
- Dawood, N., Sriprasert, E., Mallasi, Z., and Hobbs, B., (2002). *Development of an Integrated Information Resource base for 4D/VR construction process simulation*. *Automation in Construction*, 12(2002), p.p. 1874-1879.
- Deng Z.M., Li H., Tam C.M., Shen Q. P., and Love P.E.D. (2001). An application of the Internet-based project management system. *Automation in Construction*: 10 2001. 239-246
- Egan, J. (1998). *Rethinking Construction*. Dept. of the Environment, Transport and the Regions, London.
- Etzioni, A. (1964), *Modern Organizations*, Prentice-Hall, Englewood Cliffs, NJ.
- Everett, J.G., Halkali, H., et al., (1998). Time-lapse video applications for Construction Project management. *Journal of Construction Engineering and Management* 124(3):204-209
- Fellows, R. & Liu, A. (2003). *Research Methods for Construction*. 2nd ed. Blackwell Publishing.
- Hackett, M. and Robinson, I., (2003) *Pre-Contract Practice and Contract Administration*. Oxford: The Aqua Group & Blackwell Science. pp 96-105

- Hahn, M., Lawson, R. and Lee, Y.G. (1992). The effects of time pressure and information load on decision quality. *Psychology & Marketing*, 1992, 9(5) pp. 365-378.
- Haksver, A. M. and Fisher, N. (1996). A Method of Measuring Information Overload in Construction Project Management, *CIB W89 Beijing International Conference, 21-24 October, 1996*
- Halligan, D. W., Demsetz, L. D., and Brown, J. D. (1994). “Action response model and loss of productivity in construction.” *J. Constr. Eng. Manage.*, 120(1), 47–64.
- Hamilton, D.O. (1993). Records Management in Engineering Firms. *Journal of Management in Engineering*, 7(4): 346-356.
- Hamilton, B.A. (2006). *Earned Value Management Tutorial Module1: Introduction to Earned Value Management*, United States of America Department of Energy, <http://www.science.doe.gov/opa/pdf/FinalModule1.ppt>.
- Harris, F. and McCaffer. R.(2001). *Modern Construction Management*, 5th Edition Blackwell Science Ltd, Malden USA.
- Harris, P., (2006). *Comparison of Earned Value Standards*. Eastwood Harris Pvt. Ltd. Chapter 2, 03
- Hilsop, R. D. (1991). “A construction safety program.” *Professional safety*, American Society of Safety Engineers, Des Plaines, Ill., 15– 20.
- Hinze, J.W., (1998), *Construction Planning and Scheduling*, Prentice Hall Upper Saddle River, New Jersey Columbus, Ohio.
- Hiroshi, N. and Nobuoh, H. (1993). Filing of construction photos linked with database. Computing in Civil and Building Engineering, *The Fifth international Conference, Anaheim, Calif.*, June 7-9, American Society of Civil Engineers, Vol. 1, 718-721.
- Ibrahim, Y.M. and Kaka, A.M. (2008). Review of Photographic/Imaging Applications in Construction. *The Built & Human Environment Review: Volume 1*, 2008
- Jirachiefpattana, W. (1997). The Impacts of Thai Culture on Executive Information Systems Development, *International Journal Of Computer and Engineering Management*, retrieved at Feb. 2010 <http://www.journal.au.edu/ijcem/may97/article4>.
- Jones, G.R. and George, J.M. (2003). *Contemporary Management* . 3rd edition. New York: McGraw Hill.
- Kaisler, S.H. (2005). *Software Paradigm*. John Willey & Sons
- Kaniclides, A. and Kimble C. (1995). A Development Framework for Executive Information Systems, *The second Groningen International Information Technology Conference for Students (GRONICS) '95*, Groningen, The Netherlands, Ed T LOURENS, February, 47-52.

- Kruchten, P. (2004). *An Ontology of Architectural Design Decisions*. In Jan Bosch (ed.) Proceedings of the 2nd Groningen Workshop on Software Variability Management, Groningen, NL, December 3-4, 2004.
- Laufer, A. (1985). "On site performance improvement programs." *J. Constr. Eng. Manage.*, 111(1), 82-97.
- Levine, H. (1989). *A Project Management Using Micro Computers*. McGraw-Hill, United Kingdom.
- Liu, L.Y., Stumpf, A.L., and Kim, S.S. (1994). Applying Multimedia Technology to Project Control. *The First Congress on Computing in Civil Engineering* June 20-22, 1994, in Washington, D.C., 608-613.
- Lock, D. (1993). *Handbook of Engineering Management*, Butterworth-Heinemann, Oxford, United Kingdom, Chapter 20 and 27
- Malaysia Standard Method of Measurement of Building Works*. (2000). Second Edition (SMM2), The Institution of Surveyors Malaysia.
- Mazerolle, M., and Alkass, S. (1993). An Intergrated system to facilitate the analysis of construction Claims. *Computing in Civil and Building Engineering. Proceeding of the fifth International Conference, Anaheim, Calif., June 7-9*, American Society of Civilo EEngineeringings, Vol. 2 pp. 1509-1517.
- McIver, J. P., & Carmines, E. G. (1981). *Unidimensional scaling*. Thousand Oaks, CA: Sage.
- McLeod. R. & Jones. J. W., (1986). *Making Executive Information More Effective*. Business Horizons, Sept. - Oct. 1986, pp 29 - 37.
- Marosszeky, M. and Karim, K. (2002). Benchmarking-A Tool for Lean Construction, *the fifth annual Conference of the International Group for Lean Construction (IGLC-5)*, 16-17 July, 1997 Gold Coast, Australia
- Memon, Z.A., Abdul Majid, M.Z. and Mustaffar, M. (2006). Digitalizing Construction Monitoring (DCM): An Overview of Malaysian Construction Industry and Proposing Prototype Software *The 6th Asia Pacific Structural Engineering and Construction Conference (ASPEC)*, 5-6 September, Kuala Lumpur.
- Memon, Z.A., (2008). The ACPROM Model: An Expert System for Evaluating the Construction Progress. *First International Conference on Construction In Developing Countries (ICCDIC-1 "Advancing and Integrating Construction Education Research & Practice*. August 4-5, 2008, Karachi Pakistan.
- Millet I. et al. (1991). *A Path Framework for Executive Information Systems*. Transactions of the Eleventh International Conference on Decision Support Systems, 1991.

- Mintzberg H., (1975). *The manager's job: Folklore and fact*. Harvard Business Review, 53(4),1975.
- Mohd Noor. N.M. (2006). Real Time Communication and Collaboration for Supporting Construction Management. *Department of computer science, Faculty of Science and Technology KUSTEM Malaysia*
- Mohsini, R.A., and Davidson, C.H. (1992). Determinants of performance in the traditional building process, *Construction Management & Economics* 10 (4) (1992) 343– 359.
- Nagrecha, S. (2002). *An introduction to Earned Value Analysis* http://www.pmiglc.org/COMM/Articles/0410_nagrecha_eva-3.pdf
- Navon, R. (2007). Research in Automated Measurement of project performance Indicator. *Automation in construction*. 16 (2007) 176-188
- Navon, R., and Goldschmidt, E. (2002). Monitoring labor inputs: automated-data-collection model and enabling technologies. *Automation in Construction* 12 (2002) 185– 199
- Nickerson, R. C. and Muthaiyah, S. (2004). *Information Systems*. Pearson Prentice Hall.
- Nunnally, J. C., & Bernstein, I. H. (1994). *Psychometric theory* (3rd ed.). New York: McGraw-Hill.
- Oglesby, C. H., Parker, H. W., and Howell, G. A. (1989). *Productivity improvement in construction*, 1st Ed., McGraw-Hill, New York.
- Ong, V., Duan, Y., Xu, M. and Mathews, B. (2005). Revitalizing Executive Information Systems Design and Development, *EMCIS*. Page 1-17
- Osborne, D., and Gaebler, T. (1992). *Reinventing Government, How the Entrepreneurial Spirit is Transforming the Public Sector*.
- Paller A. and Laska R., (1992). *What users want today*, in Watson H. J. Rainer R. K. and Houdeshel G., *Executive Information Systems: Emergence, Development, Impact*. Chichester: John Wiley & Sons, 1992.
- PMBOK (2004). *A Guide to Project Management Body of Knowledge*. Project Management Institute, Pennsylvania.
- Rockart J. F. and Treacy M., (1982). *The CEO Goes On-line*. Harvard Business Review, 60 (1), Jan-Feb 1982.
- Root, D and Blismas, N. G. (2003). Increasing questionnaire responses from industry: practices surrounding the use of postal questionnaires. In: Greenwood, D J (Ed.), *19th Annual ARCOM Conference*, 3-5 September 2003, University of Brighton. Association of Researchers in Construction Management, Vol. 2, 623-31.
- Russell, A.D. (1993). Computerized Daily Site Reporting. *ASCE Journal of Construction Engineering and Management*, 19(2): pp. 385-402.

- Saad, I.M.H. (1999). The project Reporter: Multimedia Progress Reporting for Construction Projects. *Construction Informatics Digital Library* <http://itc.scix.net/paper/w78-1999-2358.content>
- Schleifer, T. C. (1990), *Construction Contractor's Survival Guide*, John Wiley & Sons
- Silva, L.P., Ruwanpura, J.Y., and Hewage, K.N. (2009). Virtual Supervision in Construction Projects. *Construction Research Congress, ASCE 2009*.
- Spector, P. (1992). *Summated rating scale construction*. Thousand Oaks, CA: Sage.
- Streilein, A. (1996). Utilization of CAD Models for the object oriented Measurement of Industrial and Architectural Objects. *International Archives of Photogrammetry and Remote Sensing*, Vol. XXI, Part B5, Vienna 1996, 548-553.
- Stumpf, A. L., Ganeshan, R., Chin, S., Ahn, K., and Liu, L.Y. and (1993). CADD Requirements to Support Corps of Engineers Construction Field Activities. USACERL Technical Report, September 30.
- Stumpf, A. L., Chin, S., Liu, L.Y. and Ganeshan, R. (1995). Use of a Relational Database System to Integrate Product and Process Information during Construction: *Construction Information Digital Library* <http://itc.scix.net/paper/W78-1995>, 316-326.
- Sudhakar, G. P. (2010). *Elements of Software project Management*. PHI Learning Private Limited, New Delhi. 2010.
- Syed, S. and Froese, T. (1998). Project Management Information Control Systems. *Canadian Journal of Civil Engineering*; Aug 1998; 25, 4.
- Takim, *et al.* (2003). Performance measurement systems in construction. Greenwood, D J (ed), *19th annual ARCOM Conference*, 3-5 September 2003, University of Brighton. Association of Researchers in Construction Management, Vol. 1, 423-32
- Tan. A.L. (2005). *Successful Project Management in Malaysia*. Asia Pacific Media & Publication.
- Tenah, K.A. (1986). Construction Personnel Role and Information Needs. *ASCE Journal of Construction Engineering and Management*. 112(1):33-48.
- Thierauf R. J., (1991). *Executive Information Systems: a guide for senior management and MIS information professionals*. New York: Quorum Books, 1991.
- Thomas, R. H., and Kramer, D. F. (1988). *The manual of construction productivity measurement and performance evaluation*, Construction Industry Institute, Pennsylvania State Univ., University Park, Pa.
- Thomas, R. H., and Mathews, C. T. (1986). *An analysis of the methods for measuring construction productivity*, Construction Industry Institute, Pennsylvania State Univ., University Park, Pa.

- Turban, E. and Aronson, J.E., (2001). *Decision Support Systems and Intelligent Systems*, 6th Ed. New Jersey: Prentice Hall
- Wang, S.Q. (2001). ESSCAD: Expert System Integrating Construction Scheduling with CAD Drawing. *Construction Information Digital library* <http://itc.scix.net/> paper w78-2001-46.Content.
- Ward, C.S., Curtis, B., and Chapman C.B. (1991). Objectives and Performance in Construction projects. *Construction Management Economics.*, 9, 343-354
- Warren, R. H. (1989). *Motivation and productivity in the construction industry*, Van Nostrand Reinhold, New York.
- Watson H., R. Kelly Rainer, Chang E. Koh, (1991). *Executive Information Systems: A framework for Development and a Survey of Current Practices*. MIS Quarterly, Vol. 15, No. I, March 1991.
- Willis, C.J., Ashworth, A. and Willis, J.A.(2002). *Willis's Practice and Procedure for the Quantity Surveyor*. 11th Edition London: Blackwell Science pp 172-205
- Young, D. and Watson, H. J., Determinates of EIS Acceptance. (1995). *Journal of Information Management*, Vol.29 (3), 153-164.
- Zhang and Yuan. (2007). Information Technology Application to Construction Management Modernization, *International Conference on Service System and Service Management (ICSSSM)*, 1-5.