FUZZY ANALYTIC HIERARCHY PROCESS APPROACH FOR SUPPLIER DEVELOPMENT TOWARDS SUSTAINABLE AND RESPONSIVE MANUFACTURING

RAHAYU BINTI TUKIMIN

DOCTOR OF PHILOSOPHY

2023

Faculty of Manufacturing Engineering

FUZZY ANALYTIC HIERARCHY PROCESS APPROACH FOR SUPPLIER DEVELOPMENT TOWARDS SUSTAINABLE AND RESPONSIVE MANUFACTURING

UTeM
اونيۏرسيتي تيکنيکل مليسيا ملاک
UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Rahayu binti Tukimin

Doctor of Philosophy

2023

FUZZY ANALYTIC HIERARCHY PROCESS APPROACH FOR SUPPLIER DEVELOPMENT TOWARDS SUSTAINABLE AND RESPONSIVE MANUFACTURING

RAHAYU BINTI TUKIMIN

A thesis submitted
in fulfillment of the requirements for the degree of
Doctor of Philosophy

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Faculty of Manufacturing Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2023

DECLARATION

I declare that this thesis entitled “Fuzzy Analytic Hierarchy Process Approach for Supplier Development towards Sustainable and Responsive Manufacturing” is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : ……..

Name : Rahayu binti Tukimin ……..

Date : ……..

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Doctor of Philosophy.

Signature : ……..….

Supervisor Name : Associate Professor Ts. Dr. Wan Hasrulnizzam bin Wan Mahmood

Date : ……..……

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

DEDICATION

This thesis is dedicated to my beloved mother, ***Khminah binti Bingon*** and my faithful companion, my daughter, ***Zahiyyah Raihanah binti Zamani*** who offered unconditional love and encouragement and have always been there for me.

Thank you so much.

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

ABSTRACT

In recognition of suppliers' vital role in the supply chain, manufacturing firms need to manage and develop their suppliers in line with two keys requirements; sustainability and responsiveness performance. A good relationship between manufacturers and a competent network of suppliers is required. Therefore, manufacturing firms may engage through the supplier development (SD) program. However, there is an extensive number of practices in SD, sustainable manufacturing (SM) and responsive manufacturing (RM). The impacts of each practice are diverse and not contribute equally, yet the manufacturing firms also have a limited resource. The manufacturing firms need to carefully and wisely identify which practices are more suitable for their operations environment to localise their investment for saving time, money and resources. Thus, the need for a framework to provide important information on which practices should be focused on is crucial. The selection of practices led to multi-criteria decision making (MCDM) problem. For those reasons, the MCDM method needs to be employed in the evaluation and decision-making process. Hence, this study is carried out to investigate the practices in SD, SM and RM implemented by Malaysian manufacturing firms. The survey data were collected from ISO14001 certified manufacturing firms in Malaysia as registered in Standard and Industrial Research Institute of Malaysia (SIRIM) database. Of 264 questionnaires, 78 questionnaires were returned, and only 71 (26.89%) questionnaires with completed information were accepted for further analysis. A preliminary analysis indicates that the implementation of the SD program had a significant relationship with SM and RM. From factor analysis, SD practices were extracted into five main factors, namely, Supplier Certification (SC), Green Capability (GC), Investment and Resource Transfer (IRT), Feedback and Evaluation (FE) and Knowledge Transfer (KT). Among the factors, KT produces significant, positive relationships to the three pillars of SM; economic, environmental and social. KT also significantly, positively correlate with RM. To develop the framework, the fuzzy logic and Analytic Hierarchy Process (AHP) were integrated. The results show that the priorities for SD practices associated with KT (0.247), SC (0.221), FE (0.201), GC (0.195), IRT (0.135). For SM, the priorities ranked by environmental (0.422), economic (0.333) and social (0.245) whereas, for RM, responsiveness (1.000) solely factorised and consists of seven practices. The research is beneficial to provide important information, particularly to industrial practitioners, to identify which practices need to be focused on, so investment in the supplier development programs can be localised wisely. This research significantly affects saving time, money, and resources in enhancing suppliers' capabilities who contribute to the movement of the supply chain and eventually enhance the manufacturing sustainability and responsiveness.

PENDEKATAN PROSES HIRARKI ANALITIK KABUR UNTUK PEMBANGUNAN PEMBEKAL KE ARAH PEMBUATAN MAMPAN DAN RESPONSIF

ABSTRAK

Sebagai mengiktiraf peranan penting pembekal dalam rantaian bekalan, firma pembuatan perlu mengurus dan mengembangkan pembekal mereka selaras dengan dua syarat utama; prestasi kemampanan dan prestasi responsif. Perhubungan yang baik antara pengeluar dan rangkaian pembekal yang kompeten adalah diperlukan. Bagi memastikan perhubungan tersebut dikekalkan, firma pembuatan perlu melibatkan diri dalam program pembangunan pembekal (SD). Namun, bilangan amalan yang terlibat dengan SD, pembuatan mampan (SM) dan pembuatan responsif (RM) adalah banyak. Kesan untuk setiap amalan adalah tidak sama dan sumbangannya adalah berbeza serta firma pembuatan mempunyai sumber yang terhad. Firma pembuatan perlu berhati-hati dan bijak mengenal pasti amalan yang lebih sesuai untuk persekitaran operasi mereka bagi memastikan pelaburan mereka adalah menjimatkan masa, wang dan sumber. Maka, keperluan satu kerangka yang dapat memberi maklumat penting tentang amalan mana yang perlu dititikberatkan adalah sangat penting. Pemilihan amalan yang banyak ini melibatkan masalah pembuat keputusan berbilang kriteria (MCDM). Disebabkan perkara ini, kaedah MCDM perlu digunakan dalam proses penilaian dan membuat keputusan. Oleh itu, kajian ini dijalankan bagi menentukan dan memeriksa jenis-jenis amalan SD, SM dan RM bagi firma pembuatan di Malaysia. Data kajian dikumpul daripada firma pembuatan dengan persijilan ISO 14001 yang berdaftar dalam pengkalan data Institut Piawaian dan Penyelidikan Perindustrian Malaysia (SIRIM). Daripada 264 kertas soalselidik, 78 soalselidik diterima kembali, dan hanya 71 (26.89%) soalselidik yang lengkap diterima dan digunakan untuk tujuan analisis lanjut. Analisis awalan menggambarkan perlaksanaan amalan SD mempunyai hubungan yang signifikan dengan kemampanan dan responsif pembuatan. Dari analisa faktor, amalan SD diekstrak kepada lima faktor utama, dinamakan sebagai Persijilan Pembekal (SC), Keupayaan Hijau (GC), Pelaburan dan Pemindahan Sumber (IRT), Maklumbalas dan Penilaian (FE) dan Pemindahan Pengetahuan (KT). Di antara faktor-faktor tersebut, KT mempunyai hubungan positif yang signifikan dengan tiga tonggak SM iaitu ekonomi, alam sekitar dan sosial. KT juga mempunyai korelasi yang signifikan dan positif dengan RM. Bagi menghasilkan kerangka, logik fuzzy dan Proses Hierarki Analitik (AHP) disepadukan bersama. Hasil dapatan menunjukkan bagi amalan SD, susunan keutamaan adalah KT (0.247), SC (0.221), FE (0.201),GC (0.195), IRT (0.135). Untuk SM, susunan keutamaan bermula dengan faktor alam sekitar (0.422), ekonomi (0.333) dan sosial(0.245). Manakala untuk RM, responsif (1.000) adalah faktor tunggal dan mengandungi tujuh amalan. Kajian ini bermanfaat untuk memberi maklumat penting kepada pengamal pembuatan tentang amalan yang perlu dititikberatkan supaya pelaburan terhadap program SD ini dapat di lokalisasikan. Ini sangat memberi kesan kepada penjimatan masa, kewangan dan sumber yang digunakan. Ianya akan meningkatkan keupayaan pembekal yang menyumbang kepada aliran rantaian bekalan dan akhirnya akan menghasilkan kemampanan dan responsif pembuatan yang lebih baik.

ACKNOWLEDGEMENTS

Alhamdulillah, Salawat and *Salam* to our Prophet Muhammad S.A.W, his family members, companions, and followers.

In completing this research, I would like to acknowledge the intellectual sharing of many great individuals. My foremost gratitude goes to my principal supervisor, Associate Professor Ts. Dr. Wan Hasrulnizzam bin Wan Mahmood and my co-supervisor, Professor Datuk Ts. Dr. Mohd Razali bin Muhamad for devoting much of their expertise in guiding to reach the final line of this research. Thank you for all that you did. My gratitude to Majlis Amanah Rakyat and the Ministry of Higher Education for co-funding the research.

To my beloved mother, my daughter, and all my family members, thank you so much for your support and prayers.

I am also indebted to others, the kind and brilliant people for their assistance and support during all the phases of this research.

UTeM
اونيۏرسيتي تيکنيکل مليسيا ملاک
UNIVERSITI TEKNIKAL MALAYSIA MELAKA

TABLE OF CONTENTS

		PAGE
DECLARATION		
APPROVAL		
DEDICATION		
ABSTRACT		**i**
ABSTRAK		**ii**
ACKNOWLEDGEMENTS		**iii**
TABLE OF CONTENTS		**iv**
LIST OF TABLES		**vii**
LIST OF FIGURES		**x**
LIST OF APPENDICES		**xi**
LIST OF ABBREVIATIONS		**xii**
LIST OF SYMBOLS		**xiv**
LIST OF PUBLICATIONS		**xv**
CHAPTER		
1.	**INTRODUCTION**	**1**
1.1	Background	1
1.2	Problem Statement	4
1.3	Research Objectives	8
1.4	Research Scope	9
1.5	Thesis Structure	10
2.	**LITERATURE REVIEW**	**11**
2.1	Introduction	11
2.2	Supplier Development	11
2.2.1	Concept and Definition of Supplier Development	12
2.2.2	Supplier Development Practices	13
2.2.3	Benefits of Supplier Development	22
2.2.4	Supplier Development Program in Malaysia	25
2.3	Manufacturing Performance	30
2.3.1	Sustainable Manufacturing Performance	31
2.3.1.1	Economic Sustainability Practices	33
2.3.1.2	Environmental Sustainability Practices	36
2.3.1.3	Social Sustainability Practices	41
2.3.2	Responsive Manufacturing Performance	44
2.3.2.1	Responsive Manufacturing Practices	45
2.4	Inter-Relatedness of the Supplier Development, Sustainable Manufacturing and Responsive Manufacturing	48
2.5	Multi-Criteria Decision Making	51
2.5.1	Application of FAHP in Manufacturing	54
2.6	Summary	56

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

3. RESEARCH METHODOLOGY **58**
3.1 Introduction 58
3.2 Research Flow 58
3.3 Research Population and Sample 60
3.4 Data Collection Method 61
3.4.1 Questionnaire Development 61
3.4.2 Questionnaire Content Validity 62
3.4.3 Pilot Study 63
3.5 Data Analysis 64
3.5.1 Descriptive Analysis 64
3.5.2 Correlation Analysis 65
3.5.3 Non-Parametric Statistics 66
3.6 Factor Analysis 66
3.7 Framework Development 67
3.8 Framework Validation 69
3.8.1 Instrument 69
3.8.2 Procedure 69
3.9 Summary 70

4. SURVEY RESULT AND ANALYSIS **71**
4.1 Introduction 71
4.2 Reliability Analysis of Instruments 71
4.3 Demographic Information 72
4.4 Analysis of Supplier Development Practices 75
4.4.1 Normality and Binomial Test for Supplier Development Practices 75
4.4.2 Mean Score for Supplier Development Practices 78
4.4.3 Correlation Analysis for Supplier Development Practices 81
4.4.4 Relationship Between Supplier Development Practices and Company Demographics 85
4.4.5 Factor Analysis for Supplier Development Practices 88
4.5 Analysis of Sustainable Manufacturing Practices 92
4.5.1 Analysis of Economic Sustainability 92
4.5.1.1 Normality and Binomial Test for Economic Sustainability Practices 92
4.5.1.2 Mean Score for Economic Sustainability Practices 95
4.5.1.3 Correlation Analysis for Economic Sustainability Practices 96
4.5.1.4 Relationship Between Economic Sustainability Practices with Company Demographic 98
4.5.1.5 Factor Analysis for Economic Sustainability Practices 99
4.5.2 Analysis of Environmental Sustainability Practices 101
4.5.2.1 Normality and Binomial Test for Environmental Sustainability Practices 101
4.5.2.2 Mean Score for Environmental Sustainability Practices 103
4.5.2.3 Correlation Analysis for Environmental Sustainability Practices 104
4.5.2.4 Relationship Between Environmental Sustainability Practices with Company Demographics 106
4.5.2.5 Factor Analysis for Environmental Sustainability Practices 107

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

4.5.3 Analysis of Social Sustainability Practices 109
4.5.3.1 Normality and Binomial Test for Social Sustainability Practices 109
4.5.3.2 Mean Score for Social Sustainability Practices 111
4.5.3.3 Correlation Analysis for Social Sustainability Practices 112
4.5.3.4 Relationship Between Social Sustainability Practices and Company Demographics 113
4.5.3.5 Factor Analysis for Social Sustainability Practices 114
4.6 Analysis of Responsive Manufacturing Practices 115
4.6.1 Normality and Binomial Test for Responsive Manufacturing Practices 115
4.6.2 Mean Score for Responsive Manufacturing Practices 117
4.6.3 Correlation Analysis for Responsive Manufacturing Practices 118
4.6.4 Relationship Between Responsive Manufacturing Practices and Company Demographics 120
4.6.5 Factor Analysis for Responsive Manufacturing Practices 121
4.7 Correlation Analysis Between Variables 123
4.7.1 Correlation Analysis Between Supplier Development Practices and Sustainable Manufacturing Practices 123
4.7.2 Correlation Analysis Between Supplier Development Practices and Responsive Manufacturing Practices 125
4.7.3 Correlation Analysis Between Sustainable Manufacturing Practices and Responsive Manufacturing Practices 126
4.8 Summary 128

5. DEVELOPMENT OF FUZZY ANALYTIC HIERARCHY PROCESS FRAMEWORK 129
5.1 Introduction 129
5.2 Development of Fuzzy Analytical Hierarchy Process Framework for Supplier Development 129
5.2.1 Fuzzy Analytic Hierarchy Process Stage 1 130
5.2.2 Fuzzy Analytic Hierarchy Process Stage 2 133
5.2.3 Fuzzy Analytic Hierarchy Process Stage 3 141
5.2.4 Fuzzy Analytic Hierarchy Process Stage 4 148
5.3 Scoring Method for Selecting Practices 159
5.4 Validation 165
5.4.1 Instrument and Procedure 166
5.4.2 Expert Review Findings 166
5.4.3 Justification on Expert's Comments 168
5.5 Final Framework 169
5.6 Summary 172

6. CONCLUSION AND RECOMMENDATIONS 173
6.1 Conclusion From Research Finding 173
6.2 Contributions 175
6.3 Recommendations 177

REFERENCES 178
APPENDICES 225

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

LIST OF TABLES

TABLE	TITLE	PAGE
2.1	Supplier development practices identified from the literature review	15
2.2	Benefits of supplier development implementation identified from literature	24
2.3	Supplier development program implemented by manufacturing firms in Malaysia	29
2.4	Description of sustainability performance components	31
2.5	Summary of practices in economic sustainability recorded from literature review process	34
2.6	Summary of practices in environmental sustainability recorded from literature review	38
2.7	Summary of practices in social sustainability recorded from literature review	43
2.8	Practices in responsive manufacturing identified from literature review	46
2.9	Application of multiple criteria decision-making technique in manufacturing	52
3.1	MS ISO 14001 certified firms in Malaysia (SIRIM, 2015)	60
3.2	Internal consistency reliability test results from pilot study	64
3.3	Coefficient of correlation (Akoglu, 2018)	65
4.1	Internal consistency reliability test results for research variables	72
4.2	Summary of demographic characteristics of the surveyed population	74
4.3	Summary of normality and binomial test for supplier development practices	76
4.4	Mean score for supplier development practices (priority and achievement)	78
4.5	Spearman rank order correlation for supplier development practices (priority)	81
4.6	Spearman rank order correlation for supplier development practices (achievement)	83
4.8	Results of Kaiser-Meyer-Olkin and Bartlett's test for supplier development practices	89
4.9	Result of exploratory factor analysis for supplier development practices	90
4.10	Summary of normality and binomial test for economic sustainability practices	94
4.11	Mean score for economic sustainability practices (priority and achievement)	95
4.12	Spearman rank order correlation for economic sustainability practices (priority)	96

4.13	Spearman rank order correlation for economic sustainability practices (achievement)	97
4.14	Summary of the result for Kruskal Wallis H Test and Mann-Whitney U test for economic sustainability practices	99
4.15	Results of Kaiser-Meyer-Olkin and Bartlett's test for economic sustainability practices	100
4.16	Results of factor analysis for economic sustainability practices	100
4.17	Summary of normality and binomial test for environmental sustainability practices	102
4.18	Mean score for environmental sustainability practices (priority and achievement)	103
4.19	Spearman rank order correlation for environmental sustainability practices (priority)	105
4.20	Spearman rank order correlation for environmental sustainability practices (achievement)	105
4.21	Summary of Kruskal Wallis H Test and Mann-Whitney U test results between environmental sustainability practices and company demographics	107
4.22	Results of Kaiser-Meyer-Olkin and Bartlett's test for environmental sustainability practices	108
4.23	Results of factor analysis for the environmental sustainability practices	108
4.24	Summary of normality and binomial test for the social sustainability practices	110
4.25	Mean score for social sustainability practices (priority and achievement)	111
4.26	Spearman rank order correlation for social sustainability practices (priority)	112
4.27	Spearman rank order correlation for social sustainability practices (achievement)	113
4.28	Summary of result for the Kruskal-Wallis H Test and Mann-Whitney U test for social sustainability practices	114
4.29	Result of Kaiser-Meyer-Olkin and Bartlett's test for social sustainability practices	114
4.30	Result of exploratory factor analysis for social sustainability practice	115
4.31	Summary of normality and binomial test for responsive manufacturing practices	116
4.32	Mean score of each practices in responsive manufacturing for both the level of priority and achievement	117
4.33	Spearman rank order correlation for responsive manufacturing practices (priority)	119
4.34	Spearman rank order correlation for responsive manufacturing practices (achievement)	119
4.35	Summary of the result for Kruskal-Wallis H Test and Mann-Whitney U test for responsive manufacturing practices	121
4.36	Result of Kaiser-Meyer-Olkin and Bartlett's test for responsive manufacturing practices	122
4.37	Result of exploratory factor analysis for responsive manufacturing practices	122

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

4.38	Spearman rank order correlation between supplier development practices and sustainable manufacturing practices	124
4.39	Spearman rank order correlation between supplier development practices and responsive manufacturing practices	125
4.40	Spearman rank order correlation between practices in responsive manufacturing and sustainable manufacturing	127
5.1	Scale for pair-wise comparison (Saaty T.L., 2008)	134
5.2	Pairwise comparison judgement by decision-maker A in criteria level	135
5.3	Normalised value of pair-wise judgement by decision-maker A	136
5.4	Weight column and weight sum for pair-wise comparison matrix made by decision-maker A	136
5.5	Determination of eigenvalue for pair-wise comparison matrix made by decision-maker A	137
5.6	Random index (Saaty, 2000)	138
5.7	Pair-wise comparison matrices for criteria by all decision-makers concerning SD practices	140
5.8	Characteristic function of the fuzzy numbers (Lee, 2009a)	141
5.9	Transformation of matrix by decision-maker A to fuzzified matrix	141
5.10	Fuzzified pair-wise comparison matrices for criteria under SD practices	142
5.11	Integrated fuzzified pair-wise comparison matrix for criteria in SD practices	144
5.12	Summation of elements in horizontal direction of integrated pair-wise comparison matrix for criteria in SD practices	145
5.13	Summation of element in vertical direction of integrated pair-wise comparison matrix for criteria in SD practices	145
5.14	Fuzzy synthetic extent value for criteria in SD practices	146
5.15	Degree of possibilities of criteria in SD practices	148
5.16	Normalised weight for criteria in SD practices	149
5.17	The overall weightage and ranking for supplier development practices using fuzzy analytic hierarchy process	150
5.18	The overall weightage and ranking for sustainable manufacturing practices using the fuzzy analytic hierarchy process	155
5.19	The overall weightage and ranking for responsive manufacturing practices using fuzzy analytic hierarchy process	158
5.20	Score for practices in responsive manufacturing	159
5.21	Score for practices in supplier development	160
5.22	Score for practices in sustainable manufacturing	161
5.23	Frequency response from expert review	166
5.24	Further comments from the expert	167

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

LIST OF FIGURES

FIGURE	TITLE	PAGE
2.1	Steps involved in a supplier development program at PROTON (Abdullah et al., 2008)	27
2.2	Conceptual framework for supplier development	57
3.1	Flowchart of research methodology	59
3.2	Methodology flowchart to develop hierarchy model	68
3.3	Summary of activities involved in the validation process	70
4.1	Survey respondents	73
4.2	Difference of mean scores between the level of priority and achievement for the supplier development practices	80
4.3	Difference of mean scores between the level of priority and achievement for economic sustainability practices	96
4.4	Difference of mean score between the level of priority and achievement for environmental sustainability practices	104
4.5	Difference of mean score between the level of priority and achievement for social sustainability practices	112
4.6	Difference of mean score between the level of priority and achievement for responsive manufacturing practices	118
5.1	Fuzzy analytical hierarchy process	130
5.2	Hierarchy structure for supplier development	131
5.3	Result of the consistency level made by decision-maker A using GUI developed in Visual Basic 6.0	139
5.4	GUI for calculating score developed using Visual Basic softwar	162
5.5	Window display to select practice	162
5.6	Window display for selecting practices in supplier development	163
5.7	Window display for selecting practices in sustainability performance	163
5.8	Window display for selecting practices in responsive manufacturing	164
5.9	Percentage score displayed by GUI	164
5.10	Final framework for supplier development	171

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

LIST OF APPENDICES

APPENDIX	TITLE	PAGE
A	Background of panels	225
B	Questionnaire survey	226
C	Factor analysis for practices in Supplier Development	235
D	Interview questions	241
E	Background of decision-makers	266
F	List of expert reviewers	268
G	Sample of consent form for expert	269
H	Validation instrument	270
I	Confirmation letter of editing	279

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

LIST OF ABBREVIATIONS

AHP	-	Analytical Hierarchy Process
AP	-	Automotive Product Group
CSP	-	Chemical and Scientific Product Group
CSR	-	Corporate Social Responsibility
EEP	-	Electrical and Electronic Product Group
EFA	-	Exploratory Factor Analysis
ES	-	Economic Sustainability
EvS	-	Environmental Sustainability
FAHP	-	Fuzzy Analytical Hierarchy Process
GDP	-	Gross Domestic Product
GUI	-	Graphical User Interface
KeTTHa	-	Ministry of Energy, Green Technology, and Water
MITI	-	Ministry of International Trade and Industry
MO	-	Local ownership
MP	-	Mechanical Product Group
NGO	-	Non-governmental Organisation
OP	-	Other Product Group
PETRONAS	-	Petrolium Nasional Berhad
RM	-	Responsive Manufacturing
SD	-	Supplier Development

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

SM	-	Sustainable Manufacturing
SME	-	Small Medium Enterprise
SPSS	-	Statistical Packages for the Social Sciences
SS	-	Social Sustainability
UEO	-	US and European ownership

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

LIST OF SYMBOLS

$\bar{b}_{ij}$	-	Integrated Fuzzy pair-wise comparison matrix
CI	-	Consistency index
CR	-	Consistency ratio
D_{ij}	-	Triangular Fuzzy Number
N	-	Size of matrix
RI	-	Random consistency index
S_i	-	Fuzzy synthetic extent value
$V(S_2 \geq S_1)$	-	Degree of possibilities
λ_{max}	-	Eigenvalue

UTeM
اونيۏرسيتي تيکنيکل مليسيا ملاك
UNIVERSITI TEKNIKAL MALAYSIA MELAKA

LIST OF PUBLICATIONS

Journal:

1. Rahayu Tukimin, Wan Hasrulnizzam Wan Mahmood, and Maimunah Mohd Nordin, 2022. Application of Fuzzy AHP for Supplier Development Prioritization, *International Journal of Advanced and Applied Science,* 9(12), pp. 125-134.

2. Rahayu Tukimin, Wan Hasrulnizzam Wan Mahmood, Maimunah Mohd Nordin, Mohd Razali Muhamad, and Numfor Solange Ayuni, 2021. Application of AHP and FAHP Algorithm for Supplier Development Evaluation, *Malaysian Journal on Composites Science and Manufacturing*, 5(1), pp. 21-30.

3. Tukimin, R., Wan Mahmood, W. H., Muhamad, M. R., and Mohd Nordin, M., 2020. Exploring the Impact of Supplier Development Practices on Manufacturing Responsiveness in Malaysia. *International Journal of Integrated Engineering*, 12(5), pp. 171-177.

4. Tukimin, R., Wan Mahmood, W. H., Mohamed, N., Mohd Rosdi, M. N. H, and Mohd Nordin, M., 2019. Prioritization of Supplier Development Practices: A Fuzzy Method. *International Journal of Recent Technology and Engineering,* 8(4), pp. 11020-11024.

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

5. Wan Mahmood, W. H., Tukimin, R., Muhamad, M. R. and Yusup, M. Z., 2014. Sustainable Criteria in a Supplier Selection, *Lahore Science International*, 26(5), pp. 1841-1844.

Proceedings:

1. Tukimin, R., Wan Mahmood, W. H., Mohamed, N., Mohd Rosdi, M. N. H, and Mohd Nordin, M., 2019. Prioritisation of Supplier Development Practices: A Fuzzy Analytic Hierarchy Process Approach. In *Proceeding of the International Innovation Technology Exhibition & Conferences 2019 (iTec'19)*, Kemaman, Terengganu, 24-25 September 2019.

2. Tukimin, R., Wan Mahmood, W. H., Muhamad, M. R, Mohd Nordin, M., and Abdullah, M. S. S., 2018. Exploring the Impact of Supplier Development Practices on Manufacturing Responsiveness in Malaysia. In *Proceeding of Engineering Technology International Conference ETIC'2018,* Malacca, Malaysia, 15-16 August 2018.

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

3. Tukimin, R., Wan Mahmood, W. H., Muhamad, M. R., and Mohamed, N., 2018. Supplier Development Practices: From Manufacturers' Perspectives. In *Proceeding of the Innovative Research and Industrial Dialogue 2018 (IRID'18),* Malacca, Malaysia, July 2018.

4. Tukimin, R., Wan Mahmood, W. H., and Muhamad, M. R., 2016. The Current Practices of Green Supplier Development Among Malaysian Manufacturing Firm's. In *Proceeding of the 1st Conference in Engineering, Technology, and Education (CETED 2016),* Merlimau, Malacca, 4-5 October 2016.

5. Wan Mahmood, W. H., Tukimin, R., Muhamad, M. R. and Yusup, M. Z., 2014. Sustainable Criteria in a Supplier Selection. In *Proceeding of the International Symposium on Research in Innovation and Sustainability (ISoRIS 2014),* Malacca, Malaysia, 15-16 October 2014.

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

CHAPTER 1

INTRODUCTION

1.1 Background

Manufacturing is an essential sector and can be considered as a pillar of the world economy. In Malaysia, this sector is the second largest after the service sector and contributes to the Malaysian economy. According to the Ministry of Finance and Department of Statistics Malaysia report, manufacturing activity has outstripped the growth of other principal sectors, maintaining its share in Gross Domestic Product (GDP) at 22-23% from the year 2013-2019. The manufacturing sector exceeded the targeted growth rate, mainly contributed by the electrical and electronic cluster due to new semiconductors' applications and chemical clusters (EPU, 2018). Department of Statistics Malaysia reported that the manufacturing sector recorded an increase of RM69.9 billion in April 2019. This value represented 6.8 percent in growth compared to sales in 2018, which the value is RM65.5 billion. The Malaysian Investment Development Authority data showed that the electrical and electronic industry contributes significantly to foreign investment, 84.5% of all investments in the industry. This industry also the main contributor to job opportunities (MIDA, 2018). These show the powerful presence of the manufacturing sector towards the economy of the country.

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

In today's business environment, manufacturing firms face challenges associated with getting a product and service at the right time and the lowest cost. To overcome these challenges, understanding and practising proper supply chain management has become an essential prerequisite to stay competitive (Kumar et al., 2018; Sakuramoto et al., 2019). One