



# ISAHP 2013

THE 12<sup>TH</sup> INTERNATIONAL SYMPOSIUM  
ON THE ANALYTIC HIERARCHY PROCESS  
Multi-Criteria Decision Making

*Theme: Better World through Better Decision Making*

[About ISAHP](#)

[Foreword](#)

[Committee](#)

[Contents  
\(Authors & Papers\)](#)

[Copyright & Contact](#)

Exit

**HOTEL ISTANA  
KUALA LUMPUR, MALAYSIA**  
23<sup>rd</sup>-26<sup>th</sup> JUNE, 2013



ORGANIZED BY  
الجمعية الوطنية للمعيارية  
INTERNATIONAL ASSOCIATION FOR  
OPERATIONAL RESEARCH

**ASURE**  
ASIA PACIFIC UNIVERSITY  
RESEARCH CENTER

MAIN SPONSOR



CO-SPONSORS



SUPPORTED & SPONSORED BY



# ISAHP 2013

ABOUT ISAHP

FOREWORD

COMMITTEE

CONTENTS  
(AUTHORS & PAPERS)

COPYRIGHT & CONTACT

## ◆ COPYRIGHT ISAHP 2013 PROCEEDINGS

## ◆ CONTACTS

### Online Proceedings

ISBN 1558-5158

### Printed (Hardcover) Version Proceedings

ISBN 1558-510X

### Library of Congress Publication Data

Proceedings of the 11<sup>th</sup> International Symposium on the Analytic Hierarchy Process for Multicriteria Decision Making  
Date: 15 - 18 June, 2013

Hotel Istana, Kuala Lumpur, Malaysia

Department of Business Administration  
Faculty of Economics and Management Sciences  
International Islamic University Malaysia  
Jalan Gombak, 53100 Kuala Lumpur, Malaysia  
Email: [islam@iium.edu.my](mailto:islam@iium.edu.my)

### hSam Solutions

No. 55-1, Jalan Wangsa Utama 5  
Jusai Bandar Wangsa Maju (ELAC)  
Section 5, Wangsa Maju  
53300 Kuala Lumpur, Malaysia  
Email: [rahmah.hussin@hsamsolutions.com](mailto:rahmah.hussin@hsamsolutions.com)

Copyright © 2013 by Creative Decision Foundation on behalf of the 11<sup>th</sup> International Symposium on the Analytic Hierarchy Process

4011 Ellsworth Avenue  
Pittsburgh, PA 15213  
Phone: +1-412-654-8848  
Fax: +1-412-651-4510  
Contact: Kenneth Sady  
[kenneth@creative-decisions.net](mailto:kenneth@creative-decisions.net)

All Rights reserved. The proceedings of the ISAHP meeting of 2013 are available online at [www.isahp.org](http://www.isahp.org).

No part of this publication may be reproduced, stored in retrieval system, or transmitted, in any form or by any means, electronic, mechanical, photocopying, recording, or otherwise, without the prior written permission of the publisher.



Back

Exit



**AUGUST 4 – AUGUST 7, 2016 / LONDON, UK**  
International Symposium on the Analytic Hierarchy Process

Follow @isahp2016

*Divide, compara, aggrega et impera*  
Divide, compare, pool and rule

## ISAHP2013

### Copyright of ISAHP 2013 Proceedings

#### Online Proceedings

ISSN 1556-8296

#### CD/Flashdrive Version Proceedings

ISSN 1556-830X

Library of Congress Publication of Data  
Proceedings of the 12th International Symposium on the Analytic Hierarchy  
Process for Multicriteria Decision Making  
Date : 23-36 June 2013  
Hotel Istana, Kuala Lumpur, Malaysia

Copyright © 2013 by Creative Decision Foundation on behalf of the 12th  
International Symposium on the Analytic Hierarchy Process

4922 Ellsworth Avenue  
Pittsburgh, PA 15213  
Phone : 412-621-6546  
Fax : 412-681-4510  
Contact : Rozann Saaty  
[rozann@creativdecisions.net](mailto:rozann@creativdecisions.net)

All Right reserved.

No part of this publication may be reproduced, stored in retrieve systems, or  
transmitted, in any form by any means, electronic, mechanical, photocopying,  
recording, or otherwise, without the prior written permission of the publisher.

Kuala Lumpur, Malaysia  
June 23 - 26, 2013



© 2016 CREATIVE DECISIONS FOUNDATION. ALL RIGHTS RESERVED. / [CONTACT US](#)



# ISAHP 2013

[ABOUT ISAHP](#)

[FOREWORD](#)

[COMMITTEE](#)

[CONTENTS  
\(AUTHORS & PAPERS\)](#)

[COPYRIGHT & CONTACT](#)

## ◆ About ISAHP

The International Symposium on the Analytic Hierarchy Process (ISAHP) takes place every two years. It brings together researchers, teachers and users of AHP and ANP to share their research and experiences in decision making. The symposium organizing and scientific committees represent all five continents, bringing the research, applications and perspectives of their areas of the world to this truly international forum.

The First International Symposium on the Analytic Hierarchy Process (ISAHP) was organized in Tianjin, China way back in 1988. The locations of the subsequent ten ISAHPs were Pittsburgh, USA; Washington DC, USA; Vancouver, Canada; Osaka, Japan; Bern, Switzerland; Bali, Indonesia; Hawaii, USA; Viña del Mar, Chile; Pittsburgh, USA; and Sorrento, Italy. The twelfth ISAHP is organized in Kuala Lumpur in 2013.



*Petronas Twin Towers, Kuala Lumpur*



*Genting Highland, Malaysia*

## ◆ Edited & Published By

### **Edited and Compiled by:**

Rafikul Islam  
Rozann Saaty  
Fabio De Felice  
Razali Husain

### **Published by:**

Department of Business Administration  
Kulliyah of Economics and Management  
Sciences  
International Islamic University Malaysia  
and  
bSure Solutions Sdn Bhd  
Kuala Lumpur, Malaysia



*Prime Minister's Office, Putrajaya*

[Back](#)

[Next](#)

# ISAHP 2013

ABOUT ISAHP

FOREWORD

COMMITTEE

CONTENTS  
(AUTHORS & PAPERS)

COPYRIGHT & CONTACT



## *Foreword by the Honorary Founding Chairman Professor Thomas L. Saaty, University of Pittsburgh, USA*

Our world today is more and more moving from fragmentation to integration becoming better unified and interactive in its economics, information sharing, travel, diplomacy, and in medical instruments and the importance of health and even in waging wars. There is more freedom for individuals to express themselves. It is by having a one world view that we will be able to make the best decisions. As more people express themselves, they need a way to make decisions together. Conflicts can be resolved rationally and peacefully if concessions can be traded off and by using the Analytic Hierarchy Process (AHP) which allows for the measurement of intangibles alongside tangibles, better decisions can be made about the tradeoffs. Seeing the big picture and being able to combine pieces of thinking, including positive and negative aspects of the problem, are made possible by combining analysis and synthesis scientifically in a manner that makes sense to our brain. In making group decisions, by building the model together we can incorporate different expertise and allow varying levels of authorities to be represented.

Overall change and the acceleration of change influences human psychology. We as individuals and as groups seem unable to cope with the unpredictable change and growing complexity in the world. Stress, uncertainty and frustration increase, minds are overloaded with information and knowledge fragments and values erode. Negative developments are consistently overemphasized, while positive ones are ignored. The resulting climate is one of nihilism, anxiety and despair. While the wisdom gathered in the past has lost much of its validity, we don't have a clear vision of the future either. As a result, we need something new to guide our actions. We don't have words to embrace that lay out the society of the future and how it needs to be to accommodate both technological changes and worldwide integration of cultures and mores. That would be a big positive step to overcome the challenges of today and tomorrow. Nationalistic politics also needs to be more world-oriented than for each country to increase its influence and power. But the world still does not operate with national freedoms and still works with many oppressive regimes. Decision making at such high levels could be valuable to inculcate in our educational system so people can better judge what the priorities should be.

According to the Swiss born French philosopher Jean-Jacques Rousseau (1712 -1778), original ("Natural") man had no language, no abstract thought, no moral ideas and no society. He was self-centered but not cruel and felt compassion for his kind. Social living brought about radical psychological changes. Rousseau's view is that self-love turned into aggressive competitive hostility and a state of war among men. Social life is characterized by the alienation of men from nature, from each other and from authentic selves. The conflicting demands of instinctual nature are constantly at war with the impositions of society. *The cure requires the fabrication of a new man and the proper political institutions.* It is not enough for men to obey the laws. Their minds and wills must also be engaged.

Someone wrote about "Changing the World" as follows: Yesterday I was clever so I wanted to change the world. Today I am wise, so I want to change myself.

These proceedings have been edited by able scholars which makes them officially valuable like any professional journal. I wish all the participants an enriching symposium. The excellent efforts engaged by the international scientific committee and the local organizing to organize this symposium are laudable.

Prof. Dr. Thomas L. Saaty  
Honorary Founding Chairman

Back

Next

# ISAHP 2013

ABOUT ISAHP

FOREWORD

COMMITTEE

CONTENTS  
(AUTHORS & PAPERS)

COPYRIGHT & CONTACT



## *Foreword by the Chairman 12th International Symposium on the Analytic Hierarchy Process, Kuala Lumpur*

*Praise be to Allah (subhānahu wata āla), the Most Beneficent, the Most Merciful for His divine bounty to organize and host the 12<sup>th</sup> International Symposium on the Analytic Hierarchy Process and Analytic Network Process (ISAHP 2013).*

On behalf of the International Islamic University Malaysia and bSure Solutions Ehd, I would like to extend heartiest welcome to all the presenters and participants to the ISAHP 2013 and welcome also to Malaysia! We are deeply honoured by your strong support and patronage to ISAHP 2013 to make it a reality and hopefully a success.

The task of decision-making is intimately associated with our lives. It plays a very important role to shape our careers, to shape our lives, and consequently to shape the whole world. Right decisions made by politicians, government machineries, leaders-managers and the social activists will make the world better and worth-living. Researchers have tirelessly and continuously pursued developing methods that people can use to make meaningful decisions. Two such methods are Analytic Hierarchy Process or AHP and its extension Analytic Network Process or ANP developed by Professor Thomas L. Saaty of University of Pittsburgh, USA. Over the last five decades numerous people all over the world have used these methods to come up with their decisions. The methods have been embraced by social activists, business leaders, and politicians alike. The common goal has been to make this world a better place of living. Therefore, ISAHP 2013 theme "Better world through better decision making" has been a fitting tribute to AHP and ANP.

We have received over hundred papers from more than 25 countries on various aspects of AHP and ANP – theory as well as applications. The applications cover varieties of areas such as, supply-chain management, environmental management, information systems, banking and finance, logistics and transportation, risk management, group decisions making, education, sustainable development, Project management, healthcare, performance evaluation, strategic planning, etc. I hope that the participants will find the presentations, discussions, and deliberations on varieties of areas of AHP and ANP interesting and useful. We also hope that this ISAHP will be able to generate more new ideas on further development of theory and applications of AHP and ANP that would further enhance the quality of decision making. I wish all the participants a beneficial, fulfilling and enlightening symposium.

Appreciation goes to the IIUM top management, Kuliyah of Economics and Management Sciences and Department of Business Administration of IIUM, and the bSure Solutions for their approval and all the necessary support to organize this symposium. I thank wholeheartedly Professor Thomas L. Saaty of University of Pittsburgh and Rozman Saaty of Creative Decisions Foundation for supporting us in all possible ways. I take this opportunity to thank the international scientific committee members, my deputy, the secretary, and all other local organizing committee members for their hard work, commitment and dedication in organizing this symposium. Profuse thanks to all the presenters, participants, sponsors, student volunteers and well-wishers and all other people who have directly or indirectly contributed to make ISAHP 2013 a success. May God bless us all! Ameen!

Prof. Dr. Rafikul Islam  
Chairman

12<sup>th</sup> International Symposium on the AHP/ANP

Back

Next

# ISAHP 2013

[ABOUT ISAHP](#)[FOREWORD](#)[COMMITTEE](#)[CONTENTS  
\(AUTHORS & PAPERS\)](#)[COPYRIGHT & CONTACT](#)

## ◆ LOCAL ORGANIZING COMMITTEE

### Patron

Prof. Dato' Dr. Zaleha Kamaruddin  
Rector, IIUM

### Advisor

Prof. Dr. Khaliq Ahmad  
Dean, KENMS, IIUM

### Honorary Chairman

Prof. Dr. Thomas L. Saaty  
University of Pittsburgh, USA

### Chairman

Prof. Dr. Rafikul Islam  
IIUM

### Deputy Chairman

Mr. Razali Husain  
bSure Solutions Sdn Bhd.

### Secretary

Selim Ahmed  
IIUM

### Treasurer

Mdm. Sharifah Hazam  
bSure Solutions Sdn Bhd.

## Members

Name	University	Name	University
Prof. Dr. Moussa Larbani	IIUM	Dr. Suhaimi Mohd Saif	IIUM
Dr. Anisah Abdullah	IIUM	Dr. Nurita Juhdi	IIUM
Dr. Naail Mohd. Kamil	IIUM	Mr. Asmyat Asmat	IIUM
Dr. Mohamad Rizza Othman	UMP	Dr. Mohd. Shukri AbdulHamid	UUM
Dr. Latifah Abd. Manaf	UPM	Dr. Muhammad Tahir Jan	IIUM
Dr. Wan Rohaida Wan Husain	IIUM	Dr. AbdulJalil	IIUM
Mr. Armi Abu Samah	UPM	Mr. Philip Kang Wee Siang	UPM
Ms. Nuruljanah Kharuddin	UPM	Mdm. Azilah Anis	UiTM

[Back](#)[Next](#)

# ISAHP 2013

[ABOUT ISAHP](#)
[FOREWORD](#)
[COMMITTEE](#)
[CONTENTS  
\(AUTHORS & PAPERS\)](#)
[COPYRIGHT & CONTACT](#)

## INTERNATIONAL SCIENTIFIC COMMITTEE

Name	University	Country
<b>Alberto De Toni</b>	AiIG – Italian Association of Management Engineering	Italy
<b>Alessandro Ancarani</b>	IP SERA – International Purchasing and Supply Education and Research Association	Italy
<b>Alessio Ishizaka</b>	University Portsmouth	United Kingdom
<b>Aldo Ventre</b>	University of Naples “SUN”	Italy
<b>Anna Florek-Paszowska</b>	Cracow University of Economics	Poland
<b>Anna Ostrega</b>	AGH University of Science and Technology	Poland
<b>Antonella Petrillo</b>	University of Cassino	Italy
<b>Antonio Maturo</b>	University of Chieti	Italy
<b>Asma Bahormuz</b>	King Abdul Aziz University	Saudi Arabia
<b>Azizan bin Ramli</b>	Universiti Malaysia Pahang	Malaysia
<b>Birsen Karpak</b>	Youngstown University	USA
<b>Carlos Remero</b>	Technical University of Madrid	Spain
<b>Claudio Garuti</b>	Fulcrum Ingeniería Ltda	Chile
<b>Diederik Wijnmalen</b>	TNO Company	Netherlands
<b>Edgar Osuna</b>	IESA Caracas	Venezuela
<b>Eizo Kinoshita</b>	Meijo University	Japan
<b>Elio Padoano</b>	University of Trieste	Italy
<b>Emilio Esposito</b>	University of Naples “Federico II”	Italy
<b>Fabio De Felice</b>	University of Cassino	Italy
<b>Fusco Girard</b>	University of Naples “Federico II”	Italy
<b>Giovanni Mummolo</b>	Polytechnic of Bari	Italy
<b>Giuseppe Bruno</b>	University of Naples “Federico II”	Italy
<b>Grzegorz Ginda</b>	University of Bielsko-Biala	Poland
<b>Jennifer Shang</b>	University of Pittsburgh	USA
<b>Josef Jablonsky</b>	University of Economics	Czech Republic
<b>Juan Pascual Pastor</b>	University of Valencia	Spain
<b>Karel Mls</b>	University of Hradec Kralove	Czech Republic
<b>Keyu Zhu</b>	Hefei University of Technology	China
<b>Kirti Peniwati</b>	PPM Institute of Management	Indonesia

Name	University	Country
<b>Kostantinos Kryptopoulos</b>	University of the Aegean	Greece
<b>Leandro Pecchia</b>	University of Nottingham	United Kingdom
<b>Livia D'Apuzzo</b>	University of Naples “Federico II”	Italy
<b>Luis Vargas</b>	University of Pittsburgh	USA
<b>Massimiliano Schirardi</b>	University of “Tor Vergata”	Italy
<b>Massimo Squillante</b>	University of Sannio	Italy
<b>Min Suk Yoon</b>	Chonnam University	Korea
<b>Mingzhe Wang</b>	Huazhong University of Science and Technology	China
<b>Mirosław Dytczak</b>	Białystok University of Technology	Poland
<b>Monica Garcia-Melon</b>	University of Valencia	Spain
<b>Mugan Sagir</b>	Eskisehir Osmangazi University	Turkey
<b>Oliver Mebner</b>	University of natural resources and applied life sciences (Vienna)	Austria
<b>Umberto Gori</b>	University of Firenze	Italy
<b>Patrizia Lombardi</b>	Polytechnic of Torino	Italy
<b>Peter Bath</b>	University of Sheffield	United Kingdom
<b>Peter Fiala</b>	University of Economics	Czech Republic
<b>Rainer Haas</b>	University of natural resources and applied life sciences (Vienna)	Austria
<b>Rozann W. Saaty</b>	Creative Decisions Foundation	USA
<b>Shashi Bhattarai</b>	Development Dynamics Pvt. Ltd.	Nepal
<b>Sibs von Solms</b>	University of Zihland	South Africa
<b>Stefano Testa</b>	MBDA – Missile System	Italy
<b>Thomas L. Saaty</b>	University of Pittsburgh	USA
<b>Umberto Gori</b>	University of Firenze	Italy
<b>Wiktor Adamus</b>	Jagiellonian University	Poland
<b>William Adams</b>	Decision Lens	USA
<b>William Wedley</b>	Simon Fraser University	Canada
<b>Yong Shi</b>	Academy of Science in China	China

[Back](#)
[Next](#)

# ISAHP 2013

[ABOUT ISAHP](#)
[FOREWORD](#)
[COMMITTEE](#)
[CONTENTS  
\(AUTHORS & PAPERS\)](#)
[COPYRIGHT & CONTACT](#)

## ◆ CONTENTS (AUTHORS & PAPERS)

S.L. No.	Title	Authors
1	<a href="#">Better World through Better Decision Making</a>	Thomas L. Saaty
2	<a href="#">The Analytic Hierarchy Process without the Theory of Oskar Perron</a>	Thomas L. Saaty
3	<a href="#">A Validation of the Effectiveness of Inner Dependence in an ANP Model</a>	Rozann Saaty
4	<a href="#">Voting with Intensity of Preferences</a>	Luis G. Vargas
5	<a href="#">Deriving Priorities from Partially-Filled Reciprocal Comparison Matrices</a>	Ami Arbel and Luis G. Vargas
6	<a href="#">Application of Analytic Network Process in the Performance Evaluation of Local Black-Soybean Supply to Unilever Indonesia's Soy-Sauce Product</a>	Anggi Gayatri Setiawan, Didit Herawan and Bambang Purwoko Kusumo Bintoro
7	<a href="#">Evaluation of Alternative Construction Sites with Analytic Network Process Method</a>	Li-Chung Chao
8	<a href="#">An Integrated Approach for Prioritizing Projects for Implementation Using AHP</a>	Christian Tabi Amponsah
9	<a href="#">An Integrated Mental Workload Assessment Method by Using AHP</a>	Ergün Eraslan
10	<a href="#">A Novel Approach For Implementing of a Log-Sigmoid Function on a FPGA Device Using the Sfloat24 Math Library – An Modelling .....</a>	M. C. Mighionico and F. Parillo
11	<a href="#">ISR Exploitation Cells Readiness Assessment</a>	Rahim Jassemi-Zargani
12	<a href="#">Reference Objects-Based Real Estate Valuation with MDAHP</a>	Mirosław Dytczak and Grzegorz Ginda
13	<a href="#">Social Network Analysis in Participatory Environmental Decision Making: The Case of Spanish Wetland La Albufera</a>	Mónica García Melón, Vicent Estruch Guitart, Pablo Aragonés Beltrán and Beatriz Monterde Roca
14	<a href="#">Valuating Patents Generated by Public Research Centers with the AHP Technique</a>	Mónica García Melón, Rafael López, Pablo Aragonés Beltrán and Enrique San Ambrosio
15	<a href="#">About Some Features of AHP/ANP Applications</a>	Oлга Andreichicova and Alexander Andreichicov

[Back](#)
[Next](#)

# ISAHP 2013

ABOUT ISAHP

FOREWORD

COMMITTEE

CONTENTS  
(AUTHORS & PAPERS)

COPYRIGHT & CONTACT

## ◆ CONTENTS (AUTHORS & PAPERS)

S.L. No.	Title	Authors
16	<a href="#">The Fiction of a Factual Approach to Decision-Making</a>	Sibs Von Sohm
17	<a href="#">Ranking Non-Dominated Solutions in Automated Highway Design Using the Analytic Network Process (ANP)</a>	Sobuath Mil and Mongkrot Piantanakulchai
18	<a href="#">Development of a Two-Stage ANP Option Selection Model to Use in Turkish Manufacturing Companies</a>	Yusuf Darsel Iç and Mustafa Yurdaku
19	<a href="#">Prioritization of Strategic Guidelines as Part of the Strategic Plan 2010-2014 for a Venezuelan University Using ANP</a>	Aidaelena Smith-Perera and Xavier Figuerella
20	<a href="#">Coevaluation and Grading of Engineering Students in Venezuela Using ANP</a>	Aidaelena Smith-Perera and Carmen Lucía Rojas-Lima
21	<a href="#">ANP Model for Primary School Teaching and Learning ICT Appraisal: User Perception</a>	Astrid Oddershede, Francis Fariás, Jorge Donoso and Patricia Jarufe
22	<a href="#">The Application of GIS-ANP to Develop a Strategic Planning for an Urban Farming, Fishery and Aquaculture</a>	Bagyo Surwasono and Nurul Rosana
23	<a href="#">Application of ANP to Determine Consumers' Perceptions of CSR Strategy for Organizations in the Nigerian GSM Telecommunication Industry</a>	Bolajoko Nkemdirim Dixon-Ogbedi and Sikuede Oladimeji Jagun
24	<a href="#">Usage of Group ANP Approach in Sport Shoes Selection</a>	Mohammad Ebrahim Marjani, Majid Mojahed and Soheil Marjani
25	<a href="#">A Hybrid ANP/FST Model for Regional Aircraft Evaluation</a>	Giuseppe Bruno, Emilio Esposito and Andrea Genovese
26	<a href="#">An Induction Based on a Hybrid of DRSA and DEMATEL for Analyzing Competitiveness 2012</a>	Yu-Chien Ko, Chao Hsien-Wen and Gwo-Hshung Tzeng
27	<a href="#">A Conceptual Design of a Mobile Healthcare Device – An Application of Three-Stage QFD with ANP and TRIZ</a>	Hsu-Shih Shih and Szu-Hua Chen
28	<a href="#">An Analytic Hierarchy Process (ANP) Model to Anticipate Logistics Organization's Preference for Operations Research (OR) Tools adoption</a>	Wan Fei Lai, Ming Hong Ngang and Min Young Ho
29	<a href="#">Implementing the Analytic Hierarchy Process as a Standard Method for Multi-Criteria Decision Making in Corporate Enterprises – a New ANP Excel Template with Multiple Inputs</a>	Klaus D. Goepel

Back

Next

# ISAHP 2013

ABOUT ISAHP

FOREWORD

COMMITTEE

**CONTENTS  
(AUTHORS & PAPERS)**

COPYRIGHT & CONTACT

## ◆ CONTENTS (AUTHORS & PAPERS)

S.L. No.	Title	Authors
30	<a href="#"><u>Material Selection of Thermoplastic Matrix for Hybrid Natural Fiber/Glass Fiber Polymer Composites Using Analytic Hierarchy Process Method</u></a>	Mansor M.R., Sapuan S.M., Zainudin E.S., Nuraini A.A., Hambali A. and Azman M.D
31	<a href="#"><u>Evaluating Business-to-Business M-Commerce in SMEs by Using MCDM Approach</u></a>	Ming-Tsang Lu, Gwo-Hshiang Tzeng, Shu-Kung Hu and Yung-Chang Lin
32	<a href="#"><u>Solutions for a Disjoint Supermatrix in ANP Decision Models</u></a>	Orrin Cooper and Guoqing Liu
33	<a href="#"><u>Accuracy Improvement of Object Oriented Software Design Measurement Using Analytic Network Process</u></a>	Petrus Mursanto
34	<a href="#"><u>The Analytic Hierarchy Process: Application to the Election of the Chief Minister of Perak, Malaysia 2013</u></a>	Datin Margarita Sergeevna Peredaryenko and Dato 'Hj Rais Hussin Hj Mohamed Ariff
35	<a href="#"><u>Analytic Hierarchy Process and Agent-based Simulation for Traffic Modeling</u></a>	Richard Cimler
36	<a href="#"><u>AHP Based Academic Performance Score Sheet (APS) for Holistic Assessment of Academic Achievements</u></a>	Mohamad Rizza bin Othman and Syamsul Bahari bin Abdullah
37	<a href="#"><u>Operator Allocation Selection in Labor-Intensive Manufacturing System Using AHP/DEA and DEA</u></a>	Ruzanita Mat Rani and Wan Rosmanira Ismail
38	<a href="#"><u>Fuzzy-ANP Based Research on the Risk Assessment of Biogas Production from Agriculture Biomass</u></a>	Sandija Zeverte-Rivza, Peteris Kirza and Jelgava
39	<a href="#"><u>AHP Application in Contemporary Nepalese Issues</u></a>	Shashi Bhattacharai and Prabal Sapkota
40	<a href="#"><u>Post Evaluation of Medical Decision Using AHP</u></a>	Shashi Bhattacharai and Kirshna Sharma
41	<a href="#"><u>Assessing the Sustainability of Grazing in Protected Natural Areas by Means of the ANP: A Case Study in the Cotopaxi National Park (Ecuador)</u></a>	Wilson Jácome-Erriquez, Tomás Gómez-Navarro and Ricardo Pachamama-Mérez

Back

Next

# ISAHP 2013

ABOUT ISAHP

FOREWORD

COMMITTEE

**CONTENTS**  
(AUTHORS & PAPERS)

COPYRIGHT & CONTACT

## ◆ CONTENTS (AUTHORS & PAPERS)

S.L. No.	Title	Authors
42	<a href="#"><u>Assessing the Corporate Social Responsibility Reports Based on Communication Indicators: an ANP Approach</u></a>	Tomás Gómez-Navarro, Amparo Barrera-Puig and Gabriel García-Martínez
43	<a href="#"><u>Using AHP for the Evaluation of the Development of Career Education in Latvia</u></a>	Veronika Bikse, Una Libkoviška, Peteris Kirva and Baiba Rivza
44	<a href="#"><u>On the Aggregation of Individual Priorities in Incomplete Hierarchies</u></a>	Daniel Kunzler De Souza Carmo, Fernando Augusto Silva Marins, Valerio A. P. Salomon and Carlos Henrique Pereira Mello.
45	<a href="#"><u>Path Algebraic AHP Eigenvector Based on Max and Min Operators</u></a>	Masaaki Shimohara
46	<a href="#"><u>A Correct Approach on Adding Criteria in the Analytic Hierarchy Process</u></a>	Min-Suk Yoon and Young-Woo SOHN
47	<a href="#"><u>Risk Management Decision Making</u></a>	Rabihah Md Sum
48	<a href="#"><u>How to Optimize the Specification of Built-to-Order Technology System: A Case of Wastewater Treatment System</u></a>	Yuji Sato
49	<a href="#"><u>Building an Evaluation of Performance Model for the Cloud E-Learning Service Using Hybrid MCDM</u></a>	Chiu-Hung Su, Hao-Lin Tzeng and Gwo-Hshjung Tzeng
50	<a href="#"><u>An AHP Based-Model for Sustainable Manufacturing Performance Evaluation in Automotive Industry</u></a>	Elita Amrina and Sha Yi Mohd Yusof
51	<a href="#"><u>A New Approach to Eyewitness Police Identification</u></a>	Enrique Mu and Rachel Chung
52	<a href="#"><u>Characterization of the AHP with Adjustments of Weights of Alternatives as an Optimal Solution</u></a>	Yoshihide Iida
53	<a href="#"><u>A Statistical Hypothesis Testing Method for the Rank Ordering of the Priorities of the Alternatives in Analytic Hierarchy Process</u></a>	Indrani Basak
54	<a href="#"><u>Adaptive Credit Scoring with Analytic Hierarchy Process</u></a>	Kwang Yong Koh, Murphy Choy and Michelle L.F. Cheong
55	<a href="#"><u>Solid Waste Management: Development of AHP Model for Application of Landfill Sites Selection in Kuantan, Pahang, Malaysia</u></a>	Noor Suraya Binti Romali, Nadiyah Binti Mokhtar, Wan Faisal Wan Ishak and Mohd Amri Abu Samah

Back

Next

# ISAHP 2013

ABOUT ISAHP

FOREWORD

COMMITTEE

**CONTENTS**  
**(AUTHORS & PAPERS)**

COPYRIGHT & CONTACT

## ◆ CONTENTS (AUTHORS & PAPERS)

S.L. No.	Title	Authors
56	<a href="#">Methodology for Assessment Activity of the Technology Transfer Office Based on ANP</a>	Rocío Poveda-Bautista, Juan Pascual Pastor- Ferrando, Pablo Aragóns-Beltrán and Fernando Jiménez Saéz
57	<a href="#">Habal Global Analytic Hierarchy Parameters: A Conceptual Assessment</a>	Rohana Kamaruddin, Hadijah Ibrahkim, Norlida Abdul Hamid, Rohana Abdul Rahman and Nurolain Mustapha
58	<a href="#">Quantifying Task Output and Project Value in Knowledge-Work Contexts</a>	Sam Sharp
59	<a href="#">Group Decision Making Approach in Karate Agility Test Selection</a>	Mohammad Ebrahim Marjani, Soh Kim Geok, Majid Mojahed, Nur Surayyah M. Abdullah and Soheil Marjani
60	<a href="#">Preference Matrices in Tropical Algebra</a>	Hana Tomášková and Martin Gavalec
61	<a href="#">Design of Performance Evaluation Tools for Drainage of Roads System in Developing Country (Case Study: Drainage System for City Roads in Padang Indonesia)</a>	Insaraul Kamil Buang Alias Abdul Hakim Mohammed Nilda Tri Putri and Cresti Kahni
62	<a href="#">Assessing Systems of Systems' Performance Using a Hierarchical Evaluation Process</a>	Rahim Jassem i-Zargani and Nathan Kashyap
63	<a href="#">Objectives of Islamic Banks in the Management of Asset and Liability: A Decision Process of Deriving Priority</a>	Karnila Hanim Kam il, Abdul Ghafar Ismail and <b>Shahida Shahimi</b>
64	<a href="#">Using Electre-AHP as a Mixed Method for Personnel Selection</a>	Majid Mojahed, Mohammad Ebrahim Marjani, Alireza Afshari and Soheil Marjani

Back

Next

# ISAHP 2013

ABOUT ISAHP

FOREWORD

COMMITTEE

**CONTENTS  
(AUTHORS & PAPERS)**

COPYRIGHT & CONTACT

## ◆ CONTENTS (AUTHORS & PAPERS)

S.L. No.	Title	Authors
65	<a href="#"><u>The Use of Analytical Hierarchy Process (AHP) in Product Development Process</u></a>	Mohd Azroy Mohd Razikin, Hambali Asep @Ariff, Ab Rahman Mahmood and Isa Halim
66	<a href="#"><u>Insurance Tender Selection Using Multiple Criteria Decision Making</u></a>	Poshiha Ratnayake and Eranjan Padumadasa
67	<a href="#"><u>Purchase Order Selection Model at CV. Roesman Indonesia Using Analytic Network Process</u></a>	Ririn Djar Astanti, Elizabeth Lucia Febriyanti and The Jim Ai
68	<a href="#"><u>Selecting a Profound Technical Service Provider to Perform a Technical Field Development Study From Given Multiple Criteria</u></a>	Slamet Riyadi, Lokman Effendi and Rafikul Islam
69	<a href="#"><u>Sustainable Decision-Making Model Based on Analytical Hierarchy Process and SWOT Analysis</u></a>	Fabio De Felice, Antonella Petrillo and Claudio Autorino
70	<a href="#"><u>Multi-Criteria Assessment to Automate Water Treatment Plants Using the Analytical Hierarchy Process</u></a>	Claudio Macuada, Rubén Alarcón and Astrid Oddershede
71	<a href="#"><u>The Analytic hierarchy Process (AHP) and the User need elicitation in the Health Technology Assessment (HTA)</u></a>	Leandro Pecchia and Stephen Morgan
72	<a href="#"><u>Integrating Analytic Hierarchy Process (AHP) and Geographical Information Systems (GIS) for Prioritising and Planning Conservation Choices in Wales</u></a>	Marcello Di Bonito, John Clarkson, Michelle L. Wienhold and Leandro Pecchia
73	<a href="#"><u>Market Risk Management for Public Utilities through AHP</u></a>	Massimo Puccaro, Patrizia Simeoni and Fabio De Felice
74	<a href="#"><u>Change Management Strategy Development in Information Systems / Information Technology Using Analytic Hierarchy Process</u></a>	Riri Satria
75	<a href="#"><u>Strategic Foresight Using an Analytic Hierarchy Process: Environmental Impact Assessment of the Electric Grid in 2025</u></a>	Ronald Mac-Ginty, Raúl Carrasco, Astrid Oddershede and Manuel Vargas

Back

Next

# ISAHP 2013

ABOUT ISAHP

FOREWORD

COMMITTEE

**CONTENTS  
(AUTHORS & PAPERS)**

COPYRIGHT & CONTACT

## ◆ CONTENTS (AUTHORS & PAPERS)

S.L. No.	Title	Authors
76	<a href="#"><u>Enhancing Malaysian Graduate Employability Skills: Quality Function Deployment Approach</u></a>	Mohamad Shukri Abdul Hamid, Rafikul Islam and Noor Hazilah Abd Manaf
77	<a href="#"><u>The Root Causes of Financial Crisis in Islamic Economic Perspective</u></a>	Ascarya and Dudy Iskandar
78	<a href="#"><u>Solutions to Prevent Financial Crisis in Islamic Economic Perspective: ANP Approach</u></a>	Ascarya
79	<a href="#"><u>A Novel Model Integrating the Processes of Selection and Behavioral Evaluation of Suppliers in a Supply Chain through Analytical Hierarchy Process (AHP)</u></a>	Mohamed Khendek and Moussa Larbani
80	<a href="#"><u>Prioritizing Suitable Locations of Bike Sharing Station by Using the Analytic Hierarchy Process (AHP)</u></a>	Tharathom Kanjanakorn and Mongkoot Piantanakulchai
81	<a href="#"><u>Car's Dashboard Improvement Design Concepts through Integration of AHP and TRIZ</u></a>	Mohd Usair Mohd Rosli
82	<a href="#"><u>Rating BBA and MMP in Their Stages of Product Development Based on Maqasid Framework</u></a>	Syahidawati Shaikwen and Mustafa Omar Muhammad
83	<a href="#"><u>Estimating the Prominence of AHP in Subscribed Online Databases</u></a>	Yusuf Ismail, Mohd Hasbullah B Mohamad Faudzi and Muhammad Hamidi Bin Zamri
84	<a href="#"><u>Estimating the Prominence of AHP in a Selected Internet Search Engine</u></a>	Yusuf Ismail
85	<a href="#"><u>An Overview Use of Analytic Hierarchy Process (AHP) in Design for Remanufacturing Activities</u></a>	Tajul Ariffin Abdullah, Dzuraidah Abd. Wahab and A.A Lashlem
86	<a href="#"><u>Integrating AHP, SWOT and QSPM in Strategic Planning: an Application to College of Business Administration in Saudi Arabia</u></a>	Syed Abdul Malik, Nasser Saad Al Khatani and Mohammad Naushad
87	<a href="#"><u>A Feedback-Aware Valuation of Construction Project Execution Time</u></a>	Mirosław Dytczak, Grzegorz Ginda, Barbara Jastrzębek and Tomasz Wojtkiewicz

Back

Next

# ISAHP 2013

[ABOUT ISAHP](#)[FOREWORD](#)[COMMITTEE](#)[CONTENTS  
\(AUTHORS & PAPERS\)](#)[COPYRIGHT & CONTACT](#)

## ◆ CONTENTS (AUTHORS & PAPERS)

S.L. No.	Title	Authors
88	<a href="#">Multicriteria Decision Making for Project Scheduling under Resource Constraints</a>	Rokou Elena and Kirytopoulos Konstantinos
89	<a href="#">Prioritization of Playability Heuristic Evaluation for Educational Computer Games (PHEG) Technique using Analytic Hierarchy Process</a>	Hasih Mohamed and Azizah Jaafar
90	<a href="#">Enterprise Evolution Strategy Analysis by Unearthing Superiority in ANP Supermatrix</a>	Xing Yin Xiaomeng Yin
91	<a href="#">Optimization Strategy of Cloud Computing Service Composition Research Based on ANP</a>	Xing Xu Hexi Guo
92	<a href="#">QoS Evaluation of Cloud Service Architecture Based on ANP</a>	Mingzhe Wang Yu Liu

[Back](#)[Next](#)

# AN AHP BASED-MODEL FOR SUSTAINABLE MANUFACTURING PERFORMANCE EVALUATION IN AUTOMOTIVE INDUSTRY

Elita Amrina\*  
Department of Industrial Engineering  
Andalas University  
Padang, Indonesia  
E-mail: [elita@ft.unand.ac.id](mailto:elita@ft.unand.ac.id)

Sha'ri Mohd Yusof  
Department of Manufacturing and Industrial Engineering  
Universiti Teknologi Malaysia  
Johor, Malaysia  
E-mail: [shari@fkm.utm.my](mailto:shari@fkm.utm.my)

## ABSTRACT

Sustainable manufacturing has become a critical issue for industries worldwide. In order to survive in today's competitive business environment, adopting sustainable manufacturing practices has become a necessity. A performance evaluation system is crucial for achieving a successful sustainable manufacturing in the automotive industry. Hence, an AHP based-model for sustainable manufacturing performance evaluation was developed in this study. Firstly, a set of initial key performance measures for sustainable manufacturing evaluation has been identified and derived from the literature. The measures were developed based on the triple bottom line of sustainability of environmental, economic, and social, consisting of nine criteria and further divided into a total of 41 subcriteria. Secondly, a survey was conducted to confirm the adaptability of the initial measures with industry practices. The results indicated that all the initial measures are highly important and thus proposed as the key performance measures of sustainable manufacturing evaluation for automotive industry. Finally, Analytic Hierarchy Process (AHP) is applied to sustainable manufacturing performance evaluation based on the measures. Relative importance weight of all the measures is determined by summarizing the opinions of experts. Quality and cost were found to be the top two important measures in evaluating sustainable manufacturing performance, while emission and supplier were the least important measures. It indicated that the automotive industry is still focusing more on the economic factor. The proposed model was then evaluated using a case study company from the automotive industry. The results show the existing performance level on strengths and weaknesses and provide directions for companies to take appropriate actions in improving their performance. It is hoped that the model enables and assists automotive companies in achieving the higher performance and so as increasing the competitiveness.

Keywords: AHP, evaluation, measures, sustainable manufacturing

## 1. Introduction

The increasing concerns to sustainability driven by legislation, public interest, and competitive opportunity (Linton *et al.*, 2007) have forced manufacturing companies to consider sustainability into their strategies and activities. Achieving sustainability in manufacturing activities have been recognized as a critical need due to diminishing non-renewable resources, stricter regulations related to environment and occupational safety, and increasing consumer preference for environmentally-friendly products (Jayal *et al.*, 2010). The adoption of sustainable manufacturing offers companies a cost effective route to improve their economic, environmental, and social performance as the three pillars of sustainability (Pusavec *et al.*, 2010). Companies that adopt sustainable practices are able to achieve better product quality, higher market-share, and increased profits (Nambiar, 2010). Therefore, developing sustainable manufacturing is becoming a critical global concern (Ijomah *et al.*, 2007).

---

\* Corresponding author

Sustainable manufacturing is certainly one of the critical issues for the automotive industry. The automotive industry has made remarkable positive contributions to the world economy and people's mobility, but its products and processes are a significant source of environmental impact (Nunes and Bennett, 2010). The automotive industry constitutes a product system that directly and indirectly relates to economic wealth creation as well as impacts on the natural and human environment along all phases of the product life cycle (Warren *et al.*, 2001). Thus, evaluating sustainable manufacturing performance has become a necessity for this industry.

This paper proposes an AHP based-model for sustainable manufacturing performance evaluation in automotive industry. A set of initial key performance measures for sustainable manufacturing evaluation was identified and derived from the literature based on the triple bottom line of sustainability of environmental, economic, and social. Then, a survey was conducted to confirm the adaptability of the initial measures with industry practices. Finally, Analytic Hierarchy Process (AHP) was applied to sustainable manufacturing performance evaluation based on the measures. The evaluation model enables and assists automotive companies to achieve the higher performance and increase the competitiveness.

## 2. Methodology

The methodology has three interrelated stages. First, the initial key performance measures for sustainable manufacturing evaluation were identified and derived from the literature. The initial measures were developed based on the triple bottom line of sustainability of environmental, economic, and social, and constructed by integrating the manufacturing performance measures and the sustainable manufacturing measures. Second, a survey through questionnaire was conducted to Malaysian automotive companies in order to confirm the adaptability of the initial measures with industry practices. Finally, a sustainable manufacturing performance evaluation based on the measures was developed using Analytic Hierarchy Process (AHP) methodology. The details are presented in the following sections.

### 2.1 Stage 1: Identification of key performance measures

This study starts with the development of initial key performance measures for sustainable manufacturing evaluation in automotive companies through literature review. The initial measures have been constructed by integrating the manufacturing performance measures and the sustainable manufacturing measures. The initial measures have adopted the triple bottom line of sustainability consisting of environmental, economic, and social performance factors. As a result, the initial measures consist of three factors divided into nine criteria and further divided into a total of 41 subcriteria were identified as shown in Table I.

Table 1. Initial key performance measures for sustainable manufacturing evaluation

Factors	Criteria	Subcriteria
Environmental	Emission	Air emission, Water pollution, Land contamination
	Resource utilization	Energy utilization, Water utilization, Fuel consumption, Land used
	Waste	Solid waste, Hazardous waste, Waste water
Economic	Quality	Product reliability, Product durability, Conformance to specification, Customer complaint, Scrap and rework, Reject rate
	Cost	Material cost, Setup cost, Overhead cost, Inventory cost, Labor cost, Rework cost
	Delivery	On time delivery, Delivery lead time, Delivery speed, Cycle time, Due date compliance, Schedule attainment
	Flexibility	Volume flexibility, Product flexibility, Process flexibility, Technology flexibility, New product development
Social	Employee	Training and development, Occupational health & safety, Turn over rate, Job satisfaction, Community satisfaction
	Supplier	Supplier certification, Supplier commitment, Supplier initiative

**2.2 Stage 2: Conducting industry survey**

In order to validate the initial measures, a survey was conducted to automotive companies which manufacture parts and accessories for motor vehicles and their engines listed in Proton Vendor Association (PVA) directory year 2010. Of the 118 questionnaires mailed, a total of 54 responses were received. Three of the responses were not useable due to incomplete answer, resulting in a response rate of 43.2 percent. The respondents were asked to rate the importance level of each measure of sustainable manufacturing evaluation in their companies. A five-point scale ranging from 1 (not important at all) to 5 (very important) was used to rate the perspective of respondents to the importance level of the performance measures. The mean importance values ranged from 3.902 to 4.431 as presented in Table 2.

Table 2. Mean important level of the initial measures for sustainable manufacturing evaluation

Rank	Measures	Mean
1	On time delivery	4.431
2	Material cost	4.373
3	Product reliability	4.314
4	Supplier initiative	4.294
5	Supplier commitment	4.294
6	Product durability	4.275
7	Conformance to specification	4.255
8	Occupational health and safety	4.235
9	Delivery lead time	4.216
10	Training and development	4.216
11	Fuel consumption	4.216
12	Energy utilization	4.216
13	Overhead cost	4.196
14	Volume flexibility	4.176
15	Reject rate	4.176
16	Customer complaint	4.157
17	Water utilization	4.157
18	Supplier certification	4.137
19	New product development	4.118
20	Job satisfaction	4.118
21	Due date compliance	4.118
22	Water pollution	4.118
23	Labor cost	4.098
24	Cycle time	4.098
25	Setup cost	4.098
26	Scrap and rework	4.078
27	Delivery speed	4.078
28	Turnover rate	4.078
29	Air emission	4.059
30	Inventory cost	4.059
31	Product flexibility	4.039
32	Land contamination	4.000
33	Process flexibility	4.000
34	Solid waste	4.000
35	Schedule attainment	4.000
36	Rework cost	3.980
37	Community satisfaction	3.980
38	Hazardous waste	3.980
39	Land used	3.961
40	Technology flexibility	3.941
41	Waste water	3.902

From the table, it can be seen that on time delivery had the highest value of 4.431. This is followed by material cost with importance mean of 4.373. The next sequences of importance are product reliability, supplier initiative, supplier commitment, product durability, and conformance to specification with importance mean of 4.314, 4.294, 4.294, 4.275, and 4.255 respectively. Those top measures included in the criteria of delivery, cost, quality, and supplier; and the factors of economic and social. On the other hand, land used, technology flexibility, and waste water, were ranked the least important, but their mean values are at an importance level. Therefore, it can be concluded from the results that all the initial measures are perceived at high important level, and thus, three factors with a total of nine criteria and 41 subcriteria have been proposed as the key performance measures for sustainable manufacturing evaluation in automotive companies.

### **2.3 Stage 3: Developing sustainable manufacturing performance evaluation model**

An evaluation model for sustainable manufacturing performance in automotive industry was developed based on the proposed measures. Analytic Hierarchy Process (AHP) methodology was applied in the developing of the model consisting of constructing the hierarchy, calculating the relative weight, rating the measures, and computing the scores of companies, and ranking the companies. Details are given in the following section.

## **3. Development of sustainable manufacturing performance evaluation model**

Analytic Hierarchy Process (AHP) first introduced by Thomas L. Saaty in 1971 has become one of the most widely used methods for multiple criteria decision making (MCDM) problems. It is a decision approach designed to aid in making the solution of complex multiple criteria problems to a number of application domains (Saaty, 2008). It has been known as an essential tool for both practitioner and academics to conduct researches in decisions making and examining management theories (Cheng *et al.*, 2002). AHP as a problem solving method is flexible and systematic that can represent the elements of a complex problem (Chan *et al.*, 2006). Cheng *et al.* (2002) pointed out several benefits of AHP methodology. First, it helps to decompose an unstructured problem into a rational decision hierarchy. Second, it can elicit more information from the experts or decision makers by employing the pair-wise comparison of individual groups of elements. Third, it sets the computations to assign weights to the elements. Fourth, it uses the consistency measure to validate the consistency of the rating from the experts and decision makers. The following steps show the development of an AHP-based model for sustainable manufacturing performance evaluation in automotive companies.

### **3.1 Construct the hierarchy**

The proposed key sustainable manufacturing performance measures are used in constructing a hierarchy. The five groups were defined and constructed in the hierarchy including goal, factors, criteria, subcriteria, and alternatives. In the hierarchy, evaluating sustainable manufacturing performance is set to be the goal. The next level consists of three factors of environmental, economic, and social. At the third level, there are nine criteria of emission, resource utilization, waste, quality, cost, delivery, flexibility, employee, and supplier. The fourth level consists of the subcriteria that described each of criteria with a total of 41 subcriteria. Finally, the alternatives that the decision maker needs to evaluate are presented at the bottom of the hierarchy consisting of the companies to be assessed and compared. The overall hierarchy is depicted in Figure 1 as shown in Appendix 1.

### **3.2 Calculate the relative weight**

Once the hierarchy has been constructed, the importance weight of the measures should be calculated. For that purpose, the Analytic Hierarchy Process (AHP) methodology was applied. AHP methodology was utilized to determine the importance weights of sustainable manufacturing performance measures. A pairwise comparison questionnaire was then designed and mailed to thirteen senior managers from the automotive companies in Malaysia. Those managers were carefully selected based on their experience in automotive industry. A total of 10 responses were received. The Consistency Ratio (CR) was used to check the consistency of the pairwise comparisons for each expert. The CR values are less than 0.1 which means it matches the consistency test. If it is not yet consistent, the comparison has to be repeated again.

Answers to each question were geometrically averaged before calculating the importance weights. The 1 to 9 scale of Saaty was used to reflect the preferences and a pairwise comparison matrix then constructed. The consistency test was performed to all the combined pairwise comparison matrixes. The results show that the Consistency Ratio (CR) values ranged from 0.0000 to 0.0328, which means that all the pairwise comparisons are consistent since the values

are within the acceptable level recommended by Saaty (2008). It indicates that the experts have assigned their preferences consistently in determining the importance weights of the measures to evaluate sustainable manufacturing performance in automotive companies. Table 3 presents a summary of the result of the importance weights of the sustainable manufacturing performance measures. The importance weights show the importance value of one measure over another measure. In term of factors, economic is the most important factor with an importance value of 68.02%. Resource utilization (46.23%) is regarded to the highest important dimension to environmental performance. With regard to economic performance, quality is the most important dimension with an importance value of 50.06% over another. Employee (79.02%) is considered much more important dimension than suppliers to social performance.

Table 3. The importance weights of sustainable manufacturing performance measures

Factors	Weight	Criteria	Weight	Subcriteria	Weight		
Environmental	0.1450	Emission	0.2276	Air emission	0.4323		
				Water pollution	0.2939		
				Land contamination	0.2738		
		Resource utilization	0.4623			Energy utilization	0.4046
						Water utilization	0.1549
						Fuel consumption	0.2996
						Land used	0.1409
		Waste	0.3101			Solid waste	0.2461
						Hazardous waste	0.4060
						Waste water	0.3480
Economic	0.6802	Quality	0.5006	Product reliability	0.1194		
				Product durability	0.0674		
				Conformance to specification	0.2322		
				Customer complaint	0.2826		
				Scrap and rework	0.1582		
				Reject rate	0.1402		
		Cost	0.2365			Material cost	0.3653
						Setup cost	0.1229
						Overhead cost	0.1621
						Inventory cost	0.1165
						Rework cost	0.1078
						Labor cost	0.1254
		Delivery	0.1753			On time delivery	0.3587
						Delivery lead time	0.1630
						Delivery speed	0.0921
						Cycle time	0.0839
						Due date compliance	0.1664
		Flexibility	0.0877			Schedule attainment	0.1359
						Volume flexibility	0.2039
						Product flexibility	0.0891
Process flexibility	0.2612						
Technology flexibility	0.2742						
Social	0.1748	Employee	0.7902	New product development	0.1716		
				Training and development	0.2760		
				Occupational health & safety	0.1916		
				Turnover rate	0.1273		
				Job satisfaction	0.2511		
		Supplier	0.2098			Community satisfaction	0.1540
						Supplier certification	0.1393
						Supplier commitment	0.6176
						Supplier initiative	0.2432

### 3.3 Rating the sustainable manufacturing performance measures

The next step in evaluating the sustainable manufacturing performance is to rate the measures. In this study, a scale range from 1 to 10 (where 1 = highly poor, 2 = moderately poor, 3 = lowly poor, 4 = lowly fair, 5 = moderately fair, 6 = highly fair, 7 = lowly good, 8 = moderately good, 9 = highly poor, and 10 = excellent) was utilized to assess performance of each of the measures.

### 3.4 Computing the companies score

The next step is to compute the company score. The values generated from the performance rating are combined with the corresponding importance weights of the measures to obtain the company score. The company score is calculated for the overall score and as well as for individual score of each factor and each criteria. The overall score and individual score of each factor and each criterion of companies are then classified into four performance levels based on the following rules:

- If  $1 \leq \text{scores} \leq 4$  then performance level is poor,
- If  $4 < \text{scores} \leq 7$  then performance level is fair,
- If  $7 < \text{scores} \leq 9$  then performance level is good,
- If  $\text{scores} > 9$  then performance level is excellent.

### 3.5 Ranking the companies based on the score

The overall score and the individual score of factor and criteria of the companies evaluated are then ranked in descending order. The company with the highest score can be considered as attaining best practice.

## 4. Case study result

The proposed model has been applied to a case of automotive manufacturing company in Malaysia. The production managers were asked to evaluate their supplier using the 1 to 10 scale on each of 41 sustainable manufacturing performance measures. The rating values are used to calculate the company score consisting of the overall score and the individual score of each factor and each criterion. The overall score and individual score of each factor and each criteria of the companies compared are presented in a final result. The results of four suppliers compared are shown in Table 4. From the results, the company is able to know the performance level of their suppliers on their strengths and weaknesses.

Table 4. The scores of suppliers

Measures	Supplier-1		Supplier-2		Supplier-3		Supplier-4	
	Score	Level	Score	Level	Score	Level	Score	Level
<b>Overall Score</b>	<b>7.184</b>	Good	<b>9.332</b>	Excellent	<b>7.793</b>	Good	<b>6.215</b>	Fair
<b>Individual score of factors</b>								
Environmental	5.926	Fair	8.280	Good	8.778	Good	4.505	Fair
Economic	7.073	Good	9.479	Excellent	7.415	Good	6.292	Fair
Social	8.444	Good	9.470	Excellent	8.605	Good	7.064	Good
<b>Individual score of criteria</b>								
Emission	5.293	Fair	8.991	Good	8.707	Good	3.269	Poor
Resource utilization	6.442	Fair	7.845	Good	8.845	Good	5.299	Fair
Waste	5.752	Fair	8.351	Good	8.751	Good	4.349	Fair
Quality	6.758	Fair	9.430	Excellent	7.484	Good	6.412	Fair
Cost	7.592	Good	9.415	Excellent	7.288	Good	6.484	Fair
Delivery	7.086	Good	9.757	Excellent	7.522	Good	5.976	Fair
Flexibility	7.319	Good	9.537	Excellent	7.261	Good	5.580	Fair
Employee	8.516	Good	9.597	Excellent	8.804	Good	7.330	Good
Supplier	8.165	Good	9.011	Excellent	7.842	Good	6.070	Fair

Those scores are then used to rank the sustainable manufacturing performance of each supplier relative to others. The suppliers ranking for overall score and individual score of factor are shown in Table 5. It can be seen from the table, supplier-2 is at the highest for the overall score with a total score of 9.332 and performance level of excellent.

Table 5. Ranking of overall score and individual factor score of companies

Score	Supplier Name	Score	Performance Level	Ranking
<b>Overall score</b>	Supplier-2	9.332	Excellent	1
	Supplier-3	7.793	Good	2
	Supplier-1	7.184	Good	3
	Supplier-4	6.215	Fair	4
<b>Individual score of factor</b>				
Environmental	Supplier-3	8.778	Good	1
	Supplier-2	8.280	Good	2
	Supplier-1	5.926	Fair	3
	Supplier-4	4.505	Fair	4
Economic	Supplier-2	9.479	Excellent	1
	Supplier-3	7.415	Good	2
	Supplier-1	7.073	Good	3
	Supplier-4	6.292	Fair	4
Social	Supplier-2	9.470	Excellent	1
	Supplier-3	8.605	Good	2
	Supplier-1	8.444	Good	3
	Supplier-4	7.064	Good	4

The ranking and performance level of companies obtained are quite varied. It can be seen that supplier-2 has attained the highest score on factors of economic and social, but at the second rank of environmental factor with a score of 8.280 and performance level of good. The top rank for environmental factor is company-3 with a score of 8.778 and performance level of good. It can be seen from the results that the company with the highest overall score might be not the best in all the factors. In order to make a quality decision making, these things need to be viewed in detail to prioritize the company's performance criteria when evaluating sustainable manufacturing performance level.

## 5. Conclusions

This paper has presented the development of an AHP-based model for sustainable manufacturing performance evaluation in automotive companies. The tool was developed using Analytic Hierarchy Process (AHP) methodology. The hierarchy structure was established based on the proposed key measures of sustainable manufacturing performance evaluation for automotive companies. Then, the importance weights of the measures were assigned by pairwise comparisons and calculated using AHP methodology. Values of the measures were also rated using a scale of 1 (highly poor) to 10 (excellent). The company's score was computed to assess sustainable manufacturing performance against the measures. Finally, the companies rank was determined based on their scores.

The model enables and assists companies to know and understand their existing performance level on their strengths and weaknesses. It provides suggestions and directions for companies to take appropriate actions in improving their sustainable manufacturing performance. The model aids companies in achieving the higher performance and so as increasing the competitiveness. While the proposed model provides a systematic approach for sustainable manufacturing performance evaluation, it is not entirely automated. Future work will further develop a software-based tool of sustainable manufacturing performance evaluation for automotive companies.

## REFERENCES

- Chan, F. T. S., Chan, H. K., Lau, H. C. W., and Ip, R. W. L. (2006). An AHP approach in benchmarking logistics performance of the postal industry. *Benchmarking: An International Journal*, 13(6), 636-661.
- Cheng, E. W. L., Li, H., and Ho, D. C. K. (2002). Analytic Hierarchy Process: A defective tool when used improperly. *Measuring Business Excellence*, 6(4), 33-37.
- Ijomah, W. L., McMahon, C. A., Hammond, G. P., and Newman, S. T. (2007). Development of design for remanufacturing guidelines to support sustainable manufacturing. *Robotics and Computer-Integrated Manufacturing*, 23, 712–719.
- Jayal, A. D., Badurdeen, F., Dillon Jr. O.W., and Jawahir, I. S. (2010). Sustainable manufacturing: modeling and optimization challenges at the product, process and system levels. *CIRP Journal of Manufacturing Science and Technology*, 2(3), 144–152.
- Linton, J. D., Klassen, R., and Jayaraman, V. (2007). Sustainable supply chains: an introduction. *Journal of Operations Management*, 25(6), 1075–1082.
- Nambiar, A. N. (2010). Challenges in sustainable manufacturing. *Proceedings of the 2010 International Conference on Industrial Engineering and Operations Management*. January 9-10. Dhaka, Bangladesh, 1-6.
- Nunes, B., and Bennett, D. (2010). Green operations initiatives in the automotive industry: an environmental reports analysis and benchmarking study. *Benchmarking: An International Journal*, 17(3), 396 – 420.
- Pusavec, F., Krajnik, P., and Kopac, J. (2010). Transitioning to sustainable production – part I: application on machining technologies. *Journal of Cleaner Production*, 18, 174–184.
- Saaty, T. L. (2008). The analytic hierarchy and analytic network measurement processes: application to decisions under risk. *European Journal of Pure and Applied Mathematics*, 1(1), 122-196.
- Warren, J. P., Rohdes E., and Carter, R. (2001). A total product system concept - a case study of the smart (tm) automobile. *Greener Management International*. 35, 89-104.

**Appendix 1**

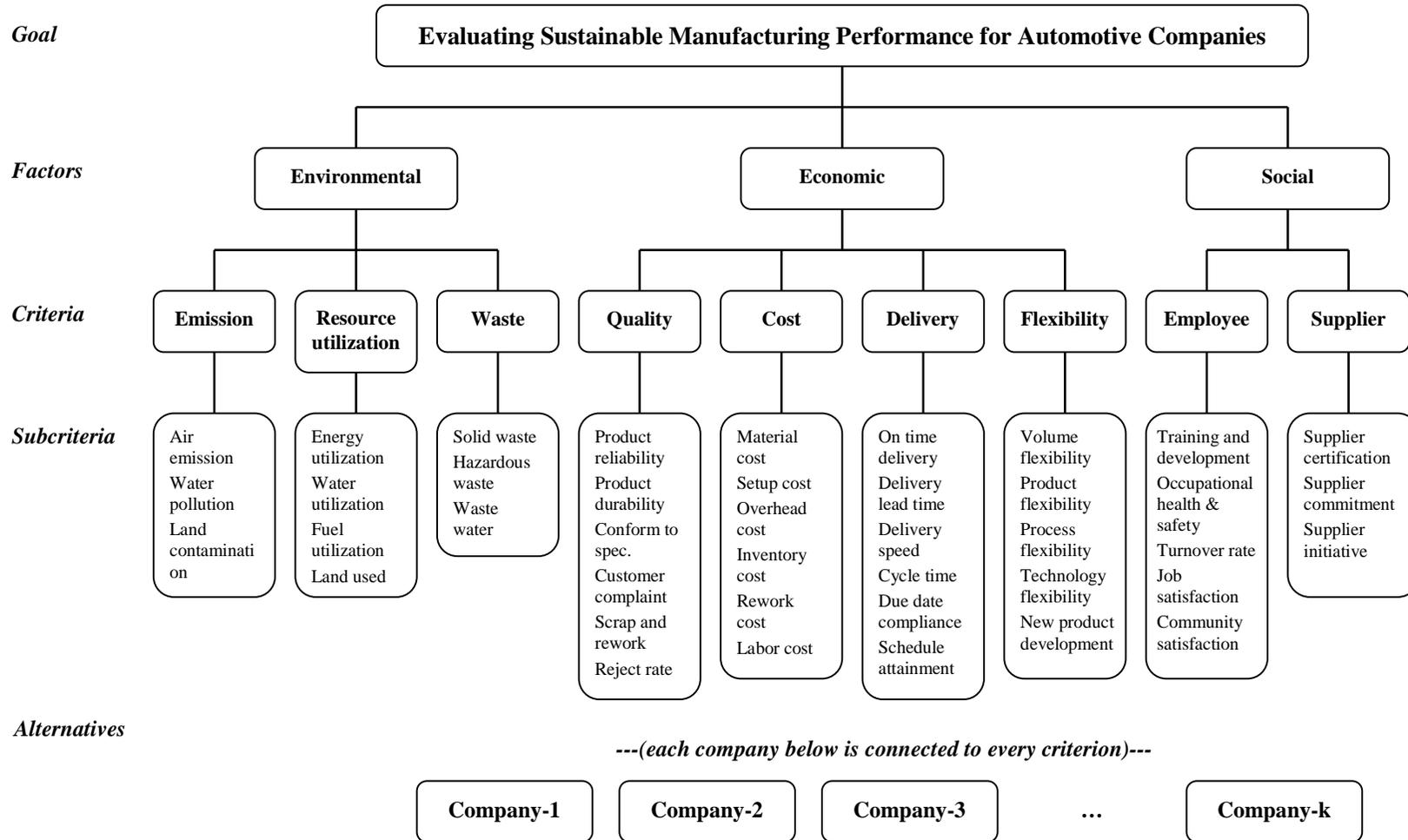
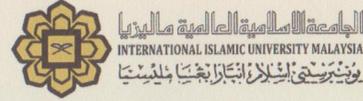


Figure 1. The hierarchy structure of sustainable manufacturing performance evaluation for automotive companies



## CERTIFICATE OF ATTENDANCE

This is to certify that

*Elita Amrina*

attended ISAHP 2013 - 12<sup>th</sup> International Symposium on the AHP  
which was held in  
Hotel Istana, Kuala Lumpur, Malaysia  
23<sup>rd</sup>- 26<sup>th</sup> June, 2013

*Prof. Rafikul Islam*  
CHAIRMAN  
International Islamic University Malaysia

*Razali Husain*  
DEPUTY CHAIRMAN  
bSure Solutions SDN BHD

June 25<sup>th</sup> 2013



**Kementerian Pendidikan dan Kebudayaan**  
**FAKULTAS TEKNIK UNIVERSITAS ANDALAS**

Kampus Limau Manis, Padang 25163, Sumatera Barat  
Telp. : 0751- 72497, Fax : 0751 - 72566  
Website : ft.unand.ac.id, e-mail : sek.dekan@ft.unand.ac.id

**SURAT TUGAS**

Nomor : 171 /XIII/I/FT/Unand-2013

Dekan Fakultas Teknik, Universitas Andalas menugaskan nama berikut:

NO	NAMA	NIP	STATUS
1	Dr. Elita Amrina	19770126 200501 2 001	Dosen Jurusan Teknik Industri

untuk mengikuti workshop dan seminar oral di the 12<sup>th</sup> International Symposium of the Analytic Hierarchy, di Kuala Lumpur, Malaysia pada tanggal 23-26 Juni 2013. Segala biaya yang digunakan untuk itu dibebankan kepada anggaran yang relevan.

Demikian surat tugas ini dibuat untuk dapat digunakan sebagaimana mestinya.

Padang, 13 Juni 2013

Dekan,



**Prof. Dr.-Ing. Hairul Abral**  
NIP. 19660817 199212 1001

Tembusan:

1. Dosen ybs
2. Kajur T. Industri FT-Unand
3. Arsip



ISO 9001



WWW.JAS.ANZ.ORG/REGISTER



LEMBAGA SERTIFIKASI SISTEM MUTU