ISAHP 2013

THE 12th INTERNATIONAL SYMPOSIUM ON THE ANALYTIC HIERARCHY PROCESS

Multi-Criteria Decision Making

Theme: Better World through Better Decision Making

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Online Proceedings
ISSN 1556-8296

CD/Flashdrive Version Proceedings
ISSN 1556-830X

Library of Congress Publication Data
Proceedings of the 12th International Symposium on the
Analytic Hierarchy Process for Multicriteria Decision Making
Date: 23 – 26 June, 2013
Hotel Istana, Kuala Lumpur, Malaysia

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ISAHP 2016 LONDON, UK

AUGUST 4 – AUGUST 7, 2016 / LONDON, UK
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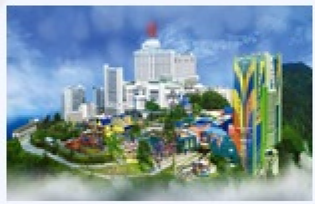
ISAHP 2013

❖ 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.

Petronas Twin Towers, Kuala Lumpur

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.



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Department of Business Administration
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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 works 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 of 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

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 12th International Symposium on the Analytic Hierarchy Process and Analytic Network Process (ISAHP 2013).

On behalf of the International Islamic University Malaysia and bSure Solutions Bhd, 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, Kulliyyah 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 Rozann 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!

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

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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).

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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
				Schedule attainment	0.1359
		Flexibility	0.0877	Volume flexibility	0.2039
				Product flexibility	0.0891
				Process flexibility	0.2612
				Technology flexibility	0.2742
				New product development	0.1716
Social	0.1748	Employee	0.7902	Training and development	0.2760
				Occupational health & safety	0.1916
				Turnover rate	0.1273
				Job satisfaction	0.2511
				Community satisfaction	0.1540
		Supplier	0.2098	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 $1 \leq$ scores ≤ 4 then performance level is poor,
If $4 <$ scores ≤ 7 then performance level is fair,
If $7 <$ scores ≤ 9 then performance level is good,
If 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**
Overall Score	**7.184**	Good	**9.332**	Excellent	**7.793**	Good	**6.215**	Fair
Individual score of factors								
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
Individual score of criteria								
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
Overall score	Supplier-2	9.332	Excellent	1
	Supplier-3	7.793	Good	2
	Supplier-1	7.184	Good	3
	Supplier-4	6.215	Fair	4
Individual score of factor				
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.

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Appendix 1

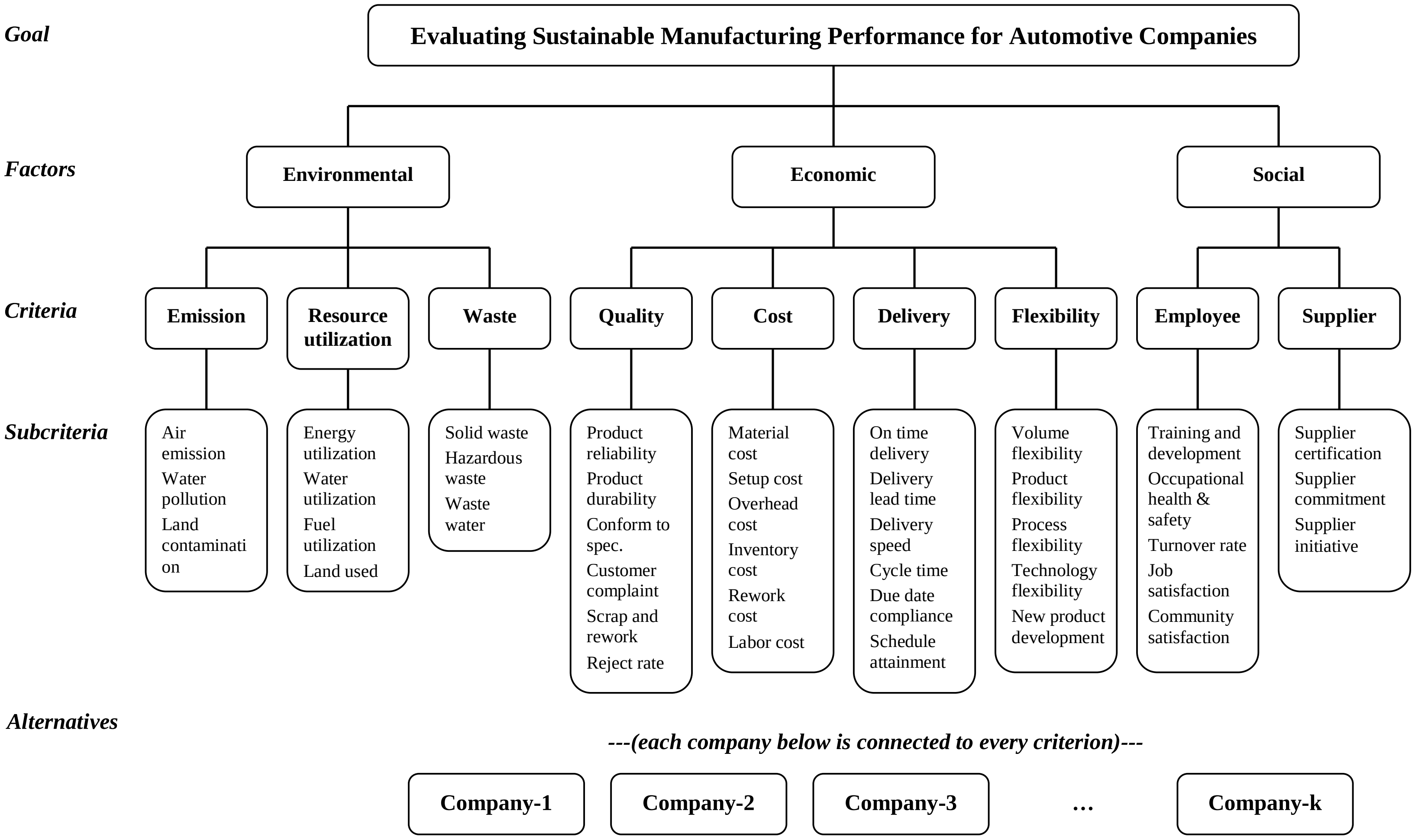

Figure 1. The hierarchy structure of sustainable manufacturing performance evaluation for automotive companies

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untuk mengikuti workshop dan seminar oral di the 12th 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.

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