The Nucleus **53**, No. 2 (2016) 121-127

www.thenucleuspak.org.pk

The Nucleus

ISSN 0029-5698 (Print)

ISSN 2306-6539 (Online)

Evaluating Suppliers' Efficiency using Conjoint Analysis

Z. Iqbal[1], H. M. K. Ali[2,*], A. Wasim[1], S. Hussain[1] and M. Jahanzaib[1]

[1]*Department of Industrial Engineering, University of Engineering and Technology, Taxila, Pakistan*

[2]*Department of Mechtronic Engineering, University of Engineering and Technology, Taxila, Sub-Campus Chakwal, Pakistan*

zbriqbal7@gmail.com; khurram.ali@uettaxila.edu.pk; wasim.ahmad@uettaxila.edu.pk; salman.hussain@uettaxila.edu.pk; jahan.zaib@uettaxila.edu.pk

ARTICLE INFO

Article history :

Received : 28 March, 2016

Revised : 20 May, 2016

Accepted : 02 June, 2016

Keywords :

Supplier Selection
Multi-criteria Decision Making (MCDM)
Conjoint Analysis (CA)
Manufacturing Industry

ABSTRACT

One of the main challenges for leading manufacturing industries to retain their competitiveness is selection of appropriate suppliers. In developing countries like Pakistan, industries need reinforcement of the supplier selection decisions using scientific techniques. This study utilizes conjoint analysis (CA), a mathematical and statistical modeling based multi-criteria decision making (MCDM) methodology, for evaluation of supplier efficiency in a real world manufacturing organization. Six attributes are extracted from respective literature with the help of expert opinions. The developed mathematical models are solved in respective CA software by using actual data. Results reveal that product performance is the most important attribute in supplier evaluation for the concerned industry followed by costs, quality, financial stability, delivery time and technical ability respectively. The findings are beneficial for both the selected manufacturing industry and the market suppliers.

1. Introduction

One of the challenging issues associated with purchasing function of any successfully running manufacturing industry is the comparative assessment of respective suppliers. Manufacturing industries normally spend a large amount of their turnover on purchasing of different materials from external suppliers. Supplier evaluation consists of a broader spectrum of qualitative and quantitative influencing attributes. Therefore it comes under the domain of multi-criteria decision making (MCDM) problems [1].

Many researchers from industry and academia around the globe have worked on evaluation of suppliers. While selecting an appropriate supplier for the manufacturing industries, we have to consider a wide range of criteria on top of the costs. Quality supplier may not be able to always offer lower costs. There is a possibility that a particular supplier is good in one dimension like 'costs' but it is not that much efficient in other dimensions like 'durability' and 'delivery time' etc. There exists a trade-off among attributes of different suppliers thus making it an MCDM problem which requires some scientific evaluations based on authentic methodologies like conjoint analysis.

Conjoint analysis (CA) is an MCDM technique for prioritization and evaluation of attributes. This approach has been started as a new expansion in mathematics and it is used by different researchers for the purpose of measuring the experimental data [2]. This approach has been utilized by different fields of applications, such as distribution, market research, product development and as a simulant in purchasing judgments [3].

Many experimental studies have been published for suppliers' selection and evaluation. Dickson identified twenty three attributes including quality, cost and delivery performance of any supplier. These are extracted from a total of twenty three attributes [4]. Some conceptual studies proved that managers should not select the suppliers only on the bases of lower costs and the factors like quality, delivery and performance etc. should never be overlooked [5]. For better performance of the products and services, innovative policies and management techniques should be utilized [6].

If a market researcher can explore and prioritize the customer preferences, he can inject the product features to target different market segments [7]. Talluri, et al. [8] presented a chance-constrained DEA approach for supplier evaluation. In that method price was input and delivery and quality were considered as outputs. Ancarani [9] developed a methodology to evaluate supplier performance and presented its theoretical implications.

Latest researchers also emphasize on the seriousness of supplier selection and its future impacts on manufacturing organizations [10].

* Corresponding author

The literature review reveals that there are very rare applications in developing countries like Pakistan particularly in perspective of recent economic crisis. Most of the organizations in Pakistan evaluate the suppliers on the basis of traditional approaches where the emphasis is mainly limited to costs of the supplied items. We are unable to find any study reported in available literature which applies a scientific approach like conjoint analysis for supplier evaluation and selection process in manufacturing industries from the defense sector of Pakistan. Unlike other MCDM techniques, conjoint analysis divides the factors into different levels thus providing a deeper insight. The aim of this research is to select the most appropriate supplier for a manufacturing set-up of Pakistan through conjoint analysis based evaluation process. It may also help the market suppliers to improve their efficiency according to customer demands.

Next section of this paper presents the theoretical background of conjoint analysis and the adopted research methodology with respect to selected manufacturing industry. Detailed results are presented in Results and Discussions section followed by the conclusion section.

2. Materials and Methods

This section provides a brief introduction of the conjoint analysis followed by the mathematical modeling of our particular problem. Afterwards, the discussion on selection of attributes is provided and the overall research methodology is presented.

2.1 Conjoint Analysis

Conjoint analysis is an MCDM approach to calculate the trade-offs among preferences. In general, conjoint analysis means breaking down the personal evaluations within the considered set of factors and levels and transforming the findings into distinct elements of utility [11]. Word "Conjoint" is used for this technique because relative importance of different factors is considered jointly.

Main aim of conjoint analysis is to measure the relative importance of the attributes of a product under investigation. Consequently, every attribute and factor comprises two or more different levels. It's very important that these levels should be realistic and presentation of factors and levels is cleared to respondents [12]. CA comprehensively highlights the available information about actual values of each level of every attribute [13]. Utilities of each level show the relative importance of that level. The involvement of different levels and importance of different factors are discovered by respondent options[14]. CA divides the preferences to conclude the value of every factor [13]. Part-worth value is calculated for each level of each factor. Maximum part-worth value is given to the most favorite levels, and minimum part-worth value is given to the least favorite levels.

Conjoint analysis approach has been used comprehensively in this research to determine the defense industry preferences for suppliers. It assumes that purchasers do not make the decisions on the basis of one attribute, instead they make decisions by evaluating a broader spectrum of attributes at the same time. For this purpose, they should make trade-off among those attributes.

2.2 Problem Modeling

In this section the problem is mathematically modeled under the domain of conjoint analysis.

The W_a value makes the relative impression of the supplier evaluation elements comparable with each other. Every factor which is used in this research is computed as following [15].

$$W_a = \frac{\max(U_a) - \min(U_a)}{\sum a[\max(U_a) - \min(U_a)]} \quad (1)$$

Here, utility of each level of any factor is indicated as U_a and relative importance as W_a. Non-linear function of the quantitative factors of part-worth analysis can be specified as a conjoint model as,

$$B_j = Z_1(N_{j1}) + Z_2(N_{j2}) + \ldots + Z_r(N_{jr}) \quad (2)$$

where $Z_t(\bullet)$ is the component utility function specific to the 't'th attribute and N_{jt} is the level for the 'j'th profile on the 't'th attribute. For the calculation of the 't'th attribute, utility function can be modeled as,

$$Z_t(N_{jt}) = Z_{t1}E_{t1} + Z_{t2}E_{t2} + \ldots + Z_{tr_t-1}E_{tr_t-1} \quad (3)$$

where r_t is the number of discrete levels for the 't'thattribute. E_{tk} is the dummy variable. Z_{tk} is the component of the part-worth function for the 'k' th discrete level of N_t. In real r_{t1} is compulsory for estimation. For example if $r_{t1} = 4$ the part-worth model will be:

$$Z_t(N_{jt}) = Z_{t1}E_{t1} + ZE_{t2} + Z_{t3}E_{t3} \quad (4)$$

In this equation, Z_{t1}, Z_{t2} ..are estimated using dummy variable. For the 't'th attribute, These are the vector model and ideal point model [15].

$$Z_t(N_{jt}) = G_t N_{jt} \text{ for the vector model} \quad (5)$$

$$Z_t(N_{jt}) = G_t(N_{jt} - N_{ot})^2 \text{ for ideal point model} \quad (6)$$

where G_t is a weight andn_t is the ideal point on the t-th attribute.

Table 1: Attributes considered in different studies

FACTORS	[4]	[16]	[17]	[18]	[19]	[20]	[21]	[22]	[23]	[24]	[25]	[26]	[27]
Quality	Y	Y	Y	Y	Y	Y	Y	Y	Y	y	Y	y	
Cost	Y	Y	Y	Y	Y	Y	Y	Y	Y	y	Y		y
Delivery me	Y	Y	Y		Y	Y	Y	Y	y	y	Y		y
Experience	Y	Y						Y					
Part safety													
Lightweight													
Recyclable		Y											
Technical ability	Y	Y	Y	Y	Y			Y					y
Process capability	Y	Y											
Design process		Y											
Reduction of wastes													
Reputation	Y	Y			Y			Y					
Using clean Technology		Y											
Demand	Y	Y					Y				Y		
Greenhouse gas Emission							Y						
Financial stability	Y	Y		Y		Y		Y					
Assortment						Y							
Flexibility	Y	Y						Y	Y				
Easy of Communication	Y	Y			Y								
Relationship		Y			Y								
Product performance	Y	Y		Y	Y							Y	
After sale/warranty	Y	Y			Y			Y					
Geographic location	Y	Y			Y					Y			
End use		Y		y				Y					
Social factor	Y	Y		y									
Environmental factor	Y	Y											
Logistic costs													
Innovation												Y	
Risk												Y	
Rejection		Y											y
Information and market service													
Maintenance	Y	Y						Y					
Reliable		y						Y					

2.3 Selection of Attributes and Levels

The first and the most critical step of conjoint analysis is to identify the attributes and their corresponding levels. Many studies by different researchers are reported in literature on this issue. An extensive literature review and experts survey had been conducted to extract the most critical factors for our particular problem. The factors used by different researchers are summarized in Table 1.

Here, ‘Y’ means that the respective authors used this attribute in their research while empty square means that attribute was not considered by authors. Based on literature review and expert opinions, eight factors were initially selected. After detailed discussions with experts from the concerned industry, it was decided that we can take six most critical factors for our particular case of supplier evaluation. These attributes were selected according to the case-specific requirements. These six factors include quality, cost, delivery time, technical ability, financial stability and product performance.

The next step of conjoint analysis is assigning different levels for evaluation of each factor. There are different patterns of these levels in available literature. The levels adopted in our study had been recommended by most of the authors [28-31]. These levels for all six factors are shown in Table 2.

2.4 Participants and Survey Design

Purchasing managers of different manufacturing industries from defense sector of Pakistan were contacted during different phases of this research. Fourteen completed questionnaires were obtained from managers having a minimum of ten years of experience in the field of supply chain. In conjoint analysis, only most important factors and their levels are considered as discussed earlier. Purchase mangers were requested to rate different choices and alternatives by creating trade-off among different attributes and levels. Flow chart of the research methodology can be seen in Fig. 1.

Table 2: Selected attributes and levels

Attribute	Levels
Quality	Poor, Good, Excellent.
Costs	5% above target price, Approximately at target price, 5% below target price.
Delivery Time	Seldom/few time, Most times, Always ontime.
Technical Ability	Latest technology, Moderate technology, Old technology.
Product Performance	Cost oriented, Cost and service oriented, Service oriented.
Financial Stability	Strong, Moderate, Weak.

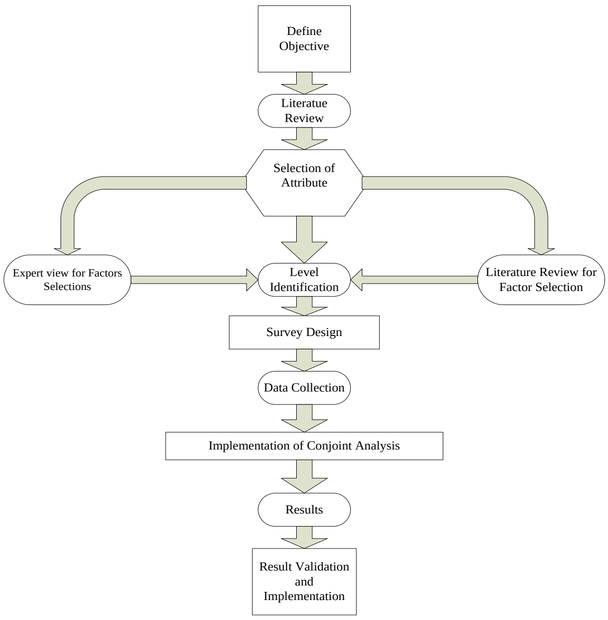

Fig. 1: Flow chart of the research

Total number of combinations for six factors and their corresponding levels should be 3×3×3×3×3×3=729. These combinations are too many for respondents to rank them efficiently. Therefore researchers always recommend reduction in these combinations [32]. Number of combinations was thus reduced and fractional factorial design was used to define the optimum number of sets instead of full factorial design.

The latest version of concerned software for conjoint analysis was used to make orthogonal design and thirty options were designated for the questionnaire. Thirty cards were, therefore, offered in a questionnaire by ID numbers. An extracted sample of the card is shown in Appendix A. Each card explained a potential supplier addressing the six attributes. Respondents were asked to rank these cards by choosing different combinations according to their preferences.

3. Results and Discussions

The developed models are solved in latest version of the concerned conjoint analysis software and results are presented in this section. The results can be classified into three categories; relative importance weights, part-worth values assigned to different levels of factors and ranking of the suppliers with respect to each factor.

Thirty cards containing different combinations of factor levels were offered to the experts as discussed earlier. The respondents were requested to rank them from one to thirty in order of preferred choice. A total of three hundred and ninety profile ranks (thirteen respondents with thirty profiles each) were, therefore, used for calculating part-worth value of utility.

Fig. 2 shows the scores of relative importance of each factor. It can be seen that 'Product performance' has achieved the highest value of relative importance followed by cost, quality, finance and delivery. The least preferred attribute is technical ability, with an importance value of 13.5%.

In order to check if the pairs of variables are inter-related, statistical correlations were also calculated. Both the Pearson and Kendall correlation coefficients were found higher than 0.5. This value not only validates the findings but also shows that strong correlations exist between the observed and estimated preferences.

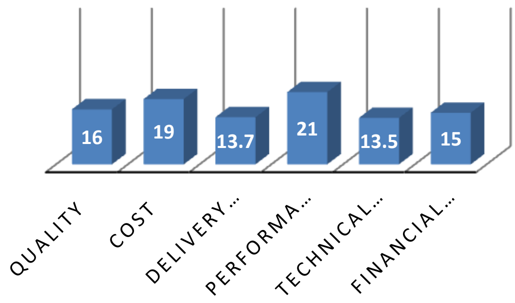

Fig. 2: Summary of relative importance

Part-worth utility scores show the impact of each factor level on purchasing managers' preferences for supplier evaluation and selection. Greater scores show more positive attitudes for that factor level. Maximum part-worth value is given to the most favorite levels, and minimum part-worth value is given to the least favorite levels. The factors with higher values are considered as important factors.

The computed part-worth utility scores presented in Table 3 and plotted graphically in Fig. 3 reveal the intricate details of respondent's preferences about different levels of each factor.

Table 3: Utilities and Std error

Utilities			
Factors	Levels	Utility Estimate	Std. Error
Quality	Good	.649	1.158
	Poor	-1.844	1.310
	Excellent	1.195	1.403
Costs	5% below target price	2.376	1.150
	5% above target price	-3.204	1.415
	Approximately at target price	.828	1.425
Delivery	Seldom/few times	-1.733	1.150
	Most times	.300	1.328
	Almost always	1.433	1.478
Performance	Cost-oriented	-1.785	1.150
	Cost and service oriented	-.471	1.425
	Service oriented	2.256	1.415
Technology	Latest technology	1.181	1.158
	Moderate technology	-.182	1.310
	Old technology	-.999	1.403
Finance	Weak	-1.957	1.158
	Strong	2.427	1.308
	Moderate	-.470	1.390
	(constant)	15.901	1.200

Utility is the preference assigned by experts to any level of factors. Unlike other MCDM techniques, conjoint analysis divides factors into different levels. Utility of any level shows the interest of experts in that particular level. Higher and positive values mean that experts have given a higher priority to the concerned level. Negative value of any level indicates that experts show less interest in that level.

For instance, among defined three levels for quality of product the level named 'poor' have got negative value whereas other two levels 'excellent' and 'good' obtained positive values. Calculated relative importance weights are dependent on results of different levels.

This research has been validated from different experts from the top management of another defense industry with similar manufacturing setups. Experts evaluated methodology, survey design and results on the basis of a questionnaire provided to them as shown in appendix B. All the experts confirmed that the attributes chosen in this study are appropriate for the supplier's selection. According to eighty percent experts this study can be applied practically in engineering and management operation organizations. About eighty five percent experts declared this research and its findings as logical ones. When the computed rankings of six attribute were presented to these experts it was found that; eighty three percent experts confirmed that performance is the most important factor, seventy eight percent confirmed that cost is the second one, seventy four percent experts confirmed that quality is the third most important and seventy five percent experts confirmed that technical ability is least important factor among the list of six factors.

This study has been implemented in one of the selected manufacturing industries for evaluation of a supplier efficiency based on findings of this study. Experts were asked to rate this supplier by assigning a value from zero to hundred for each of the six factors respectively. Expert assigned the values of sixty, sixty five, forty five, fifty five, eighty and fifty to performance, costs, quality, financial stability, delivery time and technology respectively. Using the matrix algebra, efficiency of the supplier in terms of rankings with respect to each factor has been calculated. Results showed that the supplier is 58.11% efficient when we consider these six attributes.

4. Conclusion

In today's competitive environment, manufacturing organizations have to pay special attention to the identification, selection and evaluation of supplier alternatives. Defense organizations in Pakistan normally rely on common sense approaches for supplier selection and evaluation, instead of utilizing some scientific methodologies or models in terms of quantifiable measures to assess supplier capabilities.

This study presents an innovative implementation of conjoint analysis to rank the influencing attributes and evaluate the suppliers. The proposed strategy not only covers all aspects of the supplier selection process but also returns the quantitative measures which enable us to have a comparative evaluation of the suppliers. Results show that defense industry experts are much sensitive about performance of the supplied items. This is because of the sensitive final products manufactured by these industries. However, the importance weight obtained for costs is only marginally lower than performance attribute which reveals that cost is also one

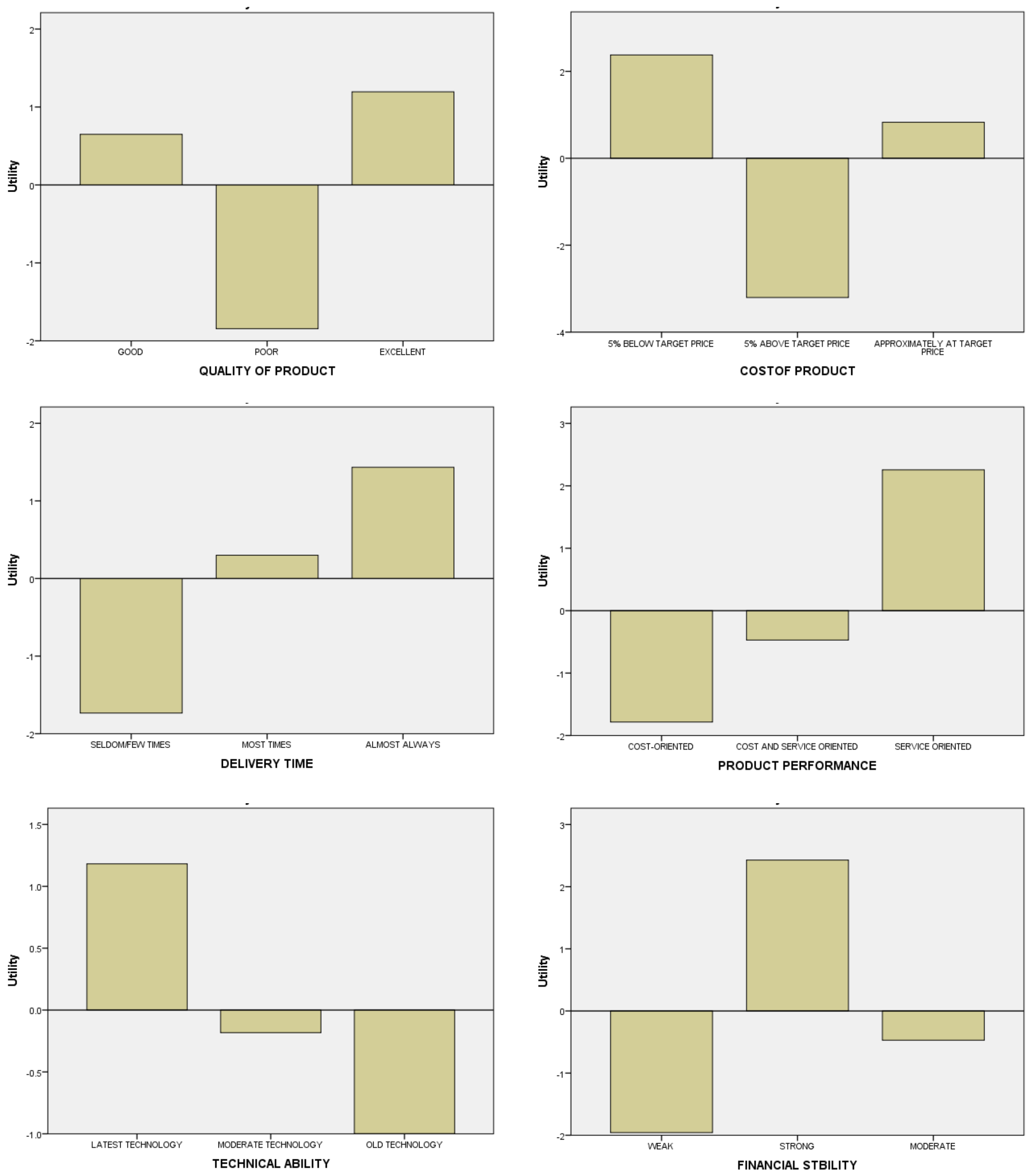

Fig. 3: Utilities of attributes

of the most important factors. Quality of products and financial stability of suppliers are the next factors in ranking lists. On contrary, it can be observed from the results that decision makers are not much sensitive about technical abilities of the suppliers. This is a particular context of a developing country like Pakistan which is struggling with economic challenges. Findings of this research are much useful not only for different manufacturing organizations in Pakistan but also for suppliers in terms of evaluating and improving their efficiencies according to market demands. However, the results are case specific and they should be handled with care when applied in other industries.

Acknowledgement

Authors are thankful to executive managers and procurement directors working in different defense industries of Pakistan for providing theirs expert opinions and sincere cooperation inevitable for the completion of this research.

References

[1] S. M. Ordoobadi, "Development of a supplier selection model using fuzzy logic", Supply Chain Management: An International Journal, vol. 14, pp. 314-327, 2009.

[2] P. E. Green and V. Srinivasan, "Conjoint analysis in consumer research: issues and outlook", J. Consumer Research, vol. 5, pp. 103-123, 1978.

[3] S. De Pelsmaeker, K. Dewettinck, and X. Gellynck, "The possibility of using tasting as a presentation method for sensory stimuli in conjoint analysis", Trends in Food Science & Technology, vol. 29, pp. 108-115, 2013.

[4] G. W. Dickson, "An analysis of vendor selection systems and decisions", J. Purchasing, vol. 2, pp. 5-17, 1966.

[5] C. A. Weber, J. R. Current, and W. Benton, "Vendor selection criteria and methods", Eur. J. Operational Research, vol. 50, pp. 2-18, 1991.

[6] M. I. Ramay, S. Hussain, A. Tanveer, Z. Jabeen and S. Ehsann, “Industrial waste management-a case study at Attock Oil Refinery Ltd., Rawalpindi”, The Nucleus, vol. 46, no. 3, pp. 279-288, 2009.

[7] E. Constantinides, "Influencing the online consumer's behavior: the Web experience," Internet Research, vol. 14, pp. 111-126, 2004.

[8] S. Talluri, R. Narasimhan, and A. Nair, "Vendor performance with supply risk: a chance-constrained DEA approach," Int. J. Production Economics, vol. 100, pp. 212-222, 2006.

[9] A. Ancarani, "Supplier evaluation in local public services: Application of a model of value for customer", J. Purchasing and Supply Management, vol. 15, pp. 33-42, 2009.

[10] O. Gurel, A. Z. Acar, I. Onden, and I. Gumus, "Determinants of the green supplier selection", Procedia-Social and Behavioral Sciences, vol. 181, pp. 131-139, 2015.

[11] T. Reutterer and H. W. Kotzab, "The use of conjoint-analysis for measuring preferences in supply chain design", Ind. Market. Manage., vol. 29, pp. 27-35, 2000.

[12] S. Alriksson and T. Öberg, "Conjoint analysis for environmental evaluation", Environ. Sci. and Pollution Res., vol. 15, pp. 244-257, 2008.

[13] P. E. Green, A. M. Krieger, and Y. Wind, "Thirty years of conjoint analysis: Reflections and prospects", Interfaces, vol. 31, pp. S56-S73, 2001.

[14] B. Keith and M. C. Simon, "Hypoxia-inducible factors, stem cells, and cancer", Cell, vol. 129, pp. 465-472, 2007.

[15] R. Myung, "Conjoint analysis as a new methodology for Korean typography guideline in Web environment", Int. J. Ind. Ergonomics, vol. 32, pp. 341-348, 2003.

[16] S. H. Ha and R. Krishnan, “A hybrid approach to supplier selection for the maintenance of a competitive supply chain. Expert Systems with Applications”, vol. 34, no. 2, pp. 1303-1311, 2008.

[17] K. Govindan, R. Khodaverdi and A. Jafarian, “A fuzzy multi criteria approach for measuring sustainability performance of a supplier based on triple bottom line approach”, Journal of Cleaner Production”, vol. 47, pp. 345-354, 2013.

[18] G. Büyüközkan, G. Çifçi, and S. Güleryüz, “Strategic analysis of healthcare service quality using fuzzy AHP methodology”, Expert systems with applications”, vol. 38, no.8, pp. 9407-9424, 201.

[19] X. Lin and S. Purchase, "Supplier selection in China: A conjoint analysis", Proc. of the Australian and New Zealand Marketing Academy (ANZMAC) Conference, University of Western Australia, Perth, Austrlia, pp. 49-56, 2005.

[20] J. Rezaei, P. B. Fahim, and L. Tavasszy, "Supplier selection in the airline retail industry using a funnel methodology: Conjunctive screening method and fuzzy AHP", Expert Systems with Applications, vol. 41, pp. 8165-8179, 2014.

[21] K. Shaw, R. Shankar, S. S. Yadav and L. S. Thakur, “Supplier selection using fuzzy AHP and fuzzy multi-objective linear programming for developing low carbon supply chain”, Expert systems with applications”, vol. 39, no. 9, pp. 8182-8192, 2012.

[22] D.R. Lehmann and J. O'shaughnessy, “Difference in attribute importance for different industrial products”. The Journal of Marketing, vol. 38, no. 2, pp. 36-42, 1974

[23] G. Büyüközkan, and G. Çifçi, “A novel hybrid MCDM approach based on fuzzy DEMATEL, fuzzy ANP and fuzzy TOPSIS to evaluate green suppliers”, Expert Systems with Applications, vol. 39. no. 3, pp. 3000-3011, 2012.

[24] A. Aksoy and N. Öztürk, “Supplier selection and performance evaluation in just-in-time production environments”, Expert systems with applications”, vol. 38, no. 5, pp. 6351-6359, 2011.

[25] A. YüCel and A. F. GüNeri, “A weighted additive fuzzy programming approach for multi-criteria supplier selection”, Expert Systems with Applications, vol. 38, no. 5, pp. 6281-6286, 2011.

[26] A. Zouggari and L. Benyoucef, “Simulation based fuzzy TOPSIS approach for group multi-criteria supplier selection problem”, Engineering Applications of Artificial Intelligence, vol. 25, no. 3, pp. 507-519, 2012.

[27] O. Jadidi, S. Zolfaghari and S. Cavalieri, “A new normalized goal programming model for multi-objective problems: A case of supplier selection and order allocation”, International Journal of Production Economics, vol.148, pp. 158-165, 2014.

[28] V. Mummalaneni, K. M. Dubas, and C.-n. Chao, "Chinese purchasing managers' preferences and trade-offs in supplier selection and performance evaluation", Ind. Market. Manage., vol. 25, pp. 115-124, 1996.

[29] M. Bendixen, K. A. Bukasa, and R. Abratt, "Brand equity in the business-to-business market", Ind. Market. Manage., vol. 33, pp. 371-380, 2004.

[30] W. Y. Wu, Y. K. Liao, and A. Chatwuthikrai, "Applying conjoint analysis to evaluate consumer preferences toward subcompact cars", Expert Systems with Applications, vol. 41, pp. 2782-2792, 2014.

[31] D. Kucukusta and B. D. Guillet, "Measuring spa-goers’ preferences: A conjoint analysis approach", Int. J. Hospitality Manage., vol. 41, pp. 115-124, 2014.

[32] E.-J. Lee, F. Chan, N. Ditchman, and M. Feigon, "Factors influencing Korean international students’ preferences for mental health professionals: A conjoint analysis", Community Mental Health Journal, vol. 50, pp. 104-110, 2014.