

# A Hybrid AHP and Taguchi Loss Function Method for Supplier Selection

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## ABSTRACT

This paper presents application of Analytic Hierarchy Process (AHP) in two different cases for selecting suppliers. This paper helps to compare the validity of AHP when used with a single decision maker and when used with multiple decision makers. Here, AHP is applied to two different cases: Firstly, for selecting a supplier in tyre manufacturing industry with single decision maker, and secondly, for selecting bidder for a State Electricity Board transgrid project with multiple decision makers. Five criteria were identified in both cases and pair-wise comparison was conducted. Priorities of criteria were identified and suppliers were also rated. Then it was further combined with Taguchi Loss Function to identify the best supplier. From the results obtained, we believe AHP with multiple decision makers is a more reliable form to select a supplier.

**Keywords:** AHP, Taguchi Loss Function, Supplier Selection, Pair-wise Comparison

## INTRODUCTION

The relation between supplier and companies is very important factor for a company's success. So, how a supplier is chosen, is essential to the result of the business. Supplier determination is the way of selecting a supplier to secure the important materials to help the yields of associations. Choice of the best and additionally the most reasonable providers depends on evaluating supplier abilities. Supplier assessment of current suppliers is the procedure that is utilized to evaluate supplier execution on an arrangement of criteria over some undefined timeframe. Over decades specialists and experts have paid supplier choice a lot of consideration. Since suppliers are the most basic parts of the inventory network, powerful supplier determination and assessment is thought to be one of the essential duties of acquiring suppliers. There are numerous techniques utilized for supplier selection. Selecting the right supplier can greatly enhance value, cost savings, quality standards and standardization throughout the manufacturing process. Therefore, it is imperative that companies select reliable suppliers and share similar strategic objectives and values that are consistent with the overall strategy of the business. The fundamental objective of the supplier selection process is essentially to reduce and obtain the most value for the buyer. The

objective of this study is to select supplier using AHP and Taguchi parameters in case of single decision maker and multiple decision makers. In supply chain management, selecting appropriate cooperation partners is the essential step at the beginning of supply chain management. This study focuses on selecting a suitable supplier by citing two situations from two different industries. First situation deals with selecting a suitable supplier for tyre manufacturing industry with a single decision maker. Second situation deals with selecting a supplier for State Electricity Board transgrid project using multiple decision makers. This study focuses on finding the best supplier from a number of available options based on different criteria that the company desires for. Supplier selection is a complex and important process. This study initially streamlines some important criteria used by tyre manufacturers from a set commonly seen criteria required for suppliers in tyre manufacturing industry and also qualifying criteria for prospective bidders in State Electricity Board transgrid project. Then a suitable method is used for supplier selection. By combining two supplier selection criteria (AHP and Taguchi Loss function) used in operations management, the best supplier is found in this study. In first case four suppliers are analyzed for finding the best supplier whereas in second case four bidders are empanelled from a list of seven bidders.

## LITERATURE REVIEW

Mathematical programming models: The supplier selection problem is formulated in terms of an objective function. The appropriate supplier is then identified by finding the optimal solution. The main functions of the mathematical models considered are maximizing the total purchase value, minimizing the total purchase cost or maximizing purchase value and minimizing purchase cost simultaneously. Aguezzou and Ladet (2007) propose a non-linear programming model for supplier selection that takes into account the transport of materials in order to select the best supply configuration. Osman and Demirli (2010) proposed a model using bilinear programming goals to achieve a compromise solution that allocates the demands of the company among the suppliers, thus minimizing the distribution cost.

Wu, Zhang, Wu, and Olson (2010) propose a multi-objective programming model for decision making on selecting suppliers, taking into account risk factors. For this purpose, the authors designed a fuzzy multi-objective programming model to deal with this problem. Mansini, Savelsbergh, and Tocchella (2012) proposed integer programming based heuristics to solve the problem of selecting a set of suppliers to satisfy product demand at minimal total costs, taking purchasing and transportation costs into account.

Artificial intelligence (AI)-based models. These models are done with computer-aided systems. Decision makers are trained and those who face similar but new situation can consult the system. Neural system (Albino & Garavelli, 1998) and case-based thinking (Ng & Skitmore, 1995; Choy, Fan, & Lo, 2003) are cases of techniques in view of AI innovation that have been connected to provider choice.

Cluster analysis (Holt, 1998). They group a number of suppliers into clusters based on a set of numerical attribute scores by using a classification algorithm. The differences between suppliers from different clusters are maximum while the differences between suppliers within a cluster are minimum.

Linear weighting models (Timmerman, 1986). Based on the importance of each criteria, weights are assigned to them. Then, the weights of the criteria are multiplied by their ratings and summed to obtain a single score for each supplier. The supplier who gets the highest score is selected.

Simulation-based approach (Soukup, 1987) considers for uncertainty. He developed a payoff matrix which can be used to assess prospective supplier's performance under different conditions.

Alencar and Almeida (2010) utilized PROMETHEE VI strategy keeping in mind the end goal to choose providers (venture colleagues) in view of cooperative choice, considering the inclination structure of every part. The model was connected in a construction field.

AHP was used by some others (Nydick & Hill, 1992; Barbarosoglu & Yazagac, 1997; Masella & Rangone, 2000; Chan & Chin, 2007) in the basic linear weighting model to eliminate the need to provide point estimates for criteria weights.

Sarkis and Talluri (2000) have applied analytic network process to determine the criteria weights as against pair-wise comparison used in this case.

Categorical methods (Timmerman, 1986). The relevant criteria based on supplier's performance are categorized as positive, neutral, and negative. The supplier who receives the most positive values is considered to have best performance.

Data envelopment analysis (DEA) (Ramanathan, 2007; Weber & Desai, 1996; Weber, Current, & Desai, 1998; Liu, Ding, & Lall, 2000). The efficiency of each supplier is the ratio of the weighted sum the performance of the supplier's to the weighted sum of the cost of using the supplier's. DEA method helps in separating suppliers into two categories: the efficient suppliers and inefficient suppliers.

Hybrid methods. Many authors have combined different model and have used a hybrid approach in supplier selection. Wang, Huang, and Dismukes (2005) and Percin (2006) have combined AHP and pre-emptive goal programming techniques and formed a methodology for supplier selection. Sevkli, Koh, Zaim, Demirbag, and Tatoglu (2008) have used AHP weighted multi-objective fuzzy linear programming model to solve supplier selection problems of an appliance manufacturer.

The Analytic Hierarchy Process (AHP) was developed by Thomas Saaty (1980). It is an effective tool that deals with complex decision making. It also helps the decision maker to set priorities by pair-wise comparison and make the best decision. AHP also helps to check the consistency of the evaluations of decision maker so as to reduce the bias in the decision making process.

Taguchi Loss Function (TLF) has been applied in the manufacturing industry (Caporaletti et al., 1993) and also in service industry (Li and Chen, 1998). Taguchi uses loss value, to measure the performance of the suppliers with respect to different criteria. Loss value makes the comparison of the supplier's or service provider's performances easy.

Gomes, Rangel, and Leal Junior (2011) dealt with the supply selection problem, considering uncertainty, by using the MAUT method, combined with the Interval Smart/Swing Weighting Method. The second method was used in the weights definition process, when making judgments by intervals. The model was applied in the selection of a printing service supplier.

Schramm and Morais (2012) proposed a multi-criteria decision model for supplier selection in the Brazilian construction industry. The model was based on a method called Simple Multi-Attribute Rating Technique Exploiting Ranking method (SMARTER).

Gencer and Gurpinar (2007) used an ANP instrument with a specific goal to assess the connection between the criteria for choosing providers in an company. Kirytopoulos, Leopoulos, and Voulgaridou (2008) additionally utilized an ANP to bolster the determination of the best trade off arrangement in nature of the pharmaceutical industry. Verdecho, Alfaro-Saiz, Rodriguez-Rodriguez, and Ortiz-Bas (2012) display an approach in light of an ANP to oversee cooperative connections by considering not just the components of inter-enterprise execution, yet in addition the elements that impact joint effort. The approach was connected in a system of teaming up endeavors from the sustainable power source division in Spain.

Basnet and Weintraub (2009) managed the issue of provider determination where there are a few providers with constrained abilities. To take care of the issue, they proposed a hereditary calculation be utilized as a part of the scan for Pareto ideal arrangements.

Yan and Wei portrayed a min-max rule based technique of inclination alterations with a limited number of ventures to discover trade off weights. The authors also examined the issue of the presence of various ideal arrangements and characterize an arrangement of most noticeably bad inclination arrange, which is autonomous of the determination of ideal arrangements.

Maggie and Tummala portrayed an AHP-based method and connected it to a genuine contextual analysis to analyze its achievability in choosing a seller for a broadcast communications framework. The utilization of the proposed method demonstrates that it can be connected to enhance the collective choice making in choosing a

seller that fulfills client determinations. Additionally, it is found that the choice procedure is precise and that utilizing the proposed AHP model can diminish the time taken to choose a seller.

Sanayei, Mousavi, Abdi, and Mohaghar proposed a coordinated approach of direct programming (LP) and multi-attribute utility theory (MAUT) for rating and selecting the best providers and characterizing the ideal request amounts among chosen ones with a specific end goal to expand add up to added substance utility.

## METHODOLOGY

By referring to nearly 20 articles (qualitative research), different criteria were considered followed by different industries/companies for their supplier selection. The best supplier for an organization, based on the company's requirement was found out, by employing an analytical tool. The decision maker of a company was asked about the different criteria they use for selecting the supplier. Data collection was done using direct interview and analysis was done using AHP and Taguchi Loss Function. The data for supplier selection in manufacturing industry was collected from purchase manager of a tyre manufacturing company and data for supplier selection in State Electricity Board transgrid project was collected from Chief Engineer, Deputy Chief Engineer, Financial Officer and Financial Advisor. The decision maker of a tyre manufacturing company was asked about the different criteria they use for selecting the supplier. Then a pair-wise comparison was done for each criteria wherein the decision maker was asked to rate on a scale of 1 to 9. Further, the decision maker was asked to rate each criteria for each supplier in a percentage scale. The same process were also repeated with different decision makers in State Electricity Board transgrid project so as to create an empaneled list of bidders.

## DATA ANALYSIS

### Case 1 – Supplier Selection in Tyre Manufacturing Industry with Single Decision Maker

#### Identifying the Required Criteria for Selecting Supplier

As per the decision makers perception, the following are the important criteria for supplier selection in tyre manufacturing industry:

- Financial stability
- Infrastructure facilities of the supplier
- Experience of the company in this field
- Quality Consensus
- Time boundness

**Eliciting Relative Importance of the Each Criteria from Decision Maker**

To accomplish this, a pair-wise comparison matrix is developed for different criteria considered to be relevant by the decision maker. The decision maker is asked to state the importance of each criterion relative to other criteria. The pair-wise comparison obtained is as follows:

**Table 1: Pair-Wise Comparison for Case 1**

	Financial stability	Infrastructure facilities of the supplier	Experience	Quality Consensus	Time boundness	Priorities
Financial stability	1	7	6	6	7	0.78399
Infrastructure facilities of the supplier	1/7	1	1/7	1/8	1/5	0.05314
Experience	1/6	7	1	8	9	0.4567
Quality Consensus	1/6	8	1/8	1	8	0.26287
Time boundness	1/7	5	1/9	1/8	1	0.10991

These priorities are calculated using the procedure suggested by Saaty (1995):

$$W_j = \frac{\sum_{k=1}^k (a_{ij} / (\sum_{j=1}^j a_{jk}))}{k}$$

Where  $w_j$  is the weight of the element,  $k$  is the number of columns and  $j$  is the number of rows.

Consistency check: The consistency of judgments is measured by means of consistency ratio (CR). The CR value should be 10 per cent or less. If the value is more than 10 per cent, the judgments may be somewhat random and must be revised (Saaty, 1995). The CR is calculated as  $CR=CI/RI$ , where  $CI$  is the consistency index and  $RI$  is the average random consistency index.

$CI = \frac{\gamma_{MAX} - n}{n - 1}$  where  $\gamma_{MAX}$  is the maximum eigen value of the matrix and  $n$  is the size of the matrix.

$RI$  is obtained from the experience data provided by Saaty (1995). The values for various matrix sizes ( $n$ ) are as shown:

**Table 2: RI Values for Consistency Check**

N	1	2	3	4	5	6	7	8	9
RI	0.0	0.0	0.52	0.89	1.11	1.25	1.35	1.40	1.45

Thus,  $CR=CI/RI = 0.399/4 = 0.399/1.11 = 0.359$  which is more than 10 per cent indicating the inconsistency of the judgments.

**Eliciting Decision Maker’s Perception of Supplier’s Performances with Respect to Each Criteria**

The decision maker is asked to evaluate the cr/i/teria for each of the four suppliers. The decision maker evaluates based on the historical data, reputation of the supplier, and the specifics of the situation at hand.

**Table 3: Performance Evaluation of Supplier**

	Financial Stability	Infrastructure Facilities of the Supplier	Experience	Quality Consensus	Time Boundness
A	80	80	50	50	60
B	70	80	60	60	70
C	85	60	90	65	60
D	75	70	60	85	85

**Determining Taguchi Function for Each Criteria**

The decision maker finds the target values and specification limits for the acceptable deviation from the target for each

criteria. The loss coefficient (k) are found based on these values and the loss functions are formed accordingly. The decision maker sets. The loss coefficient k for a criteria (whose acceptable deviation is 40) is calculated as  $k = 100/(0.40)^2 = 625$ .

**Table 4: Taguchi Loss Function**

	Target Value	Range	Specification Limit for Deviation	Loss Coefficient (k)	Taguchi Loss Function
Financial Stability	100	100-60	40	625	$L(X)=625(X-T)^2$
Infrastructure Facilities of the Supplier	100	100-50	50	400	$L(X)=400(X-T)^2$
Experience	100	100-50	50	400	$L(X)=400(X-T)^2$
Quality Consensus	100	100-60	40	625	$L(X)=625(X-T)^2$
Time Boundness	100	100-55	45	493.8	$L(X)=493.8(X-T)^2$

**Calculation of Rankings of Suppliers**

To allow the ranking of the three suppliers, one composite score is needed for each supplier. The average of the

weighted scores for each criteria is used to determine the single composite loss score for each supplier. The suppliers are then ranked according to these composite loss scores. The supplier with the smallest loss score is assigned the highest priority and is chosen as the supplier.

**Table 5: Calculating the Loss Value**

Priority for each criteria	Supplier A		Supplier B		Supplier C		Supplier D	
	TLF	TLF* Priority	TLF	TLF* Priority	TLF	TLF* Priority	TLF	TLF* Priority
0.784	25	19.6	56.25	44.1	14.06	11.0230	39.06	30.6230
0.053	16	0.848	16	0.848	64	3.392	36	1.908
0.456	100	45.6	64	29.184	4	1.824	64	29.184
0.262	156.25	40.9375	100	26.2	76.56	20.0587	14.06	3.68372
0.11	79.008	8.69088	44.44	4.8884	79.008	8.69088	11.11	1.2221
Total		115.676		105.22		44.9886		66.6208

The supplier with the least sum total (lowest value of loss function) is considered to be the best supplier. Hence, in this case supplier C is selected as the best supplier.

**Identifying the Required Criteria for Selecting Supplier**

As per the decision makers perception, the following are the important criteria for supplier selection:

**Case 2: Supplier Selection for a State Electricity Board of Transgrid Project with multiple decision makers**

- Total turnover of the company.
- Experience of supplier in similar projects.

- Qualification and experience of key site management and technical personnel.
- Equipment availability with supplier.
- Financial standing.

**Eliciting Relative Importance of the Each Criteria from Decision Maker**

To accomplish this, a pair-wise comparison matrix is developed for different criteria considered to be relevant by the decision maker. The decision maker is asked to state the importance of each criterion relative to other criteria.

The pair-wise comparison obtained is as follows:

**Table 6: Response from Financial Analyst**

	Total turnover	Experience	Qualification	Equipment availability	Financial standing
Total turnover	1	2	3	2	1/2
Experience	1/3	1	3	4	1/3
Qualification	1/3	1/3	1	5	1/4
Equipment availability	1/2	1/4	1/5	1	1/5
Financial standing	2	3	4	5	1

**Table 7: Response from Deputy Chief Engineer**

	Total turnover	Experience	Qualification	Equipment availability	Financial standing
Total turnover	1	1/5	1/2	1/3	2
Experience	5	1	1/3	1/2	3
Qualification	2	3	1	5	4
Equipment availability	3	2	1/5	1	3
Financial standing	1/2	1/3	1/4	1/3	1

**Table 8: Response from Financial Officer**

	Total turnover	Experience	Qualification	Equipment availability	Financial standing
Total turnover	1	2	3	4	1/3
Experience	1/2	1	3	4	1/2
Qualification	1/3	1/3	1	3	1/5
Equipment availability	1/4	1/4	1/3	1	1/4
Financial standing	3	2	5	4	1

**Table 9: Response from Chief Engineer**

	Total turnover	Experience	Qualification	Equipment availability	Financial standing
Total turnover	1	1/4	1/3	1/7	2
Experience	4	1	1/2	1/8	3
Qualification	3	2	1	5	6
Equipment availability	7	8	1/5	1	4
Financial standing	1/2	1/3	1/6	1/4	1

These priorities are calculated using the procedure suggested by Saaty (1995) and are averaged:

$$W_j = \frac{\sum_{k=1}^k (a_{ij} / (\sum_{j=1}^j a_{jk}))}{k}$$

Where  $w_j$  is the weight of the element,  $k$  is the index number of columns; and  $j$  is the index number of rows.

The priorities are obtained as:

**Table 10: Priorities of Criteria (Case 2)**

Criteria	Total turnover	Experience	Qualification	Equipment availability	Financial standing
Priorities	0.213	0.19	0.084	0.074	0.439

Consistency Check: The consistency of judgments is measured by means of consistency ratio (CR). The CR value should be 10 per cent or less. If the value is more than 10 per cent, the judgments may be somewhat random and must be revised (Saaty, 1995). The CR is calculated as  $CR=CI/RI$ , where CI is the consistency index and RI is the average random consistency index.

$$CI = \frac{\gamma_{MAX} - n}{n - 1} \cdot 1$$

where  $\gamma_{MAX}$  is the maximum eigen value of the matrix and n is the size of the matrix.

RI value is found from Table 2.

Thus,  $CR=CI/RI = 0.09225/1.11 = 0.082$  which is less than 10 per cent indicating the consistency of the judgments.

**Eliciting Decision Maker’s Perception of Supplier’s Performances with Respect to Each Criteria**

The decision maker is asked to evaluate the criteria for each of the four suppliers. The decision maker evaluates based on the historical data, reputation of the supplier, and the specifics of the situation at hand.

**Table 11: Supplier Scoring (Case 2)**

	Total Turnover	Experience	Qualification	Equipment Availability	Financial Standing
Supplier 1	85	85	90	95	90
Supplier 2	80	90	95	90	85
Supplier 3	95	90	90	95	95
Supplier 4	75	95	60	80	80
Supplier 5	70	75	65	80	70
Supplier 6	65	80	65	80	70
Supplier 7	90	85	85	90	95
Supplier 8	60	80	75	75	65

**Determining Taguchi Function for Each Criteria**

The decision maker finds the target values and specification limits for the acceptable deviation from the target for each

criteria. The loss coefficient (k) are found based on these values and the loss functions are formed accordingly. The decision maker sets. The loss coefficient k for a criteria (whose acceptable deviation is 40) is calculated as  $k = 100/(0.40)^2 = 625$ .

**Table 12: Taguchi Loss Function (Case 2)**

	Target Value	Range	Specification Limit for Deviation	Loss Coefficient (k)	Taguchi Loss Function
Total Turnover	100	100-60	40	625	$L(X)=625(X-T)^2$
Experience	100	100-50	50	400	$L(X)=400(X-T)^2$
Qualification	100	100-50	50	400	$L(X)=400(X-T)^2$
Equipment Availability	100	100-60	40	625	$L(X)=625(X-T)^2$
Financial Standing	100	100-55	45	493.8	$L(X)=493.8(X-T)^2$

**Calculation of Rankings of Suppliers**

To allow the ranking of the three suppliers, one composite score is needed for each supplier. The average of the

weighted scores for each criteria is used to determine the single composite loss score for each supplier. The suppliers are then ranked according to these composite loss scores. The supplier with the smallest loss score is assigned the highest priority and is chosen as the supplier.

Table 13: Loss value (Case 2)

Priority for Each Criteria	Supplier 1		Supplier 2		Supplier 3		Supplier 4		Supplier 5		Supplier 6		Supplier 7		Supplier 8	
	TLF	TLF* Priority	TLF	TLF* Priority	TLF	TLF* Priority	TLF	TLF* Priority	TLF	TLF* Priority	TLF	TLF* Priority	TLF	TLF* Priority	TLF	TLF* Priority
0.213	14.06	2.995	25	5.325	1.562	0.332	39.062	8.320	306.25	65.231	56.25	11.981	6.25	1.331	100	21.3
0.19	9	1.917	4	0.852	4	0.852	1	0.213	25	5.325	16	3.408	9	1.917	16	3.408
0.084	4	0.852	1	0.213	4	0.852	64	13.632	49	10.437	49	10.437	9	1.917	25	5.325
0.074	1.56	0.332	6.25	1.331	1.562	0.332	25	5.325	25	5.325	25	5.325	6.25	1.331	39.062	8.320
0.439	4.93	1.051	11.1	2.366	1.234	0.262	19.752	4.207	44.442	9.466	44.442	9.466	1.2345	0.262	60.490	12.884
Total		7.148		10.087		2.632		31.697		95.784		40.617		6.759		51.237

The supplier with the least sum total (lowest value of loss function) is considered to be the best supplier. Since State Electricity Board empanels the suppliers and then selects the supplier who quotes least cost, This method helped in empanelling the suppliers as Suppliers 3,7,1, and 2.

## CONCLUSIONS

The proposed decision model is an attempt to consider all the aspects of an outside supplier decision in the evaluation process. This analysis was conducted by considering two cases – single decision maker and multiple decision maker. We analyzed five most important criteria considered for a tyre manufacturing industry and State Electricity Board Transgrid project. A pair-wise comparison of these criteria by the decision maker was then conducted. Then we used AHP and Taguchi Loss function to find the best possible supplier. The result obtained as a result of single decision maker showed inconsistency, whereas, the result obtained with multiple decision makers showed consistency. This implies that when more decision makers are involved, there is higher chance of getting a reliable solution.

This method is suitable for supplier selection in large scale industries as the decision of selecting the supplier is crucial since there will be large cost incurred for the suppliers. So, when a scientific and systematic method is used for supplier selection, it will reduce the risk involved. But, the criteria comparison by decision maker does have influence on the results.

## REFERENCES

- Aguezou, A., & Ladet, P. (2007). A nonlinear multi-objective approach for the supplier selection, integrating transportation policies. *Journal Model Management*, 2(2), 157–169.
- Albino, V., & Garavelli, A. C. (1998). A neural network application to subcontractor rating in construction firms. *International Journal of Project Management*, 16(1), 9–14.
- Alencar, L., & Almeida, A. (2010). A model for selecting project team members using multicriteria group decision making. *Pesquisa Operacional*, 30, 221–236.
- Barbarosoglu, G., & Yazagac, T. (1997). An application of the analytic hierarchy process to the supplier selection problem. *Production & Inventory Management Journal*, 38, 14–21.
- Basnet, C., & Weintraub, A. (2009). A genetic algorithm for a bicriteria supplier selection problem. *International Transactions in Operational Research*, 16, 173–187.
- Bayazit, O. (2006). Use of analytic network process in vendor selection decisions. *Benchmarking: An International Journal*, 13(5), 566–579.
- Chan, C. T., & Chin, K. S. (2007). Key success factors of strategic sourcing: An empirical study of the Hong Kong toy industry. *Industrial Management & Data Systems*, 107(9), 1391–1416.
- Choy, K. L., Fan, K. H., & Lo, V. (2003). Development of an intelligent customer-supplier relationship management system: The application of case-based reasoning. *Industrial Management & Data Systems*, 103(4), 263–274.
- Davies, M. P. (1998). *Understanding marketing*. UK: Prentice-Hall.
- De Boer, L., Labro, E., & Morlacchi, P. (2001). A review of methods supporting supplier selection. *European Journal of Purchasing & Supply Management*, 7(2), 75–89.
- Gencer, C., & Gurpinar, D. (2007). Analytic network process in supplier selection: A case study in an electronic firm. *Applied Mathematical Modelling*, 31, 2475–2486.
- Gomes, L., Rangel, L., & Leal, Junior Mr. (2011). Treatment of uncertainty through the interval smart/swing weighting method: A case study. *Pesquisa Operacional*, 31(3), 467–485.
- Gonzalez, R., Gasco, J., & Liopis, J. (2010). Information systems outsourcing reasons and risks: A new assessment. *Industrial Management & Data Systems*, 110(2), 284–303.
- Gottschalk, P., & Solli-Saether, H. (2006). Maturity model for IT outsourcing relationships. *Industrial Management & Data Systems*, 106(2), 200–212.
- Holt, G. D. (1998). Which contractor selection methodology? *International Journal of Project Management*, 16(3), 153–164.
- Hui, Y. V., & Leung, L. C. (1994). Optimal economic tool regrinding with Taguchi quality loss function. *The Engineering Economist*, 39(4), 313–331.
- Jennings, D. (2002). Strategic sourcing: Benefits, problems, and a contextual model. *Management Decision*, 40(1), 26–34.
- Kirytopoulos, K., Leopoulos, V., & Voulgaridou, D. (2008). Supplier selection in pharmaceutical industry: An analytic network process approach. *Benchmarking: An International Journal*, 15(4), 494–516.
- Liu, J., Ding, F. Y., & Lall, V. (2000). Using data envelopment analysis to compare suppliers for supplier selection and performance improvement. *Supply Chain Management: An International Journal*, 5(3), 143–150.

- McCarthy, E. (1996). To outsource or not to outsource—what's right for you. *Pension Management*, 32(4), 12–17.
- Maggie, C. Y. T., & Tummala, V. M. R. (2001). An application of the AHP in vendor selection of a telecommunications system. *Omega*, 29(2001), 171–182.
- Mansini, R., Savelsberg, M., & Tocchella, B. (2012). The supplier selection problem with quantity discounts and truckload shipping. *Omega*, 40(4), 445–455.
- Masella, C., & Rangone, A. (2000). A contingent approach to the design of vendor selection systems for different types of co-operative customer/supplier relationships. *International Journal of Operations & Production Management*, 20(1), 70–84.
- Ng, S. T., & Skitmore, R. M. (1995). CP-DSS: Decision support system for contractor prequalification. *Civil Engineering Systems: Decision Making Problem Solving*, 12(2), 133–160.
- Nydick, R. L., & Hill, R. P. (1992). Using the analytic hierarchy process to structure the supplier selection procedure. *International Journal of Purchasing & Materials Management*, 28(2), 31–36.
- Ordoobadi, S. M. (2010). Application of AHP and Taguchi loss functions in supply chain. *Industrial Management & Data Systems*, 110(8), 1251–1269.
- Osman, H., & Demirli, K. (2010). A bilinear goal programming model and a modified Benders decomposition algorithm for supply chain reconfiguration and supplier selection. *International Journal of Production Economics*, 124, 97–105.
- Percin, S. (2006). An application of the integrated AHP-PGP model in supplier selection. *Measuring Business Excellence*, 10(4), 34–49.
- Raistrick, M. (1993). Outsourcing and communications facilities management. *British Telecommunications Engineering*, 12(1), 71–75.
- Ramanathan, R. (2007). Supplier selection problem: Integrating DEA with the approaches of total cost of ownership and AHP. *Supply Chain Management: An International Journal*, 12(4), 258–261.
- Saaty, T. L. (1980). *The analytic hierarchy process*. McGraw-Hill, New York.
- Saaty, T. L. (1995). *Decision making for leaders: The analytic hierarchy process for decisions in complex world*. Pittsburgh, PA: RWS.
- Sanayei, A., Mousavi, S. F., Abdi, M. R., & Mohaghar, A. (2008). An integrated group decision-making process for supplier selection and order allocation using multi-attribute utility theory and linear programming. *Journal of the Franklin Institute*, 345(2008), 731–747.
- Sarkis, J., & Talluri, S. (2000). A model for strategic supplier selection. In Leenders, M. (Ed.), *Proceedings of the 9th International IPSERA Conference* (pp. 652–661). London: Richard Ivey Business School.
- Schramm, F., & Morais, D. (2012). Decision support model for selecting and evaluating suppliers in the construction industry. *Pesquisa Operacional*, 32(3), 643–662.
- Sevklı, M., Koh, S. C., Zaim, S., Demirbag, M., & Tatoglu, E. (2008). Hybrid analytical hierarchy process model for supplier selection. *Industrial Management & Data Systems*, 108(1), 122–142.
- Sommer, R. A. (2003). Business process flexibility: A driver for outsourcing. *Industrial Management & Data Systems*, 103(3), 177–183.
- Soukup, W. R. (1987). Supplier selection strategies. *International Journal of Purchasing and Materials Management*, 23(3), 7–12.
- Tafti, M. H. A. (2005). Risks factors associated with off-shore IT outsourcing. *Industrial Management & Data Systems*, 105(5), 549–560.
- Taguchi, G., & Hsiang, T. C. (1989). *Quality engineering in production systems*. New York, NY: McGraw-Hill.
- Taner, T., & Anthony, J. (2000). The assessment of quality in medical diagnostic tests: A comparison of ROC/Youden and Taguchi methods. *International Journal of Health Care Quality Assurance*, 13(7), 300–307.
- Taner, T., & Anthony, J. (2006). Applying Taguchi methods to health care. *Leadership in Health Services*, 19(1), 26–35.
- Timmerman, E. (1986). An approach to vendor performance evaluation. *Journal of Purchasing and Supply Management*, 1, 27–32.
- Verdecho, M., Alfaro-Saiz, J., Rodriguez-Rodriguez, R., & Ortiz-Bas, A. (2012). A multi-criteria approach for managing inter-enterprise collaborative relationships. *Omega*, 40(3), 249–263.
- Wang, G., Huang, S. H., & Dismukes, J. P. (2005). Manufacturing supply chain design and evaluation. *International Journal of Advanced Manufacturing Technology*, 25(1), 93–100.
- Weber, C. A., & Desai, A. (1996). Determination of paths to vendor market efficiency using parallel co-ordinates representation: A negotiation tool for buyers. *European Journal of Operations Research*, 90(1), 142–155.
- Weber, C. A., Current, J. R., & Desai, A. (1998). Non-cooperative negotiation strategies for vendor selection.

*European Journal of Operations Research*, 108(1), 208–223.

Wu, D. D., Zhang, Y., Wu, D., & Olson, D. L. (2010). Fuzzy multi-objective programming for supplier selection

and risk modeling: A possibility approach. *European Journal of Operational Research*, 200(3), 774–787.

Yan, H., & Wei, Q. (2002). Determining compromise weights for group decision making. *Journal of the Operational Research Society*, 53(6), 680–687.