International Journal for Quality research
UDK - 005.311.121
Short Scientific Paper (1.03)

The Comparison of Solution Methods for the Problem of Giving Priority to Responses in Multiresponse Problem in Taguchi Method

Dr. Semra Boran

Engineering Faculty, University of Sakarya, Sakarya–Turkey

Dr. Kasım Baynal

Engineering Faculty, University of Kocaeli, Kocaeli–Turkey

Abstract: *In this study, the problem of giving priority to two or more quality chracteristics faced while applying Taguchi Method on multiresponse problems is studied. It was based upon Tong et al.(1997)'s approach on assignment of weights derived from individual experiences. Instead of prioritizing by personal judgments, Analytic Hierarchy Process (AHP) and Analytic Network Process (ANP) methods were used to assign priorities of quality characteristics. Comparisons were made among the results obtained by AHP, ANP medhods and the those of the expert. A spesific automative product was taken as an example which were subjected to above comparisons.*
Keywords: *Taguchi Method, Multi-response problem, The Analytic Hierarchy Process (AHP), The Analytic Network Process (ANP)*

1. INTRODUCTION

Taguchi method is an experimental design technique which minimizes the product and process variability. It provides the best combinations of controlable factor levels vs. uncontrolable (noise) factors that make variability. Traditional Taguchi method optimizes the one quality characteristic of a product. However in most real-life product improvement processes face with simultaneous optimization problem of more than one response variable generally occurs. In multi-response experiment, response variables are required to be optimized simultaneously because the investigation of each variable independently causes problems. The approaches that concern with simultaneous optimization of two or more quality characteristics generally require assign weight to quality characteristics if they have different priorities. This process though can be conducted by experienced person's experiments or with using of different methods; the first approach is generally preferred. There are different algorithms for this approach but this study is based on the experiment develeoped by Tong et al (1997). In this study, assigning weight was made by experts, AHP and ANP methods and the outcomes were evaluated.

2. MULTI RESPONSE PROBLEMS USING TAGUCHI OPTIMIZATION TECHNIQUE

The technique proposed by Tong et al. (1997) can be applied simultaneously to every kind of multi-response problems, continuos and discrete data types. It included four phases:

1. Compute the quality loss
2. Determine the multi-response signal to noise ratio (MRSN)
3. Determine the optimal factor/level combination
4. Conduct the confirmation experiment

The detailed information about this technique can be found in Tong et al. (1997)

3. THE ANALYTIC HIERARCHY PROCESS (AHP) METHOD

An AHP offers a methodolgy for ranking alternative courses of action based on the decision-maker's judgements concerning the importance of the criteria. An AHP is a decision making method for prioritizing alternatives when multiple criteria must be considered. The AHP process begins by determining the relative importance of the criteria in meeting the goals. Managerial judgements used to drive the AHP approach are expressed in terms of pairwise comparisions of items on a given level of the hierarchy with respect to their impact on the next higher level. Comparison matrix is formed with using Table 1. After forming the comparasion matrices, the mathematical process is applied to normalize and find the priority weights for each matrix (Pi and Low, 2006).

4. THE ANALYTIC NETWORK PROCESS (ANP) METHOD

The Analytic Network Process (ANP) consist of the clusters, elements, interrelationship between elements in cluster and interrelationship between clusters while AHP doesn't include interrelationship and feedback within the elements in the model.

Intensity Of Importance	Definition
1.	Equal importance
3	Moderate importance
5	Essential or strong importance
7	Very strong importance
9	Extreme importance
2,4,6,8	Intermediate valuea between adjacent scale values

Table 1. Scale of relative importance (Adapted from Saaty and Vargas 2006)

The determination of relative weight is based on the pairwise comparison as in the standard AHP used by Table 1. With respect to any criteria pairwise comparison are performed in two levels, the element level comparison and the cluster level comparison. The weights are then supermatrix that represents the interrelationships of elements in the system (Piantanakulchai, 2003). For matrix calculation, **see Saaty, 2001.**

5. THE PROPOSED MODEL

Our model includes following steps:

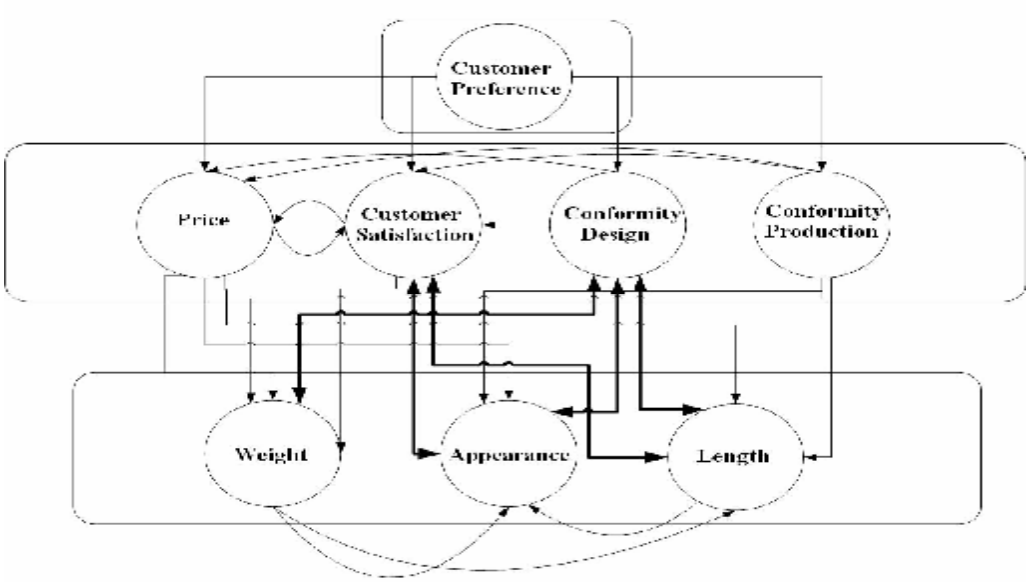

Figure 1. Structure of ANP

Step 1. Implement Taguchi technique on multi response problem,

Step 2. Compute importance degree via the Analytic Hierarchy Process (AHP),

Step 3. Compute importance degree via the Analytic Network Process (ANP),

Step 4. Calculate MRSN Values for Weights Determined by Experience, AHP and ANP

Step 5. Compare the results of experience, AHP and ANP.

5.1. Implementing of multi-response problem in Taguchi Technique

Implementation is carried on the improvement of quality characteristics of light control switch for autos. The quality characteristics are defined as the weight of product, its appearance (the brightness and being convex) and length. The nominal values for quality characteristics are respectively as follows: 8.5 gram, 45 mm and 1 (in metrics). Thirteen three-level factors determined which could be effective. L_{27} orthogonal array was chosen for experiment (Baynal, 2003).The values were found (Table 2).

5.2 Compute importance degree via the Analytic Hierarchy Process (AHP)

The AHP model includes three hierarchic levels. On the first level, the goal describes the customer preference and the priority of customer's quality characteristics. On the second level, there are four criteria defined as price, customer satisfaction, conformity design and conformity production. Finally there are alternatives which are quality characteristics (appearance, length and weight) on the third level. This hierarchic structure is similar as Figure 1 but it only consists of relationship between levels.

There are comparison with criterias and pairwise comparison with each of the criteria and quality characteristics based on the opinions of experts and the customers. The "Expert Choice" software was used in calculations. The obtained values for appearance, length and weight are respectively as fallows: 0.42, 0.40 and 0.18. These values were used as weights of quality characteristics in the implementation of Taguchi technique.

5.3 Compute importance degree via the Analytic Hierarchy Process (ANP)

The ANP model was created for determining the importance degree of quality characteristics, as is shown in Figure 1. Each of the level was designed within each cluster and between clusters. Pairwise comparisons were made for determine importance as cluster. There is a relation between elements within each cluster and between clusters. Pairwise comparisons were made for determine importance degree based on experts and customer preference as well as AHP. For design super matrix and other matrix calculations, super decision software used. The weights of quality characteristics were determined as 0.643 (for appearance), 0.266 (for length) and 0.091 (for weight).

5.4. Calculating MRSN Values for Weights Determined by Experience, AHP and ANP

For each trial MRSN values calculated tree times according to different weights which are determined by experiment, AHP and ANP methods (Table 2).

5.5. Compare the results of experience, AHP and ANP

The level of factor-level combinations determined by three different methods are the same with the exceptions of factor F, G and H (Table 3). Factor-level combinations determined by weights on the basis of experience and level of factor G and H of the factor-level combinations determined by ANP and AHP are different from the level of factor F of combination determined by AHP. The factor-level combinations determined by ANP and AHP are the same except factor F. The second level of factor F in AHP and the third level of F in ANP are defined to be the best factors. Furthermore, The MRSN ratios of factor G at three levels determined by on the basis of experience and computed by all MRSN ratios are very close to each other. Thus, the replacement of G_3 with G_1 doesn't change the situation. The level of factor F and H are different at three combinations. Factor F is among the first four factors regarding to importance degree at experience and ANP. However, it is the last third in AHP. Therefore, this factor is important too and should be in production process with its third level. Factor H

is the last factor in ANP and AHP but it is within the first three in experience method and should be considered as important. Also, because the three levels of factor H in AHP and ANP are very close to each other, they don't have a significant impact on the results. That's why; the level determined by experience is valid for the other methods as well (Table 4). As a result, the factor-level combinations determined by three methods are the same except the level of factor F, G and H. But the importance degrees of these factors on results are significantly different (Table 5).

																				Experience	AHP	ANP
Trial No	FACTORS													WEIGHT		APPERANCE		LENGTH		0.5;1.5;1.0	0.18; 0.42; 0.40	0.091; 0.643; 0.266
	A	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**L**	**M**	**Mean1**	**SS1**	**Mean2**	**SS2**	**Mean3**	**SS3**	**MRSNj**	**MRSNj**	**MRSNj**
1	1	1	1	1	1	1	1	1	1	1	1	1	1	8.64	0.00	0.10	0.316	46.91	0.749	-2.049	3,362	2.515
2	1	1	1	1	2	2	2	2	2	2	2	2	2	8.62	0.01	0.00	0.000	46.35	0.183	-	-2,518	1.886
3	1	1	1	1	3	3	3	3	3	3	3	3	3	8.60	0.02	1.00	0.000	45.46	0.051	13.623	18,055	12.127
4	1	2	2	2	1	1	1	2	2	2	3	3	3	8.63	0.05	0.20	0.422	46.2	0.380	0.174	5,323	4.916
5	1	2	2	2	2	2	2	3	3	3	1	1	1	8.64	0.02	1.00	0.000	45.2	0.043	14.677	19,109	12.250
6	1	2	2	2	3	3	3	1	1	1	2	2	2	8.65	0.06	0.10	0.316	47.19	0.902	-3.097	2,075	1.914
7	1	3	3	3	1	1	1	3	3	3	2	2	2	8.66	0.06	1.00	0.000	45.29	0.122	2.986	7,420	8.384
8	1	3	3	3	2	2	2	1	1	1	3	3	3	8.62	0.03	0.00	0.000	48.7	1.141	-	10,283	1.390
9	1	3	3	3	3	3	3	2	2	2	1	1	1	8.65	0.01	0.90	0.316	45.9	0.120	14.387	19,305	12.025
10	2	1	2	3	1	2	3	1	2	3	1	2	3	8.64	0.02	1.00	0.000	45.34	0.044	12.951	17,384	12.035
11	2	1	2	3	2	3	1	2	3	1	2	3	1	8.62	0.01	0.00	0.000	47.15	0.355	-	-2,518	1.866
12	2	1	2	3	3	1	2	3	1	2	3	1	2	8.65	0.03	0.10	0.316	46.19	0.358	-2.195	3,208	2.487
13	2	2	3	1	1	2	3	2	3	1	3	1	2	8.68	0.03	0.00	0.000	48.6	0.808	-	15,303	1.630
14	2	2	3	1	2	3	1	3	1	2	1	2	3	8.64	0.01	0.20	0.422	46.13	0.326	1.613	7,082	5.646
15	2	2	3	1	3	1	2	1	2	3	2	3	1	8.62	0.02	1.00	0.000	45.06	0.031	12.396	16,831	11.950
16	2	3	1	2	1	2	3	3	1	2	2	3	1	8.62	0.06	0.60	0.516	45.71	0.213	2.482	7,105	7.641
17	2	3	1	2	2	3	1	1	2	3	3	1	2	8.64	0.01	1.00	0.000	45.42	0.127	16.752	21,119	12.408
18	2	3	1	2	3	1	2	2	3	1	1	2	3	8.62	0.02	0.00	0.000	48.78	1.162	-	12,485	1.501
19	3	1	3	2	1	3	2	1	3	2	1	3	2	8.65	0.05	1.00	0.000	45.67	0.197	4.282	8,709	9.142
20	3	1	3	2	2	1	3	2	1	3	2	1	3	8.67	0.04	1.00	0.000	45.47	0.077	6.688	11,122	10.341
21	3	1	3	2	3	2	1	3	2	1	3	2	1	8.65	0.03	0.00	0.000	48.5	1.049	-	10,912	1.440
22	3	2	1	3	1	3	2	2	1	3	3	2	1	8.64	0.04	1.00	0.000	45.17	0.090	7.803	12,235	10.776
23	3	2	1	3	2	1	3	3	2	1	1	3	2	8.62	0.03	0.00	0.000	48.72	0.920	-	13,367	1.566
24	3	2	1	3	3	2	1	1	3	2	2	1	3	8.62	0.01	0.00	0.000	46.86	0.363	-	-2,518	1.865
25	3	3	2	1	1	3	2	3	2	1	2	1	3	8.68	0.04	0.10	0.316	49.25	2.479	-4.326	0,482	0.778
26	3	3	2	1	2	1	3	1	3	2	3	2	1	8.62	0.03	0.10	0.316	46.28	0.186	-2.155	3,265	2.520
27	3	3	2	1	3	2	1	2	1	3	1	3	2	8.61	0.02	1.00	0.000	45.19	0.078	14.500	18,921	12.227

Table 2. MRSN Values for Weights Determined by Experience, AHP and ANP

6. CONCLUSIONS

The algorithm developed by Tong et al. (1997) was handled in this study. In this algorithm when the weights of quality characteristics were assigning on the basis of experience, AHP and ANP methods were used.

It was found that the derived factor/level combinations were almost the same. The most

effective two factors were only different at importance degree at AHP method (Table 5).

METHOD	FACTOR/LEVEL COMBINATIONS
Experience	$A_2B_3C_3D_2E_3F_3G_1H_1I_2J_3K_1L_3M_1$
AHP	$A_2B_3C_3D_2E_3F_2G_3H_2I_2J_3K_1L_3M_1$
ANP	$A_2B_3C_3D_2E_3F_3G_3H_2I_2J_3K_1L_3M_1$

Table 3. Factor/Level Combinations Determined by Experience, AHP and ANP

	Main Effects on MRSN (AHP)				Main Effects on MRSN (ANP)				Main Effects on MRSN (Experience)			
	Levels			Max-Min	Levels			Max-Min	Levels			Max-Min
Factors	S1	S2	S3		S1	S2	S3		S1	S2	S3	
A	9.16	10.89	8.50	2.39	6.38	6.85	5.63	1.22	4.52	4.89	2.98	1.91
B	7.52	9.87	11.15	3.63	5.98	5.83	6.54	0.71	3.70	3.73	4.96	1.26
C	9.19	7.47	11.89	4.42	5.81	5.67	6.88	1.22	4.29	3.39	4.71	1.31
D	8.98	10.88	8.69	2.19	5.70	6.84	5.82	1.14	3.71	4.66	3.99	0.95
E	8.59	8.92	11.03	2.44	6.42	5.54	6.49	0.95	2.70	4.18	5.51	2.81
F	8.49	10.44	9.62	1.95	5.13	5.82	7.41	2.28	1.76	4.96	5.67	3.91
G	7.68	8.98	11.89	4.21	5.70	5.80	6.87	1.17	3.78	3.63	3.55	0.23
H	8.95	9.96	9.64	1.01	6.19	6.35	5.81	0.54	7.51	4.84	3.21	4.30
I	8.38	11.36	8.81	2.98	6.10	6.56	5.70	0.86	2.86	6.30	3.95	3.44
J	7.31	6.97	15.80	8.83	1.62	6.16	11.39	9.77	-1.05	2.07	11.38	12.43
K	13.30	4.16	11.08	9.14	7.66	5.18	5.52	2.48	6.71	1.90	3.78	4.80
L	10.05	7.82	10.68	2.86	6.26	5.12	6.98	1.86	4.88	2.23	5.27	3.04
M	9.96	9.73	8.86	1.10	7.00	5.74	5.62	1.38	5.28	3.69	3.41	1.87

Table 4: Factor/Level Combinations for Weights Determined by AHP, ANP and Experience

Importance ***Degree***														
	Experience	*J*	*K*	*H*	*F*	*I*	*L*	*E*	*A*	*M*	*C*	*B*	*D*	*G*
	AHP	*K*	*J*	*C*	*G*	*B*	*I*	*L*	*E*	*A*	*D*	*F*	*M*	*H*
	ANP	*J*	*K*	*F*	*L*	*M*	*A*	*C*	*G*	*D*	*E*	*I*	*B*	*H*

Table 5. Importance Degree of Factors Determined by Experience, AHP and ANP

REFERENCES:

[1] Baynal, K., Optimizing Multi-response Problems in Taguchi Method and Application, unpublished PhD. Disertation, Istanbul University, 2003.

[2] Pi, W. ve Low, C., "Supplier Evaluation and Selection via Taguchi Loss Functions and an AHP", Int. J. Adv. Technol. 2006 Vol.27, No. 5-6, 625 - 630

[3] Piantanakulchai, M., Analytic Network Process model for Highway Corridor Planning, ISAHP 2003, Honolulu Hawaii, July 8-10.

[4] Saaty, T.L. Making with Dependence and Feedback, 2nd edi., RWS Publication, 2001, pp.26.

[5] Saaty T.L. and Vargas L.G. Decision Making with the Analytic Network Process, 2006, Springer.

[6] Tong, Lee-Ing, Su, Chao-Ton, Wang, Chung-Ho, "The Optization of Multi-Response Problems in the Taguchi Method", Int.J. of Quality &Reliability Management, 1997, Vol.14, No.4, 367-380.

Recived: 04.06.2007 Accepted: 16.08.2007 Open for discussion: 1 Year