

USE OF ANALYTIC HIERARCHY PROCESS (AHP) TO SUPPORT THE DECISION-MAKING ABOUT DESTINATION OF A BATCH OF DEFECTIVE PRODUCTS WITH ALTERNATIVES OF REWORK AND DISCARD

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Oral presentation

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1. Introduction

- Application of AHP - support the decision-making - destination of a batch of defective products.
- Alternatives of destination: rework / discard.
- Mathematical development of the model: Excel.
- From a flow of analysis of quality problems - AHP method adapted and applied - using evaluation questions to establish the criteria for comparison.
- Evidence problem analysis -> answers and determination of criteria weights -> influences of the answers on cost/quality of the product -> rework or disposal.

2. Case study

- Study developed - Brazilian plant of a Japanese auto parts industry (SHOWA) - supplies world-renowned Japanese motorcycle manufacturers (Honda and Yamaha).
- Defective product - steering column of one of the models - presented the weld bead displaced from the correct position.
- Six decision criteria were used in the form of objective questions with "Yes" or "No" answers.
- The answers to the questions of the criteria - obtained from the evidence collected and verified in the technical analysis of the problem.
- Each criterion undergoes a change of importance (weight) according to the answer (yes or no) of the respective question.
- Information - collected through the engineering manager.
- Criteria - weighted consensus specialists in the areas of manufacturing, quality and engineering.

2.1 Problem Definition

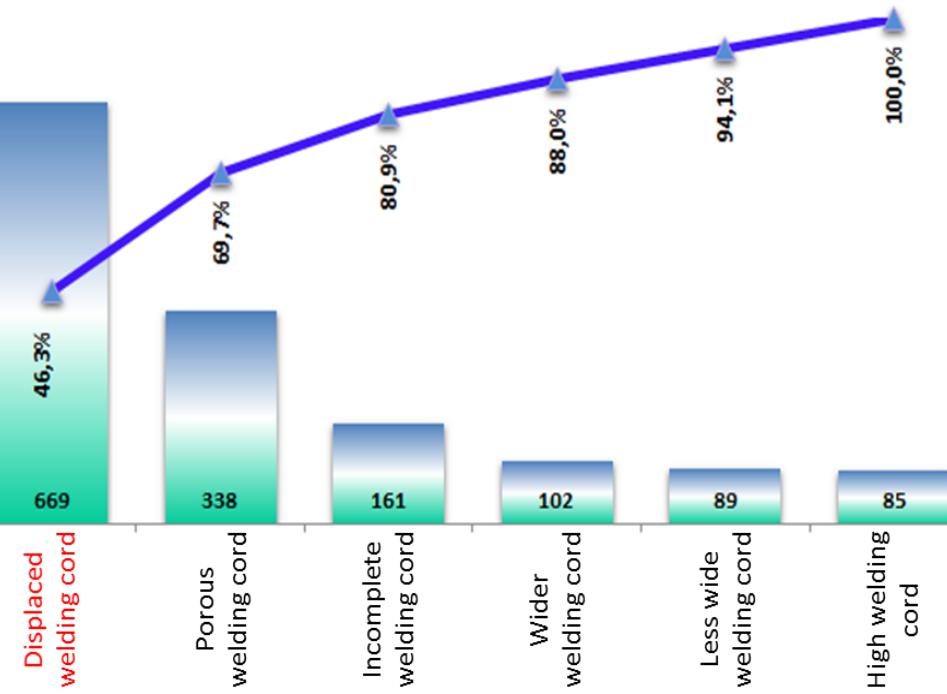


Figure 3: Type of defects in the welding process of the steering column in March 2016

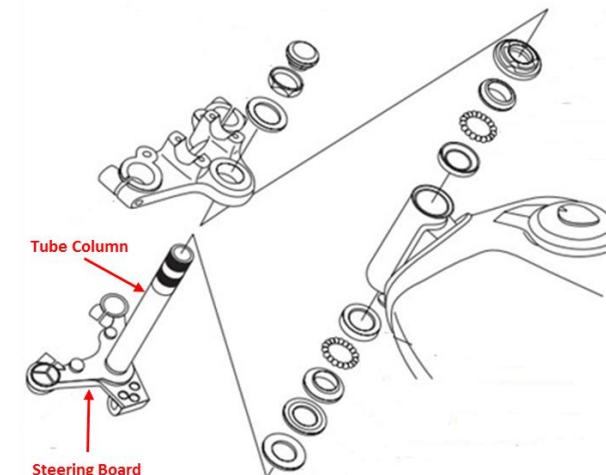
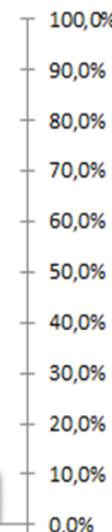


Figure 1: Complete steering column assembly

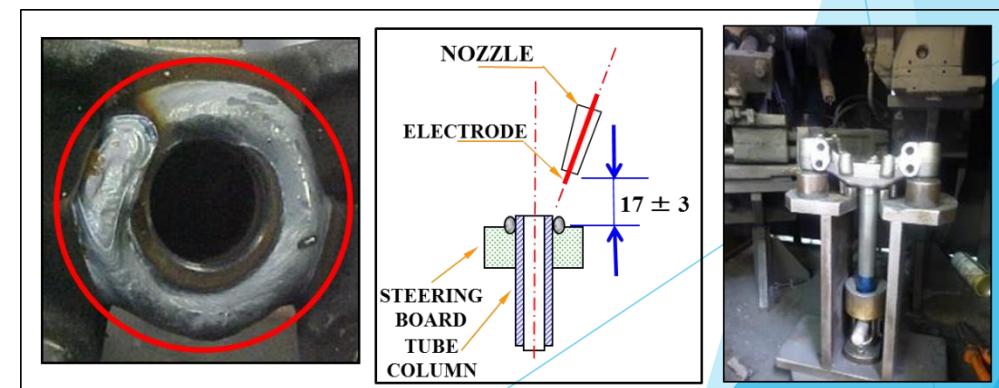


Figure 2: Weld bead of the displaced steering column (left), diagram of the welding process with alignment by the fork holes (center and right)

2.2 Definition of Decision Criteria

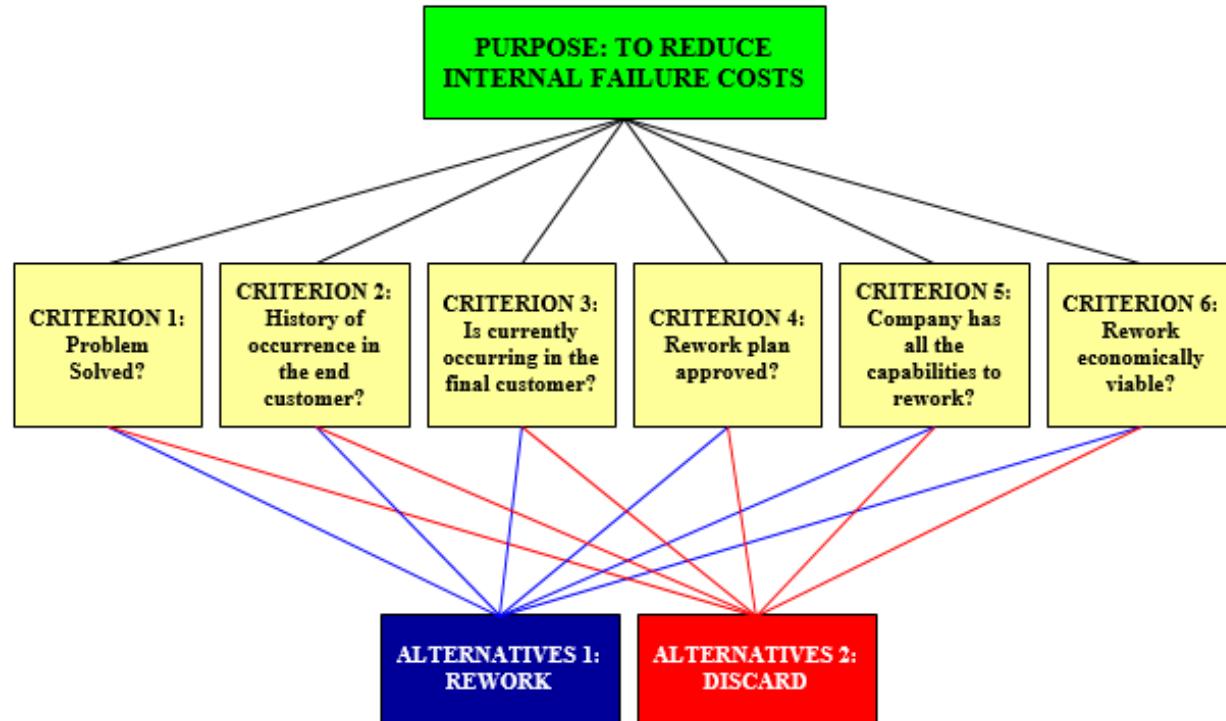


Figure 5: Hierarchical Problem Structuring

Table 1: Criteria with two possible conditions and respective tendencies

Attributes/Criteria	Responses of flow Analysis	
	Yes	No
Problem Solved?	Tendency to Rework	Tendency to Discard
History of occurrence in the final customer?	Tendency to Discard	Tendency to Rework
Is currently occurring in the final customer?	Tendency to Discard	Tendency to Rework
Rework plan approved?	Tendency to Rework	Tendency to Discard
Company has all the capabilities to rework?	Tendency to Rework	Tendency to Discard
Rework economically viable?	Tendency to Rework	Tendency to Discard



2.3 Weight and relationship of Criteria with alternatives

Table 2: Saaty Fundamental Scale – AHP

Intensity scale of importance - AHP

Intensity scale of importance	Definition	Explanation
1	Equal importance	Two elements contribute equally to the objective.
3	Weak importance of one over another	Experience and judgment moderately favor one element over another.
5	Strong importance	Experience and judgment strongly favor one element over another.
7	Very strong importance	One element is favored very strongly over another; its dominance is demonstrated in practice.
9	Absolute importance	Evidence favors one activity over another, with the highest degree of certainty.
2, 4, 6 e 8	Median of both neighboring judgments	When compromise is needed.

Table 3: Weight of the Criteria in the possibilities of answers "Yes" and "No"

Attributes/Criteria	Responses of flow Analysis		Weight AHP	
	Yes	No	Yes	No
Problem Solved?	Tendency to Rework	Tendency to Discard	2	9
History of occurrence in the end customer?	Tendency to Discard	Tendency to Rework	9	2
Is occurring currently in the end customer?	Tendency to Discard	Tendency to Rework	9	3
Rework plan approved?	Tendency to Rework	Tendency to Discard	4	9
Company has all the capabilities to rework?	Tendency to Rework	Tendency to Discard	5	9
Rework economically viable?	Tendency to Rework	Tendency to Discard	9	9

2.4 Hierarchy, criteria analysis and weight assignment for alternatives

Table 4: Result of the evaluation of required quality level and cost of rework options

Activity	Welding production piece with cord displacement	(1) Rework to remove the cord for new welding	(2) Rework fill with welding
Time	28 seconds	83 seconds	16 seconds
Condition of Cost	22,82 BRL	43,31 BRL	3,92 BRL
Visual Inspection	Not satisfy quality	Satisfy quality	Satisfy quality
Rupture test	Satisfy maximum load	Satisfy maximum load	Satisfy maximum load
Test macrography	Not satisfy penetration	Satisfy penetration	Not satisfy penetration
Appraisal Report	Necessary to rework or dispose of the part	High cost, bigger than to produce a new piece	Lack of penetration possible premature fatigue
		Not satisfy cost	Not satisfy quality

2.4 Hierarchy, criteria analysis and weight assignment for alternatives

Table 5: Problem hierarchy and assignment of analysis flow responses

PROBLEM: WELD BEAD OF THE STEERING COLUMN MOVED								
Goal	Dimension	Attributes/Criteria	Responses of flow Analysis		Weight AHP		Alternatives	
			Yes	No	Yes	No	(1) Rework	Discard
Reduce the cost of quality, mainly with internal and external flaws (depending on the external impact of rework in the field).	Quality	Problem Solved?	1	0	2	9	2	1
		History of occurrence in the end customer?	1	0	9	2	1	9
		Is occurring currently in the end customer?	0	1	9	3	3	1
		Rework plan approved?	0	1	4	9	1	9
	Cost	Company has all the capabilities to rework?	1	0	5	9	5	1
		Rework economically viable?	0	1	9	9	1	9

2.5 Construction of the preference matrices of the alternatives for each criterion.

Table 6: Matrices of preference of the alternatives for each criterion

Preference for Criterion 1	Result of the analysis	
	YES	NO
Problem Solved?	1	0
C1	Rework	Discard
Rework	1	2
Discard	1/2	1

Preference for Criterion 2	Result of the analysis	
	YES	NO
History of occurrence in the end customer?	1	0
C2	Rework	Discard
Rework	1	1/9
Discard	9	1

Preference for Criterion 3	Result of the analysis	
	YES	NO
Is occurring currently in the end customer?	0	1
C3	Rework	Discard
Rework	1	3
Discard	1/3	1

Preference for Criterion 4	Result of the analysis	
	YES	NO
Rework plan approved?	0	1
C4	Rework	Discard
Rework	1	1/9
Discard	9	1

Preference for Criterion 5	Result of the analysis	
	YES	NO
Company has all the capabilities to rework?	1	0
C5	Rework	Discard
Rework	1	5
Discard	1/5	1

Preference for Criterion 6	Result of the analysis	
	YES	NO
Rework economically viable?	0	1
C6	Rework	Discard
Rework	1	1/9
Discard	9	1

2.6 Normalization of each criterion

Table 7: Normalization of criteria

Normalize the Criterion 1			Normalize the Criterion 2			Normalize the Criterion 3			Normalize the Criterion 4		
Problem Solved?			History of occurrence in the end customer?			Is occurring currently in the end customer?			Rework plan approved?		
	Rewor	Discar	C2 - Criterion	Rewor	Discar	C3 - Criterion 3	Rewor	Discar	C4 - Criterion	Rewor	Discar
C1 - Criterion 1	k	d	2						4		
Rework	1	2	Rework	1	1/9	Rework	1	3	Rework	1	1/9
	+	+		+	+		+	+		+	+
Discard	1/2	1	Discard	9	1	Discard	1/3	1	Discard	9	1
	=	=		=	=		=	=		=	=
	1 1/2	3		10	1 1/9		1 1/3	4		10	1 1/9
Normalization			Normalization			Normalization			Normalization		
Rework	2/3	2/3	Rework	1/10	1/10	Rework	3/4	3/4	Rework	1/10	1/10
	+	+		+	+		+	+		+	+
Discard	1/3	1/3	Discard	9/10	9/10	Discard	1/4	1/4	Discard	9/10	9/10
	=	=		=	=		=	=		=	=
	1	1		1	1		1	1		1	1

2.6 Normalization of each criterion

Table 7: Normalization of criteria

Normalize the Criterion 5

Company has all the capabilities to rework?

	Rewor	Discar
C5 - Criterion 5	k	d
Rework	1	5
	+	+
Discard	1/5	1
	=	=
	1 1/5	6
<hr/>		
Normalization		
Rework	5/6	5/6
	+	+
Discard	1/6	1/6
	=	=
	1	1

Normalize the Criterion 6

Rework economically viable?

	C6 - Criterion	Rewor	Discar
	6	k	d
Rework		1	1/9
		+	+
Discard		9	1
		=	=
		10	1 1/9
<hr/>			
Normalization			
Rework	1/10	1/10	
	+	+	
Discard	9/10	9/10	
	=	=	
	1	1	

2.7 Average of the alternatives for each criterion

Table 8: Matrices of the averages of the alternatives for each criterion

Calculation of the average of the Criterion 1

Problem Solved?			
C1- Criterion 1	Rework	Discard	Average
Rework	0,667	0,667	0,667
Discard	0,333	0,333	0,333

Calculation of the average of the Criterion 2

History of occurrence in the end customer?			
C2- Criterion 2	Rework	Discard	Average
Rework	0,100	0,100	0,100
Discard	0,900	0,900	0,900

Calculation of the average of the Criterion 3

Is occurring currently in the end customer?			
C3- Criterion 3	Rework	Discard	Average
Rework	0,750	0,750	0,750
Discard	0,250	0,250	0,250

Calculation of the average of the Criterion 4

Rework plan approved?			
C4- Criterion 4	Rework	Discard	Average
Rework	0,100	0,100	0,100
Discard	0,900	0,900	0,900

Calculation of the average of the Criterion 5

Company has all the capabilities to rework?			
C5- Criterion 5	Rework	Discard	Average
Rework	0,833	0,833	0,833
Discard	0,167	0,167	0,167

Calculation of the average of the Criterion 6

Rework economically viable?			
C6- Criterion 6	Rework	Discard	Average
Rework	0,100	0,100	0,100
Discard	0,900	0,900	0,900

2.8 Definition of preferences for each criterion

Table 9: Averages of the alternatives for each criterion which is the array of preferences

ALTERNATIVES	CRITERIA					
	C1	C2	C3	C4	C5	C6
Rework	0,667	0,100	0,750	0,100	0,833	0,100
Discard	0,333	0,900	0,250	0,900	0,167	0,900

2.9 Comparison between criteria

Table 10: Matrix of comparison between the criteria

CRITERIA		C1	C2	C3	C4	C5	C6
C1	Problem Solved?	Problem Solved?	History of occurrence in the end customer?	Is occurring currently in the end customer?	Rework plan approved?	Company has all the capabilities to rework?	Rework economically viable?
C1	Problem Solved?	1	4	2	2	2	1/5
C2	History of occurrence in the end customer?	1/4	1	1/4	1/4	1/4	1/5
C3	Is occurring currently in the end customer?	1/2	4	1	1	1	1/5
C4	Rework plan approved?	1/2	4	1	1	1	1/5
C5	Company has all the capabilities to rework?	1/2	4	1	1	1	1/5
C6	Rework economically viable?	5	5	5	5	5	1
SUM		7,75	22,00	10,25	10,25	10,25	2,00

2.10 Normalization and average of the criteria

Table 11: Normalization and average of the comparison between the criteria

2.11 Calculation to obtain the preference index for the alternatives

Table 12: Indexes of preference of the alternatives from the averages of the alternatives by criterion and average of the comparison between the criteria

ALTERNATIVES	CRITERIA						Average of the Criteria	Result
	C1	C2	C3	C4	C5	C6		
Rework	0,667	0,100	0,750	0,100	0,833	0,100	0,166	0,34
Discard	0,333	0,900	0,250	0,900	0,167	0,900	0,042	0,66

2.12 Consistency check

Table 13: Total of the entries from the comparison between the criteria and the average of the comparison between the criteria

CRITERIA	C1	C2	C3	C4	C5	C6	X	Average of the Criteria	=	TOTALS
C1	1,000	4,000	2,000	2,000	2,000	0,200	X	0,166	=	1,0668
C2	0,250	1,000	0,250	0,250	0,250	0,200	X	0,042	=	0,2577
C3	0,500	4,000	1,000	1,000	1,000	0,200	X	0,107	=	0,6643
C4	0,500	4,000	1,000	1,000	1,000	0,200	X	0,107	=	0,6643
C5	0,500	4,000	1,000	1,000	1,000	0,200	X	0,107	=	0,6643
C6	5,000	5,000	5,000	5,000	5,000	1,000	X	0,473	=	3,1094

Table 15: Random Index according to the number of criteria

Random Index (RI)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Dimension of the array	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Random consistency	0,00	0,00	0,58	0,90	1,12	1,24	1,32	1,41	1,45	1,49	1,51	1,48	1,56	1,57	1,59

Table 14: Maximum eigenvalue from the totals of the entries and average of the comparison between the criteria

Calculation of the Maximum eigenvalue (λ_{max})		
Totals	Average of the Criteria	Result
1,0668 /	0,1660	= 6,4253
0,2577 /	0,0418	= 6,1637
0,6643 /	0,1065	= 6,2375
0,6643 /	0,1065	= 6,2375
0,6643 /	0,1065	= 6,2375
3,1094 /	0,4726	= 6,5788
Sum		= 37,8803
Average (λ_{max})		6,3134

Table 16: Consistency Result

CONSISTENCY INDEX	CI	0,0627
CONSISTENCY RATIO	CR	0,0445
CONSISTENCY		

3. Results and discussion

Table 17: Final result of the application of the AHP Method in the case of study considering the comparison of the Alternative Discard with the Alternative (1) Rework to remove the cord for new welding.

Goal	Dimension	Attributes/Criteria	Responses of flow Analysis		Weight AHP		Alternatives		
			Yes	No	Yes	No	(1) Rework	Discard	
Reduce the cost of quality, mainly with internal and external flaws (depending on the external impact of rework in the field).	Quality	Problem Solved?	1	0	2	9	2	1	
		History of occurrence in the end customer?	1	0	9	2	1	9	
		Is occurring currently in the end customer?	0	1	9	3	3	1	
		Rework plan approved?	0	1	4	9	1	9	
	Cost	Company has all the capabilities to rework?	1	0	5	9	5	1	
		Rework economically viable?	0	1	9	9	1	9	
INDEX/RESULT						0,34	0,66		
						DISCARD			

4. Conclusions

- The applied method assisted in the decision to discard the parts in this study.
- AHP method - allowed the systematization of the decision process.
- This type of model can be used in other quality problems involving the destination of defective products.
- The contribution of this work is the adaptation of the AHP method to the application of problems of this type, using questions and answers.
- The format can be adapted to the reality of other companies with inclusion or exclusion of criteria and weightings as necessary.

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Thank you for your attention!