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Using AHP Approach, Evaluation of Quality: A Case Study with Respect to a Washing Machine Company

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Abstract
Supplier evaluation is performed by companies to continuously improve quality, to mitigate risks, to reduce costs or to improve performance. Thus, it forms an important and integral function that a company carries out to remain competitive in a given market. This paper attempts to propose a model that can assist a washing machine company to evaluate the quality aspect of its suppliers. This model is based on the Analytical Hierarchy Process (AHP) approach, which follows the principle of Linear Weighing Model. This paper is an attempt to give a variation of the traditional and a very common method that is widely used in many companies to evaluate the quality aspect – the quality history which is either about the percentage or parts per million of non-conformance components supplied. So, this paper suggests that along with the past quality history other parameters can also largely help in supplier evaluation and so this work has tried to identify the important criteria that may enable the company to not just evaluate the suppliers' performance, but also to concentrate in those areas where improvements may be required. It also tries to exhibit how a multi-criteria decision-making method can ease the work of a Vendor Management or a Quality Department in evaluating the quality aspect of their suppliers.

Keywords
Supplier evaluation, Analytical hierarchy process, Quality, Washing machine company, Suppliers.

Introduction
It is observed that companies evaluating their suppliers achieve a minimum of 20% improvement in their supplier performance matrices which are quality, time, and cost (Gordon, 2006). Hence, it becomes necessary to have a Supplier Evaluation System.

The particular scheme discussed in this paper is for a XYZ washing machine company in India. Its main product is front loading washing machine supported by top loading washing machines and dryers. The manufacturing line mainly consists of component assembling line to give the final product. Suppliers play a major role as the quality of the final product mainly depends on the quality of the components supplied by its suppliers. The XYZ company gives 50% weightage to quality, 20% to each delivery and cost, and the rest 10% to response, service, and development for supplier evaluation. Since the company gives the highest weightage to quality, the scheme discussed in this paper is about supplier quality evaluation.

Supplier quality evaluation would have been easier if only quality history was considered where the percentage or the parts per million (PPM) of non-conformance components are taken into account. In PPM, rejections for the month are extrapolated to find the number of rejections if the production was 1 million (Kubiak, 2009). But, since supplier evaluation are undertaken to determine the long-term success of the company (Stueland, 2004), evaluating supplier on the basis of one criterion fails to predict the long-term performance of the supplier. An example of this could be a supplier not updating its Production Part Approval Process (PPAP) documents with recent design changes will have quality issues at some time in future if not soon. The supplier quality evaluation needs to be implemented as a system for the following reasons: (1) A large number of suppliers need to be evaluated, (2) a substandard part delivered by any one of the supplier would reduce the quality of the entire product, (3) the rise in production that will require a high percentage of components complying to conformance, and (4) improved quality which is required to have an edge over other washing machine companies. Prioritization of the criteria needs to be done because when the XYZ company is asked to evaluate its' supplier quality based on multiple criteria it becomes a daunting task because the criteria and the priorities of evaluation criteria may differ from evaluator to evaluator. Also, the criteria have to be shared with all the suppliers. So, they can adhere to the list of prioritized evaluation criteria and conduct their internal audits on the basis of it. This will be helpful since it is not feasible in every quarter to conduct Supplier Audits of all the suppliers and also suppliers whose PPM falls in the acceptable range (as defined in the supplier quality manual of XYZ company) might be reluctant to allow plant visits.

There are multiple criteria on which suppliers can be evaluated, so tradeoff can be made by the Vendor Management or Quality Department on the criteria that are deemed to be more necessary than the remaining criteria. Thus, this is a situation which can be characterized to the group of multiple criteria decision making field (Coulter et al., 2006). The various approaches that are used to evaluate suppliers in most of the companies are Linear Weighing Models, Total Cost of Ownership Model, Mathematical Programming Model, Artificial Intelligence Based Model, and Statistical Models (Missopoulos et al., 2009; Saravanan et al., 2012). Out of all these, Analytical Hierarchy Process (AHP) which belongs to the approach used by Linear Weighing Model is the most used method (Missopoulos et al., 2009; Nguyen et al., 2010). It is flexible and can adapt to unique analysis situations, and it can also be understood by lay audience

(Coulter et al., 2006). There have been many instances where AHP has been successfully used for supplier evaluation (Tahriri et al., 2008; Politis et al., 2010; Asamoah et al., 2012).

AHP can be defined as a comprehensive framework which is designed to cope up with the intuitive, the rational, and the irrational when we make multi-objective, multi-criterion, and multi-factor decisions with and without certainty for any number of alternatives (Harker and Vargas, 1987; Massaeli, 2011). AHP enables to derive ratio scale priorities or weights as opposed to arbitrarily assigning them (Saaty, 1997). In AHP, the hierarchy starts with the top level containing the ultimate objective of the problem then the sub-objectives or criterion constitute the next level and so on. The hierarchy follows down to the options or alternatives. Therefore, each hierarchical level can be seen as being made up of elements (or criterion variables) that in turn, are decomposed into sub-elements that make up the next level of the hierarchy (Bagchi and Rao, 1992).

Methodology

The criteria, sub criteria, and sub sub criteria for evaluating supplier quality were identified by working along with the team that resolves suppliers' quality issues for XYZ Company. The duration of the study was 5½ months. During these months, we interacted closely with a group of suppliers who agreed to allow visits to their plants frequently that enabled us to identify the criteria, sub criteria, and sub sub criteria. It is important to note that these criteria, sub criteria, and sub sub criteria pertain mainly to this company.

Define supplier evaluation criteria

The three evaluation criteria are processes quality (PQ), system quality (SQ), and gauge calibration (GC).

Define sub criteria and sub sub criteria for supplier evaluation

At this stage, the sub criteria and sub sub criteria are defined for the above-mentioned criteria. The sub criteria incoming quality control (IQC), process quality control (PQC), and outgoing quality control (OQC) are defined under PQ. Similarly under SQ, the sub criteria are supplier control, training and auditing, documentation, and system. The last GC includes the calibration of the gauges and the instruments that the supplier uses for quality inspection and for different processes.

Under these sub criteria, a total of 25 sub sub criteria were identified. These sub sub criteria take into account most of the essential quality control/improvement requirements which when ensured by the supplier will result in the delivery of quality

Table 1: Identified criteria, sub criteria and sub sub criteria

PQ	SQ	GC
IQC	System	Calibration
Availability of gauges/instruments as per Ctrl plan	Company ISO certified	In-house calibration facility
Easy traceability/identification of material	MRM conducted and quality performance reviewed	Conducting calibration as per plan and availability of certificates
Monitoring material shelf life	Preventive maintenance plan for all machines	
FIFO ensured	TQM approach and application of Kaizen and Poke Yoke techniques	
PQC	6 sigma approach	
Process validation of machines	Training and auditing	
Critical processes operated by skilled personnel	Avail and updating skill matrix	
Avoiding unauthorized modification of process parameters	Training program conducted	
Display of limit samples	Internal audit conducted by certified personnel	
OQC	Supplier control	
FIFO ensured	Evaluation of suppliers before approval	
Packaging standards maintained and varied as per requirements (during rainy season extra covering of plastic)	Supplier audit plan followed	
Easy traceability/identification of material	Conduct supplier rating	
	Documentation	
	Easy avail of latest drawings, control plans and PPAP doc along with updated RCA and action plan for defects	

IQC: Incoming quality control, PQC: Process quality control, OQC: Outgoing quality control, FIFO: First in first out, MRM: Management review meeting, PPAP: Production part approval process, PQ: Processes quality, SQ: System quality, GC: Gauge calibration, TQM: Total quality management, RCA: Root cause analysis

components to the XYZ Company. Table 1 shows the identified criteria, sub criteria, and sub sub criteria.

Hierarchy of criteria

In this step, the hierarchy of criteria was developed. Figure 1 shows the structure of the hierarchy that consists of four levels: Goals, criteria, sub criteria, and sub sub criteria. The goal is evaluating supplier quality for the XYZ Washing Machine Company. The second level consists of criteria: PQ, SQ, and calibration. The third level consists of 8 sub criteria and the fourth level has 25 sub sub criteria. Below fourth level are the alternatives that will be evaluated as samples.

Then a priority weight for each criterion in each level was determined using pair-wise comparison – the 9-point scale proposed by Saaty (Saaty, 1980) as shown in Table 2. An example of the pairwise comparison is shown in the Table 3.

Then local weights were calculated. For this, the pairwise comparison table was first normalized. This was done by summing the column values and then dividing each of the column values with the column total. Then, the row-wise average was calculated (Saaty, 1994). Table 4 shows the normalized matrix for Table 3. The local weights can also be calculated using the software Expert Choice. It is a decision to support software tool-based on AHP (Hunter and Tan, 2007). It incorporates the intuitive graphical user interfaces, and automatic calculation of priorities and inconsistencies (Ishizaka and Labib, 2009). So, the rest of the local weights (sub criteria and sub sub criteria) were calculated using Expert Choice. Table 5 shows the local weights of criteria, sub criteria, and sub sub criteria.

For the priorities to make sense, a Consistency Ratio (CR) Test needs to be performed (Ishizaka and Labib, 2009). Priorities to make sense means if A, B, and C are three priorities and A>B and B>C then logically A>C. This logic is transitive property. Now, if A<C, then it is said to be inconsistent or the priorities do not make sense (Teknomo, 2006). So, if CR is less than 10% then the matrix has an acceptable consistency (Saaty, 1998). Expert choice is used to determine the inconsistency (Tahriri

Table 2: Measurement scales

Verbal judgment or preference	Numerical rating
Extremely preferred	9
Very strongly preferred	7
Strongly preferred	5
Moderately preferred	3
Equally preferred	1
Intermediate values between two adjacent judgments	2, 4, 6 and 8

Table 3: Example of criteria pair wise comparison matrix

Criteria for supplier performance evaluation	SQ	PQ	GC
SQ	1	1	8
PQ	1	1	6
GC	1/8	1/6	1

SQ: System quality, PQ: Processes quality, GC: Gauge calibration

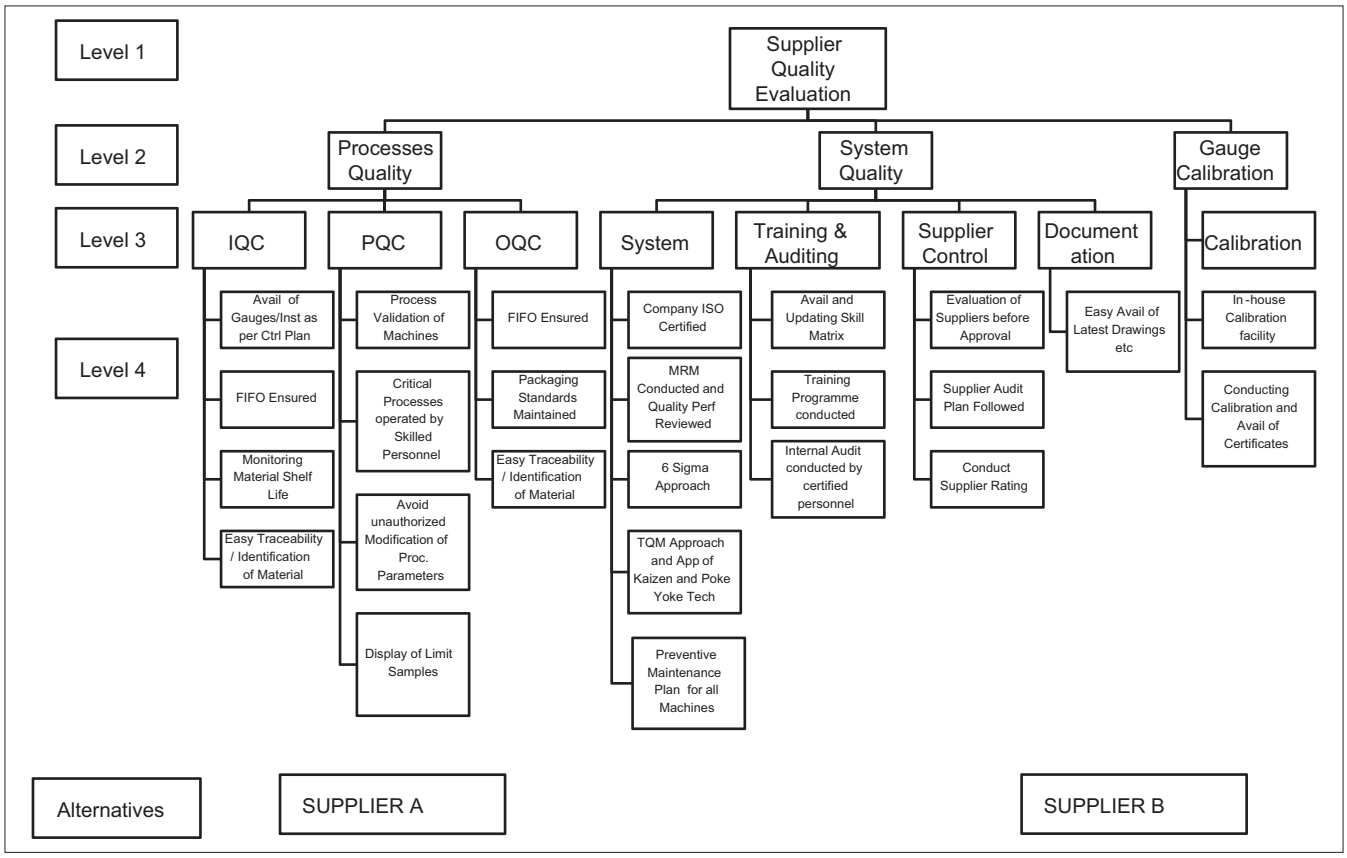

Figure 1: Hierarchy of criteria

Table 4: Normalized matrix

Criteria for supplier performance evaluation	SQ	PQ	GC	AVG (local weights)
SQ	0.4706	0.4615	0.5333	0.4885
PQ	0.4706	0.4615	0.4	0.444
GC	0.0588	0.0769	0.0667	0.0675
SUM	1	~0.9999	1	1

SQ: System quality, PQ: Processes quality, GC: Gauge calibration

et al., 2008; Lepetu, 2012). The "INCON" i.e. CR calculated by Expert Choice for the example shown in Table 4 is 0.01.

Prioritize the order of sub sub criteria

The global weights of the sub sub criteria were calculated by multiplying the correspondent local weights of the criteria, sub criteria, and sub sub criteria (Tahriri et al., 2008). For example, the global weight for company ISO certified (Global Weight – 0.1995) is calculated by multiplying the local weights of SQ (0.583), system (0.609) and company ISO certified (0.562). Global weights for each sub sub criteria is calculated and arranged in the descending order of priority as shown in Table 6.

Table 5: Summary of local weights and global weights

Criteria	Local weights	Sub criteria	Local weights	Sub sub criteria	Local weights	Global weights
SQ	0.489	System	0.609	Company ISO certified	0.562	0.167
				6 Sigma approach	0.164	0.049
				TQM approach and application of Kaizen and Poke Yoke techniques	0.153	0.046
				Preventive maintenance plan for all machines, tool life identified and critical spares available in inventory	0.079	0.024
				MRM conducted and quality performance reviewed	0.041	0.012
		Supplier control	0.187	Evaluation of suppliers before approval	0.683	0.062
				Supplier audit plan followed	0.200	0.018
				Supplier rating conducted	0.117	0.011
		Training and auditing	0.133	Avail of training program plan and conducted the same	0.443	0.029
				Internal audit conducted by certified personnel	0.387	0.025
				Availability of updated skilled matrix	0.169	0.011
		Documentation	0.071	Easy avail of latest drawings, Ctrl plans and PPAP doc along with updated RCA and action plan for defects	1	0.035
PQ	0.444	IQC	0.627	Avail of gauges/instruments as per Ctrl plan	0.581	0.162
				Easy traceability/identification of material	0.205	0.057
				FIFO ensured	0.145	0.040
				Monitoring material shelf life	0.068	0.019
		PQC	0.280	Process validation of machines	0.468	0.058
				Critical processes operated by skilled personnel	0.344	0.043
				Avoiding unauthorized modification of process parameters	0.121	0.015
				Display of limit samples	0.068	0.008
		OQC	0.094	FIFO ensured	0.540	0.023
				Packaging standards maintained and varied as per requirements (during rainy season extra covering of plastic)	0.297	0.012
				Easy traceability/identification of material	0.163	0.007
GC	0.067	Calibration	1	Conducting calibration as per plan and avail of cert	0.800	0.054
				In-house calibration facility	0.200	0.013

SQ: System quality, PQ: Processes quality, GC: Gauge calibration, IQC: Incoming quality control, PQC: Process quality control, OQC: Outgoing quality control, FIFO: First in first out, MRM: Management review meeting, PPAP: Production part approval process, TQM: Total quality management, RCA: Root cause analysis

The top 10 of the 25 are - whether the company is ISO certified (0.167), availability of gauges/instruments as per control plan for the incoming quality inspection (0.162), whether the supplier evaluates the second tier suppliers before the approval (0.062), process validation carried out of all the machines involved in the production of the components (0.058), easy identification/ traceability of materials during IQC (0.057), conducting calibration of all the gauges and the instruments (0.054), implementation of 6 sigma approach, i.e., mainly the Define, Measure, Analyze, Improve, Control *(*DMAIC) process (0.049), implementation of Total Quality Management (TQM) approach, and whether the employee follow the Kaizen or 5S principle and implement the Poke Yoke Techniques (0.046), critical processes are carried out by skilled personnel for example operations like injection molding need to be carried out by personnel who is aware of the molding defects, their possible causes and the remedies (0.043) and first in, first out ensured (0.040). It is important to note that along with ISO certification rest of the criteria are also important. This can be based on the fact that sometimes the certifications could be misleading and/or forged (Beil, 2010). Also, because the certifications do not guarantee best practices, focus is mainly on documenting procedures and is not specific to customer requirements (Gordon, 2006).

Table 6: Ranking of sub sub criteria

Rank	Sub sub criteria	Global weights
1	Company ISO certified	0.167
2	Avail of gauges/instruments as per Ctrl plan	0.162
3	Evaluation of suppliers before approval	0.062
4	Process validation of machines	0.058
5	Easy traceability/identification of material	0.057
6	Conducting calibration as per plan and avail of cert	0.054
7	6 sigma approach	0.049
8	TQM approach and application of Kaizen and Poke Yoke techniques	0.046
9	Critical processes operated by skilled personnel	0.043
10	FIFO ensured	0.04
11	Easy avail of latest drawings, Ctrl plans and PPAP doc along with updated RCA and action plan for defects	0.035
12	Avail of training program plan and conducted the same	0.029
13	Internal audit conducted by certified personnel	0.025
14	Preventive maintenance plan for all machines, tool life identified and critical spares available in inventory	0.024
15	FIFO ensured	0.023
16	Monitoring material shelf life	0.019
17	Supplier audit plan followed	0.018
18	Avoiding unauthorized modification of process parameters	0.015
19	In-house calibration facility	0.013
20	MRM conducted and quality performance reviewed	0.012
21	Packaging standards maintained and varied as per requirements (during rainy season extra covering of plastic)	0.012
22	Supplier rating conducted	0.011
23	Availability of updated skilled matrix	0.011
24	Display of limit samples	0.008
25	Easy traceability/identification of material	0.007
Total		1

FIFO: First in first out, MRM: Management review meeting, PPAP: Production part approval process, TQM: Total quality management, RCA: Root cause analysis

Measure supplier performance

Here an example is taken to show how the prioritized criteria can help to evaluate a supplier and also compare the supplier performance. So, to illustrate this, two suppliers A and B were evaluated using the software Expert Choice. For this, A and B were inserted in the "Alternatives" column in Expert Choice by clicking on the +A icon on the right side of the screen and then both are compared for each of the 25 sub sub criteria.

Results

The result obtained: Supplier A better than Supplier B as shown in the Figure 2. Figures 3a and 3b show the comparison of priority weights for each of the sub sub criteria which is obtained under the "Details" tab in Expert Choice. Also, it can be seen that though Supplier B conducts more training programs than Supplier A approaches like 6 sigma and TQM are not practiced or implemented effectively at Supplier B as compared to Supplier A. It can either be said that the training programs of B are not effective or it has to revamp its training programs. Also, Supplier B needs to improve its IQC, PQC and OQC.

Conclusion

A study was carried out for the duration of 5½ months. During this duration, the criteria, sub criteria, and sub sub criteria were

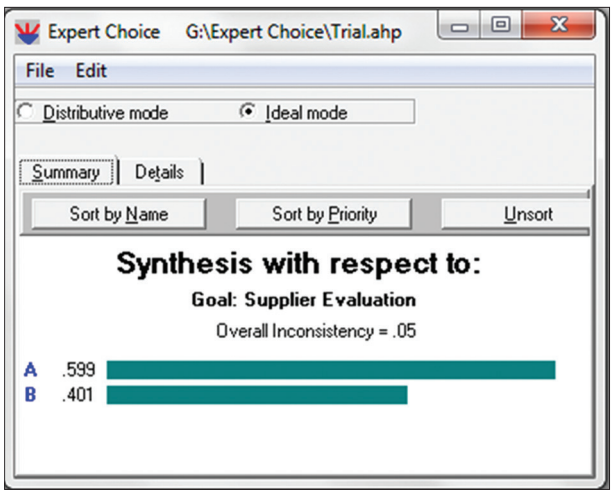

Figure 2: Supplier A versus Supplier B

Level 1	Level 2	Level 3	Alts	Prty
System Quali...	System (L: .609)	COmpany ISO certified (L: .562)	A	.107
			B	.107
		6 Sigma Approach (L: .164)	A	.031
			B	.008
		TQM Approach & Applications o...	A	.029
			B	.010
		Preventive Maintenance Plan fo...	A	.015
			B	.005
		MRM conducted and Quality Pe...	A	.008
			B	.002
	Supplier Quality (...	Evaluation of Suppliers before a...	A	.040
			B	.020
		Supplier Audit Plan followed (L:	A	.012
			B	.006
		Conduct Supplier Rating (L: .117)	A	.007
			B	.002
	Training And Aud...	Training Programme conducted ...	A	.009
			B	.018
		Internal Audit conducted by cert...	A	.016
			B	.008
		Availability and Updating Skill M...	A	.007
			B	.007
	Documentation (...	Easy Avail of latest drawings, ctr...	A	.022
			B	.022

Figure 3a: Details tab for system quality

Level 1	Level 2	Level 3	Alts	Prty
Processes Q...	IQC (L: .627)	Easy traceability/Identification o...	A	.036
			B	.007
		FIFO Ensured (L: .145)	A	.026
			B	.009
		Monitoring Material Shelf Life (L:...	A	.012
			B	.004
	PQC (L: .280)	Process Validationof Machines (...	A	.012
			B	.037
		Critical Processes operated by S...	A	.027
			B	.027
		Avoiding Unauthorized Modifica...	A	.010
			B	.005
		Display of Limit Samples (L: .068)	A	.005
			B	.005
	OQC (L: .094)	FIFO Ensured (L: .540)	A	.014
			B	.005
		Packaging Standards maintaine...	A	.008
			B	.008
		Easy Traceability/Identification ...	A	.004
			B	.002
Gauge Calibr...	Calibration (L: 1.0...	In-house Calibration Facility (L:	A	.034
			B	.017
		Conducting Calibration & Avail o...	A	.004
			B	.009

Figure 3b: Details tab for process quality and guage calibration

identified and prioritized using AHP approach. This enabled the supplier evaluation to be established as a system and avoid inconsistency, while evaluating all the suppliers. It can also be used to compare the supplier performance. It also shows the area in which improvement is required. Finally, an example was taken to demonstrate this wherein one supplier was found to have better supplier performance than the other. This can also be useful in a situation where the higher management has decided to increase the production. The additional demand for a component can be satisfied by awarding the additional demand to a supplier evaluated who is better than the others in case there is more than one supplier supplying the same components. In future, a study with other companies in the washing machine industry would refine the criteria, sub criteria, and sub sub criteria.

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