Vendor Consolidation for a Small Appliance Company

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***Abstract*—**Vendor consolidation is becoming an important management focus in recent years due to the need to sharpen cost performance to increase competition in the fast changing business environment. Vendor consolidation can assist company to streamline its operation, concentrate buying power and reduce purchase price and transaction cost. This paper proposed an intelligent vendor consolidation support system (VCSS) by integrating Analytical Hierarchical Process (AHP), Genetic Algorithms (GA) and Artificial Neural Network (ANN) to rank vendors according to the predefined elimination criteria and the performance of individual vendors in each area of the criteria. With this ranking of vendors, the vendors with inferior performance will be isolated and eliminated to achieve the target number of vendors.

Keywords*—*Vendor consolidation, Supplier base reduction, AHP, GA, ANN, Mathematical modelling

I. Introduction

With the slowdown in world economic growth and the heighten in possibility of economic stagnation or economic depression, the Asia manufacturing industry face a hard time in the coming years. According to Hong Kong Trade Development Council, the domestic export had been increased by 3% in the Jan-July of 2015, while the total exports of household electrical appliances decreased drastically by 12% in the first half of 2015[1].

With the increase in competition and decrease in profit margin, the small appliance industry has to improve its performance and strengthen its competence in order to survive and stay in the industry. One alternative is to reduce operating cost. It is costly to maintain a massive number of vendors of which majority of them are in-active and some are of inferior performance. It is thus necessary to consolidate the existing vendors to locate and highlight the inferior vendors so that they will be isolated and eliminated and orders will only be allocated to the qualified out-perform vendors to obtain quantity discount while on the other hand meets the quality, reliability and safety requirements. It also enables the company to formulate its strategy in alliance with the out-perform vendors.

The existing method to consolidate vendors is heavily relying on human judgement. Weighting is assigned to each performance factors for each vendor. The total weightings are summed up to obtain a total score for each vendor. The vendors with lowest score in the ranking hierarchy are them identified and isolated. This method induces risks in the consolidation process due to the subjective human judgement and interpretation.

To increase accuracy of the vendor consolidation process and to quantify the result to provide information to assist senior management of the small appliance industry to make final judgement on the isolation and elimination list of vendor, it is proposed to develop and formulate an intelligent vendor consolidation support system (VCSS) to be incorporated into the decision support system of the company to facilitate management decision in vendor consolidation.

This paper is divided into 6 sections. Section 2 contains a literature study that includes a review of vendor base reduction and application of AHP, GA and ANN in ranking of vendors. This is followed by the approach of study and framework of methodology for the proposed VCSS in section 3. Section 4 is a case study conducted on the proposed system. Section 5 presents the results and compares the feasibility of the proposed method with the existing manual method. Section 6 presents the conclusion of this paper and future research direction.

II. Literature Review

Vendor consolidation is a continuous process that involves reducing the supplier base so as to achieve economies of scale to lower prices and freight charges, improving quality and strengthening supply agreements. According to Sarkar and Mohapatra [2], the concept of supplier base reduction refers to the downsizing of the number of existing suppliers within the supplier base. Sollish & Semanik [3] stated that company needs to identify criteria to determine which vendors should be targeted for elimination. Sarkar and Mohapatra [2] pointed out performance, as an important criterion when selecting suppliers for elimination and Ogden & Carter [4] mentioned that a systematic elimination of inferior vendors can be based on poor cost performance, quality, delivery performance etc. After the elimination criteria had been determined, it will be necessary to rank the vendor based on the elimination criteria. There are qualitative and quantitative means to evaluate and rank the vendor based on the elimination criteria. This paper will focus on the adaptation of Analytical Hierarchical Process (AHP), Genetic Algorithms (GA) and Artificial Neural Network (ANN) to rank the vendors based on the elimination criteria.

AHP is a popular and elementary multi-criteria decision making method. This method helps choose the best from numerous alternatives which are assessed regarding a few criteria. Nydick and Hill [5], Barbarosoglu and Yazgac [6] propose the use of AHP to deal with imprecision in supplier ranking. AHP rank the vendor based on the relative importance of one criterion versus another criterion and also the relative preference for one supplier versus the other on a criterion.

The GA is a global search procedure that searches from one population of solutions to another, focusing on the area of the best solution so far, while continuously sampling the total parameter space. GA is a search and optimization algorithm that derive their computational mechanisms from natural selection and natural adaption. GA is widely used because it can solve multi-dimensional, non-differential, non-continuous, and even non-parametrical problems. Arsovski et al. [11] used GA to solve supplier selection problem. Rungreunganaun and Woarawhichai [12] applied GA for inventory lot sizing problem with suppler selection.

ANN had been developed by Larson G.B. [7] and Quin L. [8]. ANN based algorithms are claimed to be helpful for practical industrial applications especially for dynamic situations. The network is defined by the neurons and their connections and weights. All neurons are organized into layers and the layers define the order in which the activations are computed. Supplier selection using ANN alone is represented in Jinlong et al. [9]. An analysis on various activation functions of ANN was represented by Jones et al. [10]. Sigmoid activation function was found to give minimum error for the number of epochs.

A hybrid method using AHP and ANN for supplier selection was provided by Ariffin et al. [13], Kumar and Roy [14] and Lakshmanpriya et al. [15], where AHP is used to determine the weights of criteria, and the ANN to select the supplier. Other approach on applications of GA to ANN involves optimization of the NN using GA for the weights computation. To summarize, the review of the above literature shows that it is essential to have an intelligent system integrating AHP, GA and ANN for achieving an accurate result for vendor consolidation by incorporating the strengths of each method.

III. Approach of the Study

In the proposed intelligent vendor consolidation support system (VCSS), the evaluation criteria for vendor isolation and elimination will first be established. AHP will be adopted for pairwise comparison to calculate the weight of each elimination criterion identified for vendor consolidation, and consistency test will be conducted with AHP. The integrate weights from AHP will be fed to GA for fitness evaluation and to optimize the weights. The optimum weights from GA will be input to ANN together with the weights of criteria and weights of supplier generated from AHP. ANN will then be utilized to generate the final output i.e. the final score of the vendor for location and isolation of inferior performance vendor. Finally, the output from the intelligent VCSS will be evaluated to see if it fits the company's requirements and environment. This can be done by comparing the output result on vendor scoring with the company's manual system on vendor ranking. The similarities and differences will then be cross-referenced and benchmarked with the managers' final decision.

The proposed framework of methodology for the intelligent vendor consolidation support system (VCSS) is depicted in Fig. 1.

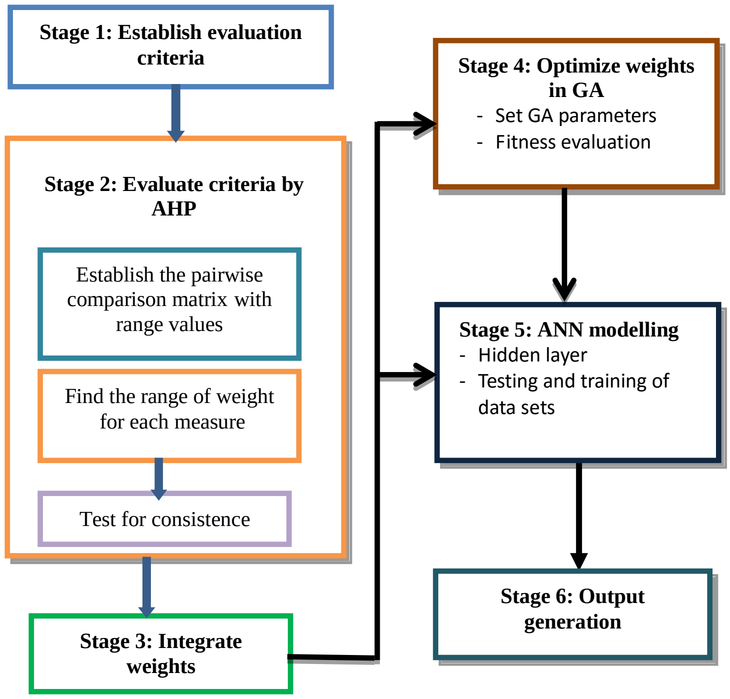

Fig. 1. Framework of methodology for VCSS

IV. Case Study

This section covers (i) company background, (ii) ranking of vendors for elimination of inferior performance vendors.

A. *Company background*

XYZ is a Hong Kong based family own small appliance company. It has 4 factories in South China employing around 20,000 workers. Like typical manufacturing companies in South China, it is highly vertical integrated to produce finished products with manufacturing capabilities of plastic injection molding, electronic assembly of PCBA, die-casting, metal stamping, painting and final assembly. The supplier base includes raw materials of metal, plastic resins, electronic components, packaging items, chemicals and electro-mechanical items.

B. *Existing vendor performance*

Table 1 depicts the vendor performance data from the small appliance company on the supply of electronic components from 5 current vendors.

TABLE 1 VENDOR PERFORMANCE

Vendor code	Quality (% defect)	Cost (% increase)	Service (response time)	Technical Capability	Delivery (days)
	max 0.009%	max 5%	max 24 hrs	max 9	max 8 days
1	0.005	2.0	5	7	3
2	0.002	1.5	13	7	5
3	0.004	3.5	20	6	5
4	0.008	3.5	5	3	2
5	0.001	4.5	8	4	8

Quality is in terms of percentage defect and the maximum limit is 0.009%. Cost is the percentage increase compared with the past purchase, the smaller the better and it is preferred to have cost reduction, i.e. negative cost increase. Service is in terms of response time from supplier and the preferred response time is within 24 hours. Technical capability is a valuable asset and supplier with higher technical competence is more preferable. Delivery is in terms of days and minimum deviation from the required delivery date of the goods is preferred.

C. *AHP Pairwise Comparison*

Table 2 shows the relative importance of each of the elimination criteria, i.e. quality, cost, service, technical capacity and delivery for the small appliance company.

TABLE 2 RELATIVE IMPORTANCE OF PERFORMANCE CRITERIA

Cost	Delivery	Quality	Service	Technical capability	**Total Score**
25%	15%	40%	20%	20%	**120%**

Based on this, a pairwise comparison of elimination criteria based on the AHP method is conducted and results are shown in Table 3.

TABLE 3 PAIRWISE COMPARISONS OF CRITERIA

	Quality	Cost	Service	Technical	Delivery
Quality	1	4	5	5	9
Cost	1/4	1	3	3	5
Service	1/5	1/3	1	1	3
Technical	1/5	1/3	1	1	3
Delivery	1/9	1/5	1	1/3	1
Total	1 137/180	5 13/15	11	10 1/3	21

Random consistency index (RI) = 1.12. By using MATLAB to calculate the Consistency ratio (CR) Consistency ratio (CR) is found to be 0.0979 which is smaller than 0.1 and is determined as acceptable result. Subsequently, the weights of criteria can then be determined by the AHP method and the results depicted in Table 4.

TABLE 4 WEIGHTS OF CRITERIA

	Quality	Cost	Service	Technical	Delivery	Average
Quality	0.5678	0.6818	0.4545	0.4839	0.4286	0.5233
Cost	0.1420	0.1705	0.2727	0.2903	0.2381	0.2227
Service	0.1136	0.0568	0.0909	0.0968	0.1429	0.1002
Technical	0.1136	0.0568	0.0909	0.0968	0.1429	0.1002
Delivery	0.0631	0.0341	0.0909	0.0323	0.0476	0.0536

The average weights are input weights U1 (Quality), U2 (Cost), U3 (Service), U4 (Technical) and U5 (Delivery) for the input layer of the ANN. From Table 1, the following constraints are set for the elimination criteria:

- Maximum allowable percentage defect is 0.009%
- Maximum cost increase is within 5%
- Maximum service response time is 24 hrs.
- Maximum deviation from delivery date is 8 days

Table 5 shows the scale of quality, cost, service, technical and delivery according to these constraints based on measure scale by Saaty [16].

TABLE 5 SCALES FOR THE CONSTRAINTS

Scale	Quality (% defect)	Cost (% increase)	Service response time (hr)	Technical	Delivery (day)
1	0-0.001	0.00-0.55	0.00-2.50	1	0
2	0.0011-0.0020	0.56-1.10	2.51-5.00	2	1
3	0.0021-0.0030	1.11-1.65	7.51-10.00	3	2
4	0.0031-0.0040	1.66-2.20	10.01-12.50	4	3
5	0.0041-0.0050	2.21-2.75	12.51-15.00	5	4
6	0.0051-0.0060	2.76-3.30	15.01-17.50	6	5
7	0.0061-0.0070	3.31-3.85	17.51-20.00	7	6
8	0.0071-0.0080	3.86-4.40	20.01-22.50	8	7
9	0.0081-0.0090	4.41-5.00	22.51-24.00	9	8

Weights (Wi) of the output layer are obtained from the relative comparison of suppliers for each criterion, based on vendor performance in Table 1 and rating scale in Table 5. By repeating the steps for Table 3 and Table 4 using AHP and Consistency Ratio calculation by MATLAB, the results are depicted in Table 6 – 10.

TABLE 6 RELATIVE MATRIX OF VENDORS WITH RESPECT TO QUALITY (CONSISTENCY RATIO = 0.0294)

	v1	v2	v3	v4	v5
v1	1	1/3	1	5	1/3
v2	3	1	2	7	1
v3	1	1/2	1	6	1
v4	1/5	1/7	1/6	1	1/8
v5	3	1	1	8	1
Tot	8 1/5	2 41/42	5 1/6	27	3 11/24

	v1	v2	v3	v4	v5	Average
v1	0.1220	0.1120	0.1935	0.1852	0.0964	0.1418
v2	0.3659	0.3360	0.3871	0.2593	0.2892	0.3275
v3	0.1220	0.1680	0.1935	0.2222	0.2892	0.1990
v4	0.0244	0.0480	0.0323	0.0370	0.0361	0.0356
v5	0.3659	0.3360	0.1935	0.2963	0.2892	0.2962

TABLE 7 RELATIVE MATRIX OF VENDORS WITH RESPECT TO COST (CONSISTENCY RATIO = 0.0287)

	v1	v2	v3	v4	v5
v1	1	1/2	3	3	9
v2	2	1	4	4	10
v3	1/3	1/4	1	1	6
v4	1/3	1/4	1	1	6
v5	1/9	1/10	1/6	1/6	1
Tot	3 7/9	2 1/10	9 1/6	9 1/6	32

	v1	v2	v3	v4	v5	Average
v1	0.2647	0.2381	0.3273	0.3273	0.2813	0.2877
v2	0.5294	0.4762	0.4364	0.4364	0.3125	0.4382
v3	0.0882	0.1190	0.1091	0.1091	0.1875	0.1226
v4	0.0882	0.1190	0.1091	0.1091	0.1875	0.1226
v5	0.0294	0.0476	0.0182	0.0182	0.0313	0.0289

TABLE 8 RELATIVE MATRIX OF VENDORS WITH RESPECT TO SERVICE (CONSISTENCY RATIO = 0.0293)

	v1	v2	v3	v4	v5
v1	1	4	8	1	2
v2	1/4	1	5	1/4	1/3
v3	1/8	1/5	1	1/8	1/7
v4	1	4	8	1	2
v5	1/2	3	7	1/2	1
Tot	2 7/8	12 1/5	29	2 7/8	5 10/21

	v1	v2	v3	v4	v5	Average
v1	0.3478	0.3279	0.2759	0.3478	0.3652	0.3329
v2	0.0870	0.0820	0.1724	0.0870	0.0609	0.0978
v3	0.0435	0.0164	0.0345	0.0435	0.0261	0.0328
v4	0.3478	0.3279	0.2759	0.3478	0.3652	0.3329
v5	0.1739	0.2459	0.2414	0.1739	0.1826	0.2035

TABLE 9 RELATIVE MATRIX OF VENDORS WITH RESPECT TO TECHNICAL (CONSISTENCY RATIO = 0.0627)

	v1	v2	v3	v4	v5
v1	1	1	2	4	3
v2	1	1	2	4	3
v3	1/2	1/2	1	3	2
v4	1/4	1/4	1/3	1	1/2
v5	1/3	1/3	1/2	2	1
Tot	3 1/12	3 1/12	5 5/6	14	9 1/2

	v1	v2	v3	v4	v5	Average
v1	0.3243	0.3243	0.3429	0.2857	0.3158	0.3186
v2	0.3243	0.3243	0.3429	0.2857	0.3158	0.3186
v3	0.1622	0.1622	0.1714	0.2143	0.2105	0.1841
v4	0.0811	0.0811	0.0571	0.0714	0.0526	0.0687
v5	0.1081	0.1081	0.0857	0.1429	0.1053	0.1100

TABLE 10 RELATIVE MATRIX OF VENDORS WITH RESPECT TO DELIVERY (CONSISTENCY RATIO = 0.0125)

	v1	v2	v3	v4	v5
v1	1	3	3	1/2	7
v2	1/3	1	1	1/4	4
v3	1/3	1	1	1/4	4
v4	2	4	4	1	8
v5	1/7	1/4	1/4	1/8	1
Tot	3 17/21	9 1/4	9 1/4	2 1/8	24

	v1	v2	v3	v4	v5	Average
v1	0.2625	0.3243	0.3243	0.2353	0.2917	0.2876
v2	0.0875	0.1081	0.1081	0.1176	0.1667	0.1176
v3	0.0875	0.1081	0.1081	0.1176	0.1667	0.1176
v4	0.5250	0.4324	0.4324	0.4706	0.3333	0.4388
v5	0.0375	0.0270	0.0270	0.0588	0.0417	0.0384

All the average values obtained from the above calculations are summarized in the final weight matrix table as shown in Table 11.

TABLE 11 WEIGHT MATRIX OF SUPPLIERS WITH RESPECT TO ALL CRITERIA

	Quality	Cost	Service	Technical	Delivery
v1	0.1418	0.2877	0.3329	0.3186	0.2876
v2	0.3275	0.4382	0.0978	0.3186	0.1176
v3	0.1990	0.1226	0.0328	0.1841	0.1176
v4	0.0356	0.1226	0.3329	0.0687	0.4388
v5	0.2962	0.0289	0.2035	0.1100	0.0384

D. Optimization of elimination criteria by GA

The company target to minimize % defect, cost, service response time, delivery and maximize technical competence, the vendors with inferior performance in these areas areisolated. This will be the base for formulation of the lower bound and upper bound for the linear objective function of the form $\Sigma WiXi$ for each criterion to be input to MATLAB GA Toolbox. The equations are as follows:

a. Function of quality

Minimize $F(Q) = \Sigma WiQi = 0.1418Q1+0.3275Q2+0.1990Q3 + 0.0356Q4 + 0.2962Q5$,
$0 \le Q1, Q2, Q3, Q4, Q5 \le 0.009$

b. Function of cost

Minimize $F(C) = \Sigma WiCi = 0.2877C1+0.4382C2+0.1226CQ3 + 0.1226C4 + 0.0289C5$,
$C1, C2, C3, C4, C5 \le 5$

c. Function of Service

Minimize $F(S) = \Sigma WiSi = 0.3229S1+0.0978S2+0.0328S3 + 0.3329S4 + 0.2035S5$

$0 < S1, S2, S3, S4, S5 \le 24$

d. Function of Technical

Maximize $F(T) = \Sigma WiTi = 0.3186T1+0.3186T2+0.1841T3 + 0.0687T4 + 0.1100T5$,
$1 \le T1, T2, T3, T4, T5 \le 9$

e. Function of Delivery

Minimize $F(D) = \Sigma WiDi = 0.2876D1+0.1176D2+0.1176D3 + 0.4388D4 + 0.0384D5$
$0 \le D1, D2, D3, D4, D5 \le 8$

The above equations are optimized using GA Toolbox in MATLAB software, using the following parameter settings:

- Population size = 25
- Population type = Double vector
- Scaling function = rank
- Selection = roulette wheel
- Crossover fraction = 0.8
- Crossover function = scattered
- Mutation = adaptive feasible
- Hybrid function = none
- Stopping criteria = 50

The GA function in MATLAB assumes the fitness function will take one input X where X has as many elements as number of variables in the problem. The fitness function computes the value of the function and returns that scalar value in its one return argument F(X).

Table 12 shows the optimum function value of each of the criteria obtained from GA Toolbox in MATLAB and these optimum function values are used as an input to the input layer of the ANN decision making model

TABLE 12 OPTIMUM VALUES OF CRITERIA

Criteria	Optimum Value
Function of Quality	-9.97
Function of Cost	-12.11
Function of Service	-5.8935
Function of Technical	9.8
Function of Delivery	-12.05

E. Determination of Final Score by ANN

Assumptions

a. Single layer feed forward neural network

b. SIGMODIAL function

c. $Yci = 1/(1+e^{-\alpha I})$, $I = (\Sigma XiWci + Bias)$, Wci = weigh of criteria, Xi = input value for input layer, Yci = output value for hidden layer

d. $Yvi = 1/(1+e^{-\alpha P})$, $P = (\Sigma YciWvi + Bias)$, Wvi = weigh of criteria for vendor, Yvi = Total score of vendor

e. α= slope parameter =1

f. Bias = 0.3

1) Input Layer Calculation

Let the optimum value in Table 12 be the input Xi and use the average of weights in Table 4 to be the weigh Wi, the output of the input layer can be derived, as shown in Table 13. For example, ΣXiWci + Bias = -9.97x0.5233 + (-9.97x0.22271) + (-9.97x0.10018) + (-9.97x0.10018) + (-9.97x0.05359) + 0.3 = -9.67.

TABLE 13 INPUT LAYER CALCULATION

input X i	weight W i	bias	sum X iW ci + bias	Y ci
-9.97	0.52333	0.3	-9.67	6.31459E-05
-12.11	0.22271	0.3	-11.81	7.42983E-06
-5.8935	0.10018	0.3	-5.5935	0.003708176
9.8	0.10018	0.3	10.1	0.999958922
-12.05	0.05359	0.3	-11.75	7.88926E-06

2) Output Layer Calculation

Using the same formula, let Yi from Table 13 to be the input to the output of final score, and use values from Table 11 as the weighs, the output layer for the final score is calculated, as shown in Table 14. For example, ΣYciWvi + Bias = 6.31459E-05 x 0.141814067 + 7.42983E-06 x 0.287719315 + 0.003708 x 0.3329201 + 0.99995892 x 0.31860191 + 7.889E-06 x 0.287621887 + 0.3 = 0.650181

TABLE 14 OUTPUT LAYER CALCULATIONS FOR THE FINAL SCORE

input to output layer	6.31459E-05	7.4E-06	0.00370818	0.99995892	7.889E-06	sum Y ciW vi + bias	Score Y vi	Rank
v1	0.141814067	0.28772	0.332920097	0.31860191	0.287621887	0.619836711	0.6501814	1
v2	0.327473264	0.43817	0.097832723	0.31860191	0.117605988	0.618976466	0.6499857	2
v3	0.198975691	0.12259	0.032783936	0.184112985	0.117605988	0.484241394	0.6187489	3
v4	0.035565985	0.12259	0.332920097	0.068673034	0.438757287	0.369911358	0.5914376	5
v5	0.296170994	0.02893	0.203543146	0.110010161	0.03840885	0.410779635	0.6012748	4

Based on the final score, vendor 4 and vendor 5 should be isolated and eliminated.

V. RESULTS AND DISCUSSION

Based on the past record on manual weighing assignment and judgement system currently utilized by the company, Table 15 depicted the current ranking of the suppliers adopted by the company.

TABLE 15 RESULT OF MANUAL RANKING SYSTEM

Vendor code	Cost	Delivery	Quality	Service	Technical Capability	Total Score 120%	Supplier Selection Priority
	25%	15%	40%	20%	20%		
1	19	12	35	19	14.9	100	1
2	20	10	38	16	14.8	99	2
3	16	10	36	12	14.1	88	4
4	16	13	29	19	12.6	90	3
5	10	8	39	18	13.3	88	4

Compared result of Table 14 with Table 15, it can be seem that for the manual system, vendor 3 and 5 should be isolated while for the mathematical model revealed that vendor 4 and 5 should be isolated and eliminated. The supplier ranking based on AHP alone can be calculated and is shown in Table 16.

TABLE 16 RESULT OF AHP RANKING

	Quality	Cost	Service	Technical	Delivery	Total	Rank
v1	0.1418	0.2877	0.3329	0.3186	0.2876	1.3687	1
v2	0.3275	0.4382	0.0978	0.3186	0.1176	1.2997	2
v3	0.1990	0.1226	0.0328	0.1841	0.1176	0.6561	5
v4	0.0356	0.1226	0.3329	0.0687	0.4388	0.9985	3
v5	0.2962	0.0289	0.2035	0.1100	0.0384	0.6771	4

Subsequently, the comparison of manual ranking, AHP ranking and intelligent model ranking is shown in Table 17.

TABLE 17 RESULTS OF DIFFERENT METHODS

	Manual System	AHP	AHP+GA+ANN
v1	1	1	1
v2	2	2	2
v3	4	5	3
v4	3	3	5
v5	4	4	4

The reason for the deviation is due to the fact that vendor 4 scores very high marks on delivery and service which contributes to the higher total marks for vendor 4 compared to vendor 3 and 5, even though vendor 4 scores the lowest mark on quality (as shown in Table 18). Since quality is a very important aspect and carries highest weights, taken this into account, it should affect the final weight of vendor 4 and thus vendor 4 should have a lower ranking when compared to vendor 3 and 5. Hence the result of AHP+GA+ANN can reflect this hidden aspect which the manual system and AHP alone cannot take this into account.

TABLE 18 PERFORMANCE OF VENDORS

Vendor Code	Cost	Delivery	Quality	Service	Technical capability
	25%	15%	40%	20%	20%
1	19	12	35	19	14.9
2	20	10	38	16	14.8
3	16	10	36	12	14.1
4	16	13	29	19	12.6
5	10	8	39	18	13.3

VI. CONCLUSION

The model derived provide result better than the result obtained from the existing manual system of the company and thus can be incorporated in the decision support system of the company to provide valuable information to the senior management for timely and efficiently decision making on vendor consolidation. With the proposed VCSS, manual efforts and judgements involved in calculation and identification of the inferior vendor for isolation and elimination will inevitable be minimize and more accurate results can be obtained. Intensify training of model will further fine tune the result. Further analysis should be conducted on single model such as run on GA alone and ANN alone to exam if same result will be achieved using different model and algorithm and also to determine which method is the best. Sensitivity analysis should also be conducted to see how a minor change in each of the criteria will affect the overall result. With this, it will be able to push the suppliers to improve their performance in order to be more competitive than its competitors. The criteria for vendor elimination should also be further breakdown to include more details for comparison. For example, the measure of defect on quality aspect can be further breakdown into incoming quality defect, in-line defect, and after sales defect reported by after sales service. Different weighing can be assigned to defect percentage in each stage which have different impact and consequences to the operation, the image and the profit of the company.

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