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TOPSIS-AHP Based Approach for Selection of Reverse Logistics Service Provider: A Case Study of Mobile Phone Industry

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Abstract

Reverse supply chain logistics, means mobility of goods from end consumers towards core manufacturer in the channel of product distribution. In the turbulent business environment, the companies must promote alternative uses of resources that may be cost-effective and ecology friendly by extending products' routine life cycles. Reveres logistics activities i.e. storing, transporting and handling of used products poses a great challenge to reverse logistics managers as there is always chances of uncertainty in terms of quantity, quality and timing of return of EOL products in case of reverse supply chains. Business organizations including those of white/electronics goods manufacturing industries would like to focus on their core competency areas and there is need of making outsourcing decisions of their reverse logistics process to Third-Party reverse Logistics Providers (3PRLPs). Thus, most important strategic issue for top management is the evaluation and selection of third party logistics service provider who can effectively provide reverse logistics operation services to the firms. The objective of this work is to develop decision support system to assist the top management of the company in selection and evaluation of different 3PRL service providers by hybrid approach using Analytical Hierarchy Process (AHP) and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) method. A real life case study of a mobile phone manufacturing company is presented to demonstrate the steps of the decision support system. Present study also enables the logistics managers to better understand the complex relationships of the key attributes in the decision making environment and subsequently improve the reliability of the decision making process.

Keywords: Technique for order preference by similarity to ideal solution; Mobile industry; Analytical hierarchical process; reverse logistics operation.

1. Introduction

Supply chain management systems have seen a dynamic change in operational style since last two decades. In earlier business practices, supply chain flow happens in the forward direction only. In current business environment industries are facing the problem of return flow of the products in the supply chain for a variety of reasons like product recalls, warranty failure, service failure, commercial returns, manufacturing returns, end-of-life (EOL) and end-of-use returns. Reverse logistics is the process of return product handling mechanism in forward supply chain. The industries may have earned more benefits during the process of reuse recycle and remanufacturing of the used products. In general, the producer collects their used products from consumers and then again sells to new customers as new ones after reprocessing or remanufacturing process. Closed loop supply chain mainly focuses on how to take back the used products and recover the useful components efficiently and economically in eco-friendly manners. It is beneficial to save environment, natural resource, increase financial benefits, enhance enterprises competition, for the industries to implement reverse logistics activities in their supply chain. However, reverse logistics activities collection, inspection/testing, transporting and handling of used products/components poses a great challenge to reverse logistics supervisors as there is very high level uncertainty involves in terms of quantity, quality and timing of return of end-of life products in case of close loop supply chains. Diversion of electronics and white goods products from landfills is important issue, because they contain substances various hazardous elements like cadmium, lead, and mercury which may have ill effects on human health if dispose off in appropriately manner. Day by day increasing volume and rapid rates of obsolescence of these used products only serves to enhance the problem. PCs alone contribute 300 million pounds of lead to the waste stream each year (V. Ravi, 2012).

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The productive utilization of 3PLS providers for reverse logistics activities may lead to enhancement of profit margin and effective integrated supply chain network for organizations. An efficient collection & processing used products is important for maintaining sustainability. Therefore, a very important strategic issue for company management is the evaluation and selection of 3PL logistics service providers who can efficiently provide reverse logistics services to organization. In this paper, a hybrid approach (a combination of TOPSIS and AHP) has been used for making strategic decision in multi-attribute decision environment for selection of 3PL service providers for collection of end-of-life (EOL) mobile phones. This paper organized as follows. In Section 2, AHP-TOPSIS approach for decision making is presented. Subsequently, section 3 presents a case study of mobile industry. In the section 4, proposed decision support system steps are explained. The section 5 evaluates 3PL service providers. In the section 6, managerial implications of the model discussed. Finally, section 7 discusses conclusion & future research directions.

2. TOPSIS-AHP Method

The foundation of the Analytic Hierarchy Process (AHP) is a set of axioms that carefully delimits the scope of the problem environment (Saaty, 1988). It is based on the well- defined mathematical structure of consistent matrices and their associated eigenvector's ability to generate true or approximate weights (V. Ravi, 2012). The analytic hierarchy process compares criteria, or alternatives with respect to a criterion, in a natural, pair wise mode. The analytic hierarchy process uses a fundamental scale of absolute numbers that has been proven in practice and validated by physical and decision problem experiments. The fundamental scale has been shown to be a scale that captures individual preferences with respect to qualitative and quantitative attributes just as well or better than other scales (Saaty1980, 1994). It converts individual preferences into ratio scale weights that can be combined into a linear additive weight for each alternative. The resultant can be used to compare and rank the alternatives and, hence, assist the decision maker in sound decision making. (Saaty1980, 1994). In year 1981 Yoon and Hwang developed TOPSIS method that simultaneously considers the distance to the ideal solution and negative-ideal solution regarding each alternative and selecting the closest relative to the ideal solution as the best alternative. One of the unique features of AHP is that it provides a powerful procedure to determine the relative importance of different attributes with respect to the objective. A hybrid MADM approach using TOPSIS and AHP has been used in this research for selection of 3PL service providers for collection of used mobile/end-of-life cell phones. The MCDM approach based on AHP-TOPSIS is explained in the following steps:

Step 1: TOPSIS method begins with decision matrix having 'n' criteria/attributes and 'm' alternatives and decision matrix can be represented as:

$$D = \begin{pmatrix} X_{11} & X_{12} & X_{13} & \dots & \dots & X_{1n} \\ X_{21} & X_{22} & X_{23} & \dots & \dots & X_{2n} \\ X_{31} & X_{32} & X_{33} & \dots & \dots & X_{3n} \\ \dots & \dots & \dots & \dots & \dots & \dots \\ \dots & \dots & \dots & \dots & \dots & \dots \\ X_{m1} & X_{m2} & X_{m3} & \dots & \dots & X_{mn} \end{pmatrix} \quad (1)$$

Where, x_{ij} is the performance of the i^{th} alternative with respect to j^{th} attribute.

Step 2: The normalized decision matrix is obtained, which is given herewith:

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}} \quad \text{Where } j = 1, 2, 3 \dots\dots\dots m \quad (2)$$

Step 3: In this step, relative importance of different attributes with respect to the overall objective is determined, and weights for attributes are given according to their importance. A nine-point preference scale of Saaty (1980) has been used for construction of pair-wise comparison matrices. One of the salient properties of this scale is reflexive property between the relatedness of two criteria being compared. For example, if a criterion 'B' is 7 times more important compared to another criterion 'C', then 'C' will be 1/7 times as important as 'B'.

Let P represent an n X n pair-wise comparison matrix,

$$P = \begin{pmatrix} 1 & p_{12} & \ldots & p_{1n} \\ p_{21} & 1 & \ldots & p_{2n} \\ \ldots & \ldots & \ldots & \ldots \\ p_{n1} & p_{n2} & \ldots & 1 \end{pmatrix} \tag{3}$$

In matrix P, diagonal elements are self-compared and those elements have equal importance. Thus, $p_{ij} = 1$, where $i = j$, and $i, j = 1, 2, \ldots n$.

The strength of relative importance of the i^{th} variable compared with the j^{th} attribute is the values on the left and right sides of the matrix diagonal. Thus, $p_{ij} = 1/p_{ij}$, where $P_{ij} > 0$, $i \neq j$ as p is a positive reciprocal square matrix.

For normalization the Geometric Mean method is used to determine the importance degree of the considered attributes. If W_i denotes the importance degree for the i^{th} attribute, then:

$$W_i = \frac{\prod_{j=1}^{n} (a_{ij})^{1/n}}{\sum_{i=1}^{n} \prod_{j=1}^{n} (a_{ij})^{1/n}} \tag{4}$$

Consistency check is then performed to ensure that the evaluation of the pair-wise comparison matrix is reasonable and acceptable.

Let us denote Q as an n-dimensional column vector, which describes the sum of the weighted values of the importance of degrees of attributes, then,

$$Q = [q_i]_{nx1} = PW^T \quad i = 1, 2, 3 \ \ldots \ \ldots \ N \tag{5}$$

Where,

$$PW^T = \begin{pmatrix} 1 & p_{12} & \ldots & p_{1n} & \\ p_{21} & 1 & \ldots & p_{2n} \\ \ldots & \ldots & \ldots & \ldots \\ P_{n1} & p_{n2} & \ldots & 1 \end{pmatrix} \begin{pmatrix} W1, & W2 \ldots\ldots, & Wn \end{pmatrix} C_n = \begin{pmatrix} C_1 \\ C_2 \\ \ldots \end{pmatrix} \tag{6}$$

Consistency values of attributes can be represented by vector:

$QV = [qv_i]_{1\times}n$ with a typical element qv_i defined as: $qv_i = (q_i/w_i)$, $i = 1, 2, \ldots\ldots, n$.

It should be ensured that inconsistency in pair-wise comparison matrix is avoided. Saaty (1980) has suggested use of maximum Eigen value (λ_{max}) to calculate the Effectiveness of the judgment for this purpose.

λ_{max} is calculated as:

$$\lambda_{max} = \left(\frac{\sum_{i=1}^{n} qVi}{n}\right), \quad i=1, 2, \ldots. n \tag{7}$$

Consistency Index (CI) is estimated as:

$$CI = \left(\frac{\lambda_{max} - n}{n-1}\right) \tag{8}$$

The closer the λ_{max} is to n, the more consistent is the evaluation. In most cases, Consistency Ratio (CR) is used as a guide for checking consistency of evaluation. CR is calculated as:

$$\text{Consistency Ratio (CR)} = \frac{CI}{RI} \tag{9}$$

Where random consistency index (RI) obtained from a large number of simulation runs and varies depending upon the order of the matrix (Saaty, 1980). Research has shown that if value of consistency ratio is below the threshold of 0.10, the evaluation of importance of degrees of attributes is considered to be reasonable.

Step 4: The weighted normalized matrix is constructed by multiplying each column of the Matrix r_{ij} by weight w_j, thus,

$$V_{ij} = w_j . r_{ij} \quad (10)$$

Step 5: In this step, ideal solutions (v+) and negative-ideal solutions (v–) are calculated It can be expressed as:

$$v^+ = \{v_1^*, v_2^*, v_3^*, \ldots\ldots v_n^*\} = \{(\max_i v_{ij} \mid j\varepsilon J),(\min_i v_{ij} \mid j\varepsilon J'), i = 1,2,3.......m\} \quad (11)$$

$$v^- = \{v_1^*, v_2^*, v_3^*, \ldots\ldots v_n^*\} = \{(\min_i v_{ij} \mid j\varepsilon J),(\max_i v_{ij} \mid j\varepsilon J'), i = 1,2,3.......m\} \quad (12)$$

Here J and J′ are associated with beneficial and non-beneficial attributes, respectively.

Step 6: The Euclidean separation distance between the ideal solution (S_i^+) and the Negative-ideal solution (S_i^-) for each alternative is calculated as:

$$S_i^+ = \sqrt{(v_{ij} - v_j^+)^2}\ , i = 1,2,3,\ldots\ldots m \quad (13)$$

$$S_i^- = \sqrt{(v_{ij} - v_j^-)^2}\ , i = 1,2,3,\ldots\ldots m \quad (14)$$

Step 7: The relative closeness to the ideal solution of each alternative is calculated as:

$$C_i = \frac{S_i^-}{S_i^- + S_i^+} \quad (15)$$

Step 8: A set of alternatives can be preference ranked in descending order of C_{i*}. In this, larger index values indicate better performance of the alternatives.

3. Problem Description

Profitable reuse and remanufacturing of cell phones must meet the challenges of turbulent business environment which may includes continuous change in design pattern, frequent price fluctuations of new cell phone models, disassembly of unfriendly designs, short life cycles, and prohibiting transport, labor and machining costs in high-wage countries. In current business environment, the remanufacturing of expensive, long-living investment machine/equipments, e.g., jet fans, machine tools, defense equipment or automobile engines, is extended to a large number of consumer goods with short life cycles and relatively low values. Reuse is an alternative to material recycling to comply with recovery rates and quantities as well as special treatment requirements (Franke, 2006). The company segment selected for this research is mobile phones manufacturing industry situated in the north India. The aim of present research is to evaluate logistics service providers for hiring their service to collect & supply the end-of-life (EOL) mobile phones to the company door step for reclaiming the useful components for remanufacturing of mobile phones. According to Greenpeace report, few mobile phones having toxic materials like polyvinyl Chloride plastic (PVC) bars, phthalates antimony tried, beryllium oxide and Brominates Frame Retardant (BFR).These toxic materials posses a great threat to environment and human health if not disposed off in a proper method. E-waste rule 2011 (Management and handling Rules) came into effect in May 2012 in India. It places responsibility on the producers for the entire life cycle of a product. Under electronic waste management rules producer/ original equipment manufacturer (OEM) will set up collection centers to dispose of e- waste, and fix the duty of manufacturers to collect electronic waste of their products. Till now, three years has been completed since the rules were notified by government, but most of the companies have failed to set up their collection centers. An old non working mobile may fetch up anything between Rs.200 to Rs.1000 depending on its condition. A laptop may get you a little more; but your old fridge or a television may not get you much primarily because of its high transportations cost to the electronic recycling unit. These new rules, however, may put any law–abiding citizen in a fix because the designated centers, where they are actually meant to dispose of the e–waste have not come up in most cities. The effective implementation of the rules looked very unlikely in light of the present circumstances. Mostly consumers even today, do not how to dispose off their e-waste (Toxics-link).

E- Waste is turning out to be one of the greatest threats to the environment. Around 1.46 lakh tones of e–waste were generated in India in 2005 and 2013, the quantity is expected to grow up to 8.5 lakh tones. More than 60% of India's e-wate is generated by 65 cities in India-the foremost being Delhi, Bangalore, Chennai, Kolkata, Ahmadabad, Hyderabad, Pane, Surat and Nagpur. In the internal supply chain of cell phones, the major components such as printed circuit board (PCB), Display Unit, SIM IC, Battery, Charging Jack, Speaker & MIC and plastic body are procured from different suppliers for new mobile phones production. Once the mobile phones are assembled in different production units it has to be shipped through distributors, wholesalers, retailers and end users. After end of life of the products, end users do not know how to e-waste is to be disposed. As there is no authentic mechanism is available in Indian business environment to collect e-waste from homes, it is mostly lands in municipal bins. Generally used mobile phones are collected at the retailers and should be quickly transported to centralized collection center, where returned mobile phones are inspected for quality failure, sorted for potential reuse, repair or recycling. After inspection, the useless phones/batteries (not able to recycle) are disposed off by eco-friendly manner and reusable components are transported to disassembly/recycling plants and recovered components are used in new phones assembly.

A series of interviews and discussion sessions were held with the mobile phone industry managers, retailers, state pollution control boards officials during this project and following problem areas are identified for improvement in reverse supply chain of the mobile phones.

- Uncertainty is always involved in the supply of used mobile phones to the OEM and industries are unable to forecast collection of EOL mobile phones quantity.
- Most of the e- waste generated in India is recycled but recycling operations has been conducted in hazardous manner by informal sector.
- Presence of illegal recycling operators in the recycling business and there is no government control in the state for unauthorized mobile collection & PVC recycling operation.
- The case company does not have any well-structured business model of reverse logistics practice.
- Huge cost involved in setting of mobile collection centers at prime locations under the directions of new management & handling rules, 2011, Government of India.

To solve aforesaid problems and business performance improvement mobile phones manufacturing industry is ready to assign the work of regular supply of end-of-life (EOL) phones to logistics service provider. The team of industry managers must have enough knowledge to define the aims and benefits from outsourcing of logistics service and may be able to convince about the goal and desired objectives of the company to the service provider. The top management must exactly understand the goals and objectives of the company want to achieve. An accurate estimation of business and service requirements of the company would minimize the need of assumptions on the part of the service provider and ensure a high service level. Service level desired from the logistics service providers must include both the present and the future service standards of the industry. The problem addressed here is to build a sound decision support methodology to evaluation & selection of best reverse logistics service provider. It will help to minimize the forward and reverse supply chain cost including procurement, production, distribution, inventory, collection, disposal, dis-assembly and recycling costs.

4. Decision Support System for the Selection of a Logistics Service Provider

The proposed decision support system require for the assessment of alternative logistics service providers in two steps: (i) Initial screening of the providers by a team of concerned managers from industry and (ii) AHP-TOPSIS based decision support system for the final evaluation of the service providers. Often, the initial screening of the service providers is an easy task but the final selection from the list of short-listed providers is a difficult task. In this section, we present a methodology for the initial screening of the providers. Later, these short-listed providers would be ranked by the AHP-TOPSIS based approach.

The steps of decision support methodology are enlisted as follows:

1. Constitution of a team of senior managers & consultants.
2. Decision regarding type of outsourcing service level required and collection target.
3. Preparation of the functional specifications of the proposed task.
4. Identification of potential reverse logistics service providers in the business environment.
5. Evaluation of proposal of the RL logistics service providers (RLLSP).
6. Submission of request for proposal offer submission from 3PL reverse logistics service providers
7. Evaluation of service proposal offer supplied by the logistics service providers.
8. Field visits and inspection of facilities of the logistics service providers by the team of industry senior managers.
9. Collection of feed backs from the exiting customers of the service providers
10. Final selection using AHP-TOPSIS approach and agreement of services offered by the service providers.

AHP-TOPSIS based decision modeling methodology, which is discussed in the next section of the paper, is recommended for the final selection of a RL service provider. For any long term business relationship a business contract between two parties must address scope of work, responsibilities, liabilities, rate adjustments, service compensations limitations, compensation, insurance, risks and rewards, remedies, extra services, damages types, individual status, termination, agreement modification, performance measurement issues, etc.

5. Evaluation of 3PLRL Service Provider Using AHP-TOPSIS Hybrid Approach

The TOPSIS-AHP based MCDM approach presented in this work and applied in evaluation & selection of 3PL for a mobile phone manufacturing industry. There are 20 outsourcing service providers were interested to conduct reverse logistics operation for the cell manufacturing industry. In the preliminary screening 11 service providers were rejected easily by the company management. The final selection from the remaining nine potential 3PRLPs (A, B, C, D, E, F, G, H and I) was very tough task because almost all the service providers fulfill the requirement of the company. Due to fund limitations and other operational constraints, the case company was keen interested to apply a scientific technique to evaluate all eligible 3PL service providers and determine the best 3PL service providers among the nine bidding submitted for the deal.

The company management identified 10 important parameters/attributes that were relevant to their business. These attributes are E-Waste Storage Capacity (EWSC), Availability of Skilled Personnel (AOSP), Level of Noise Pollution (LNP) and Impacts of Environmental Pollution (IEP), Safe Disposal Cost (SDC), Availability of a covered and closed Area (ACCA), Possibilities to work with NGOs (PWNGO), Inspection/sorting and disassembly cost (ISDC), Mobile phone Refurbishing cost (MPRC), Mobile recycling cost (MRC). Among these attributes, ISDC (thousands of Rupees), EWSC (in tones), MPRC (INR/hour), MRC (thousands of INR) and final disposal cost (thousands of INR) are quantitative in nature, having absolute numerical values. Attributes AOSP, LNP, ACCA, IEP and PWNGO have qualitative measures and for these a ranked value judgment on a scale of 1–5 (here 1 corresponds to lowest, 3 is moderate and 5 corresponds to highest) has been recommended. The cost of recycling of EOL or used mobiles phones ranges from INR.1000 to INR.1600 per unit and INR.1200 to INR.2000 per unit for safe disposal of hazardous waste from mobile. A single mobile refurbishing technician can test and troubleshoot a used mobile, make necessary repairs and upgrade and package it for reuse in 3 hours at a cost of on an average INR.1500 (Techsoup, 2008). These data was provided by various remanufacturing companies during this research project and has been used as the reference for the formulation of reverse logistics data for the case company dealt in this work. The data for all 3PL with respect to various attributes are provided in Table 1.

Table 1 Decision matrix representing the performance of various RLSP

3PRLSPs	EWSC	ISDC	MPRC	MRC	SDC	ACCA	PWNGO	AOSP	LNP	IEP
A	150	160	130	1200	1400	3	4	3	4	5
B	140	170	150	1300	1800	5	5	4	3	4
C	170	160	180	1350	1480	4	3	5	5	5
D	180	165	160	1500	1600	2	3	3	1	2
E	110	150	160	1500	1400	1	3	5	2	5
F	120	180	130	1400	1400	5	3	4	4	2
G	130	165	150	1300	1750	3	2	4	3	5
H	200	160	130	1550	1800	4	1	2	4	4
I	150	110	140	1200	1650	5	2	2	4	5

The implementation of the TOPSIS-AHP model and analysis are explained in the following eight steps:

Step 1: Based upon the information provided by concerned industry segment, the decision matrix has been prepared as shown in table 1, which illustrates the performance of service providers with respect to all 10 attributes:

Step 2: The normalization of decision matrix by using equation (2) as shown below in table 2:

Table 2 Normalized decision matrix

3PRL SPs	**EWSC**	**ISDC**	**MPRC**	**MRC**	**SDC**	**ACCA**	**PWNGO**	**AOSP**	**LNP**	**IEP**
A	0.3279	0.3357	0.2915	0.2915	0.2926	0.2631	0.0465	0.2694	0.3780	0.3892
B	0.3060	0.3567	0.3363	0.3159	0.3762	0.4385	0.0581	0.3592	0.2835	0.3114
C	0.3716	0.3357	0.4036	0.3280	0.3093	0.3508	0.03490	0.4490	0.4725	0.3892
D	0.3934	0.3462	0.3587	0.3643	0.3344	0.1754	0.0348	0.2694	0.09450	0.1557
E	0.2404	0.3147	0.3587	0.3644	0.2926	0.0877	0.0348	0.4490	0.1890	0.3892
F	0.2623	0.3777	0.2915	0.3401	0.2925	0.4385	0.0348	0.3592	0.3780	0.1557
G	0.2842	0.3462	0.3364	0.3158	0.3658	0.2631	0.02325	0.3592	0.2835	0.3892
H	0.4372	0.3357	0.2914	0.3765	0.3762	0.3508	0.0116	0.1796	0.3780	0.3114
I	0.3279	0.2308	0.3140	0.2915	0.3449	0.4385	0.0232	0.1796	0.3780	0.3892

Table 3 Pair-wise comparison of attributes

Attributes	EWSC	ISDC	MPRC	MRC	SDC	ACCA	PWNGO	AOSP	LNP	IEP	Wi
EWSC	1	5	1/3	1/2	6	6	8	9	1/2	1/5	0.1078
ISDC	1/5	1	1/3	1/3	4	5	6	7	1/5	1/5	0.0611
RFB	3	3	1	4	6	8	9	8	1/3	1/4	0.1588
MPRC	2	3	1/4	1	6	6	8	9	1/3	1/4	0.1123
MRC	1/6	1/4	1/6	1/6	1	4	5	6	1/6	1/6	0.0361
ACCA	1/6	1/5	1/8	1/6	1/4	1	4	5	1/7	1/8	0.0239
PWNGO	1/8	1/6	1/9	1/8	1/5	1/4	1	5	1/8	1/7	0.0162
AOSP	1/9	1/7	1/8	1/9	1/6	1/5	1/5	1	1/9	1/8	0.0107
LNP	2	5	3	3	6	7	8	9	1	4	0.2529
IEP	5	5	4	4	6	8	7	8	1/4	1	0.2199

Step 3: In present research project, five experts, three from the mobile manufacturing/ recycling companies and other two from academia, were consulted for making required pair-wise comparison of attributes. Two senior executives from industry

were the members of the team. The team members from industry and academia having life long experience in the field of reverse logistics practices in electronics goods industry. The pair-wise comparison matrix is given herewith:
The normalized weights of the attributes computed using equation (4) is given in table 3:
EWSC = 0.1078, ISDC = 0.0611, MPRC= 0.1588, MRC = 0.1123, SDC = 0.03613, ACCA = 0.02390, PWNGO = 0.0162, AOSP = 0.0107, LNP = 0.2529 and IEP= 0.2199.
λmax value is 10.81 and that of CR is 0.08, which is less than allowable value 10%. Thus, there is no inconsistency in judgments made by the team and the pair-wise comparison matrix is free from any undue bias.
Step 4: The weighted normalized matrix has been computed and given in table 4:
Table 4 Weighted normalized matrix

	EWSC	ISDC	MPRC	MRC	SDC	ACCA	PWNGO	AOSP	LNP	IEP
A	0.0353	0.0205	0.0463	0.0327	0.0106	0.0063	0.0007	0.0029	0.0956	**0.0856**
B	0.0333	0.0218	0.0534	0.0355	**0.0136**	**0.0105**	**0.0009**	0.0038	0.0717	0.0685
C	0.0401	0.0205	**0.0641**	0.0369	0.0112	0.0084	0.0006	**0.0048**	**0.1195**	**0.0856**
D	0.0424	0.0211	0.0570	0.0409	0.0121	0.0042	0.0006	0.0029	0.0239	0.0342
E	0.02593	0.0192	0.0570	0.0409	0.0106	0.0021	0.0006	**0.0048**	0.0478	**0.0853**
F	0.0283	**0.0231**	0.0463	0.0382	0.0106	**0.0105**	0.0005	0.0040	0.0956	0.0342
G	0.0306	0.0212	0.0534	0.0355	0.0132	0.0063	0.0004	0.0040	0.0717	**0.0856**
H	**0.0471**	0.0205	0.0463	**0.0423**	**0.0136**	0.0084	0.0002	0.0019	0.0956	0.0685
I	0.03535	0.0141	0.04990	0.0327	0.01246	**0.0105**	0.0004	0.0019	0.0956	**0.0856**

Step 5: By the use of equations (11) and (12) the ideal (best) and negative-ideal (worst solutions are calculated and given in table 5.

Table 5 Ideal (best) solution matrix and Negative-ideal (Worst solution matrix)

	Ideal (best)		Negative-ideal
v_{1+}	0.047142562	v_{1-}	0.025928409
v_{2+}	0.023107555	v_{2-}	0.014121284
v_{3+}	0.064098721	v_{3-}	0.046293521
v_{4+}	0.042285422	v_{4-}	0.032737101,
v_{5+}	0.013594477	v_{5-}	0.010573482,
v_{6+}	0.01048479	v_{6-}	0.002096958,
v_{7+}	0.0009439	v_{7-}	0.0001888,
v_{8+}	0.004814769	v_{8-}	0.001925908,
v_{9+}	0.1195015	v_{9-}	0.0239003
v_{10+}	0.085604133	v_{10-}	0.034241653

Table 6 Euclidean separation distance

	Ideal (best)		Negative-ideal (worst)
s_{1+}	0.033991	s_{1-}	0.08904
s_{2+}	0.054233	s_{2-}	0.060899
s_{3+}	0.009836	s_{3-}	0.11136
s_{4+}	0.109096	s_{4-}	0.022604
s_{5+}	0.07575	s_{5-}	0.058526
s_{6+}	0.062521	s_{6-}	0.073016
s_{7+}	0.05235	s_{7-}	0.071285
s_{8+}	0.034659	s_{8-}	0.083334
s_{9+}	0.033089	s_{9-}	0.089189

Step 6: The euclidean separation distances has been computed using equations (13) and is given in table 6.
Step 7: The relative closeness to the ideal solution of each alternative has been calculated using equation (15) and given in table 7.

Table 7 Relative closeness to the ideal solution to each Alternative

Relative Closeness	Value	Alternatives
c_1	0.723720499	A
c_2	0.528946401	B
c_3	0.918842279	C
c_4	0.171635183	D
c_5	0.435862761	E
c_6	0.538715407	F
c_7	0.576578637	G
c_8	0.706260564	H
c_9	0.72939389	I

Table 8 Ranking of 3 PL service providers

Alternatives (3PRLPs)	Value	Rank
A	0.723720499	3
B	0.528946401	7
C	**0.918842279**	**1**
D	0.171635183	9
E	0.435862761	8
F	0.538715407	6
G	0.576578637	5
H	0.706260564	4
I	0.72939389	2

Step 8: On the basis of the relative closeness values, the case company can be ranked and choose 3PL for their operations as **C-I-A-H-G-F-B-E-D** in the decreasing order of preference as shown in table 8. It is clear here that these results must be seen in the light of the business environment of mobile manufacturing company and the inputs provided by a team of experts in the pair-wise comparison of the attributes.

6. Discussion and managerial implications

A good number of electronics products contain large volumes of waste and substantial quantities of toxic materials. Industries under tight regulatory pressure from both governments and environmentally focused NGOs 'reduce', 'recycle', and 'reuse' their industrial waste. The results from mobile phones case study indicate that 3PL service provider ‘C’ is the first choice for the case company. An analysis of data provided by 3PL service provider ‘C’ reveals that the logistics firm ‘C’ has been take care about environmental aspects like proper disposal of end of life and used products. Results indicates that logistics firm ‘C’ have scored high values on almost all quantitative attributes as compared to other logistics service providers. Day by day environmental issues are gaining more importance in Indian business environment. So, most important managerial implication of the developed model is that only the firms who are dealing with environmental issues significantly will get success in competitive business environment. The proposed hybrid model in the present research has find out several significant attributes for evaluation of logistics firms for conduct of reverse logistics operation with respect to mobile phones manufacturing companies. This may provide support to management and consultants for making strategic decisions like selection of logistics firm, selection of new plant site, selection of business partner in competitive business environment. In the present work 10 relevant attributes has been identified for evaluation and selection of 3PL service provider for reverse logistics operation for the mobile phone manufacturing industry. The developed model provide flexibility in accommodating new attributes according to industry needs time to time for sound decision making.

7. Conclusions & future research scope

The evaluation and selection of the 3PL for mobile industry segment is a top management level strategic decision. The quantity of e-waste is tremendously increasing and it has become menace to society and environmental burden. The legislations like Restriction on Hazardous Substances (RoHS) Directive and Waste Electrical and Electronic Equipment Directive (WEEE) gaining importance in current business environment. The electronics appliances manufacturing companies are more interested to focus upon their core competencies and services of 3PL is a right choice for them to separate reverse logistics operations. Therefore, hiring the services of 3PL is an importance issue and present work is very significant in this regards. Now-a-days, efficient reverse logistics operation is regarded as a focused problem. Development of a sound reverse logistics system is beneficial to environmental protection, and the companies may improve their financial health also by handing the return in a professional way. Mostly the manufacturing industries does not have enough competence to manage their product reverse flow in supply chain, thus they have to only option to outsource their reverse logistics operations to the 3PL service provider for conduct of reverse logistics (RL) activities. To make AHP-TOPSIS model more effective, top management must establish key criteria for evaluation and selection of third party logistics service providers. The attributes may be increase or decrease as per the needs of the industry. In real life business environment it is very difficult to find suitable criteria for the evaluation and selection of outsourcing partner. In the present work, a decision model has been developed for the mobile phones manufacturing company only. However, the same decision model may be applicable for different market segment with minor modification.The hybrid AHP-TOPSIS method presented in this research properly guides policy makers for evaluation of 3PL reverse logistics service providers and support them visualize the intensity of impact of various criteria on the alternatives available before reaching at the final decision.

There is always a scope for further improvement in the research, so a comparative study may be conducted by using other multi-criteria decision-making methods to validate the results obtained by present method. An analytic network process (ANP) approach may be used for consideration the interactions between attributes and the results could be compared by using interpretive structural modeling (ISM) based approach. Matlab version 11 has been used for calculation purpose in this work. Customized software may be developed to reduce computational speed and simplification of calculations.

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References

[1] Franke, C., B. Basdere, M. Ciupek, and S. Seliger(2006) 'Remanufacturing of Mobile Phones—Capacity, Program and Facility Adaptation Planning" Omega, 34 (2006) 562 – 570.
[2] Hwang, C.L. and Yoon, K. (1981) Multiple Attribute Decision Making-Method and Applications: A State-of-the-Art Survey, Springer-Verlag, New York.
[3] Knemeyer, A.M., Ponzurick, T.G. and Logar, C.M. (2002) 'A qualitative examination of factors affecting reverse logistics systems for end-of-life computers', International Journal of Physical Distribution and Logistics Management, Vol. 32, No. 6, pp.455–479.
[4] Qureshi, M.N., Kumar, P. and Kumar, D. (2009) 'Selection of Logistics Services Provider (LSP) under fuzzy environment: a graph-theoretic and matrix approach', International Journal of Logistics Systems and Management, Vol. 5, No. 5, pp.551–573.
[5] Ravi, V., Shankar, R. and Tiwari, M.K. (2005) 'Analyzing alternatives in reverse logistics for end-of-life computers: ANP and balanced scorecard approach', Computers and Industrial Engineering, Vol. 48, No. 2, pp.327–356.
[6] Ravi, V., Shankar, R. and Tiwari, M.K. (2008) 'Selection of a reverse logistics projects for end-of-life computers: ANP and goal programming approach', International Journal of Production Research, Vol. 46, No. 17, pp.4849–4870.
[7] Saaty, T.L. (1980) The Analytic Hierarchy Process, McGraw-Hill, New York.
[8] Sasikumar, P. and Haq, A.N. (2010) 'A multi-criteria decision making methodology for the selection of reverse logistics operating modes', International Journal of Enterprise Network Management, Vol. 4, No. 1, pp.68–79.
[9] Schultz, G. (2002) 'The recurring side of supply chain management', APICS – The Performance Advantage, Vol. 10, pp.35–38.
[10] Saaty, T. L. (1988). Multicriteria decision making: The analytic hierarchy process. New York: McGraw-Hill.
[11] Saaty, T. L. (1994). Highlights and critical point in the theory and application of the analytic hierarchy process. European Journal of Operational Research, 74, 426–447.
[12] Vijayvargiya, A. and Dey, A.K. (2010) 'An analytical approach for selection of a logistics Provider', Management Decision, Vol. 48, No. 3, pp.403–418.