Application of AHP-VIKOR Hybrid MCDM Approach for 3PL selection: A Case Study

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ABSTRACT
Multi-criteria decision making (MCDM) is one of the most common activities in human society. It consists of selecting the optimal one from a set of available alternatives with respect to the predefined criteria or attributes. In this paper, a hybrid decision making approach integrating Analytical hierarchical process (AHP) operators into VIKOR is proposed for tackling multi criteria problems with conflicting and non-commensurable (different units) criteria. A manufacturer produces new products by using original components or by remanufactured components. The used products are collected by the manufacturer or the retailer or a third party logistics operator. Companies can no longer afford to treatment of recovered products. It needs to be a core capability within the supply chain organization. Understanding and properly managing the reverse logistics can not only reduce costs, but also increase revenues. It can also make a huge difference in retaining consumer loyalty and protecting the brand. Due to intricacies, considerable risks are involved in product recovery operations; therefore core competency and experience are prerequisite for successful implementation of reverse logistics process to Third-Party Logistics Providers (3PLPs). The selection of third-party logistics provider is an intriguing practical and research question. The objective of this work is to develop decision support system to assist the decision-makers in selection and evaluation of different third-party reverse logistics providers by Analytical hierarchical process (AHP) and Višekriterijumsko kompromisno rangiranje (VIKOR) methods. A real life case of a mobile manufacturing company is taken to demonstrate the steps of the decision support system.

General Terms
Reverse logistics, supply chain, MCDM methods, 3PRL Selection

Keywords
Višekriterijumsko kompromisno rangiranje (VIKOR); Mobile industry; Analytical hierarchical process (AHP); reverse logistics operation;

1. INTRODUCTION
Multi-criteria decision making (MCDM) is regarded as a main part of modern decision science and operational research, which contains multiple decision criteria and multiple decision alternatives. The increasing complexity of the engineering and management environment makes it less possible for single decision maker to consider all relevant aspects of a problem. As a result, many decision making processes, in the real world, take place in group setting (Merigó, 2011 and, Yang et al., 2012). Therefore, multiple criteria group decision making (MCGDM) problem is a hot research topic which has received a great deal of attention from researchers recently.

In classical MCDM methods, the ratings and the weights of the criteria are known precisely, whereas in the real world, in an imprecise and uncertain environment, it is an unrealistic assumption that the knowledge and representation of a decision maker or expert are so precise. A suitable approach for dealing with such a problem is to use linguistic assessments instead of numerical ones to represent the subjective judgment of decision makers by means of linguistic variables. A very useful technique for multiple criteria decision making is the VIKOR method, which is based on ideas of compromise programming. The main advantages of the VIKOR method are that it can solve discrete decision problems with conflicting and non-commensurable (different units) criteria and provide a solution that is the closest to the ideal. The VIKOR method focuses on ranking and selecting from a set of alternatives, and determines compromise solutions for a problem with conflicting criteria, which can help the decision makers to reach a final decision. Recently, the VIKOR method has been studied and applied in a wide range of problems. Generally, when using VIKOR in decision making, the separate measures from the best and worst values are calculated by using the weighted average and maximum weighted method, respectively. In some cases, it may be interest to consider the possibility of parameter zing the results from the maximum separation to the minimum separation.

The usage of VIKOR method has been increasing. In the literature, Chen and Wang (2009) optimized partners' choice in IS/IT outsourcing projects by fuzzy VIKOR. In this study, we applied the VIKOR method, which was developed for multi-criteria optimization for complex systems, to find a compromise priority ranking of alternatives according to the selected criteria for a selection problem. Sayadi, Heydari, and Shahanaghi (2009) used extension VIKOR method for the solution of the decision making problem with interval numbers. Liou, Tsai, Lin, and Tzeng (2010) used a modified VIKOR method for improving the domestic airlines service quality and Chang and Hsu (2009) used VIKOR method for prioritizing land-use restraint strategies in the Tseng–Wen reservoir watershed. On the other hand some researchers have evaluated VIKOR method under fuzzy environment. For example Kaya and Kahraman (2010) used an integrated fuzzy VIKOR and AHP methodology for multi-criteria renewable energy planning in _Istanbul and also Sanayei, Mousavi, and Yazdankhah (2010) used VIKOR method for a supplier selection problem with fuzzy sets. The objective of present work is to develop decision support system (DSS) to assist the decision-makers in selection and evaluation of different third-party reverse logistics providers by Analytical hierarchical process (AHP) and Višekriterijumsko kompromisno rangiranje (VIKOR) methods. A real life case study of a cell phone manufacturing company has been developed to demonstrate the steps of the decision support system.

2. REVERSE SUPPLY CHAIN MANAGEMENT

Recently, product and material recovery has received growing attention throughout the world, with its three main motivators that include governmental legislations, economic value to be recovered and environmental concerns (Ali Cetin Suyabatmaz, et. al., 2014). Reverse supply chain or reverse logistics is the series of activities required to retrieve a used product from a customer and dispose of it properly or reuse after processing. The chain connects end users with manufacturer in reverse direction. So Reverse Logistics – RL have an important role in green supply chains by providing customers with the opportunity to return end life products to the manufacturer, thus re-evaluating them and including them again in the production cycle (Efendigil et al., 2008). Reverse logistics is process of reclaiming recyclable and reusable materials, returns, and reworks from the point of consumption or sue for repair, remanufacturing, redistribution, or disposal. Often, the reprocessing stage requires the highest investments within reverse logistics network. The process involves disassembly, repair work, reuse in new products and re-assembly. The critical issues involved are how to reduce the uncertainty in the supply of products to be manufactured, how to ensure a sustainable volume of products to be manufactured and whether to outsource remanufacturing (open-loop system) or to integrate with existing operation (closed-loop system). Decisions regarding selecting of services and products suppliers are, in general, complex due to various conflicting objectives involved and, consequently, various qualitative and quantitative criteria. Taking this into account, the processes of identifying the best suppliers for services and/or products or even evaluating the performance of a former supplier are challenging for decision makers (DM), but essential in business processes. Furthermore, growing environmental concerns have motivated businesses to include environmental criteria when selecting services and product suppliers (Efendigil et al., 2008). Returning used products is becoming an important logistics activity due to government legislation and the increasing awareness in society (Kannan et al., 2012).

As shown in Figure 1 (Appendix 1), based on the current demand for reverse logistics activities companies have basically two options to comply with the law/policy: i) execute reverse logistics activities internally; and ii) outsource reverse logistics activities. This article focuses on the second option and to be able to select the most appropriate 3PRLP, it is proposed a conceptual framework using MCDA modeling is proposed, which has systematized steps with the purpose of support decision makers in these kinds of decisions. The steps assist DMs to structure the decision problem regarding selecting of 3PRLP from the identifying objectives and the set of criteria to defining the most suitable MCDA approach and method, depending on the rationality of the DM. In this paper AHP-VIKOR has been used for making strategic decision in multi-attribute decision environment for selection of third-party reverse logistics providers (3PRLPs) for collection of end of life mobile phones.

Reverse Supply Chain Network-Characteristics

- Convergent in nature from end-user to manufacturer
- Reverse flow of used products
- Supply driven
- Relatively slow movement
- Value declines with time while moving upstream
- Very small value addition in some cases
- MH and transportation are not with care
- Inventory available in different nodes

Drivers of Reverse Supply Chain Initiatives

- Environmental legislations
- Economic value from returns
- Green Image
- Material Resource constraints like lead and other precious resource

3. AHP METHOD

For complex decision making problem one of the most popular analytical techniques is the analytical hierarchy process (AHP). AHP is developed by Saaty (1980, 2000), which decomposes a decision making problem into a system of hierarchies of objectives, attributes (for criteria), and alternatives.

A particular decision situation having as many levels as needed can be fully characterized by an AHP hierarchy. Various functional characteristics of AHP make it a useful methodology. These include the ability to handle decision situations involving subjective judgments, multiple decision makers, and the ability to provide measures of consistency of preference (Triantaphyllou, 2000). It is designed to reflect the way people actually think, and this is the reason that AHP is the most highly regarded and widely used decision-making method. AHP can efficiently deal with objective as well as subjective attributes, especially where the subjective judgments of different individuals constitute an important part of the decision process. The main procedure of AHP is as follows:

Step 1: First the objective and the evaluation attributes are determined and then a hierarchical structure with a goal or objective is developed at the top level, the attributes at the second level and the alternatives at the third level.

Step 2: The relative importance of different attributes with respect to the goal or objective is determined,

- A pair-wise comparison matrix is constructed using a scale of relative importance. The judgments are entered using the fundamental scale of the analytic hierarchy process (Saaty 1980, 2000). When an attribute is compared with itself is always assigned the value 1, so the main diagonal entries of the pair-wise comparison matrix are all 1. The numbers 2, 3, 4, and 5 correspond to the subjective judgments 'moderate importance', 'strong importance', 'very strong importance' and 'absolute importance'. When M attributes are assumed, the pair-wise comparison of attribute i with attribute j gives a square matrix R_{m*m} where a_{ij} denotes the comparative importance of attribute i with respect to attribute j. In the matrix, b_{ij} = 1 when I = j and $r_{ji} = 1/r_{ij}$.

$$R_{m*m} = \begin{bmatrix} 1 & \cdots & r_{1m} \\ \vdots & \ddots & \vdots \\ r_{m1} & \cdots & 1 \end{bmatrix}$$

- The relative normalized weight (w_i) of each attribute is determined by first calculating the geometric mean of the i-th row, and then normalizing the geometric means of rows in the comparison matrix. This can be calculated as

$$GM_i = \left\{\prod_{j=1}^{m} r_{ij}\right\}^{1/m} \quad (1)$$

$$w_i = \frac{GM_i}{\sum_{i=1}^{m} GM_i} \quad (2)$$

To determine the relative normalized weights of the attributes commonly the geometric mean method of AHP is used, because of its simplicity, easy determination of the maximum Eigen value, and reduction in inconsistency of judgments.

- Matrices A3 and A4 are calculated such that A3 = A1 * A2 and A4 = A3/A2, where A2 = $[w_1, w_2, \ldots, w_i]^T$.
- The maximum Eigen value λ_{max} is determined, that is the average of matrix A4.
- The consistency index CI = ($\lambda_{max} - M$)/(M-1) is calculated. The smaller the value of CI, the smaller is the deviation from the consistency.
- The random index (RI) is obtained for the number of attributes used in decision making.
- The consistency ratio CR = CI/RI is calculated. Usually, a CR of 0.1 or less is considered as acceptable, and it reflects an informed judgment attributable to the knowledge of the analyst regarding the problem under study.

4. VIKOR PROCEDURE

Multi criteria decision making (MCDM) is one of the most prevalent methods for resolving conflict management issues (Deng & Chan, 2011). MCDM deals with decision and planning problems by consideration of multiple criteria and the importance of each (Haleh & Hamidi, 2011). Among the many MCDM methods, VIKOR is a compromise ranking method to optimize the multi-response process (Opricovic, 1998). It uses a multi criteria ranking index derived by comparing the closeness of each criterion to the ideal alternative. The core concept of VIKOR is the focus on ranking and selecting from a set of alternatives in the presence of conflicting criteria (Opricovic, 2011). In VIKOR, the ranking index is derived by considering both the maximum group utility and minimum individual regret of the opponent (Liou, Tsai, Lin, & Tzeng, 2011).

VIKOR denotes the various n alternatives as$a_1, a_2, \ldots, a_n$. For an alternative a_i, the merit of the jth aspect is represented by f_{ij}; that is, f_{ij} is the value of the jth criterion function for the alternativea_i, n being the number of criteria. The VIKOR procedure is divided into the following five steps:

(1) The best f_j^* and worst f_j^- values of all criterion functions are determined. If the jth criterion function represents a merit, then

$$f_j^* = \text{Max}_i\, f_{ij}, \quad f_j^- = \text{Min}_i\, f_{ij} \quad (3)$$

(2) The values S_i and R_i are computed, i = 1,2,3,. . .,m, by the relations

$$S_i = \sum_{j=1}^{n} \frac{w_i(f_j^* - f_{ij})}{f_j^* - f_j^-} \quad (4)$$

$$R_i = \max\left[\frac{w_i(f_j^* - f_{ij})}{f_j^* - f_j^-}\right] \quad (5)$$

Where, w_i is the weight of the jth criterion which expresses their relative importance of the criteria

(3) The value Q_i, i = 1,2,3,...,m, is computed by the relation

$$Q_i = v\left[\frac{S_i - S^*}{S^- - S^*}\right] + (1-v)\left[\frac{R_i - R^*}{R^- - R^*}\right] \quad (6)$$

where $S^* = \min_i S_i$, $S^- = \max_i S_i$, $R^* = \min_i R_i$, $R^- = \max_i R_i$, and v is the weight of the strategy of maximum group utility, whereas (1-v) is the weight of the individual regret. Here, when v is larger than 0.5, the index of Q_i follows majority rule

(4) The alternatives are ranked by sorting the values of S, R and Q, in decreasing order.

5. PROBLEM DESCRIPTION

Profitable reuse and remanufacturing of cell phones must meet the challenges of turbulent business environment which may include continuously change in design pattern, falling prices for new phone models, disassembly of unfriendly designs, short life cycles, and prohibiting transport, labor and machining costs in high-wage countries (Jayant et al. 2014). Today, the remanufacturing of expensive, long-living investment goods, e.g. machine tools, jet fans, military 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 industry segment selected for this study is Mobile Phones manufacturing industry situated in the northern part of India. The aim of this study 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 possess 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 (OEM) will set up collection centers to dispose of e-waste, and make manufacturers liable for collection of electronic waste of their products, three years since the rules were notified most companies have failed to set up 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. This new rule, 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 do not know where the e-waste is to be disposed (Toxicslink).

Once the mobile phones are assembled in different production units it has to be shipped through distributors, wholesalers, retailers and then customers. After its end of life, consumers do not know where the e-waste is to be disposed. As there is no mechanism 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 was held with the mobile phone industry managers, retailers, and state pollution control boards officials during this project and following problem areas are identified for improvement in closed loop supply chain of the mobile phones.

- Uncertainty involved in supply of used mobile phones to the OEM and industries are unable to forecast collection of EOL mobile phones quantity.
- Though most of the e- waste generated in India is recycled and it is done in a very hazardous manner by informal sector.
- Presence of illegal recycling units in the state for unauthorized mobile collection & PVC recycling operation in business environment.
- The company is not having any well-structured model of reverse logistics practice.
- Huge cost involved in setting of mobile collection centers at prime locations under the 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 logistics 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 provider exactly understands what goals and objectives the user wants to achieve. An accurate estimation of business and service requirements of the company would minimize the need of assumptions on the part of the 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. The problem addressed here is to build a sound decision support methodology to evaluation & selection of best reverse logistics service provider in the mobile phones reverse supply chain to minimize the forward and reverse supply chain cost comprising procurement, production, distribution, inventory, collection, disposal, dis-assembly and recycling cost by making a responsive supply chain environment.

5.1 DSS for the selection of 3PL Service Provider

The developed decision support methodology requires 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-VIKOR 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 tough 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-VIKOR based approach.

The various steps of decision support methodology are enlisted as follows:

1. Constitution of a team of competitive managers & Consultant
2. Decision regarding type of outsourcing service level required and collection objectives
3. Development of collection and functional specifications of the proposed task
4. Identification of potential reverse logistics service providers
5. Evaluation of request of RL logistics service providers (RLLSP)
6. Develop request for proposal offer 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
9. Collection of feed backs from the exiting customers of the service providers
10. Final selection using AHP-VIKOR approach and agreement for service

AHP-VIKOR 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, risks and rewards, remedies, extra services, damages types, individual status, termination, agreement modification, liabilities, rate adjustments, service compensations limitations, compensation, insurance, , performance measurement issues, etc.

5.2 Evaluation of 3PL using AHP-VIKOR

The AHP-VIKOR based MCDM approach presented in this work and applied in evaluation & selection of 3PL for a mobile phones manufacturing industry. There are 20 outsourcing service providers are interested to conduct reverse logistics operation for the case company. In the preliminary screening the 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 who were almost fulfill the requirement of the case 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 of the nine bidding for the deal. The company management identified 10 important attributes that were relevant to their business that they deemed it necessary for the 3PL they intended to choose. These attributes were E-Waste Storage Capacity (EWSC), Availability of Skilled Personnel (AOSP), Level of Noise Pollution (LNP) and Impacts of Environmental Pollution (IEP), Safe Disposal Costs (SDC), Availability of a Covered and Closed Area (ACCA), Possibilities to Work with NGOs (PWNGO), Inspection/Sorting and Disassembly Costs (ISDC), Mobile Phone Refurbishing Costs (MPRC), Mobile Recycling Costs (MRC). Among these attributes, ISDC (thousands of Rupees), EWSC (in tons), MPRC (INR/hour), MRC (thousands of INR) and final disposal costs (thousands of INR) are quantitative in nature, having absolute numerical values. Attributes AOSP, LN P, 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 suggested. 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 donated 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 were used as the reference for the formulation of reverse logistics data for the case company dealt in this paper. The data for all 3PL with respect to various attributes are provided in Table 1.The implementation of the AHP-VIKOR model and analysis are explained in the Following eight steps:

Step 1: Based upon the information provided by various concerned companies, the decision matrix has been prepared as shown in table 1, which illustrates the performance of s providers with respect to all 10 attribute

Table 1. Decision matrix representing the performance of various RLSP

3PRSPs	EWSC	ISDC	MPRC	MRC	SDC	ACCA	PWNGO	AOSP	LNP	IEP
A	150	1600	130	1200	1400	3	4	3	4	5
B	140	1700	150	1300	1800	5	5	4	3	4
C	170	1600	180	1350	1480	4	3	5	5	5
D	180	1650	160	1500	1600	2	3	3	1	2
E	110	1500	160	1500	1400	1	3	5	2	5
F	120	1800	130	1400	1400	5	3	4	4	2
G	130	1650	150	1300	1750	3	2	4	3	5
H	120	1600	130	1550	1800	4	1	2	4	4
I	150	1100	140	1200	1650	5	2	2	4	5

Step 2: 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:

Table 2. Pair-wise comparison of attributes

	EWSC	ISDC	MPRC	MRC	SDC	ACCA	PWNGO	AOSP	LNP	IEP
EWSC	1	5	4	4	1/3	4	½	1/5	2	3
ISDC	1/5	1	3	3	4	1/3	3	½	5	4
MPRC	¼	1/3	1	¼	3	2	1/3	4	1/5	2
MRC	¼	½	4	1	4	3	¼	4	2	1/5
SDC	3	¼	1/3	¼	1	1/5	2	½	3	4
ACCA	¼	3	½	1/3	5	1	4	1/3	2	5
PWNGO	2	1/3	3	4	½	¼	1	2	¼	3
AOSP	5	2	¼	¼	2	3	½	1	3	1/5
LNP	½	1/5	5	½	1/3	½	4	1/3	1	2
IEP	1/3	¼	½	5	¼	1/5	1/3	5	½	1

The weights of the attributes computed using equation (3) is given below
EWSC = 0.16, ISDC = 0.14, MPRC= 0.008, MRC = 0.11, SDC = 0.08, ACCA = 0.02, PWNGO = 0.11, AOSP = 0.10, LNP = 0.08 and IEP= 0.06

Step 3. The best f_j^* and worst f_j^- values of all criterion functions are determined using equation (3) and given in table 3.

Table 3. Best f_j^* and worst f_j^- values

f_j^*	200	1800	180	1550	1800	5	5	5	5	5
f_j^-	110	1100	130	1200	1400	1	1	2	1	2

Step 4. Value of $\frac{w_i(f_j^*-f_{ij})}{f_j^*-f_j^-}$ is calculated and given in table 4.

Table 4. Value of $\frac{w_i(f_j^*-f_{ij})}{(f_j^*-f_j^-)}$,,,,, when weights are equal

	EWSC	ISDC	MPRC	MRC	SDC	ACCA	PWNGO	AOSP	LNP	IEP
A	0.088	0.04	0.008	0.11	0.08	0.01	0.027	0.066	0.02	0
B	0.10	0.02	0.005	0.078	0	0	0	0.033	0.04	0.02
C	0.053	0.04	0	0.062	0.064	0.005	0.055	0	0	0
D	0.035	0.028	0.003	0.015	0.04	0.015	0.055	0.066	0.08	0.06
E	0.16	0.06	0.003	0.015	0.08	0.02	0.055	0	0.06	0
F	0.14	0	0.008	0.047	0.08	0	0.055	0.033	0.02	0.06
G	0.124	0.028	0.005	0.078	0.01	0.01	0.082	0.033	0.04	0
H	0	0.04	0.008	0	0	0.005	0.11	0.1	0.02	0.02
I	0.088	0.14	0.006	0.11	0.03	0	0.082	0.1	0.02	0

Step 5: Based on the Table 5, Eq. (3), Eq. (4) and Eq. (5) values of S_i, R_i and Q_i are obtained for each alternative, as shown in Table 5. Here, the Q_i value of each alternative is calculated using each v value as v = 0.5.
S^*= 0.279, S^- =576, R^*=0.064, R^- =0.16,

Table 5. Q_i value and ranking

	S_i	R_i	Q_i	Rank
A	0.449	0.11	0.52	5
B	0.296	0.1	0.216	2
C	0.279	0.064	0	1
D	0.397	0.08	0.281	4
E	0.453	0.16	0.793	8
F	0.443	0.14	0.672	7
G	0.41	0.124	0.532	6
H	0.303	0.11	0.274	3
I	0.576	0.14	0.896	9

Step 6: On the basis of the Q_i values, the case company can be ranked and choose 3PL for their operations. Raking of 3PL is **C-B-H-D-A-G-F-E-I** in the decreasing order of preference as shown in table 5.

6. CONCLUSIONS & FUTURE SCOPE

The VIKOR method was developed as a MCDM method to determine the preference ranking from a set of alternatives in the presence of conflicting criteria. The obtained compromise solution could be accepted by the decision makers because it provides a maximum group utility for the ‘‘majority’’ and a minimum individual regret for the ‘‘opponent’’. This work presents the use of Analytic Hierarchy Process (AHP) operators in the VIKOR method and developed an integrated hybrid AHP-VIKOR method to solve multi-criteria problems with conflicting and non-commensurable criteria, specifically considering the complex attitudinal character of the decision maker. Present work illustrates, 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.

In future research, 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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8. APPENDIX 1

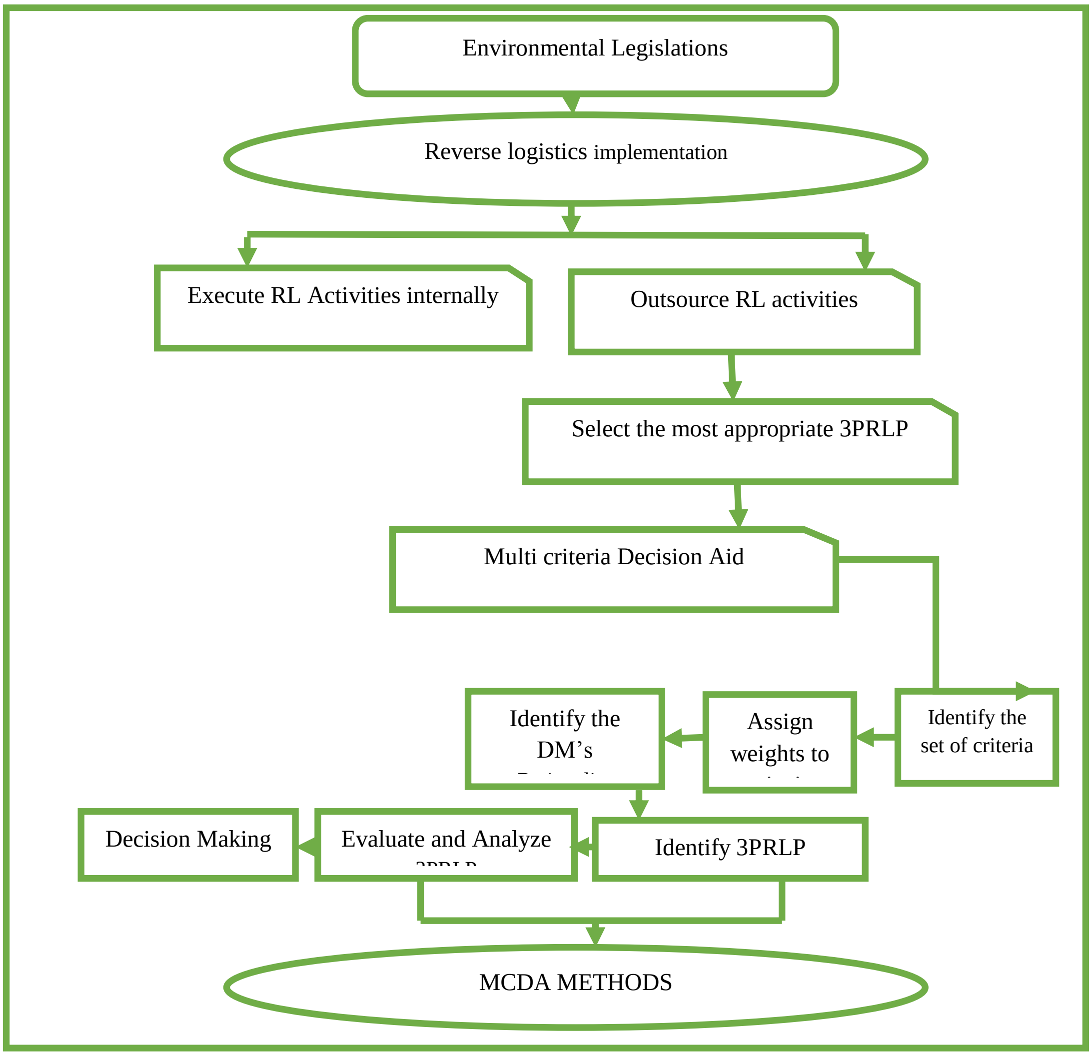

Figure 1. Adapted and modified from Guarnieri, P. et. al (2014)