# An Integrated Approach with MOORA, SWARA, and WASPAS Methods for Selection of 3PLSP

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## Abstract

Mobile production in India has already crossed the 100-million-units mark, and is set to touch 500 million in the next two years. 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. In the present work problem related to recovery of used cell phones is formulated by various MCDM approaches namely MOORA (multi-objective optimization by ratio analysis), SWARA (step-wise weight assessment ratio) and WASPAS (weighted aggregated sum product assessment). SWARA method is used to find the criterion weight of alternative and the other methods such as MOORA and WASPAS is used to give the rankings of alternatives and chooses the best alternative from the rest. All known multi-attribute methods cannot value the attribute weights as one weight of attribute is higher or lower significant than the other attribute, SWARA allows expert opinion about significance ratio of the attributes in the process of rational decision determination. In WASPAS method, we combine the subjective weight expressed by decision makers with objective weights to obtain more realistic weights which help to increase the stability of the proposed approach. This approach is efficient and well consistent with other methods. MOORA method is a general method and can consider any number of quantitative and qualitative attributes simultaneously and offer a more objective and simple decision making-approach. The present approach links the financial and nonfinancial, tangible and intangible, internal and external factors, thus providing a holistic framework for the selection of an alternative for the reverse logistics operations for EOL cell phones. Many criteria, sub-criteria, determinants, etc. for the selection of reverse manufacturing options are interrelated. Thus, MCDM methods proposed in this paper provides a more realistic and accurate representation of the problem for conducting remanufacturing logistics operations for EOL cell phones in Indian business environment.

**Keywords**
Reverse Supply Chain Management, MOORA, SWARA, WASPAS

## 1. INTRODUCTION

Supply Chain Management (SCM) is a business term that has emerged in the last few years and is gaining in popularity. The typical definition of the term Supply Chain Management (Bowersox and Closs, 1996[1]) is as The Supply Chain refers to all those activities associated with the transformation and flow of goods and services, including their attendant information flows, from the sources of materials to end users. Management refers to integration of all these activities, both internal and external to the firm. The different decisions associated with supply chain management have been classified as strategic (long-term), tactical and operational (short-term), and can be treated as location, production, distribution, or transportations problems (Beamon, 1998[2]). Reverse logistics is a recoverable system that increases product life by means of recycling, repair, refurbishment, and manufacturing. In 1998 Stock[3] defined reverse logistics as the processes associated with the flows of product returns, source reduction, recycling, material substitution, material reuse, waste disposal, material refurbishment, repair, and remanufacturing. Hence, the recoverable system deals with the physical flows of products, components and materials from end-users to re-users. Efficient management of reverse logistics will benefit to enterprises and contribute to environmental protection. Many scholars have proceeded in the study of product recycling, and assumed that the remanufactured product can be revamped into the original state of a brand new product (Huang and Chen 2008 [4]). In the last decade, many companies such as Dell, General Motors, Kodak, and Xerox focused on remanufacturing and recovery activities and have achieved significant successes in this area (Uster and Easwaran 2007[5]). 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.

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, MOORA, SWARA and WASPAS techniques 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, Section 2 gives the review of literature. In section 3 thoroughly propose the problem related to mobile phone, Section 4 present MOORA approach, Section 5 define the complete procedure of WASPAS method, section 6 define the significance value according to SWARA method and finally section 7 present the conclusions.

## 2. LITERATURE REVIEW

Since there are numerous researches on remanufacturing systems which address many various topics from definition to practical cases in real industry, only key relevant literatures are introduced in this section. For remanufacturing, discarded products are completely disassembled through a series of industrial process in factory environment. Usable parts are cleaned, refurbished and put into part inventory. Rajesh et al. (2014) [7] studied production system life cycle, studied application multi-objective optimization based on ratio analysis approach. Explored the ways to solve production systems problems by decision making techniques and MOORA for decision making problems.

Neslihan et al. (2007) [8] developed integer mathematical model for a remanufacturing system, which included both forward and reverse flows. Proposed model provides the optimal values of production and transportation quantities of manufactured and remanufactured products while solving the location problem of disassembly, collection and distribution facilities, validated results by sensitivity analysis.

Yongshenget. al. (2008) [9] developed mixed integer formulation was developed for Reverse Logistic Network Design, which was solved by standard B&B techniques and done parametric analysis for remanufacturing and repairing network to illustrate the efficiency and practicability.
Reynaldo et al. (2008) [10] modeled reverse logistic network of end of life vehicles in Mexico and modelled through an incapacitated facility location problem. Used software SITATION for generation of results, results were collected for three collection networks with in Mexico, which corresponded to three scenarios that considered 100%, 90% and 75% respectively, of collection coverage.

Jayant et al. (2014) [11] studied reverse logistic network and sustainable supply chain systems of used inverter batteries collections in North India. Aim was to model and Simulate the Reverse Logistic Systems for collection of End of Life (EOL) by using Arena 2011 Simulation and modeling software.

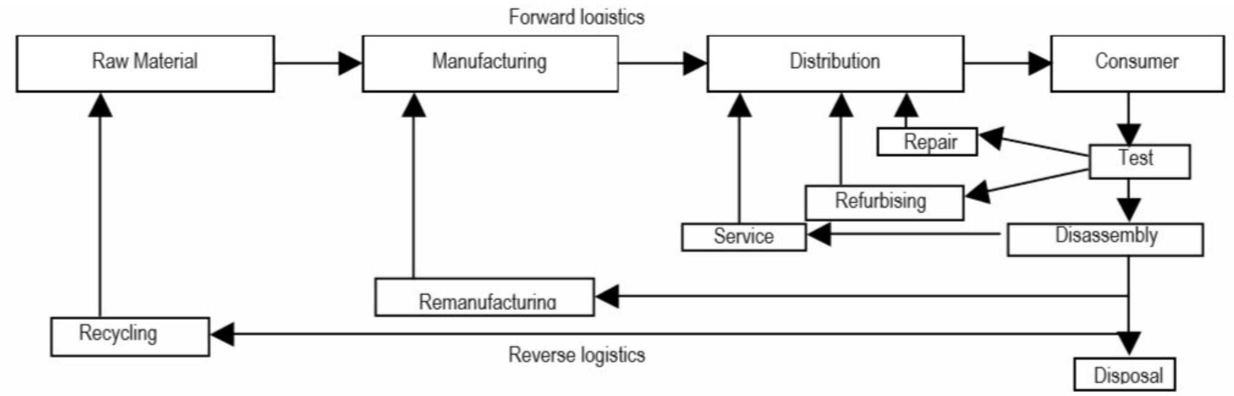


Figure 1. Forward and Reverse logistic flows (Srivastava 2008[12])

From the literature survey it is found that, till now application of MCDM in field of reverse logistic network for mobile industry has not been done yet. In developing countries like India, where mobile communication network and mobile user are expanding day by day, optimum End of Life of e waste generated by mobile companies is necessary for Germination of Sustainability in Supply Chain Network. Improper disposal of e waste and poor reverse logistic network cause serious environmental issue, which is an international concern cause. Mobile industry part components face problem of improper e waste disposal, and lack of remanufacturing and reuse causes steeping cost in the supply chain network, and in turn cause loss at customer end too.

In this research by application of MOORA, SWARA, WASPAS out of given alternatives based upon calculations for the given parameters, they were ranked as per their concern in reverse logistic network, yielding to optimized network generation which could be implemented for the problem identified.

## 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 many 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 possess a great threat to environment and human health if not disposed off in a proper method. 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. 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 meant to dispose of the e–waste have not come up in most cities. The effective implementation of the rules looked very unlikely in 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-waste 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 should 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. 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.

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.

The MCDM approaches 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 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. 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 has been 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**

| 3PRLs | 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 |

## 4. MOORA METHOD

Multi-objective optimization on the based of ratio analysis (MOORA) is also known as multi-criteria or multi-attribute optimization. It is defined as the process of simultaneously optimizing two or more conflicting attributes subject to some constraints (Chakraborty 2011; Karande and Chakraborty 2012). Multi-criteria problem can be found in different stages of production system life cycle such as product design, process design, material selection, machine tool or cutting tool selection, material handling system selection, advanced manufacturing system selection. This approach was introduced by Brauers (2004). This approach starts with a matrix consisting of performance measures of different alternatives with respect to various criteria.

$$X = \begin{cases} X11 & X12 & X1n \\ X21 & X22 & X2n \\ Xm1 & Xm2 & Xmn \end{cases} \quad (1)$$

where xij is the performance measure of the ith alternative on the jth attribute, m is the number of alternatives and n is the number of the attributes. MOORA approach consists of two parts namely ratio system approach, the reference point approach.

### 4.1 Ratio System Approach

In the ratio system approach, the initial data in the decision matrix is normalized. The reason behind the normalization is to make the decision matrix dimensionless. This makes all the elements of the decision matrix comparable. For normalization, different procedures are suggested by the authors Karande and Chakraborty (2012) and Brauers et al. (2010). According to Karande and Chakraborty (2012), normalization can be done by comparing the performance of an alternative on a criterion to a denominator which is a representative for all the alternatives concerning that criterion.

$$Xij *= \frac{Xij}{\sum_{i=1}^{m} \mathrm{Xij}} \quad (2)$$

Where Xij * is a dimensionless number in the [0, 1] interval, which represents the normalized performance of the ith alternative on the jth criterion. The elements of the matrix are normalized without considering the type of the attribute i.e. beneficial attribute or non-beneficial attribute. Beneficial attributes are those attributes whose higher values are required, while for non-beneficial attributes, lower values are required.

For optimization based on ratio system approach of MOORA method, normalized performances are added in case of beneficial attributes (maximization) and subtracted in case of non-beneficial attributes (minimization), which can be expressed by following expression:

$$Yi *= \sum_{j=1}^{g} Xij * - \sum_{j=g+1}^{n} Xij * \qquad (3)$$

Where yi * is the assessment value of the ith alternative with respect to all the criteria, g is the number of criteria to be maximized, and (n - g) is the number of the criteria to be minimized.

Furthermore the value of yi * can be positive or negative depending on the totals of beneficial and non-beneficial attributes in the matrix. The alternative with highest value of yi * would be the best alternative. An ordinal ranking of yi * shows the final preference. In some cases, some attributes are more significant than others. In these cases attribute weight is taken into deliberation. The weights of the attribute can be determined by applying entropy method and analytical hierarchy process (AHP). When weights of the attributes are considered, Eq. (3) becomes as follows:

$$Yi *= \sum_{j=1}^{g} wiXij * - \sum_{j=g+1}^{n} wiXij * \qquad (4)$$

Where wi is the weight of the jth attribute.

## 4.2 Reference Point Approach

In the reference point theory, a maximal objective reference point is deduced from the ratios found in Eq. (2). This approach is also known as realistic and non-subjective when the coordinates (ri) selected for the reference points are realized in one of the candidate alternatives (Brauers et al. 2008). The set of reference point series is obtained on the basis of the beneficial and non-beneficial attributes. It will consist of maximum value in case of beneficial attribute and minimum value in case of non-beneficial attribute. The deviation of a criterion value from the set reference point (ri) is computed as:

$$ri - Xij* \qquad (5)$$

From the reference point approach of MOORA, best alternative is one which would possess the maximum values in all of its beneficial attributes and minimum values in its non-beneficial attributes. It is not possible all the times that a specific alternative having all of the maximum values in its beneficial attributes and minimum values in its non-beneficial attributes. In such cases, there will be deviation from the set of reference point series.

Karlin and Studden (1966); Brauers and Zavadskas (2006) have proposed following formula for optimization based on reference point approach:

$$Pi = Min \{ Max |ri - Xij *| \} \qquad (6)$$

Where Pi is the performance index. The best alternative would be one which has the total minimum deviation from the set of reference point series. In other words, it will have the minimum value of Pi.

## 4.3 Implementation of MOORA method

To demonstrate the applicability, accuracy and potentiality of the MOORA method in decision making the following step should be followed:

Step 1: To find the decision matrix this is to be given in Table 1

Step 2: Normalization matrix of initial data where Xij* is equal to

$$\frac{Xij}{\sqrt{\sum_{i=1}^{m} Xij^2}}$$ Where j = 1, 2, 3 ……. m

It is obtained by dividing each element by under root of summation of square of each element in the column. Normalization is done without considering the beneficially of attribute.

**Table 2 Normalization Matrix**

| 3PRLSP | EWSC | ISDC | MPRC | MRC | SDC | ACCA | PWNGO | AOSP | LNP | IEP |
|---|---|---|---|---|---|---|---|---|---|---|
| A | 0.3278 | 0.335 | 0.29 | 0.291 | 0.29 | 0.263 | 0.43 | 0.269 | 0.377 | 0.39 |
| B | 0.30 | 0.356 | 0.336 | 0.315 | 0.376 | 0.438 | 0.537 | 0.359 | 0.283 | 0.312 |
| C | 0.37 | 0.335 | 0.403 | 0.328 | 0.309 | 0.350 | 0.322 | 0.449 | 0.471 | 0.39 |
| D | 0.39 | 0.346 | 0.358 | 0.364 | 0.334 | 0.175 | 0.322 | 0.269 | 0.094 | 0.156 |
| E | 0.24 | 0.314 | 0.358 | 0.364 | 0.292 | 0.087 | 0.322 | 0.449 | 0.188 | 0.39 |
| F | 0.26 | 0.377 | 0.291 | 0.34 | 0.292 | 0.438 | 0.322 | 0.359 | 0.377 | 0.156 |
| G | 0.28 | 0.346 | 0.336 | 0.315 | 0.365 | 0.263 | 0.215 | 0.359 | 0.283 | 0.39 |
| H | 0.437 | 0.335 | 0.29 | 0.376 | 0.376 | 0.35 | 0.107 | 0.179 | 0.377 | 0.312 |
| I | 0.327 | 0.23 | 0.314 | 0.29 | 0.345 | 0.438 | 0.215 | 0.179 | 0.377 | 0.39 |

Step 3: To find the attribute are beneficial or non-beneficial.

Beneficial attributes are those whose higher values are required, while for non-beneficial attributes lower values are required.

Step 4: To find the assessment value and ordinal ranking of assessment value.

In present research project, five experts, three from the mobile manufacturing/ recycling companies and other two from academia, were consulted. 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 normalized weights of the attributes are given on which assessment value (Yi*) can be found. These normal weights are: 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.

Assessment value can be found by:

$$Yi *= \sum_{j=1}^{g} wiXij * - \sum_{j=g+1}^{n} wiXij *$$

Where wi is the weight defined above of the jth attribute.

**Table 3: Assessment Value and Ranking**

| 3PRLSPs | ASSESSMENT VALUE | RANKING |
|---|---|---|
| A | -0.23930 | 2 |
| B | -0.20889 | 7 |
| C | -0.27906 | 1 |
| D | -0.13469 | 9 |
| E | -0.22278 | 6 |
| F | -0.20007 | 8 |
| G | -0.23659 | 4 |
| H | -0.22715 | 5 |
| I | -0.23892 | 3 |

The value of assessment can be positive or negative depending upon the beneficial and non-beneficial attribute. The alternative with highest value would be the best alternative and bear rank one.

## 5. WASPAS METHOD

The weighted aggregated sum product assessment (WASPAS) method is a unique combination of WSM and WPM methods. In this method, a joint generalized criterion of weighted aggregation of additive and multiplicative methods is proposed as follows (Zavadskas et al., 2013a, b):

$$Qi = 0.5\ Qi(1) + \ 0.5\ Qi(2) \quad (7)$$

$$Qi = 0.5\sum_{j=1}^{n} Xijwj + 0.5\prod_{j=1}^{n} \mathrm{Xij}^{wj} \quad (8)$$

To have increased ranking accuracy and effectiveness of the decision-making process, in WASPAS method, a more generalized equation for determining the total relative importance of ith alternative is developed as below (Zavadskas et al., 2012):

$$Qi = \lambda Qi(1) + (1-\lambda)Qi(2) \quad (9)$$

$$Qi = \lambda\sum_{i-1}^{n} Xijwj + (1-\lambda)\prod_{i-1}^{n} Xij^{wj} \quad (10)$$

The candidate alternatives are now ranked based on the Q values and the best alternative has the highest Q value. When the value of λ is 0, WASPAS method is transformed to WPM, and when λ is 1, it becomes WSM method. It has now been applied for solving MCDM problems for increasing ranking accuracy and it has the capability to reach the highest accuracy of estimation. Till date, WASPAS method has limited successful applications in location selection (Hashemkhani Zolfani et al., 2013), civil engineering domain (Dėjus & Antuchevičienė, 2013; Staniūnas et al., 2013; Šiožinyte & Antuchevičiene, 2013), port site selection (Bagočius et al., 2013) and manufacturing decision-making (Chakraborty & Zavadskas, 2014).

### 5.1 Implementation of WASPAS Method

WASPAS is a recently presented method and is known as one of the newest methods proposed by the scientific community. This new methodology is based on the Weighted Sum Model (WSM) and Weighted Product Model (WPM). Zavadskas, Turskis, Antucheviciene, and Zakarevicius (2012) are the innovators of this new method and, in their research, they prove that this aggregated method gets the better accuracy compared with the accuracy of applying just one of WSM or WPM.

WASPAS calculation is based on the following steps.

Step 1: Decision Matrix that is to be given in Table 1

Step 2: Normalized decision-making matrix based on

$$Xij = \frac{xij}{opt\ Xij}$$ , where i=1, m; j=1, n (11)

If the optimum value is a maximum

$$Xij = \frac{optXij}{Xij}$$ , where i = 1, m; j =1, n (12)

If the optimum value is a minimum

**Table 4 Normalized Decision matrix**

| 3PRLSP | EWSC | ISDC | MPRC | MRC | SDC | ACCA | PWNGO | AOSP | LNP | IEP |
|---|---|---|---|---|---|---|---|---|---|---|
| A | 0.75 | 0.687 | 1 | 1 | 1 | 0.6 | 0.8 | 0.6 | 0.25 | 0.4 |
| B | 0.70 | 0.647 | 0.867 | 0.923 | 0.778 | 1 | 1 | 0.8 | 0.33 | 0.5 |
| C | 0.85 | 0.687 | 0.772 | 0.889 | 0.945 | 0.8 | 0.6 | 1 | 0.2 | 0.4 |
| D | 0.90 | 0.667 | 0.812 | 0.80 | 0.875 | 0.4 | 0.6 | 0.6 | 1 | 1 |
| E | 0.55 | 0.733 | 0.812 | 0.80 | 1 | 0.2 | 0.6 | 1 | 0.5 | 0.4 |
| F | 0.60 | 0.611 | 1 | 0.857 | 1 | 1 | 0.6 | 0.8 | 0.25 | 1 |
| G | 0.60 | 0.667 | 0.867 | 0.857 | 0.80 | 0.6 | 0.4 | 0.8 | 0.33 | 0.4 |
| H | 1 | 0.687 | 1 | 0.923 | 0.778 | 0.8 | 0.2 | 0.4 | 0.25 | 0.5 |
| I | 0.75 | 1 | 0.928 | 1 | 0.848 | 1 | 0.4 | 0.4 | 0.25 | 0.4 |

Step 3: Calculating WASPAS weighted and normalized decision-making matrix for the summarizing part

$$Xij, sum = Xijqj$$ , where 1, m; j=1, n (13)

Step 4: Calculating WASPAS weighted and normalized decision-making matrix for the multiplication part

$$Xij, multi = Xij^{qj}$$ , where i =1, m; j =1, n (14)

Step 5: Final calculation for evaluating and prioritizing alternatives based on

$$WPSi = 0.5 \sum_{j=1}^{n} Xij + 0.5 \prod_{j=1}^{n} Xij$$

Where i=1,m ; j =1,n (15)

**Table 5 Aggregated measure and final ranking**

| 3PRLSP | Xij,sum | Xij,mult | WPSi | RANK |
|---|---|---|---|---|
| A | 0.6149 | 0.534 | 0.5744 | 3 |
| B | 0.6272 | 0.583 | 0.6053 | 7 |
| C | 0.5603 | 0.482 | 0.5212 | 1 |
| D | 0.8867 | 0.874 | 0.8803 | 9 |

| | | | | |
|---|---|---|---|---|
| E | 0.5986 | 0.568 | 0.5834 | 5 |
| F | 0.7184 | 0.628 | 0.6736 | 8 |
| G | 0.5764 | 0.532 | 0.5542 | 2 |
| H | 0.6234 | 0.546 | 0.5847 | 6 |
| I | 0.6182 | 0.535 | 0.5766 | 4 |

The best alternative is for which the rank obtained is one i.e, C and the worst is for which the rank is nine i.e., D.

## 6. SWARA METHOD

There have been several MADM methods, such as the analytic hierarchy process (AHP) (Saaty, 1980), analytic network process (ANP) (Saaty & Vargas, 2001), entropy (Shannon, 1948; Su šinskas, Zavadskas, & Turskis, 2011; Keršulienė & Turskis, 2011), FARE (Ginevicius, 2011), SWARA (Keršulienė, Zavadskas, & Turskis, 2010), etc., in dealing with the multiple criteria problems. In all of the above-mentioned methods, weight assessment is one of the crucial and controversial issues. In most MADM problems, in the process of ranking the alternatives in a decision-making process, a method or an approach is required to calculate the weight of criteria to follow further steps and finally rank the alternatives. Moreover, the final order of alternatives can be calculated in some weight calculation techniques applied for ranking, while in the others it cannot.

Experts' viewpoints are the major determinant of the SWARA method. To be more precise, each expert chooses the importance of each criterion. In the next step, all the criteria are ranked from the first to last, based on each expert's idea. Experts 'opinions, their own implicit knowledge, information and experiences are applied in all evaluation processes. The most important and influencing criterion gets the first rank, and the least important criterion gets the last rank. To determine the overall rank of the decision model, the mediocre value of ranks is used (Kersuliene & Turskis, 2011). The experts' ability and mastery are the most vital and influencing points in determining the importance of each criterion in the SWARA method (Kersuliene et al., 2010).

The fundamental feature of this method of decision-making is that there is no need to evaluate and rank the criteria since the policies of companies or countries are utilized to define some problems' priorities. Hence, SWARA can be useful whenever the priorities exist but the weight of each criterion is pivotal. SWARA's framework is totally different from other similar methodologies such as FARE, AHP and ANP. SWARA prepares this opportunity in which policy makers make decisions based on different situations and prioritize criteria based on their needs and goals. The other important point is the role of experts. Experts play a key role in the process of every important project. The SWARA method is useful to apply in the process of decision and policy-making at the top level of decision-making in important topics (Hashemkhani Zolfani & Saparauskas, 2013).

In the following, some of the recent developments of decision-making models based on the SWARA method are listed: the design of products (Hashemkhani Zolfani, Zavadskas, & Turskis, 2013), selecting the optimal alternative of mechanical longitudinal ventilation of tunnel pollutants (Hashemkhani Zolfani, Esfahani, Bitarafan, Zavadskas, & Lale Arefi, 2013), investigating the success factors of online games based on explorers (Hashemkhani Zolfani, Farrokhzad, & Turskis, 2013), machine tool selection (Aghdaie, Hashemkhani Zolfani, & Zavadskas, 2013a), market segmentation and selection (Aghdaie, Hashemkhani Zolfani, & Zavadskas, 2013b) and sustainable development of rural areas' building structures based on local climate (Hashemkhani Zolfani & Zavadskas, 2013).

### 6.1 Implementation of SWARA METHOD

The process of determining the relative weights of criteria using SWARA method can accurately be shown by using the following steps:

Step 1: The criteria are sorted in descending order based on their expected significances.

Step 2: Starting from the second criterion, the respondent expresses the relative importance of criterion j in relation to the previous (j-1) criterion, for each particular criterion. According to Kersuliene et al. (2010), this ratio is called the Comparative importance of average value, Sj.

Step 3: Determine the coefficient kj as follows:

$$Kj = \begin{cases} 1 & j = 1 \\ Sj + 1 & j > 1 \end{cases} \quad (16)$$

Step 4: Determine the recalculated weight qj as follows:

$$qj = \begin{cases} 1 & j = 1 \\ \frac{Kj-1}{kj} & j > 1 \end{cases} \quad (17)$$

Step 5: The relative weights of the evaluation criteria are determined as follows:

$$wj = \frac{qj}{\sum_{k=1}^{n} qk} \quad (18)$$

where wj denotes the relative weight of criterion j.

**Table 6 Relative weights of evaluation criteria**

| CRITERIA | AVERAGE VALUE (Sj) | Kj = (1+Sj) | $Qj= Q_{j-1} / Kj$ | Wj = Qj/ Σ Qj |
|---|---|---|---|---|
| EWSC | 0.1078 | 1.1078 | 1 | 0.1388 |
| ISDC | 0.0611 | 1.0611 | 0.9424 | 0.1308 |
| MPRC | 0.1588 | 1.1588 | 0.8132 | 0.1128 |
| MRC | 0.1123 | 1.1123 | 0.7311 | 0.1014 |
| SDC | 0.0361 | 1.0361 | 0.7056 | 0.0979 |
| ACCA | 0.0239 | 1.0239 | 0.6891 | 0.0956 |
| PWNGO | 0.0162 | 1.0162 | 0.6781 | 0.0941 |
| AOSP | 0.0107 | 1.0107 | 0.6709 | 0.0931 |
| LNP | 0.2529 | 1.2529 | 0.5354 | 0.0743 |
| IEP | 0.2199 | 1.2199 | 0.4388 | 0.0609 |
| TOTAL | | | 7.2046 | 1.00 |

The table satisfies the result as the summation of relative weights is equal to one.

## 7. CONCLUSIONS

Ranking of alternatives was performed applying WSM, WPM methods, a joint criterion of weighted aggregation of the latter methods such as WASPAS, also the ratio system and the reference point approach as a part of MOORA. Nine series of ranks were calculated, respectively. It has been proved that the most preferable alternative depended on λ value when applying a joint weighted method WASPAS. Alternative C was ranked as the best and alternative G remained in the second place when λ=0.5. Alternative D was ranked as worst alternative for conducting reverse logistics operation in the integrated supply chain. MOORA method consisting of the ratio system and the reference point approach has also applied in the selection of 3PRLSP in the present study. The best ranked alternative decisions coincided in the current case as alternative C was ranked as best and alternative A was ranked as second and alternative D was considered as worst for conducting reverse logistics operation for the mobile phone company.

Reliability of the joint criterion was tested and verification of results was performed when comparing it to MOORA. It was proved that WASPAS results coincided with the ratio system MOORA. The SWARA method has a powerful and logical perspective for decision and policy-making because priorities have different dimensions, such as politics, culture, and so on. In this study SWARA is applied in the process of decision-making for evaluating the weights and priorities of criteria. SWARA result can be verified as the summation of criteria weights comes out to be one.

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