PATRICIJA BAJEC, Ph.D.[1]
(Corresponding author)
E-mail: patricija.bajec@fpp.uni-lj.si
DANIJELA TULJAK-SUBAN, Ph.D.[1]
E-mail: danijela.tuljak@fpp.uni-lj.si
IVONA BAJOR, Ph.D.[2]
E-mail: ibajor@fpz.unizg.hr
[1] University of Ljubljana
Faculty of Maritime Studies and Transport
Pot pomorščakov 4, 6320 Portorož, Slovenia
[2] University of Zagreb
Faculty of Transport and Traffic Sciences
Vukelićeva 4, 10000 Zagreb, Croatia

Science in Traffic and Transport
Original Scientific Paper
Submitted: 7 Nov. 2019
Accepted: 6 May 2020

A WAREHOUSE SOCIAL AND ENVIRONMENTAL PERFORMANCE METRICS FRAMEWORK

ABSTRACT

To improve the supply chain performance in all three aspects of sustainability (social, economic, and environmental), a comprehensive sustainable performance measurement system that captures all the supply chain partners' efforts and commitments is required. Warehouse, as the second largest logistics source of environmental pollution in the supply chain has been almost completely overlooked and ignored in the past studies. To fill this gap, a warehouse performance metrics framework for environmental and social performance measures was proposed using a novel Fuzzy Delphi and Best-worst methodological approach. The method is less time-consuming than the Analytic Hierarchy Process or Analytic Network Process, it does not address whether criteria are dependent or independent, requires fewer comparisons of criteria, but still produces reliable and credible results. The presented framework consists of 32 equally formulated environmental and social performance indicators, including formulas and measurement units. The 14 most important indicators are ranked according to the requirements of different stakeholders.

KEY WORDS

warehouse; performance indicators; environmental performance; social performance; Fuzzy Delphi; Best-worst method;

1. INTRODUCTION

To generate higher performance and consequently more opportunities for competition, the companies are trying to maintain balance between economic, social and environmental performance of all supply chain partners. Creating a so-called "triple win solution" is a great challenge for several reasons [1]. First, appropriate sustainable measures have to be created and implemented. Conventional sustainable indicators are not sufficient as they often focus only on the economic perspective [1]. There are few standards of sustainable measurement. The social and environmental dimensions of sustainability are ignored. Second, not all performance indicators can be quantified, which allows for subjectivity and bias [2]. And third, there are trade-off situations in cases of simultaneous improvement of performance in different sustainable areas [3]. For example, higher performance in one dimension of sustainability can lower the performance of another sustainable dimension [4].

An essential starting point for facing these challenges is the establishment of a framework or approach in regard to sustainable measures, which answers three crucial questions: (1) What are the goals of the assessment? (2) What must be measured to achieve the goals? (3) How must the selected elements be measured? [1], and (4) Who should perform the assessment?

Many articles have investigated frameworks for evaluating sustainable performance of the whole supply chain [5-10]. However, given the complexity of a supply chain, which involves a number of participating companies, it is very difficult to take into account every aspect of sustainability and every single indicator [11]. Deeper analyses were applied in the past on the performance measurements of a single supply chain partner or supply chain activity. Most papers are focused on the purchasing and supplier selection [12-17], production and manufacturer [18-23]. In logistics, the main focus was placed on mode of transportation, vehicle routing, transportation speed, and logistics network design [7]. However, there are only a few papers that comprehensively investigate the warehouse sustainability performance-related issue [24-32] and no attempt has been made to provide a framework for performance measurement in warehousing [7] considering all three pillars of sustainability.

Most of the papers found on sustainable warehousing [24-30] deal with general models of sustainable warehouses, which are mainly focused on economic and less on the environmental pillar of sustainability. The social aspect of sustainability has been completely overlooked.

Some studies [25-29] were found on constructs and elements for environmental sustainability of warehouses. They are very exhaustive and up-to-date. The same can be confirmed for those studies that present solutions in warehouses for reducing negative impacts on the environment [28-31]. One paper [29] even made very extensive impact analyses of constructs-elements on all three dimensions of sustainability, which could serve in performance evaluations, enabling consideration of desirable and undesirable criteria.

Almost all of these papers discuss the performance indicators that cover at least one aspect of sustainability. Very few of the papers discuss the specific units in regard to the means of measuring the metrics, propose mathematical equations, or describe the way to calculate performance.

Warehousing is the fastest growing element of the supply chain logistics industry [24], since many producers and retailers decide to outsource non-core activities to third party logistics providers. The warehousing business is worth approximately 10% of the total supply chain logistics value [24]. This share will increase in the future, because the warehouse function is no longer only storage and distribution, but a complex added value service (assembly, production, post-sale logistics). More services, a higher level of automation, a growing number of warehouses lead to higher consumption of energy, fuel and material and also increase environmental pollution [24]. Warehousing is already "considered to be an important cause of emissions and the second largest single source of environmental pollution in the logistics chain" [33]. However, its important role in sustainable supply chains has been almost completely overlooked in the past research. Neglecting it, might induce a sharp increase in overall supply chain emissions that might even offset reduction measures in the other sectors of supply chains [34].

During one of the projects ordered by a private company, the authors realised that there exists no practical guidance for measuring sustainable performance in warehousing. Moreover, there is a lack of uniformly defined and harmonized indicators, including measurement units and equations.

The primary purpose of this study is to propose a general warehouse performance metrics framework, which enables warehouse managers and decision-makers the assessment of two dimensions of sustainability, social and environmental, which are harmonised with the key groups of stakeholders. The economic dimension of sustainability will not be the subject of this study. Unlike the criteria of the other two dimensions of sustainability, the economic criteria have already been harmonised, and the measurement units and equations defined [35]. To reach the purpose, the following questions have to be answered:

1) What criteria are appropriate for environmental and social performance evaluation in warehousing?
2) Which of them are strategically relevant for different stakeholders (warehouse owners, focal firms, policy makers)?
3) How should performance data be prepared and measured to be useful for them?

To this end, the three-step methodological approach was applied: (1) literature review for the identification of the initial set of potential environmental and social indicators; (2) Fuzzy Delphi method (FDM) for selecting the most important criteria from the initial set of potential performance; (3) The Best-worst method (BWM) to rank criteria according to their importance.

Out of 32 detected environmental and social performance measures, 14 were selected as important. The seven most important criteria originate from the environmental family of criteria. However, it is encouraging that about a third of criteria derive from the social pillar of sustainability. Only two aspects of social sustainability, safety and training, are covered.

This paper contributes to the literature primarily by presenting an environmental and social performance metrics framework, including equations and measurement units. The framework is harmonised with three groups of stakeholders. Besides, the most important indicators are highlighted. The second contribution of this paper is an integrated FDM and BWM approach, on which the current warehouse performance metrics framework is based and also individual performance frameworks will be developed. Neither of the methods is new. However, this is the first time they have been integrated at all and applied for warehousing purposes. FDM and BWM approach require a few comparisons of criteria, are easier to use for the warehouse manager, practitioner, or any other user, and are more consistent than the most frequently used method in multi-criteria decision-making in general, the Analytic Hierarchy Process (AHP).

The presented framework should be helpful to warehouse managers, decision-makers and practitioners in the initial phase of performance measurement – proper input data collection for assessing the warehouse performance on two sustainability dimensions, but not in the further phases of the evaluation. Individual warehouse managers and decision-makers have their own needs and requirements. Some of them relate to the company policy, others to the type of warehouse. Other indicators will be, therefore, also included in the framework and in the ranking.

The presented framework also serves to standardize the data collection, which reduces the information asymmetry and facilitates exchanging data between the focal firm and its partners and increases transparency within the supply chain, which further enables easier prediction of the overall performance of the logistics chain.

The methodological approach enables the selection of a proper set of social and environmental indicators, but it also enables the inclusion of additional criteria, which refers to the individual needs of warehouse managers and ranks the completed set of criteria (those that are proposed in the framework and those that are identified individually by each warehouse).

2. LITERATURE REVIEW

2.1 Sustainable warehousing

Few papers were found on sustainable warehouses. Bank and Murphy [24] discussed the motivation for developing sustainability standards, outlined future directions in warehouse performance metrics, but they did not define any specific metrics and guidelines for sustainable performance. However, they emphasized all three aspects of sustainability.

Tan et al. and Rudiger et al. [25, 26] represent the few authors that address the interconnectivity between disparate sustainability dimensions when modelling the sustainable warehouse. Their simulation, however, includes only the key indicators, without defining their metrics and units.

The paper by Zuchowski [27] is focused on an environmentally sustainable warehouse facility. It presents three basic groups of sustainable solutions for facilities (reducing harmful emissions, reducing the consumption of resources and increasing the ecological value of a facility) and factors that influence them. The author also highlights some basic parameters for evaluating a sustainable building, but defines no metrics or measurement units.

Fictinger et al. [28] examine the interaction between inventory management and warehouse-related greenhouse gas emissions and conclude that the choice of inventory control policy and parameters have a significant impact on warehouse energy consumption and hence, on the emissions. They even claim that the degree of warehouse mechanisation notably influences the overall warehousing emissions. Two energy parameters are identified in this paper, including their equations and units.

Amjed and Harrison [29] highlight eight major warehouse constructs and elements of sustainable warehouse and their impact on various dimensions of sustainability. They found that 63% of elements impact more than one dimension of sustainability.

Warehouse indicators classified according to time, quality, costs, productivity and warehouse activities were presented by Staud et al. [35]. They list a set of indicators, their definitions and a very precise explanation of each. However, only economic indicators are highlighted.

Chen et al. [30] analyse the optimal decisions on warehouse management and green technology investments considering trade-offs between the economic and environmental objectives.

Bartolini et al. [31] made a comprehensive analysis on the environmental impact of warehouse building, lighting and ventilation and air conditioning. They found that lighting is the main contributor to energy consumption.

2.2 Environmental and social performance indicators in warehousing

A review of the literature on sustainable performance measurements in warehousing services revealed that studies mainly deal with the economic pillar of sustainability. Staudt et al. [35] succeeded in the most comprehensive way to define 39 performance criteria, including definitions, mathematical expressions, and also measurements units.

Social and environmental performances are rarely measured. The authors managed to collect one performance indicator (including definition, equation and measurement unit) for measuring energy consumption [28], one for measuring greenhouse gas (GHG) emissions [26], one for the use of electricity, liquid fuel usage and water consumption, one for measuring employee's safety and community service [24].

The most commonly mentioned environmental indicator was the GHG emissions. Only two social criteria were found to exist. Both were identified in the same paper [24]. Moreover, for both dimensions of sustainability a common understanding on the definitions and even measurement units of these two aspects of criteria is very scarce or does not even exist.

The low number of indicators and inconsistent definitions and units of measurement forced the authors to review in detail the general literature on this field [36-43]. Each indicator found in the literature was evaluated in terms of the suitability and feasibility of use in warehouses. A potential list of criteria is presented in *Table 1*.

3. RESEARCH METHODOLOGY

The paper addresses the research question of identifying all proper environmental and social performance indicators in warehousing and highlighting the most important ones to efficiently cope with sustainable performance. The following steps were used to carry out the environmental and social performance metrics framework of warehouses:

1) Identifying the initial set of potential environmental and social indicators through a literature review;
2) Selecting the most important criteria from the initial set of potential performance using FDM;
3) After a reliability analysis and defuzzification, the BWM is used to rank criteria according to their importance.

3.1 Environmental performance indicators

For the environmental dimension of sustainability three categories (emissions category, resource category, ecosystem) of criteria are most frequently mentioned [34, 44-46] in the literature and are appropriate for measuring performance in warehouses (*Table 1*).

The author [26] stated that "GHG emissions of warehousing activities are generated by a variety of processes. Thus, several resources of consumption must be considered". Lighting is the main one, followed by heating, cooling, ventilation and air conditioning [34]. Large consumers of energy are fixed (steady conveyors) or mobile material handling equipment (forklifts, etc.). Frequently used sources of energy are electricity, natural gas and fuels.

To calculate the amount of CO_2 emissions, energy consumption of different energy sources must be multiplied by means of the emission intensity factor.

A direct measurement of GHG emissions, calculated on the basis of measured quantities of energy and resource consumption, is, in the view of Rudiger et al. [26], not practical nor likely to be completely accurate. Instead, they propose sorting GHG emissions into three groups: GHG emissions of energy, GHG emissions of maintenance, which should be both allocated to floor-space (m^2), and GHG emissions of packaging, allocated to the number of outgoing items ($items_i$) of type i.

$$E_{total} = e_{packaging} + e_{warehousing} \tag{1}$$

$$e_{packaging} = \frac{\sum_{i=1}^{n} pf_i \cdot items_i}{\sum_{i=1}^{n} items_i} \tag{2}$$

where n is the number of items and pf_i is the packaging factor related to item i (expressed in gCO_2/item) defined as:

$$pf_i = \sum_{k=1}^{m} q_{k_i} \cdot EF_k \tag{3}$$

where m is the packaging categoriy and q_{k_i} is the quantity of packaging consumption of packaging category k for item i.

$$e_{warehousing} = \frac{e_{energy} + e_{maintenance}}{\sum_{i=1}^{n} \frac{items_i \cdot t_i}{360} sf_i} \tag{4}$$

where sf_i presents the floor-space factor per item, expressed in m^2/item, and t_i is the average storage time measured in days.

3.2 Social performance indicators

Social well-being indicators are those for which an organisation has a societal impact through general health and safety practices and human rights. There are two categories of indicators [44] (*Table 2*).

Table 1 – Environmental indicator categorization

Category	Name of indicator	Unit of measure
Emissions category concerns indicators which measure warehouse releases (solid waste such as paper, plastic and metal; packaging, organic materials, air emissions, water effluents) [41].	Water discharge [40].	m^3 per year
	Total volume of effluents, used water and unused water, released to surface water, groundwater or a third destination [40].	
	Solid waste [47].	tonnes per year
	Total weight of solid waste [47].	
	Significant spills [47].	m^3 per year
	Total volume of recorded significant spills [47].	
	GHG emissions (for warehouse).	tonnes per year
	Total weight of all energy sources consumed and emission factor per each source of energy or *Equations 1-5*.	
Resource category includes indicators which measure the material, energy, water, and/or land use of a warehouse.	Water consumed [40].	m^3 per year
	Total volume of water used by a warehouse such that it is no longer available for use by the ecosystem or local community [40].	
	Purchased electricity consumed [39].	kWh per year
	Total quantity of purchased electricity consumed [39].	
	Self-generated electricity consumed (wind, solar, etc.) [39].	kWh per year
	Total quantity of self-generated electricity consumed [39].	
	Self-generated electricity sold [39].	kWh per year
	Total quantity of self-generated electricity sold [39].	
	Percentage of self-generated electricity used [39].	%
	The ratio of electricity consumption to the total amount of electricity produced [39].	
	Natural gas consumed [39].	m^3 per year or kWh km travelled per year (transport)
	Total volume of natural gas consumed (39].	
	Diesel fuel consumed [39].	tonnes per year km travelled per year (transport)
	Total weight of diesel fuel consumed [39].	
	Gasoline consumed [39].	tonnes per year km travelled per year (transport)
	Total weight of gasoline consumed [39].	
	Renewable fuel consumed (biofuels) [39].	tonnes per year km travelled per year (transport)
	Total weight of renewable fuel consumed [39].	
	Refrigerant gas consumed [39].	m3 per year or kWh
	Total volume of refrigerant gas consumed [39].	
	Material used for packaging purposes and transport (wood, paper, cardboard, plastic, etc.) [38].	tonnes, m^3
	Total weight or volume of material [38].	
	Recycled material used for packaging purposes and transport (wood, paper, cardboard, plastic, etc.) [38].	tonnes,m^3
	Total weight or volume of material [38].	
	Percentage of recycled material used [38].	%
	The ratio of total and recycled material used, multiplied by 100 [38].	
Ecosystem concerns indicators which show warehouse impact on the surrounding biodiversity and habitat.	Size of land to protect biodiversity [48].	km^2 or number
	Size of land owned, leased, managed to protected areas and areas of high biodiversity value outside protected areas [48]. or Number of lands owned, leased, managed to protected areas and areas of high biodiversity value outside protected areas.	
	Significant impact of activities on biodiversity [48].	verbal description
	Description of significant impacts of activities, products, and services on biodiversity in protected areas and areas of high biodiversity value outside protected areas [48].	
	Number of habitats [48].	number
	Number of habitats protected or restored [48].	

Table 2 – Social indicator categorization

Category	Name of indicator	Unit of measure
Employee indicators concern the health and safety of employees, education and satisfaction with an organisation.	Number/rate of new employees.	number
	Total number and rate of new employees (by age group, gender and region) hired per year.	
	Number/rate of employee turnover.	number
	Total number and rate of employee turnover per year, by age group, gender and region.	
	Parental leave [49].	number
	Total number of employees that returned to work in the reporting period after parental leave ended, by gender [49].	
	Identification of work-related hazards [43].	number, text
	The frequency and scope of processes undertaken on a routine basis to identify work-related hazards and assess risks on a routine and non-routine basis, and to apply the hierarchy of controls in order to eliminate hazards and minimize risks [49].	
	Health and safety training.	number
	Number of hours devoted to any occupational health and safety training to workers per year.	
	Healthcare services.	number
	Number of healthcare services (preventive examinations) provided by the employer per year.	
	Work-related injuries.	number
	The number of work-related injuries per year.	
	Types of work-related injuries.	text
	The main types of work-related injuries.	
	Hours of training [42].	number
	Average hours of training that the organization's employees have undertaken by employee category (management, administration, operative workers) per year [42].	
	Type of training [42].	text
	Type and scope of programs implemented and assistance provided to upgrade employee skills [42].	
	Performance and career development.	%, number
	Percentage of total employees by gender and by employee category (management, administration, operative workers) who received performance and career development per year.	
	Ratio of basic salary of women to men [50].	%
	Ratio of the basic salary and remuneration of women to men for each employee category [50].	
	Number of incidents of discrimination [50].	number
	Total number of incidents of discrimination per year [50].	
Community indicators concern an organisation's relations with the community (donations, social amenities, etc.).	Local community engagement [51].	number
	Number of operations with implemented local community engagement (environmental impact assessments and ongoing monitoring, local community development programs, etc.) [51].	
	Negative impact on local community [51].	number
	Number of operations with significant actual and potential negative impacts on local community [51].	

3.3 Fuzzy Delphi method (FDM)

The classical Delphi technique calculations are based on experts' opinions, anonymous response, iteration, controlled feedback and statistical group response [8, 52-54]. The method is useful where the opinions and judgements of experts on complex matters are necessary and where precise information is unavailable.

Some of its weaknesses (repetitive surveys which are cost- and time-consuming, inconsistency in the assessment of experts' opinions affects the result of calculations [55], low convergence in retrieving outcomes, loss of important information, and a lengthy progress of investigation [56]) can be reduced or even eliminated using the upgraded version of Delphi, the FDM. Using fuzzy sets is more consistent with human linguistics [57] and it is better for decision-makings in the real world given the applicability of fuzzy numbers. In addition, the fuzzy Delphi technique could be used in a single round for screening criteria. Thus, FDM was used here to determine the criteria to be included in the final analysis.

FDM consists of four steps:

1) *Collecting opinions of selected decision-makers.* Firstly, a set of alternatives (criteria) $C=\{C_1, C_2,\ldots, C_n\}$ and also a set of decision-makers $DM=\{DM_1, DM_2,\ldots, DM_m\}$ must be defined. Then the decision-makers are asked to verbally evaluate alternatives using verbal evaluation term proposed in *Table 3* [58].
   Let $\tilde{w}_{ij}=(l_{ij}, m_{ij}, u_{ij})$ be the corresponding triangular fuzzy number evaluation of decision-maker DM_i to criteria C_j. Correspondence is defined using *Table 3*.
2) *Definition and aggregation of fuzzy evaluations.* Obtained evaluations have to be aggregated in an overall triangular fuzzy rating $\tilde{w}_j=(l_j, m_j, u_j)$, where the lower limit value is defined as $l_j = \min_{i=1,\ldots,m}\{l_{ij}\}$, the mid-value is defined as an arithmetic average $m_j = \frac{1}{m}\sum_{i=1}^{m} m_{ij}$ and the upper limit value is defined as $u_j = \max_{i=1,\ldots,m}\{u_{ij}\}$.
3) *Defuzzification of fuzzy evaluations.* Using a proper defuzzification method it is possible to obtain crisp ratings from the triangular fuzzy ratings obtained in Step 2. The signed distance defuzzification method computes a crisp value that has a greater membership grade than the crisp value obtained with the most commonly used Centre of Gravity defuzzification method, [59]. This increases the accuracy of the obtained crisp value.
   For the triangular fuzzy weights $\tilde{w}_j=(l_j, m_j, u_j)$, the defuzzified value obtained with the signed distance method could be defined as the signed distance of $\tilde{w}_i$ to the real number 0, $d(\tilde{w}_i, 0)$. Also in the case of triangular fuzzy numbers the signed distance of a fuzzy value to zero is equal to the expected value $E[\tilde{w}_i]$ [59]:
   $$d(\tilde{w}_j,0) = E[\tilde{w}_j] = \frac{l_j + 2m_j + u_j}{4} \quad (5)$$
4) *Screen evaluation of alternatives (criteria).* The elements of the alternatives (criteria) $C=\{C_1, C_2, \ldots, C_n\}$ set can be arranged decreasing from those with the maximum crisp weight to those with the minimum crisp weight (computed in Step 3). Then a threshold value $\alpha\in[1,9]$ is defined to screen criteria and define the final set of criteria that will be used:
   - $d(\tilde{w}_j,0)\geq\alpha$ then criterion C_j will be part of the final set.
   - $d(\tilde{w}_j,0)<\alpha$ then criterion C_j will not be part of the final set.

3.4 Best-worst (BWM) method

Researchers are using different approaches and methods to prioritize items by relevance. Some, for example, divide elements into several classes using Pareto analysis and 20/80 or any other ratio. This method is out of the question in the present case, due to the extremely low frequency of application of criteria (only a few criteria were identified on warehouse performance measurements). In addition, the frequency may not reflect real requirements.

To determine the relevance of each criterion in the final evaluation multi-criteria decision-making (MCDM) methods, most commonly AHP or the extended Analytic Network Process (ANP) method,

Table 3 – Verbal evaluations and associated triangular fuzzy numbers [58]

Verbal evaluation terms	Triangular fuzzy evaluation value
Equality of importance	$\tilde{1}$=(1,1,2)
Judgment values between equally and moderately	$\tilde{2}$=(1,2,3)
Moderately more important	$\tilde{3}$=(2,3,4)
Judgment values between moderately and strongly	$\tilde{4}$=(3,4,5)
Strongly more important	$\tilde{5}$=(4.5.6)
Judgment values between strongly and very strongly	$\tilde{6}$=(5,6,7)
Very strongly more important	$\tilde{7}$=(6,7,8)
Judgment values between very strongly and extremely	$\tilde{8}$=(7,8,9)
Extremely more important	$\tilde{9}$=(8,9,9)

have recently been applied. With these approaches, a scale of priorities is derived from pairwise comparison measurements, which are made with judgments using numerical values taken from the AHP absolute fundamental scale of 1 to 9 [60]. "The very significant challenge to the pairwise comparison method comes from the lack of consistency of the pairwise comparison matrices, which usually occurs in practice mainly from lack of concentration" [61]. Concentration very often declines in the case of a large number of elements that need to be compared and in the case of very similar criteria by relevance. "When a comparison matrix is inconsistent, the recommended course of action is to revise the comparison such that the comparison matrix becomes consistent. Although this is a very common approach, it has been shown not to be successful" [62].

Thus, a new BWM was presented, that requires fewer, only $2n$-3 comparisons (where n is the total number of criteria). BWM provides more consistent comparisons than AHP. Consistency ratio is, therefore, used to determine the level of reliability and not to check the consistency. BWM is moreover much easier to use than AHP and can also be combined with other methods. Due to the large number of general performance criteria (not criteria on warehouse performance), identified by the authors and due to the disadvantages of AHP and the advantages of BWM, the authors decided to use it in the practical example.

In the BWM, as in the AHP and ANP, a criteria set $C=\{C_1, C_2,\ldots, C_n\}$ is defined. As opposed to the other two methods, here there are no particular requirements related to the number of criteria or interdependency check. The only step necessary is to detect the best criterion B and the worst criterion W.

As explained in [62], the AHP nine-stage scale and roles of comparison can be used to define the decision-makers' preference evaluations of all criteria in respect to the worst criterion and preference evaluations of the best criterion to all other. In such a way two sets are defined: $A_B=\{a_{B1}, a_{B2}, \ldots, a_{Bn}\}$ is the set of comparisons between the best criterion and the others and $A_W=\{a_{W1}, a_{W2}, \ldots, a_{Wn}\}$ is the set of comparisons between all criteria and the worst; clearly, all values are integers and between 1 and 9 and also $a_{BB}=a_{WW}=1$, $a_{BW} = \max\{A_B\} = \max\{A_W\}$ [63].

Let $W=\{w_1, w_2,\ldots, w_n\}$ be the set of weights that have to be computed and related to the previously defined criteria set C. The base of the BWM is the intuition that the ideal value of the relative preference a_{ij}, of criterion i in respect to criterion j, can be expressed as the quotient $\frac{w_i}{w_j}$ [62]. Hence, using sets A_B and A_W it is possible to define the next relations: (a) $\frac{w_i}{w_W} = a_{iW},\ i = 1,\ldots,n$ and (b) $\frac{w_B}{w_j} = a_{Bj},\ j = 1,\ldots,n$.

Since inconsistency could occur in the sets of preferences, weights could be computed as values from the set $S = \left\{ w_i \middle| 0 \leq w_i \leq 1, \sum_{i=1}^{n} w_i = 1, i = 1,2,\ldots,n \right\}$ that minimises the maximum absolute distance in (a) and (b) [62]:

$$\min \max_{i=1,\ldots,n} \left\{ \left| \frac{w_i}{w_W} - a_{iW} \right|, \left| \frac{w_B}{w_i} - a_{Bi} \right| \right\} \tag{6}$$

This is the first original Rezaei [62] formulation of the BWM method as a non-linear problem that can have more than one solution. In practice, linear model approximations are used, which can be easily improved by a software tool.

The most frequently used linear equivalent formulation [64] can be written using an objective term ξ, as:

$$\begin{aligned} & \min \xi \\ & \text{s.t. } |w_i - a_{iW} w_W| \leq \xi, \\ & \quad |w_B - a_{Bi} w_i| \leq \xi, \\ & \quad \sum_{i=1}^{n} w_i = 1, \\ & \quad w_i \geq 0, \text{ for } i = 1,\ldots,n. \end{aligned} \tag{7}$$

The solution of the linear equivalent formulation is composed of optimal weights set $W^*=\{w_1^*, w_2^*, \ldots, w_n^*\}$ and optimum value ξ^*, that need to be, to the degree possible, close to 0.

The Consistency Ratio (CR) must be less than or equal to 0.25 and can be calculated as:

$$CR = \frac{\xi^*}{CI} \tag{8}$$

where the Consistency Index (CI) is connected to the values of a_{BW} and is defined in *Table 4* [62]. In case of inconsistency different linear approximations have to be used [63].

Table 4 – Consistency index [64]

a_{BW}	1	2	3	4	5	6	7	8	9
ξ^*	0	0.44	1	1.63	2.30	3.00	3.73	4.47	5.23

4. APPLICATION OF THE METHODOLOGY

For applying FDM 26 experts (one from the government domain, six from the academic and nineteen from the industrial domain - logistics service providers, retailers and producers) from Slovenia, with a minimum of five years of experience in warehousing and/or sustainable logistics, were asked to assess the appropriateness of the identified criteria using verbal evaluations presented in *Table 3*. The results of the evaluation are presented in *Table 5* (columns 1-4). Based on the Pareto analysis, the authors decided that α would be 70% of the maximum rating. Consequently, 14 criteria, signed "used" were found to be appropriate for further analysis (*Table 5*, column 5).

Experts were then requested to select the best and worst criterion from the set of 14 criteria. The best criterion was B="GHG emissions" and the worst was W="hours of training". Then, the BWM model (*Equation 7*) was applied to compute the

Table 5 – FDM steps (i-iv) and final results

Name of indicator	l_i	m_i	u_i	$d(\tilde{w}_j,0)$ using *Equation 5*	Screen evaluation α= 6.3
Number of columns	1	2	3	4	5
Number/rate of employee turnover	4	5	6	5	not used
Parental leave	3	4	5	4	not used
Identification of work-related hazards (C1)	7	8	9	8	used
Health and safety training (C2)	7	8	9	8	used
Healthcare services (C3)	7	8	9	8	used
Work-related injuries (C4)	7	8	9	8	used
Types of work-related injuries	1	2	3	2	not used
Hours of training (C5)	7	8	9	8	used
Type of training	1	2	3	2	not used
Performance and career development review	5	6	7	6	not used
Ratio of basic salary of women to men	4	5	6	5	not used
Number of incidents of discrimination	4	5	6	5	not used
Local community engagement	1	2	3	2	not used
Negative impact on local community	1	2	3	2	not used
Water discharge	1	2	3	2	not used
Solid waste (C6)	6	7	8	7	used
Significant spills	1	2	3	2	not used
GHG emissions (C7)	7	8	9	8	used
Water consumed (C8)	7	8	9	8	used
Purchased electricity consumed (C9)	7	8	9	8	used
Self-generated electricity consumed	5	6	7	6	not used
Percentage of self-generated electricity used	5	6	7	6	not used
Natural gas consumed (C10)	7	8	9	8	used
Diesel fuel consumed (C11)	7	8	9	8	used
Gasoline consumed (C12)	7	8	9	8	used
Renewable fuel consumed (biofuels)	5	6	7	6	not used
Refrigerant gas consumed (C13)	7	8	9	8	used
Material used for packaging purposes and transport (C14)	6	7	8	7	used
Recycled material used for packaging purposes and transport	5	6	7	6	not used
Size of land to protect biodiversity	1	1	2	1.25	not used
Significant impact of activities on biodiversity	1	2	3	2	not used
Number of habitats	1	2	3	2	not used

weights of criteria. A linear model was implemented using IBM Cplex software. A linear model was implemented using IBM ILOG CPLEX Optimization Studio (Version: 12.9.0.0) software on an Intel® Core™ i7-8750H CPU 2.20 GHz and the execution time 0.818 s. The obtained results are presented in *Figure 1*.

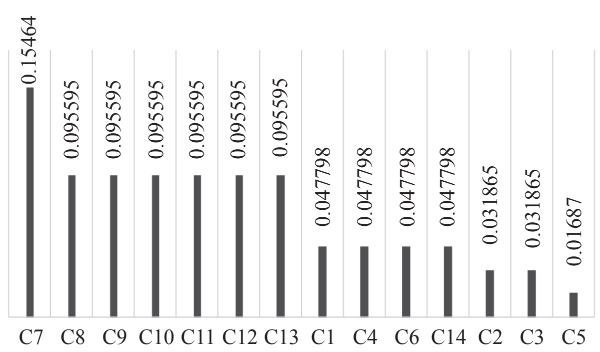

Figure 1 – Weights of criteria

The value of ξ^* is 0.036551. Using *Equation 8* and *Table 4*, the consistency ratio CR=0.0098, which is less than 0.25, is computed to confirm that the results are reliable and the computed judgements consistent.

The sensitivity analysis was performed for the criterion that obtained the highest weight. The value of the highest weight (C7) varied from 0.1 to 0.2 and, consequently, the weights of all the other criteria varied. *Figure 2* represents the variations of all the weights in accordance with the highest weight.

Figure 2 presents clearly that there is not much variability in the final ranks and that the consistency ratio is always less than 0.25. Thus, the proposed analysis is free from any bias and the model is robust.

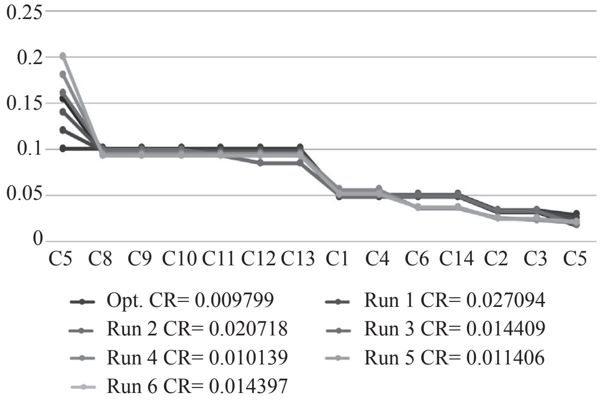

Figure 2 – Sensitivity analysis

The model could be solved with tools that employ a mathematical linear and non-linear programming and optimization tool.

5. RESULTS ANALYSIS

Of 32 detected environmental and social performance measures, 14 were selected as important. Unsurprisingly, the seven most important criteria (C7-C13) originate from the environmental family of criteria. However, criteria C8-C13, according to *Equation 1* are part of criterion C1, which means that they could be grouped in only one criterion. In the authors' view, grouping of criteria is important at the stage of comprehensive assessment of the performance of a warehouse company, while at the stage of defining the criteria, grouping can lead to neglect of any of the criteria.

From *Figure 1* it is possible to note that experts still believe that the environmental criteria are more important than social ones. But at the same time it is encouraging that about a third of criteria derive from the social pillar of sustainability. However, they only cover two aspects of social sustainability, safety and training. At this time, when companies are facing a large labour shortage, it would be reasonable to pay attention to other social indicators as well (rate of employee turnover, career development, etc.). Also, encouraging is the fact that the criteria renewable fuel consumed, recycled material used for packaging purposes, transport and self generated electricity consumed did not rank in the group of most important criteria, but right behind it. Warehouse companies are aware of the importance of environmental protection: perhaps policy makers can speed things up in this regard.

The framework should be regarded as a starting point of the measurement system development. The framework facilitates each warehouse manager's selection of appropriate and most important environmental and social indicators among the list of indicators, which were harmonised with different stakeholders' requirements. The aim of the paper was not to present a framework for a particular type of warehouse. Individual warehouses have different needs that reflect their activities but also their own requirements. Even warehouses that are of the same type have their unique needs. Other criteria could and should be added to the criteria selected from the proposed framework. Then the FDM and BWM approach can be used to select and rank the most important criteria.

The methodological FDM and BWM approach is simpler to use than AHP or ANP, since it does not address whether criteria are dependent or independent and requires fewer comparisons (in the present case 25, in the case of AHP 91). These facts consequently lead to a higher level of consistency and also save time. Nevertheless, the method produces reliable and credible results, facilitating the firm's ability to comprehensively assess warehouse performance and improve their levels of efficiency in regard to three facets of sustainability.

All these advances also assist the focal supply chain companies in their efforts to assess the overall supply chain performance. The framework enables that data required to perform the supply chain performance analysis are available and prepared by using the same formulas and measurement units by all supply chain partners that provide warehousing services, reduces data asymmetry among the partners and allows the performance analysis, made by the focal firm. At the same time, the performance analysis is less time-consuming, more accurate and subsequently the green supply chain could be improved.

Results are also helpful to policy makers as well. Due to the considerable amount of emissions caused by warehouses, policy makers should start (1) encouraging warehouses to measure at least the criteria that are highly ranked, and (2) demanding warehouses to ensure they positively impact biodiversity and habitat, a significant but often ignored interaction. Policy makers should start promoting social sustainability, too. A wider range of social criteria should be considered (rate of employee turnover, performance and career development, parental leave, for instance, should be included).

The presented framework is the innovative synthesis of both existing and new knowledge. It is an initial step toward a standard guide for developing measured sets for assessing environmental and social sustainability in warehousing.

6. CONCLUSION

Warehouses, in addition to transport, as one of the major causes of logistics chain emissions and environmental pollution have been almost completely overlooked in the past studies. This paper addresses this research gap by first identifying all the potential environmental and social indicators in warehousing, including equations and measurement units, and, second, by highlighting the most important sustainable and social criteria, which match the interests and reflect the expectations of different stakeholders. A novel FDM and BWM methodological approach, which decreases subjectivity and complexity and can be used in any similar decision-making process, was applied.

Since this is one of the first papers that so comprehensively analyses the topic, the authors believe that the framework will be a lever for further examinations and enhancements. The paper can be improved or upgraded in the following ways: (1) Research on analyzing the interrelationships between performance indicators (potential trade-offs) for different warehouse types is required in order to achieve sustainable objectives in warehousing. For example: What is the impact of the increased volume of freight on the criteria weights? How does the increase of services or a higher level of services influence the weight of criteria? (2) Another challenge would be to evaluate the influence of each indicator on the overall warehouse performance, which would highlight criteria that significantly impact the performance and would, consequently, help in formulating optimal decisions in management and investments in warehouses. The findings would also support policy makers developing effective policies that would, for example, enable green warehousing, or to standardize the way of calculating (equations, units) at least those criteria that require particular attention. (3) To increase the reliability of the proposed methodological FDM and BWM approach, procedures for selecting the experts and other stakeholders that mirror the topic being researched can also be formalized and documented. (4) To develop an appropriate framework for different types and characteristics of warehouses, (warehouses for palletized goods, warehouses with controlled temperature regime) using FDM and BWM methodology. For broader generalisation, several case studies are also required in the future for every single type of warehouse.

One limiting factor of this study is the rather low number of interviews that were performed. Future studies could expand the sample size to enhance the proposed framework on one hand, but also to generalize the results. In addition, the challenge for future research is to empirically authenticate the usefulness and validity of the presented performance measurement framework using triangulation, which gives an even more balanced picture of the situation. In addition, several case studies are also required for broader generalisation.

Dr **PATRICIJA BAJEC**[1]
E-mail: patricija.bajec@fpp.uni-lj.si
Dr **DANIJELA TULJAK-SUBAN**[1]
E-mail: danijela.tuljak@fpp.uni-lj.si
Dr **IVONA BAJOR**[2]
E-mail: ibajor@fpz.unizg.hr
[1] Univerza v Ljubljani
Fakulteta za pomorstvo in promet
Pot pomorščakov 4, 6320 Portorož, Slovenija
2 Univerza v Zagrebu
Fakulteta prometnih znanosti
Vukelićeva 4, 10000 Zagreb, Hrvaška

SOCIALNI IN OKOLJSKI KRITERIJI ZA MERJENJE USPEŠNOSTI V SKLADIŠČU

POVZETEK

Za izboljšanje uspešnosti dobavne verige na vseh treh vidikih trajnosti (socialni, ekonomski, okoljski) je potreben celovit sistem trajnostnega merjenja uspešnosti, ki zajema prizadevanja in zavezanost vseh partnerjev v oskrbovalni verigi. Skladišče, kot drugi največji logistični vir onesnaževanja okolja v oskrbovalni verigi, je bilo v preteklih študijah skoraj v celoti spregledano in prezrto. Za zapolnitev te vrzeli je bil predlagan pristop merjenja socialnega in okoljskega trajnostnega vidika uspešnosti skladišč z uporabo nove metode Fuzzy Delphi in Best-worst. Metoda je manj zamudna kot Analytic Hierarchical Process ali Analytic Network Process. Metoda ne preverja ali so kriteriji odvisna ali neodvisna, zahteva manj primerjav kriterijev, vendar kljub temu daje zanesljive in verodostojne rezultate. Predstavljeni okvir ali pristop sestavlja 32 enako formuliranih okoljskih in družbenih kazalnikov uspešnosti, vključno s formulami in merskimi enotami. 14 najpomembnejših kazalnikov je razvrščenih glede na zahteve različnih deležnikov.

KLJUČNE BESEDE

skladišče; kazalci uspešnosti; okoljska učinkovitost; socialna učinkovitost; fuzzy Delphi; Best-worst metoda;

REFERENCES

[1] Beske-Janssen P, Johnson MP, Schaltegger S. 20 years of performance measurement in sustainable supply chain management–what has been achieved? *Supply chain management: An International Journal*. 2015;20(6): 664-80.

[2] Burritt R, Schaltegger S. Accounting towards sustainability in production and supply chains. *The British Accounting Review*. 2014;46(4): 327-43.

[3] Tajbakhsh A, Hassini E. A data envelopment analysis approach to evaluate sustainability in supply chain networks. *Journal of Cleaner Production*. 2015;105: 74-85.

[4] Hahn T, Pinkse J, Preuss L, Figge F. Tensions in corporate sustainability: Towards an integrative framework. *Journal of Business Ethics*. 2015;127(2): 297-316.

[5] Kusi-Sarpong S, Gupta H, Sarkis J. A supply chain sustainability innovation framework and evaluation methodology. *International Journal of Production Research*. 2019;57(7): 1990-2008.

[6] Maas K, Schaltegger S, Crutzen N. Integrating corporate sustainability assessment, management accounting, control, and reporting. *Journal of Cleaner Production*. 2016;136: 237-48.

[7] Jakhar SK. Performance evaluation and a flow allocation decision model for a sustainable supply chain of an apparel industry. *Journal of Cleaner Production*. 2015;87: 391-413.

[8] Tseng M-L, Lim MK, Wong W-P, Chen Y-C, Zhan Y. A framework for evaluating the performance of sustainable service supply chain management under uncertainty. *International Journal of Production Economics*. 2018;195: 359-72.

[9] Chardine-Baumann E, Botta-Genoulaz V. A framework for sustainable performance assessment of supply chain management practices. *Computers & Industrial Engineering*. 2014;76: 138-47.

[10] Erol I, Sencer S, Sari R. A new fuzzy multi-criteria framework for measuring sustainability performance of a supply chain. *Ecological Economics*. 2011;70(6): 1088-100.

[11] Schaltegger S, Burritt R, Varsei M, Soosay C, Fahimnia B, Sarkis J. Framing sustainability performance of supply chains with multidimensional indicators. *Supply Chain Management: An International Journal*. 2014;19(3): 242-257.

[12] Baskaran V, Nachiappan S, Rahman S. Indian textile suppliers' sustainability evaluation using the grey approach. *International Journal of Production Economics*. 2012;135(2): 647-58.

[13] Büyüközkan G, Çifçi G. A novel hybrid MCDM approach based on fuzzy DEMATEL, fuzzy ANP and fuzzy TOPSIS to evaluate green suppliers. *Expert Systems with Applications*. 2012;39(3): 3000-11.

[14] Kannan D, de Sousa Jabbour ABL, Jabbour CJC. Selecting green suppliers based on GSCM practices: Using fuzzy TOPSIS applied to a Brazilian electronics company. *European Journal of Operational Research*. 2014;233(2): 432-47.

[15] Kumar A, Jain V, Kumar S. A comprehensive environment friendly approach for supplier selection. *Omega*. 2014;42(1): 109-23.

[16] Shaw K, Shankar R, Yadav SS, Thakur LS. Supplier selection using fuzzy AHP and fuzzy multi-objective linear programming for developing low carbon supply chain. *Expert Systems with Applications*. 2012;39(9): 8182-92.

[17] Zeydan M, Çolpan C, Çobanoğlu C. A combined methodology for supplier selection and performance evaluation. *Expert Systems with Applications*. 2011;38(3): 2741-51.

[18] Benjaafar S, Li Y, Daskin M. Carbon footprint and the management of supply chains: Insights from simple models. *IEEE Transactions on Automation Science and Engineering*. 2012;10(1): 99-116.

[19] Carmona R, Fehr M, Hinz J, Porchet A. Market design for

emission trading schemes. *Siam Review.* 2010;52(3):403-52.

[20] Diabat A, Govindan K. An analysis of the drivers affecting the implementation of green supply chain management. *Resources, Conservation and Recycling.* 2011;55(6): 659-67.

[21] Gong X, Zhou SX. Optimal production planning with emissions trading. *Operations Research.* 2013;61(4): 908-24.

[22] Lee K-H, Saen RF. Measuring corporate sustainability management: A data envelopment analysis approach. *International Journal of Production Economics.* 2012;140(1): 219-26.

[23] Subramanian R, Subramanyam R. Key factors in the market for remanufactured products. *Manufacturing & Service Operations Management.* 2012;14(2): 315-26.

[24] Bank R, Murphy R. Warehousing Sustainability Standards Development. In: Prabhu V, Taisch M, Kiritsis D. (eds) *Proceedings of the IFIP International Conference on Advances in Production Management Systems, 9-12 Sep 2013, State College, PA, USA*. Springer; 2013. p. 294-301.

[25] Tan K-S, Daud Ahmed M, Sundaram D. Sustainable enterprise modelling and simulation in a warehousing context. *Business Process Management Journal.* 2010;16(5): 871-86.

[26] Rüdiger D, Schön A, Dobers K. Managing Greenhouse Gas Emissions from Warehousing and Transshipment with Environmental Performance Indicators. *Transportation Research Procedia.* 2016;14: 886-95.

[27] Żuchowski W. Division of environmentally sustainable solutions in warehouse management and example methods of their evaluation. *LogForum*. 2015;11(2).

[28] Fichtinger J, Ries JM, Grosse EH, Baker P. Assessing the environmental impact of integrated inventory and warehouse management. *International Journal of Production Economics*. 2015;170: 717-29.

[29] Amjed TW, Harrison NJ, editors. A Model for sustainable warehousing: From theory to best practices. *Proceedings of the International Decision Sciences Institute and Asia Pacific DSI Conference*; 2013.

[30] Chen X, Wang X, Kumar V, Kumar N. Low carbon warehouse management under cap-and-trade policy. *Journal of Cleaner Production.* 2016;139: 894-904.

[31] Bartolini M, Bottani E, Grosse EH. Green warehousing: Systematic literature review and bibliometric analysis. *Journal of Cleaner Production*. 2019;226: 242-58.

[32] Banaszewska A, Cruijssen F, Dullaert W, Gerdessen JC. A framework for measuring efficiency levels—The case of express depots. *International Journal of Production Economics*. 2012;139(2): 484-95.

[33] McKinnon A. Environmental sustainability. *Green logistics: Improving the environmental sustainability of logistics*. London; 2010.

[34] Ries JM, Grosse EH, Fichtinger J. Environmental impact of warehousing: A scenario analysis for the US. *International Journal of Production Research*. 2017;55(21): 6485-99.

[35] Staudt F, Di Mascolo M, Alpan G, Rodriguez CMT. Warehouse performance measurement: Classification and mathematical expressions of indicators. *ILS 2014 – 5th International Conference Information Systems, Logistics and Supply Chain, Aug 2014, Breda, Netherlands*; 2014.

[36] ISO 14000:2015. *Environment Management System - Requirements with guidance to use.* Geneva, Switzerland: ISO; 2015.

[37] ISO 14063:2006. *Environmental Management – Environmental communication – Guidelines and Examples*. Geneva, Switzerland: ISO; 2006.

[38] GRI 301: *Materials.* Amsterdam: Global Reporting Initiative; 2018. p. 10.

[39] GRI 302: *Energy.* Amsterdam: Global Reporting Initiative (GRI); 2018. p. 15.

[40] GRI 303: *Water and effluents.* Amsterdam: Global Reporting Initiative (GRI); 2018. p. 23.

[41] GRI 305: *Emissions.* Amsterdam: Stichting Global Reporting Initiative (GRI); 2018. p. 21.

[42] GRI 404: *Training and education.* Amsterdam: Global Reporting Initiative (GRI); 2016. p. 12.

[43] GRI 403: *Occupational health and safety*. Amsterdam: Global Reporting Initiative (GRI); 2018. p. 31.

[44] Sarkar P, Joung CB, Carrell J, Feng SC. Sustainable manufacturing indicator repository. *ASME Proceedings on 31st Computers and Information in Engineering Conference, 29-31 Aug 2011, Washington, DC*; 2011.

[45] Kibira D, Brundage MP, Feng S, Morris K. Procedure for selecting key performance indicators for sustainable manufacturing. *Journal of Manufacturing Science and Engineering*. 2018;140(1): 011005.

[46] Defra. *Environmental Key Performance Indicators: Reporting Guidelines for UK Business.* London: Department for Environment, Food and Rural Affairs; 2005. p. 76.

[47] GRI 306: *Effluents and waste*. Amsterdam: Global Reporting Initiative (GRI); 2016. p. 13.

[48] GRI 304: *Biodiversity*. Amsterdam: Global Reporting Initiative (GRI); 2016. p. 13.

[49] GRI 402: *Labor/Management relations.* Amsterdam: Global Reporting Initiative (GRI); 2016. p. 9.

[50] GRI 406: *Non-discrimination.* Amsterdam: Global Reporting Initiative (GRI); 2016. p. 8.

[51] GRI 413: *Local communities.* Amsterdam: Global Reporting Initiative (GRI); 2016. p. 13.

[52] Ishikawa A, Amagasa M, Shiga T, Tomizawa G, Tatsuta R, Mieno H. The max-min Delphi method and fuzzy Delphi method via fuzzy integration. *Fuzzy Sets and Systems.* 1993;55(3): 241-53.

[53] Wang M-L, Lin Y-H. To construct a monitoring mechanism of production loss by using Fuzzy Delphi method and fuzzy regression technique – A case study of IC package testing company. *Expert Systems with Applications*. 2008;35(3): 1156-65.

[54] Mlinarić TJ, Đorđević B, Krmac E. Evaluation Framework for Key Performance Indicators of Railway ITS. *Promet – Traffic&Transportation*. 2018;30(4): 491-500.

[55] Habibi A, Jahantigh FF, Sarafrazi A. Fuzzy Delphi technique for forecasting and screening items. *Asian Journal of Research in Business Economics and Management.* 2015;5(2): 130-43.

[56] Saffie NAM, Rasmani KA. Fuzzy delphi method: Issues

and challenges. *2016 International Conference on Logistics, Informatics and Service Sciences (LISS), 24-27 July 2016, Sidney, Australia.* IEEE; 2016.

[57] Abdi K, Talebpour M, Fullerton J, Ranjkesh MJ, Jabbari Nooghabi H. Converting sports diplomacy to diplomatic outcomes: Introducing a sports diplomacy model. *International Area Studies Review.* 2018;21(4): 365-81.

[58] Hsu Y-L, Lee C-H, Kreng VB. The application of Fuzzy Delphi Method and Fuzzy AHP in lubricant regenerative technology selection. *Expert Systems with Applications.* 2010;37(1): 419-25.

[59] Tuljak-Suban D, Bajec P. The Influence of Defuzzification Methods to Decision Support Systems Based on Fuzzy AHP with Scattered Comparison Matrix: Application to 3PLP Selection as a Case Study. *International Journal of Uncertainty, Fuzziness and Knowledge-Based Systems.* 2018;26(03): 475-91.

[60] Saaty TL. Decision making with the analytic hierarchy process. *International Journal of Services Sciences.* 2008;1(1): 83-98.

[61] Herman MW, Koczkodaj WW. A Monte Carlo Study of Parwise Comparison. *Inf Process Lett.* 1996;57(1): 25-9.

[62] Rezaei J. Best-worst multi-criteria decision-making method. *Omega*. 2015;53: 49-57.

[63] Beemsterboer DJC, Hendrix EMT, Claassen GDH. On solving the Best-Worst Method in multi-criteria decision-making. *IFAC-PapersOnLine.* 2018;51(11): 1660-5.

[64] Rezaei J. Best-worst multi-criteria decision-making method: Some properties and a linear model. *Omega.* 2016;64: 126-30.