Sustainability **2015**, *7*, 2113-2144; doi:10.3390/su7022113

OPEN ACCESS

sustainability

ISSN 2071-1050

www.mdpi.com/journal/sustainability

Article

Proposal of a Sustainability Index for the Automotive Industry

Miguel F. Salvado [1,†], Susana G. Azevedo [2,†,*], João C. O. Matias [1,†] and Luís M. Ferreira [3,†]

[1] Department of Electromechanical Engineering, University of Beira Interior, 6200-001 Covilhã, Portugal; E-Mails: miguelsalvado91@gmail.com (M.F.S.); matias@ubi.pt (J.C.O.M.)

[2] UNIDEMI, Department of Management and Economics, University of Beira Interior, 6200-001 Covilhã, Portugal

[3] GOVCOPP, Department of Economics, Management and Industrial Engineering (DEGEI), University of Aveiro, 3810-193 Aveiro, Portugal; E-Mail: lmferreira@ua.pt

† These authors contributed equally to this work.

* Author to whom correspondence should be addressed; E-Mail: sazevedo@ubi.pt; Tel.: +351-275-319-654; Fax: +351-275-329-183.

Academic Editor: Giuseppe Ioppolo

Received: 10 November 2014 / Accepted: 9 February 2015 / Published: 16 February 2015

Abstract: In a scenario of increasing globalization, sustainable development has emerged as an attractive and strategic issue for both countries and individual organizations and their supply chains. Companies have faced different challenges in seeking to combine the best economic performance with increased social and environmental responsibility. Monitoring sustainability is essential for decision-making and management of activities that comprise an organization's system processes. Evaluation can be performed using indices or a set of indicators. In addition to increasing organizational effectiveness and improving competitiveness, customer service and profitability, it is also a crucial influence on the development of business sustainability. This paper proposes a sustainability index that provides companies with information about their level of economic, social and environmental sustainability, showing their performance at both individual and supply chain level. The importance of the indicators is assessed by using the Analytic Hierarchy Process (AHP) methodology applied to a case study of a supply chain in the automotive industry. The various stages experienced during the construction of the index are also shown. The final results achieved are then presented and discussed in light of the objectives.

Keywords: development sustainability; sustainability index; AHP; supply chain management

1. Introduction

Sustainable development has been presented as critical for businesses and countries where they operate, contributing to the satisfaction of human needs and preserving the environment for present and future generations. Thus, monitoring the level of sustainability has become a crucial part of decision support in any management system. Policy makers from industry have paid increasing attention to the implementation of sustainable development of business activities due to fierce competition in the global market and rigorous environmental standards. Indicators of sustainable development are recognized as useful tools for assessing and anticipating production performance and trends, providing early warning information and helping avoid environmental, economic and social damage, but are especially useful in supporting decision making [1].

Organizations face new challenges, not only as they seek the best economic performance but also in their drive to be more environmentally and socially responsible. In other words, companies are changing from a pure economic business perspective to one including more sustainable development, adding more economic, social and environmental concerns to their business operations. The perspective of sustainability has evolved from an internal focus on the company to a global perspective of the supply chain [2].

Supply chain management is crucial not only in increasing organizational effectiveness, competitiveness, customer service, and profitability, but also in influencing sustainable business development. Companies must not only implement practices that promote the company and the efficiency of the global supply chain, but also those that focus on social, economic and environmental issues [1].

In this paper, a sustainability index is proposed to allow individual companies and their respective supply chains to gain information on their level of economic, social and environmental sustainability. Analytic Hierarchy Process (AHP) methodology is used to obtain the weights of the indicators and a case study is performed to illustrate the application of the suggested sustainability index in an automotive supply chain.

This paper begins with a theoretical framework in Section 2 which covers the different meanings attributed to the concept of sustainability. Then, different measurement tools for obtaining an index of sustainability are presented; the main tools related to corporate sustainability (indices of the Commission on Sustainable Development, the Global Reporting Initiative, the Dow Jones Sustainability Index, the triple bottom line and ETHOS and Ecoinvent indicators) are also described. Section 3 proposes a sustainability index that gives individual companies and their respective supply chains information about their level of economic, social and environmental sustainability. A working methodology to build the proposed index and consisting of five stages is suggested. Section 4 follows the stages associated with the construction of the proposed sustainability index using a case study, showing their results. Finally, a critical review and concluding remarks are drawn in the light of the results of the sustainability index and suggestions for improvements are made.

1.1. Concept of Sustainability

Today, there is much discussion about how we define sustainability. Critics argue that the concept cannot be "properly defined" [3]. According to Pinar *et al.* [4] sustainability is an elusive concept being very rare to find two identical descriptions of its different components. Sustainable development is a pattern of resource use that aims to meet human needs while preserving the environment so that these needs can be met not only in the present but also for future generations. The term was used by the World United Nations Commission on Environment and Development (WCED), which published "*Our Common Future"* (also known as the Brundtland Report) [5]. It was the Commission that made famous the definition of sustainable development as that which "meets the needs of the present without compromising the ability of future generations to meet their own needs". The report was inspired on the results of the United Nations Conference about the Human Environment (the Stockholm Conference), which had introduced environmental concerns into the development problem [6]. From a corporate perspective, the WCED [5] definition suggests not only a focus on the economic aspects of a business, but also a need to focus on the sustainability of natural resources companies and the companies they serve. This fundamental requirement was the starting point for developing concepts for the implementation of sustainability initiatives [7].

In other areas, the term "sustainability" has been defined in various disciplines, such as science and engineering, operations management and social sciences [8]. Bithas and Christofakis [9] and Fischer *et al.* [10] argue that there is no consensus on the operational content of environmentally sustainable development.

The three dimensions of sustainability (social, environmental and economic) are most enlightening when kept separate. Although there is some overlap between the three dimensions and some of their links, they have been addressed separately by different disciplines. Social scientists defend that social sustainability, and environmentalists have an important role in enhancing the sustainability area [11].

The approaches to the social dimension of sustainable development are diverse. As mentioned by Martin [12], a specific definition of the social dimension of sustainable development is less clear. The diversity of economic, social and cultural conditions of each country makes the development of a uniform definition of social sustainability very difficult [13].

In general, there has been a strong focus on defining sustainability as a condition, and on measuring it with a series of indicators. Social sustainability is a condition marked by the improvement of life in communities, and a process within communities that can achieve this condition [14].

The basic understanding of the term "environmental sustainability", established by Morelli [15], essentially expands our common perception of human activity. This makes the connection more clearly with the ecological concept of interdependence, thus delineating the limits of use of sustainability to match the overlap of human activities with ecosystem functioning support.

From this perspective, the needs of the present generation are met without compromising the ability of future generations to meet their needs means that the needs of resources and services for current and future generations are met without compromising the health of the ecosystems that provided them [5].

The success and competitiveness of a company in the long term is the basis of its economic dimension. In contrast to the social and environmental dimension, the economic dimension is primarily quantitative in nature, being focused on the efficient use of resources to achieve a return on investment [16].

The widely accepted definition of economic sustainability states that capital is preserved intact. It has been used by accountants since the Middle Ages to allow traders to understand how much of their sales revenue they and their families could consume. Thus, the modern definition of income is already sustainable [17].

1.2. Sustainability Index

The concept of sustainable development has been quite important for the responsible by making decisions in industry [1].

Delai and Takahashi [18] argue that the measurement of sustainability is a driver for the inclusion of sustainability as an important issue in decision-making and organization system process activity. The sustainability rating can be accomplished via an index or a set of indicators. The unit of measurement used for sustainability is not relevant, since its function is the same: helping to take responsible decisions to assess corporate performance in terms of sustainability, as well as providing information that will enable future planning.

Several tools and indices for measuring corporate sustainability have been proposed, namely: (i) Indicators of the Commission on Sustainable Development; (ii) Global Reporting Initiative; (iii) Dow Jones Sustainability Index; (iv) Triple Bottom Line (TBL); (v) ETHOS indicators; (vi) Ecoinvent 2000 and (vii) ISO 14031 indicators.

(i) The index of the Commission on Sustainable Development is a set of indicators for sustainable development suggested by the UN in 1995. The main goal was to become the indicators of sustainable development accessible to managers, explaining their methodologies [19]. It is a tool that follows Brundtland's concept of sustainable development and focuses on four dimensions of sustainability: social, environmental, economic and institutional (Table 1). Since its beginning, the primary objective of the Commission on Sustainable Development indicators has been to inform policy at national level. In addition to using indicators to assess global progress towards sustainable development, many countries successfully use them to measure success in their national sustainable development strategy. Beyond this purpose, there are other important factors for selecting the indicators of sustainable development.

Table 1. Framework of the Commission on Sustainable Development indicators.

Commission on Sustainable Development—Indicators			
Social	Environmental	Economic	Institutional
Equity	Atmosphere	Economic structure	Institutional framework
Health	Earth	Patterns of consumption and production	Institutional capacity
Education	Oceans, seas and coasts		
Habitation	Fresh-water		
Security	Biodiversity		
Population			

Source: adapted from Singh *et al.* [1].

(ii) Global Reporting Initiative (GRI). This is a volunteer board with information on the economic, environmental and social performance of an organization. Launched in 1997 by the Coalition for Environmentally Responsible Economies (CERES) and the United Nations Environment Programme (UNEP), it aims to provide assistance to businesses and their associates in understanding and communicating their contributions to sustainable development contributing by this way for improving the quality and usefulness of sustainability reports. The GRI focuses on the Triple Bottom Line concept, balancing the complex relationships between current economic, environmental and social needs, in order not to jeopardize the future [20]. Some of the indicators suggested by the GRI are present in Table 2.

Table 2. Structure of the Global Reporting Initiative indicators.

Global Reporting Initiative (GRI)				
Category	Economic		Environmental	
	Economic performance Presence in the market Indirect economic impact Practice of contracts		Materials Energy Water Biodiversity Emissions Effluents and waste Products and services Compliance Transport Global Environmental assessment of supplier Environmental complaint mechanisms	
Category	Social			
Sub-Category	Labor practices	Human rights	Society	Product Responsibility
	Labor management relations; Occupational safety and health; Training and education; Diversity and equal opportunities; Equal pay for men and women; Evaluation of supplier for labor practices; Labor practices complaint mechanisms	Investment; Non-discrimination; Freedom of association and collective bargaining; Child labor; Forced or compulsory labor -Safety practices -Indigenous rights -Evaluation -Human rights assessment of the supplier -Human rights complaint mechanisms	Local communities; Anti-corruption; Public policy; Anticompetitive behavior; Compliance; Supplier assessment for impact on society; Complaint mechanisms for impact on society	Customer health and safety; Products and labelling services; Marketing communications; Customer privacy; Compliance

Source: adapted from GRI [20].

(iii) The Dow Jones Sustainability Index (DJSI) is one of the most important sustainability indices. It was launched in 1999 to track the performance of the global index of the top 10 per cent of companies in the Dow Jones, leading in terms of corporate sustainability. According to this index, sustainability means creating long-term value for shareholders by embracing opportunities and managing risks deriving from economic, environmental and social developments (Table 3) [21]. Over time, regional indices have also been created. The Dow Jones STOXX Sustainability Index (DJSSI) for the sustainability leaders of Europe was created in 2001, the DJSI North America (DJSINA) was created in 2005 and the Sustainability Index Dow Jones Asia Pacific was established in early 2009. Performance of the company is easier controlled by assessing corporate sustainability, whose explicit goal is to measure and verify the performance of corporate sustainability in financial terms [22].

Table 3. Examples from the structure of the Dow Jones Sustainability Index (DJSI).

Dow Jones Sustainability Index (DJSI)		
Social	**Environmental**	**Economic**
-Contribution of health outcomes	-Biodiversity	-Brand management
-Human capital development	-Climate strategy	-Risk and crisis management
-Practical work indicator	-Environmental footprint	
-Contentious issues	-Environmental reports	-Marketing practices

Source: adapted from DJSI [22].

(iv) The Triple Bottom Line (TBL/3BL) is an aggregated index to assess the sustainability performance of companies (Table 4). Sustainability is the balance between financial growth and ethics and fairness [23]. Sustainability should cover TBL/3BL, which considers environmental quality, economic prosperity and social justice [24,25].

Table 4. Examples of Triple Bottom Line (TBL) indicators.

Indicators of TBL		
Social	**Environmental**	**Economic**
Unemployment rate	Concentration of sulfur dioxide	Personal income
Female labor participation rate	Selected priority pollutants	Cost of underemployment
Average household income	Excess nutrients	
Percentage of the population with a post-secondary degree or certificate	Electricity consumption	Size of establishment
Average time of journey	Fossil fuel consumption	Employment growth
Violent crimes per capita	Solid waste management	Distribution of employment by sector
Health-adjusted life expectancy	Hazardous waste management	Percentage of firms in each sector
	Concentration of nitrogen oxides	Revenue per sector contributing to gross state product

Source: adapted from Slaper and Hall [26].

(v) ETHOS indicators of social responsibility were launched in 2002, introducing a set of indicators designed to help Brazilian companies learn and evaluate company management, with respect to business practices, social responsibility, business strategy and monitoring the overall performance of the company (Table 5) [27]. This guide to self-assessment and reporting focuses primarily on the social aspects of sustainability and considers Corporate Social Responsibility as a way of management while addressing competitiveness, sustainability and the needs of society [18].

Table 5. ETHOS indicators.

ETHOS Indicators			
Social	**Environmental**	**Economic**	**Vision and strategy**
Human rights	Climate change	Organizational governance	Strategies for sustainability
Work practices	Management and monitoring of impact on ecosystem services and biodiversity	Operation and management practices	Value proposition—Business model
Consumer issues	Impact of consumption		
Community outreach and development			

Source: Adapted from ETHOS [26].

The current generation of ETHOS indicators, presents a new approach to the management of companies and seeks to integrate the principles and behaviors of corporate social responsibility and environmental concerns into the traditional vision of sustainability focusing mainly on the economic dimension (Figure 1). They are based on the concept of sustainable and responsible business which still in development. In addition, ETHOS indicators are designed to integrate the guidelines on the GRI sustainability reporting, the ISO 26000 Standard Social Responsibility standards and other initiatives.

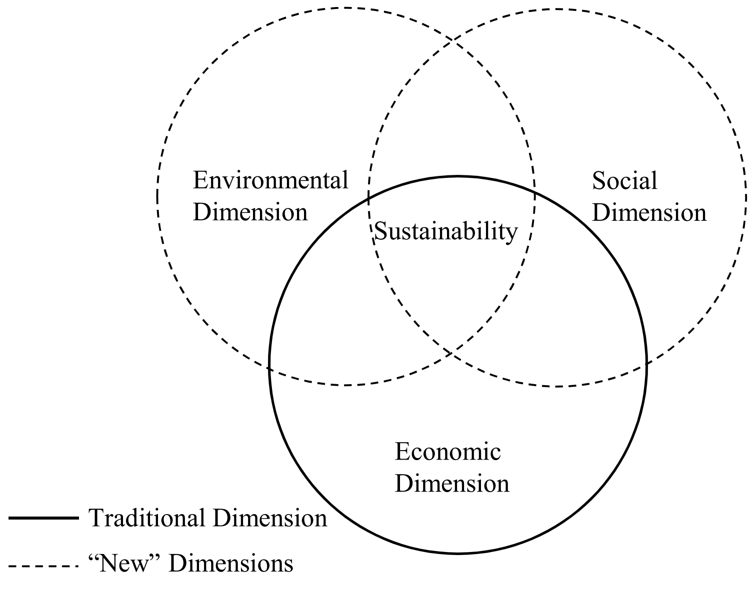

Figure 1. Sustainability Dimensions. (Source: adapted from Winter and Knemeyer [7].)

(vi) In late 2000, the Ecoinvent 2000 project was officially launched. Several Swiss federal offices and research institutes of the ETH (Eidgenössische Technische Hochschule/Federal) Institute of Technology agreed on a set of efforts to harmonize and update inventory life cycle data, based on life cycle inventory (LCI) for use with life cycle assessment (LCA) [28]. There are several thousands of

LCI datasets in the areas of agriculture, energy, transport, biofuels, biomaterials, construction and packaging materials, base and precious metals and metals processing supply as well as waste treatment. The databases aim to support and improve the environmental performance of different products, processes and services from different organizations.

The Ecoinvent establishes and provides a scientific evaluation of LCA and Life Cycle Management (LCM) data and services for the industry, consultants, public authorities and research institutions [29].

(vii) ISO 14031 indicators cover environmental management, environmental performance and evaluation guidelines. The standards laid down by ISO 14031 provide guidance on the design and use of environmental performance evaluation for an organization. It is applicable to all organizations, regardless of type, size, location and complexity. Many organizations found ways to understand, demonstrate and improve their environmental performance.

Environmental performance evaluation is the theme of this international standard. This is an internal management system, providing reliable and verifiable information on an ongoing basis to determine whether an organization's environmental performance is meeting the criteria established by the organization's management.

This international standard describes two broad categories of indicators for environmental performance evaluation (Table 6): environmental performance indicators and environmental conditions indicators.

Table 6. ISO 14031 indicators.

ISO 14031 Indicators	
Environmental Performance Indicators	**Environmental Condition Indicators**
Performance management indicators; Provides information about management efforts in order to influence the environmental performance of the organization's operations.	Provides information about the state of the environment, which may be affected by the organization.
Operational performance indicators; Provides information about the environmental performance of the organization's operations	

Source: adapted from ISO 14031:2013 [30].

2. Proposal of a Sustainability Index

This section proposes a sustainability index that provides companies with information about their level of economic, social and environmental sustainability, both for the individual company's operations and for the supply chain. Thus, it is possible to identify priority areas for action and changes to behavior that can contribute to improve sustainability and competitiveness. It is important to note that the proposal of a sustainability index represents an economic opportunity for companies and corresponding supply chains to improve their competitive advantage since it contributes for enhancing companies image, reputation and revenues gained [31,32]. Knowing that, the assessment of a sustainability index can be an important driver in integrating sustainability into the core business practices of companies and to view the subject as an essential long-term performance factor on radar of investors [33].

In this regard, the Figure 2 is proposed to illustrate a framework composed by five stages.

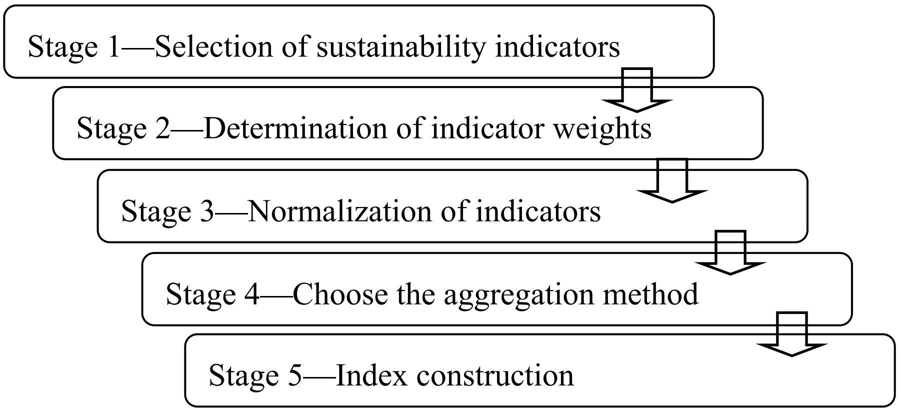

Figure 2. Stages to build the sustainability index.

The following is a brief explanation of each stage.

2.1. Stage 1—Selection of Sustainability Indicators

The lack of a coherent framework linking what it is to be sustained to specific measurable variables is a critical barrier to better understanding progress toward sustainability Indicators perform various functions which may lead to better decisions and more effective actions to simplify, clarify and make aggregation more accessible. They can help not only to incorporate knowledge on physics and social science in decision-making [34,35], but also can help to measure and calibrate progress towards the goals of sustainable development. They may also prevent economic, social and environmental setbacks and are useful tools for communicating ideas, thoughts and values [19].

Another issue challenging sustainability measurement is the lack of consensus on sustainability indicators [23,36,37]. The inability of existing frameworks to guide selection of indicators has been recognized by several authors [38–40].

The selection of appropriate criteria and indicators of sustainability and sustainable development is a technical and normative decision since the search for indicators is guided more by what can be measured (a technical issue) than by what should be measured (a normative issue) [41].

Some tailored sustainability indicator sets have been developed [42–46], however only few have an integrative focus measuring environmental, economic and social dimensions [42,46,47]. Also, some sets of sustainability indicators do not address some key issues related to air, water quality biodiversity and their impacts on whole value chain. Moreover, some indicators focus on management practices (means) not on its results (ends) [41].

Furthermore, from the point of view of Martin [12] and Dowse [48] sustainability measures and reports, in most cases, have little relevance to the daily realities of business. Bearing in mind this, a different set of sustainability indicators is suggested in this work (Table 7) attending to the following methodology/criteria: (1) the Triple Bottom Line (TBL) is adopted balancing the relationships between economic, environmental, and social needs; (2) the social and economic indicators are selected having as reference the version G4 of the Global Reporting Initiative (GRI); (3) the environmental indicators are selected from the proposed operational indicators of the ISO 14031; and (4) a set of mandatory characteristics of the selected indicators was followed (objectives, understandable, worktables and measurable indicators).

Table 7. Sustainability indicators proposed.

Dimension of Sustainability	Sustainability Indicators	Source	$I_{i,j}^{\varepsilon}$	Unit of Measure
Social G4—LA2	Number of accidents per year by organization	G4-LA6 Accident rate (TA)	$Acid_i^-$ The lower the better	Quantity
	Loss of productivity by organization *i*	G4—LA7	$Prodlost_i^-$ The lower the best (−)	%
	% contracted women by the organization *i*	G4—LA12 Composition of governance bodies and breakdown of employees per employee category according to gender, age, and other indicators of diversity	Wom_i^+ The bigger the better (+)	%
	% temporary workers by organization *i*	G4—LA4	$TempW_i^-$ The lower the better (−)	%
	Absenteeism rate by organization *i*	G4—LA6 Type of injury and injury rates, diseases, lost days, absenteeism and work-related deaths	$Abst_i^-$ The lower the better (−)	%
	Rotation of workers by organization *i*	G4—LA1 Total number and rate of new employee hires and employee turnover	$TurnOv_i^-$ The lower the better (−)	Quantity
	% people with special needs by organization *i*	G4—LA12	$Peopesp_i^+$ The higher the better (+)	%
Economic	Direct economic value generated and distributed	G4—EC1 (operating costs + salaries and employee benefits + payment to suppliers of capital)		€
	R&D expenditures	Keeble *et al.* [49], Seuring *et al.* [50], Welford *et al.* [51]		€
	Number of persons employed	Szekely and Knirsch [52]		Quantity
Environmental	Rate of non-hazardous waste	ISO 14031	$ResND_i^+$ The higher the better (+)	%
	Rate of hazardous waste	ISO 14031	$ResD_i^-$ The lower the better (−)	%
	Amount of water consumed per year in industrial processes	ISO 14031	Wat_i^- The lower the better (−)	m^3
	Amount of energy used per year	G4—EN3 Power consumption within the organization ISO 14031	$Energ_i^-$ The lower the better (−)	kW/h

2.2. Stage 2—Determination of Indicator Weights

The relative importance of indicators becomes a source of contention when companies' decision makers have different point of views and are interested in different indicators. However, the weights of the indicators can be computed through statistical models, or from participatory methods and conjoint analysis [53]. In this case, the participatory method is proposed, more specifically the Analytic Hierarchy Process (AHP).

AHP is one of the techniques that assists decision makers in solving complex problems by organizing thoughts, experiences, knowledge and judgment in a hierarchical structure and guiding them through a sequence of paired comparison judgments [54]. The AHP method has been widely used to incorporate the qualitative and quantitative considerations of human perception [55].

AHP methodology is capable of converting human perception into a numerical value of importance. Basically, AHP involves comparing pairs to a number of different criteria after dividing the criteria into a hierarchy of multiple levels [56]. These factors will be compared to each other in a matrix, as shown in Table 8.

Table 8. Pairwise comparisons of the Analytic Hierarchy Process (AHP)

	A	**B**	**C**	**D**
A	1	X_{12}	X_{13}	$1/X_{14}$
B	$1/X_{12}$	1	X_{23}	X_{24}
C	$1/X_{13}$	$1/X_{23}$	1	$1/X_{34}$
D	X_{14}	$1/X_{24}$	X_{34}	1

A, B, C and D are the factors and X_{12}, X_{13} and X_{14} are compared to the value of the pairs AB, AC and DC, respectively. The value is obtained from a basic range of absolute numbers in order to capture human perceptions regarding qualitative and quantitative attributes.

After all the matrices are formed, the relative weights and the maximum eigenvalue (λ_{max}) for each matrix are calculated. The λ_{max} value is used to calculate the consistency (CR) ratio of the estimated vector in order to validate the array of paired comparison. The CR is calculated according to the following steps:

(1)—Calculate the relative weights and λ_{max} for each matrix of order n

(2)—Calculate the consistency index (CI) for each matrix of order n, using the formula (1);

$$[CI = \frac{\lambda\max - \mathrm{n}}{\mathrm{n} - 1}] \tag{1}$$

(3)—CR is then calculated using the formula (2)

$$[CR = \frac{CI}{RI}] \tag{2}$$

where the random consistency index (RI) varies depending on the order of the matrix [52].

Theoretically the importance of each indicator should be equal for all companies belonging to the same supply chain. This assumption makes possible performing benchmarking analysis and guarantees that all the companies belonging to the same supply chain are using the same instrument to assess their level of sustainability. To assure that the suggested weights for each indicator reflect the reality of the automotive industry, the AHP technique with a panel of academics and professionals from different tiers of the automotive supply chain is suggested. It is also important to note that the same instrument should be used to calculate the sustainability index among suppliers belonging to the same tier of the automotive supply chain otherwise it is not possible to make comparisons between them.

2.3. Stage 3—Normalization of the Indicators

Normalization is necessary since the indicators are usually expressed in different units [53]. In this case, the Min-Max method is used for the normalization of indicators. According to this method, each indicator with a positive impact on the sustainability ($I^{+}_{i,j}$) is normalized using the following Equation (3):

$$I^{+}_{Ni,j} = \frac{I^{+}_{i,j} - I^{+MIN}_{i,j}}{I^{+MAX}_{i,j} - I^{+MIN}_{i,j}} \quad (3)$$

where: $I^{+}_{Ni,j}$—is the normalized indicator *i* for the dimension of sustainability *j* with positive impact on sustainability;

$I^{+}_{i,j}$ —represents the indicator *i* for the dimension of sustainability *j* with positive impact on sustainability;

$I^{+MIN}_{i,j}$—represents the lowest value of the indicator *i* for the dimension of sustainability *j* with positive impact on sustainability. That is $I^{+MIN}_{i,j} = \min I^{+}_{i,j}$

$I^{+MAX}_{i,j}$—represents the highest value of the indicator *i* for the dimension of sustainability *j* with positive impact on sustainability. That is $I^{+MAX}_{i,j} = \max I^{+}_{i,j}$

Normalization of indicators with negative impact on sustainability is calculated using the following Equation (4):

$$I^{-}_{Ni,j} = \frac{I^{-}_{i,j} - I^{-MIN}_{i,j}}{I^{-MAX}_{i,j} - I^{-MIN}_{i,j}} \quad (4)$$

where: $I^{-}_{Ni,j}$—is the normalized indicator *i* for the dimension of sustainability *j* with negative impact on sustainability;

$I^{-}_{i,j}$ —represents the indicator *i* for the dimension of sustainability *j* with negative impact on sustainability;

$I^{-MIN}_{i,j}$—represents the lowest value of the indicator *i* for the dimension of sustainability *j* with negative impact on sustainability.

$I^{-MAX}_{i,j}$—represents the highest value of the indicator *i* for the dimension of sustainability *j* with negative impact on sustainability.

2.4. Stage 4—Choose the Aggregation Method

In this case, the aggregation method selected is the additive weighting method. Nardo *et al.* [57] report that in the linear additive aggregation method the indicators must have the same unit of measurement, which implies that poor performance in some indicators can be compensated by high values of other indicators. Zhou *et al.* [58] report that the transparency and ease of understanding of the additive weighting method has been justified by its wide use by non-specialists. Since the additive weighting method is a linear model, it is only applicable if independence exists between the variables. However, if the assumption of independence between variables is not breached, the additive weighting method would give results very close to the optimal value function [59]. In this situation, Nardo *et al.* [57] argue that the model could be applied, but the resulting aggregate indicator may be biased.

The proposed model for evaluating the behavior of the supply chain in terms of the I_{C_SUSTJ} model can be used by supply chain managers, taking into account that:

- The set of economic, social and environmental practices should reflect the type of supply chain
- The weight of the practice and paradigms must be obtained through AHP
- The independence of the variables must be checked for the aggregated additive weighting index to be correctly interpreted.

2.5. Stage 5—Index Construction

Figure 3 shows the three sub-indices proposed for the economic (I_{i1}), social (I_{i2}) and environmental (I_{i3}) dimensions, represented respectively by economic indicators ($I^E_{1,1} \ldots I^E_{i,1}$), social indicators ($I^S_{1,2} \ldots I^S_{i,2}$) and environmental indicators ($I^A_{1,3} \ldots I^A_{i,3}$).

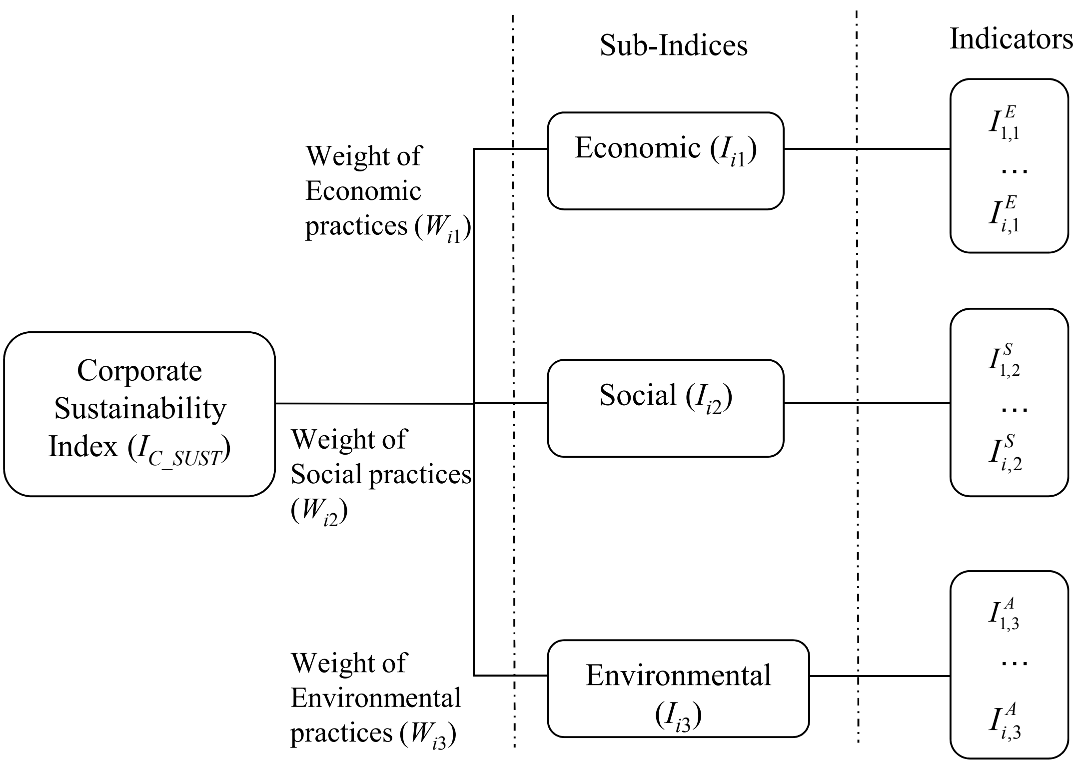

Figure 3. Hierarchical scheme for computing the corporate sustainability Index.

For each company *j* sub-indices (I_s) may be aggregated with the corresponding indicator according to the following Equation (5):

$$(I_S)j = f\left[W_{i1} \times \left(I_{i1}\right)j, \ldots W_{iy-1} \times \left(I_{iy-1}\right)j, W_{iy} \times \left(I_{iy}\right)j \right] \tag{5}$$

where:

$(I_s)j$—is the behavior of company *j* according to the sustainability dimension *s*;

$(I_{is})j$—is the value of the indicator *i* associated to the dimension of sustainability *s* for company *j*; *y* represents the indicators considered for each model;

(W_{is}) is the weight of the indicator *i* for the sub-index associated to the dimension of sustainability *s*.

As stated above in Section 2.2, the importance of each indicator should be equal for all companies belonging to the same supply chain. The total sustainability index for each company is given by the Equation (6).

$$I_{C\_SUSTj} = f\left[W_{i1}\, x\left(I_{i1}\right)j, W_{i2}\, x\left(I_{i2}\right)j, W_{i3}\, x\left(I_{i3}\right)j\right] \tag{6}$$

where: $(I_s)j$ denotes the behavior of dimension *s* (associated to each sub-index) for each company *j* and W_{i1}, W_{i2}, W_{i3} are the weights for each considered sub-index. The I_{C_SUSTj} assumes values between 0 (not sustainable) to 1 (extremely sustainable).

After establishing the index for each company, it is also possible to achieve the same result for the supply chain but using information from all companies belonging to it. Using the supply chain as the unit of analysis, the sustainability index for the supply chain can be computed through the following equation:

$$SCI_s = \frac{\sum_{j=1}^{n} (Ii)j}{n} \tag{7}$$

In Equation (7), *n* represents the number of companies that make up a certain supply chain, while $(I_s)_j$ is the behavior of company *j* in terms of sub-indices I_1, I_2 and I_3.

Finally, the use of this index for a particular supply chain (I_{C_SUSTSC}) is a function of the indicators of sustainability for each weighted sub-indices (Equation (8)).

$$I_{C\_SUSTSC} = f\left(W_{i1} \times SCI_{i1}, W_{i2} \times SCI_{i2}, W_{i3} \times SCI_{i3}\right) \tag{8}$$

The various items SCI_{si} indicate the behavior of the supply chain in accordance with sub-indices; W_{si} corresponds to the weight of each sub-index (environmental, economic and social). These contributions symbolize the importance of each sub-index/behavior to the s of the supply chain.

3. Determination of Sustainability: Case Study

Since the main goal of this research involves the application of a sustainability index, a case study of a supply chain in the SC AUTO group, was chosen. The research company belongs to the automotive industry but because of confidentiality reasons its real name will be omitted and will be named as "AUTO". The company was selected attending to the following factors: (i) its relevance for the Portuguese automotive industry; (ii) It is a membership of a large automotive group; (iii) it is recognized in the Portuguese industry as a reference in subjects related to sustainability; (iv) it is strongly interested in developing an instrument to support the assessment of the sustainability level of its supply chain; (v) willingness to collaborate with this research; and (iv) its geographical proximity to ensure the right conditions for the research team. The case study selection was made on the basis of "planned opportunism", which is to say there was an anticipation of gaining access to secondary data [60]. Case selection is often opportunistic, given that it is frequently difficult to find suitable case studies that allow insight into the research topic, and those that can be pursued often emerge from existing contacts a researcher has with an industry [61].

The analysis focuses on the upstream supply chain, specifically on their suppliers. Being so, a database of 146 active suppliers with whom the company works directly was provided. Of those, only 46 will be included in the research sample, since only these provided data on the sustainability indicators studied in this work, allowing the application of the sustainability index. To gauge the importance of sustainability indicators, a survey was performed using the AHP methodology.

In this context, this research intends to verify the contribution of the economic, environmental and social sustainability dimensions for the overall sustainability of the automotive supply chain. Then, this research intends to investigate the importance of the different indicators with respect to social, economic and environmental dimensions, evaluating each measure of sustainability in the automotive supply chain.

3.1. Profile of Case-Study Companies

Given the research design the SC AUTO group was chosen as an example of a supply chain in the European automotive industry. The company is a multinational conglomerate located in various countries, representative of major automotive markets. Overall, their production and development relies on electronic and mechanical locking systems, authorization systems, passive entry systems, vehicle access systems, door systems and handling systems for airbags and the rear of vehicles. The company has a relevant international market share and is the global leader in this segment.

The research company has approximately 350 employees, and applies locksets and mounts latches to steering columns using modern technology and a network of domestic partnerships. The company focuses its upstream supply chain specifically on its providers. From the 146 active suppliers 46 are included in this study for the application of the suggested sustainability index.

This study comprises companies producing components for the automotive industry (Table 9). Table 9 summarizes the profile of the research companies according to the main product produced and the standards and certificates. For confidentiality reasons a fictitious name was assigned to them.

Table 9. Companies profile.

	Main Product Produced	**Standards/Certifications**
company 1	Parts for the automobile industry	ISO 9001, ISO 14001
company 2	n.a.	ISO 9001
company 3	Tapes	ISO 9001
company 4	Panels and handles	ISO 9001, ISO/TS 16949
company 5	Stamping parts and carbon steel	ISO 9001, ISO/TS 16949
company 6	n.a.	ISO 9001
company 7	Compression springs, extension and torsion	ISO 9001, ISO/TS 16949, ISO 14001
company 8	n.a.	ISO 9001, ISO/TS 16949, ISO 14001
company 9	Wiring	ISO 9001, ISO/TS 16949, ISO 14001
company 10	Plastic parts	ISO 9001, ISO/TS 16949, ISO 14001

Table 9. *Cont.*

	Main Product Produced	Standards/Certifications
company 11	Rotary light switches	ISO 9001, ISO/TS 16949, ISO 14001
company 12	n.a.	ISO 9001
company 13	Parts for the automotive industry	ISO 9001, ISO/TS 16949
company 14	Keys	ISO 9001
company 15	Plastic parts	ISO 9001, ISO/TS 16949
company 16	Connections/accessories	ISO/TS 16949
company 17	Electronic components	ISO 9001, ISO/TS 16949, ISO 14001
company 18	Parts for braking systems and safety	ISO 9001, ISO/TS 16949, ISO 14001
company 19	Transformation components	ISO 9001, ISO/TS 16949
company 20	Compression springs	ISO 9001
company 21	n.a.	ISO 9001, ISO/TS 16949, ISO 14001, OHSAS 18001
company 22	n.a.	ISO 9001, ISO/TS 16949, ISO 14001
company 23	Springs	ISO 9001, ISO 14001
company 24	Several devices/batteries	ISO 9001, ISO 14001
company 25	Dyeing	ISO 9001, ISO 14001
company 26	n.a.	ISO 9001
company 27	n.a.	ISO/TS 16949, ISO 14001
company 28	Casting	ISO/TS 16949
company 29	Lubricants for engines	ISO 9001, ISO 14001
company 30	Dyeing	ISO 9001, ISO 14001
company 31	Grilles, radiators	ISO 9001, ISO/TS 16949, ISO 14001
company 32	Plastic bags	
company 33	Sealants	ISO 9001
company 34	Covers for motor cars	ISO/TS 16949, ISO 14001
company 35	n.a.	ISO 9001, ISO/TS 16949, ISO 14001, OHSAS 18001
company 36	n.a.	ISO/TS 16949, ISO 14001
company 37	Integrated circuits	ISO 9001, ISO/TS 16949, ISO 14001, OHSAS 18001
company 38	Metal products	EC-1624/04
company 39	n.a.	ISO 9001
company 40	Keys	ISO 9001, ISO 14001
company 41	Paper labels	ISO 9001
company 42	Moving parts	ISO 9001, ISO/TS 16949
company 43	Plastic injection components	ISO 9001, ISO/TS 16949
company 44	Casting	ISO 9001, ISO/TS 16949
company 45	Casting	ISO/TS 16949
company 46	Fineblanking	ISO 9001, ISO/TS 16949

Note: n.a. = there is no information.

According to Table 9, almost all companies work to produce parts for the automotive industry, such as compression springs, plastic parts and dyeing the electronic components. Regarding the standards and certificates, it appears that the ISO 9001 and the Quality Management Systems are used by almost all companies.

Other standards that exist in some companies are ISO 14001, Environmental Management Systems and ISO/TS 16946 (this is a specification for meeting the requirements of car manufacturers, especially quality, cost and delivery just in time (JIT)) and OHSAS 18001 Safety and Health Management Systems at Work.

The relationship between members of an automobile supply chain is unique. The automakers have great flexibility because they have full control of the manufacturing cycle (from product design to assembly, through the supply of parts) and, in some situations, the processes of supplying. Although the substantial supply of parts and components to original equipment manufacturers is primarily ensured by direct suppliers, their range is limited and the same supply can be extended to second-level suppliers, and the purchase of materials and elements by the first level can only be made through approved/certified suppliers [60].

3.2. Application of the Framework for Building a Sustainability Index

To determine the sustainability index, the five stages previously defined in Section 3 are applied.

3.2.1. Stage 1—Selection of Sustainability Indicators

In this first stage, the aim is to select indicators for further evaluation; as such, it is also necessary to take into account the unit of measure. The indicators used in this case study and the corresponding unit of measures are the ones previously defined in Table 7.

3.2.2. Stage 2—Determination of Indicator Weights

The AHP (Analytic Hierarchy Process) methodology is an intuitive tool for formulating and analyzing decisions. Applying AHP contributes to provide solutions to specific types of problems involving the prioritization of potential alternative options by making pair-wise comparisons of a set of elements. This formula has already been applied to a number of decision-making issues, in particular issues related to the automotive sector [62]. The weights were determined through a meeting that one of the researchers had with the purchasing and environmental manager of the company. The pair-wise comparisons inherent to the AHP application was performed as a team exercise and the final decision was reached by consensus [63–65]. The three academics also answered the questionnaire but only with the purpose of testing it. It was possible to produce a coherent and consistent table (Table 10) besides the small sample, since it only serves to illustrate the application.

Analyzing the results of Table 10, it can be seen that to the economic dimension (I_1) is given greatest importance with a weight of 66%, while the social dimension was considered least important at 13%. For the social dimension indicators, the number of accidents per year ($I_{1,2}^{S}$) was seen as the most important with a weight of 33%, while the percentage of women employed ($I_{2,2}^{S}$) was considered least important at 5%. For the economic dimension, the "direct economic value generated and distributed" ($I_{1,1}^{E}$) was rated as the most important indicator with a weight of 72%, while the number of persons employed ($I_{3,1}^{E}$) was considered the least important with a weight of 12%. Finally, the evaluation indicators for the environmental dimension ranked the rate of hazardous waste ($I_{2,3}^{A}$) with the greatest importance at 38% and the quantity of water consumed per year in industrial processes ($I^{A}_{3,3}$) was considered the least important at 16%.

Table 10. Determination of weights for the three dimensions of sustainability.

Variables	**Statistics**	
AHP model	Ranking	Weight
I_1 Economic	1	0.66
I_3 Environmental	2	0.21
I_2 Social	3	0.13
Number (*n*)	3	
Average ratings (total)	3.67	
Eigenvalue (λ)—average value	3.11	
Consistency ratio (CR)—average value	0.12	
α—average value	0.1	
Social	Ranking	Weight
$I^{S}_{1,2}$ Number of accidents per year	2	0.33
$I^{S}_{2,2}$ % women contractors	6	0.05
$I^{S}_{3,2}$ % temporary workers	4	0.09
$I^{S}_{4,2}$ Rate of absenteeism	3	0.11
$I^{S}_{5,2}$ Rotation of workers	3	0.10
$I^{S}_{6,2}$ % people with special needs	2	0.32
Number (*n*)	6	
Average ratings (total)	2.7	
Eigenvalue (λ)—average value	7.55	
Consistency ratio (CR)—average value	0.25	
α—average value	0.1	
Economic	Ranking	Weight
$I^{E}_{1,1}$ Direct economic value generated and distributed	1	0.72
$I^{E}_{2,1}$ R & D expenditures	2	0.16
$I^{E}_{3,1}$ Number of persons employed	3	0.12
Number (*n*)	3	
Average ratings (total)	5.72	
Eigenvalue (λ)—average value	3.39	
Consistency Ratio (CR)—average value	0.42	
α—average value	0.1	
Environmental	Ranking	Weight
$I^{A}_{1,3}$ Rate of non-hazardous waste	2	0.26
$I^{A}_{2,3}$ Rate of hazardous waste	2	0.38
$I^{A}_{3,3}$ Quantity of water consumed per year in industrial processes	3	0.16
$I^{A}_{4,3}$ Amount of energy used per year	3	0.20
Number (*n*)	4	

Table 10. *Cont.*

Variables	**Statistics**	
Environmental	Ranking	Weight
Average ratings (total)	2.97	
Eigenvalue (λ)—average value	4.50	
Consistency ratio (CR)—average value	0.18	
α—average value	0.1	

3.2.3. Stage 3—Normalization of the Indicators

Since the indicators are expressed in different units, normalization is necessary (Equation (3)). This makes possible to integrate the selected indicators into an aggregated index for sustainability assessment.

Using the Excel spreadsheet it was possible to obtain the normalized indicators. Normalization of the indicators for economic dimension was not included due to lack of data from the SC AUTO. In Table 11 the normalized indicators of social and environmental dimensions are present using Equation (3).

Table 11. Normalization of indicators.

	Social						**Environmental**			**Economic**
	$I^+_{N1,2}$	$I^+_{N2,2}$	$I^+_{N3,2}$	$I^+_{N4,2}$	$I^+_{N5,2}$	$I^+_{N6,2}$	$I^+_{N1,3}$	$I^+_{N2,3}$	$I^+_{N3,3}$	$I^+_{N,1}$
company 1	n.a.	0.250	0	0.470	0.017	1	n.a.	n.a.	n.a.	n.a.
company 2	0	0.625	0.046	0	0	0	n.a.	n.a.	n.a.	n.a.
company 3	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	0	1	n.a.	n.a.
company 4	0.286	0.594	0.275	0.626	1	0.299	0.147	0.853	0.0003	n.a.
company 5	0.071	0.050	0.435	0.336	0.012	0.299	0.029	0.971	0.0001	n.a.
company 6	0	0.515	0	0	0.006	0.878	0	1	n.a.	n.a.
company 7	n.a.	0.375	0.343	0.418	n.a.	n.a.	0.044	0.956	0.0005	n.a.
company 8	0.095	0.834	0.975	0.196	0.001	0	n.a.	0.943	n.a.	n.a.
company 9	0.881	0.359	0.261	0.835	0.339	0.111	0.030	0.957	0.0007	n.a.
company 10	0.047	0.550	0.046	0.311	0.062	0.299	0.039	0.962	0.0003	n.a.
company 11	1	0.938	0.229	0.802	n.a.	n.a.	0.029	0.971	0.0011	n.a.
company 12	0	0.625	0.046	0	0	0	n.a.	n.a.	n.a.	n.a.
company 13	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
company 14	0.476	n.a.	n.a.	n.a.	n.a.	n.a.	0.368	0.632	0.0076	n.a.
company 15	0.024	0.600	0.114	0.104	0.006	0.149	n.a.	n.a.	n.a.	n.a.
company 16	n.a.	n.a.	0	n.a.	n.a.	n.a.	n.a.	n.a.	0.0312	n.a.
company 17	0.138	n.a.	0.458	n.a.	n.a.	n.a.	0.051	0.949	8.55×10^{-5}	n.a.
company 18	0.095	0.250	0.229	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
company 19	0.143	0.313	1	0.104	0.017	0.448	0.001	0.999	n.a.	n.a.
company 20	0.024	0.500	0	0.522	0.056	0.597	0	1	0	n.a.
company 21	0	0.163	0.080	0.460	n.a.	n.a.	0.001	0.997	0.0052	n.a.
company 22	0	0.315	n.a.	0.157	0.020	n.a.	0	1	0.9999	n.a.
company 23	0	0	n.a.	0.052	0	0	0.003	0.997	n.a.	n.a.
company 24	0.214	0.354	0.465	0.418	0.014	n.a.	n.a.	n.a.	n.a.	n.a.
company 25	n.a.	n.a.	0.229	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.

Table 11. *Cont.*

	Social						Environmental			Economic
	$I^{+}_{N1,2}$	$I^{+}_{N2,2}$	$I^{+}_{N3,2}$	$I^{+}_{N4,2}$	$I^{+}_{N5,2}$	$I^{+}_{N6,2}$	$I^{+}_{N1,3}$	$I^{+}_{N2,3}$	$I^{+}_{N3,3}$	$I^{+}_{N,1}$
company 26	0	1	0	n.a.	n.a.	0	n.a.	n.a.	n.a.	n.a.
company 27	0.167	0.384	n.a.	0.552	0.013	n.a.	n.a.	n.a.	n.a.	n.a.
company 28	0.095	0.386	0.069	0.376	0.038	0.746	0.191	0.809	0.0002	n.a.
company 29	0.167	0.250	n.a.	n.a.	n.a.	0.299	0.853	0.147	0.0002	n.a.
company 30	n.a.	n.a.	0	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
company 31	n.a.	0.434	0.053	0.470	n.a.	n.a.	0.978	0.022	n.a.	n.a.
company 32	0	n.a.	0.297	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
company 33	0	0.325	n.a.	n.a.	0	0.149	n.a.	n.a.	n.a.	n.a.
company 34	0.286	0.469	0.664	0.337	n.a.	0	0	1	0.0019	n.a.
company 35	0.452	0.600	0.229	0.416	0.040	0.001	0.006	0.994	0.0006	n.a.
company 36	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	0.082	0.932	n.a.	n.a.
company 37	0.119	0.913	0.664	0.908	0.015	0	0.001	0.999	0.0346	n.a.
company 38	0.048	0.150	0.229	0.240	n.a.	0	n.a.	n.a.	n.a.	n.a.
company 39	0.024	0.625	n.a.	0.008	0.565	0	n.a.	n.a.	0.0009	n.a.
company 40	0.667	0.225	0.343	0.418	0.028	0	1	0	0.0038	n.a.
company 41	0.048	0.125	0.114	0.001	n.a.	0	0	1	n.a.	n.a.
company 42	0.048	0.150	0.343	0.835	0.056	0	0	1	n.a.	n.a.
company 43	0.286	0.538	0.389	n.a.	0.001	0.746	n.a.	n.a.	0.0005	n.a.
company 44	n.a.	0.500	0.343	1	0.073	0.299	0	1	0.0003	n.a.
company 45	0.119	0.236	0.178	0.522	0.011	0.746	0.118	0.882	0.0001	n.a.
company 46	0.857	0.375	0.572	0.470	0.023	n.a.	n.a.	n.a.	n.a.	n.a.

3.2.4. Stage 4—Aggregation Method

Before aggregating the data it is necessary to determine the behavior of its distribution, especially checking to see if the data are correlated. Using the Excel spreadsheet, correlations were calculated between indicators of the social and environmental dimensions (Tables 12 and 13 respectively). Since it was not possible to obtain the normalized values of the economic dimension (due to lack of data from the SC AUTO), this was not considered.

Table 12. Correlations between the social dimension indicators.

	Social					
	$I^{S}_{1,2}$	$I^{S}_{2,2}$	$I^{S}_{3,2}$	$I^{S}_{4,2}$	$I^{S}_{5,2}$	$I^{S}_{6,2}$
$I^{S}_{1,2}$	1					
$I^{S}_{2,2}$	0.147	1				
$I^{S}_{3,2}$	0.122	0.256	1			
$I^{S}_{4,2}$	0.530	0.149	0.257	1		
$I^{S}_{5,2}$	0.128	0.147	0.035	0.143	1	
$I^{S}_{6,2}$	−0.092	−0.157	−0.182	0.077	−0.059	1

Table 13. Correlations between the environmental dimension indicators.

Environmental				
	$I^A_{1,3}$	$I^A_{2,3}$	$I^A_{3,3}$	$I^A_{4,3}$
$I^A_{1,3}$	1			
$I^A_{2,3}$	−0.999	1		
$I^A_{3,3}$	−0.136	0.137	1	
$I^A_{4,3}$	−0.182	0.193	−0.187	1

The correlation coefficient values range from −1 to 1 indicating respectively the extremes of the array of perfect negative and positive ratios. In this case the correlation coefficient is −0.02 which indicates that the indicators of the three dimensions (environmental, social and economic) are not related. According to Figure 4 most of the variables were not significantly correlated. Thus, the sub-indicators are independent of one another, which makes possible that a linear additive aggregation paradigm can be applied. As can be seen from Tables 14 and 15 correlation coefficients between the different indicators are not correlated allowing the use of the linear aggregation method.

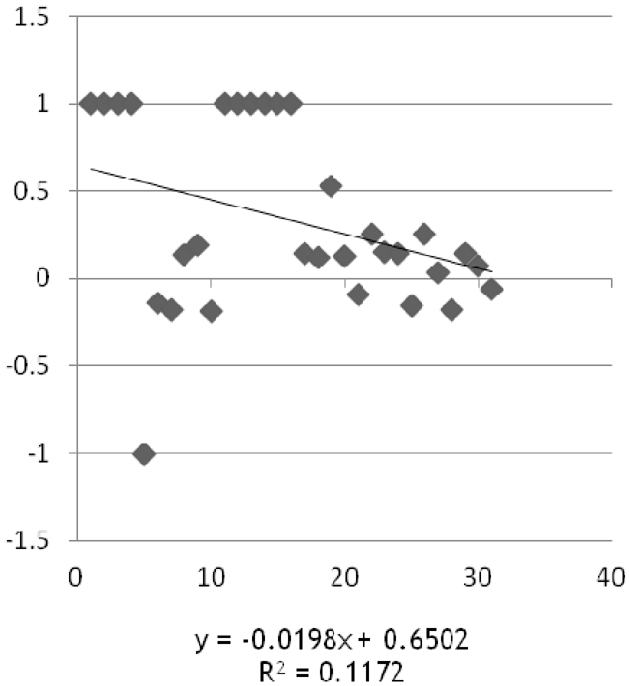

Figure 4. Linear data aggregation.

Table 14. Social sub-index by company.

Social Sub-Index												
	$I^S_{1,2}$	W_{S1}	$I^S_{2,2}$	W_{S2}	$I^S_{3,2}$	W_{S3}	$I^S_{4,2}$	W_{S4}	$I^S_{5,2}$	W_{S5}	$I^S_{6,2}$	W_{S6}	TOTAL
company 1	n.a.	0.33	0.250	0.05	0	0.09	0.470	0.11	3	0.10	1	0.32	0.386
company 2	0	0.33	0.625	0.05	0.046	0.09	0	0.11	0	0.10	0	0.32	0.035
company 3	n.a.	0.33	n.a.	0.05	n.a.	0.09	n.a.	0.11	n.a.	0.10	n.a.	0.32	n.a.

Table 14. *Cont.*

Social Sub-Index													
	$I_{1,2}^{S}$	W_{S1}	$I_{2,2}^{S}$	W_{S2}	$I_{3,2}^{S}$	W_{S3}	$I_{4,2}^{S}$	W_{S4}	$I_{5,2}^{S}$	W_{S5}	$I_{6,2}^{S}$	W_{S6}	TOTAL
company 4	0.286	0.33	0.594	0.05	0.275	0.09	0.626	0.11	177	0.10	0.299	0.32	0.413
company 5	0.071	0.33	0.050	0.05	0.435	0.09	0.336	0.11	2.2	0.10	0.299	0.32	0.199
company 6	0	0.33	0.515	0.05	0	0.09	0	0.11	1	0.10	0.878	0.32	0.307
company 7	n.a.	0.33	0.375	0.05	0.343	0.09	0.418	0.11	n.a.	0.10	n.a.	0.32	0.096
company 8	0.095	0.33	0.834	0.05	0.975	0.09	0.196	0.11	0.04	0.10	0	0.32	0.183
company 9	0.881	0.33	0.359	0.05	0.261	0.09	0.835	0.11	60	0.10	0.111	0.32	0.494
company 10	0.047	0.33	0.550	0.05	0.046	0.09	0.311	0.11	11	0.10	0.299	0.32	0.183
company 11	1	0.33	0.938	0.05	0.229	0.09	0.802	0.11	n.a.	0.10	n.a.	0.32	0.486
company 12	0	0.33	0.625	0.05	0.046	0.09	0	0.11	0	0.10	0	0.32	0.035
company 13	n.a.	0.33	n.a.	0.05	n.a.	0.09	n.a.	0.11	n.a.	0.10	n.a.	0.32	n.a.
company 14	0.476	0.33	n.a.	0.05	n.a.	0.09	n.a.	0.11	n.a.	0.10	n.a.	0.32	0.157
company 15	0.024	0.33	0.600	0.05	0.114	0.09	0.104	0.11	1	0.10	0.149	0.32	0.108
company 16	n.a.	0.33	n.a.	0.05	0	0.09	n.a.	0.11	n.a.	0.10	n.a.	0.32	n.a.
company 17	0.138	0.33	n.a.	0.05	0.458	0.09	n.a.	0.11	n.a.	0.10	n.a.	0.32	0.046
company 18	0.095	0.33	0.250	0.05	0.229	0.09	n.a.	0.11	n.a.	0.10	n.a.	0.32	0.054
company 19	0.143	0.33	0.313	0.05	1	0.09	0.104	0.11	3	0.10	0.448	0.32	0.219
company 20	0.024	0.33	0.500	0.05	0	0.09	0.522	0.11	10	0.10	0.597	0.32	0.328
company 21	0	0.33	0.163	0.05	0.080	0.09	0.460	0.11	n.a.	0.10	n.a.	0.32	0.079
company 22	0	0.33	0.315	0.05	n.a.	0.09	0.157	0.11	3.6	0.10	n.a.	0.32	0.125
company 23	0	0.33	0	0.05	n.a.	0.09	0.052	0.11	0	0.10	0	0.32	0.006
company 24	0.214	0.33	0.354	0.05	0.465	0.09	0.418	0.11	2.4	0.10	n.a.	0.32	0.143
company 25	n.a.	0.33	n.a.	0.05	0.229	0.09	n.a.	0.11	n.a.	0.10	n.a.	0.32	n.a.
company 26	0	0.33	1	0.05	0	0.09	n.a.	0.11	n.a.	0.10	0	0.32	0.050
company 27	0.167	0.33	0.384	0.05	n.a.	0.09	0.552	0.11	2.36	0.10	n.a.	0.32	0.178
company 28	0.095	0.33	0.386	0.05	0.069	0.09	0.376	0.11	6.8	0.10	0.746	0.32	0.355
company 29	0.167	0.33	0.250	0.05	n.a.	0.09	n.a.	0.11	n.a.	0.10	0.299	0.32	0.163
company 30	n.a.	0.33	n.a.	0.05	0	0.09	n.a.	0.11	n.a.	0.10	n.a.	0.32	n.a.
company 31	n.a.	0.33	0.434	0.05	0.053	0.09	0.470	0.11	n.a.	0.10	n.a.	0.32	0.080
company 32	0	0.33	n.a.	0.05	0.297	0.09	n.a.	0.11	n.a.	0.10	n.a.	0.32	n.a.
company 33	0	0.33	0.325	0.05	n.a.	0.09	n.a.	0.11	0	0.10	0.149	0.32	0.064
company 34	0.286	0.33	0.469	0.05	0.664	0.09	0.337	0.11	n.a.	0.10	0	0.32	0.160
company 35	0.452	0.33	0.600	0.05	0.229	0.09	0.416	0.11	7	0.10	0.001	0.32	0.256
company 36	n.a.	0.33	n.a.	0.05	n.a.	0.09	n.a.	0.11	n.a.	0.10	n.a.	0.32	n.a.
company 37	0.119	0.33	0.913	0.05	0.664	0.09	0.908	0.11	2.7	0.10	0	0.32	0.246
company 38	0.048	0.33	0.150	0.05	0.229	0.09	0.240	0.11	n.a.	0.10	0	0.32	0.070
company 39	0.024	0.33	0.625	0.05	n.a.	0.09	0.008	0.11	100	0.10	0	0.32	0.097
company 40	0.667	0.33	0.225	0.05	0.343	0.09	0.418	0.11	5	0.10	0	0.32	0.311
company 41	0.048	0.33	0.125	0.05	0.114	0.09	0.001	0.11	n.a.	0.10	0	0.32	0.032
company 42	0.048	0.33	0.150	0.05	0.343	0.09	0.835	0.11	10	0.10	0	0.32	0.152
company 43	0.286	0.33	0.538	0.05	0.389	0.09	n.a.	0.11	0.11	0.10	0.746	0.32	0.395
company 44	n.a.	0.33	0.500	0.05	0.343	0.09	1	0.11	13	0.10	0.299	0.32	0.269
company 45	0.119	0.33	0.236	0.05	0.178	0.09	0.522	0.11	2	0.10	0.746	0.32	0.365
company 46	0.857	0.33	0.375	0.05	0.572	0.09	0.470	0.11	4	0.10	n.a.	0.32	0.407

Table 15. Environmental sub-index by company.

Environmental Sub-Index									
	$I_{1,3}^{A}$	W_{A1}	$I_{2,3}^{A}$	W_{A2}	$I_{3,3}^{A}$	W_{A3}	$I_{4,3}^{A}$	W_{A4}	TOTAL
company 1	n.a.	0.26	n.a.	0.38	n.a.	0.16	6.16×10^{-9}	0.20	1.23×10^{-9}
company 2	n.a.	0.26	n.a.	0.38	n.a.	0.16	n.a.	0.20	n.a.
company 3	0	0.26	1	0.38	n.a.	0.16	n.a.	0.20	0.380
company 4	0.147	0.26	0.853	0.38	0.0003	0.16	3.15×10^{-9}	0.20	0.362
company 5	0.029	0.26	0.971	0.38	0.0001	0.16	0.0003	0.20	0.378
company 6	0	0.26	1	0.38	n.a.	0.16	0	0.20	0.380
company 7	0.044	0.26	0.956	0.38	0.0005	0.16	3.4×10^{-6}	0.20	0.375
company 8	n.a.	0.26	0.943	0.38	n.a.	0.16	n.a.	0.20	0.358
company 9	0.030	0.26	0.957	0.38	0.0007	0.16	0.0197	0.20	0.375
company 10	0.039	0.26	0.962	0.38	0.0003	0.16	n.a.	0.20	0.366
company 11	0.029	0.26	0.971	0.38	0.0011	0.16	5.31×10^{-8}	0.20	0.376
company 12	n.a.	0.26	n.a.	0.38	n.a.	0.16	n.a.	0.20	n.a.
company 13	n.a.	0.26	n.a.	0.38	n.a.	0.16	n.a.	0.20	n.a.
company 14	0.368	0.26	0.632	0.38	0.0076	0.16	3.67×10^{-10}	0.20	0.337
company 15	n.a.	0.26	n.a.	0.38	n.a.	0.16	n.a.	0.20	n.a.
company 16	n.a.	0.26	n.a.	0.38	0.0312	0.16	n.a.	0.20	0.005
company 17	0.051	0.26	0.949	0.38	8.55×10^{-5}	0.16	n.a.	0.20	0.374
company 18	n.a.	0.26	n.a.	0.38	n.a.	0.16	n.a.	0.20	n.a.
company 19	0.001	0.26	0.999	0.38	n.a.	0.16	6.05×10^{-7}	0.20	0.380
company 20	0	0.26	1	0.38	0	0.16	n.a.	0.20	0.380
company 21	0.001	0.26	0.997	0.38	0.0052	0.16	2.37×10^{-7}	0.20	0.380
company 22	0	0.26	1	0.38	0.9999	0.16	0.0002	0.20	0.540
company 23	0.003	0.26	0.997	0.38	n.a.	0.16	9.86×10^{-8}	0.20	0.380
company 24	n.a.	0.26	n.a.	0.38	n.a.	0.16	n.a.	0.20	n.a.
company 25	n.a.	0.26	n.a.	0.38	n.a.	0.16	n.a.	0.20	n.a.
company 26	n.a.	0.26	n.a.	0.38	n.a.	0.16	n.a.	0.20	n.a.
company 27	n.a.	0.26	n.a.	0.38	n.a.	0.16	6.26×10^{-6}	0.20	1.25×10^{-6}
company 28	0.191	0.26	0.809	0.38	0.0002	0.16	0.0419	0.20	0.365
company 29	0.853	0.26	0.147	0.38	0.0002	0.16	8.5×10^{-7}	0.20	0.278
company 30	n.a.	0.26	n.a.	0.38	n.a.	0.16	n.a.	0.20	n.a.
company 31	0.978	0.26	0.022	0.38	n.a.	0.16	n.a.	0.20	0.263
company 32	n.a.	0.26	n.a.	0.38	n.a.	0.16	n.a.	0.20	n.a.
company 33	n.a.	0.26	n.a.	0.38	n.a.	0.16	n.a.	0.20	n.a.
company 34	0	0.26	1	0.38	0.0019	0.16	3.15×10^{-6}	0.20	0.380
company 35	0.006	0.26	0.994	0.38	0.0006	0.16	8.11×10^{-6}	0.20	0.380
company 36	0.082	0.26	0.932	0.38	n.a.	0.16	n.a.	0.20	0.376
company 37	0.001	0.26	0.999	0.38	0.0346	0.16	1	0.20	0.585
company 38	n.a.	0.26	n.a.	0.38	n.a.	0.16	4.76×10^{-7}	0.20	9.52×10^{-8}
company 39	n.a.	0.26	n.a.	0.38	0.0009	0.16	4.62×10^{-7}	0.20	0.0001
company 40	1	0.26	0	0.38	0.0038	0.16	6.8×10^{-7}	0.20	0.261
company 41	0	0.26	1	0.38	n.a.	0.16	0.0006	0.20	0.380
company 42	0	0.26	1	0.38	n.a.	0.16	n.a.	0.20	0.380
company 43	n.a.	0.26	n.a.	0.38	0.0005	0.16	0.0229	0.20	0.005
company 44	0	0.26	1	0.38	0.0003	0.16	1.37×10^{-5}	0.20	0.380
company 45	0.118	0.26	0.882	0.38	0.0001	0.16	1.87×10^{-5}	0.20	0.368
company 46	n.a.	0.26	n.a.	0.38	n.a.	0.16	n.a.	0.20	n.a.

3.2.5. Stage 4—Index Construction

Once weights determined and indicators normalized, the sustainability index can be computed, both for the individual company and for the supply chain.

The social and environmental sub-indices (Tables 14 and 15) were determined using the worksheet in Excel according to the following equation:

$$(I_S)j = f\left[W_{i1} \times \left(I_{i1}\right)j, \ldots W_{iy-1} \times \left(I_{iy-1}\right)j, W_{iy} \times \left(I_{iy}\right)j \right] \quad (9)$$

where $(I_{i1})j$, corresponds to the value of the indicator removed from the normalization table (Table 11); and W_{i1} is the value of the corresponding weight for each indicator. As there is no data on the indicators of the economic sub-index it was not used in the construction of the sustainability index.

Computing the social and environmental sub-index for each company allows companies to be ranked at the social and environmental level. The analyze of the social sub-index in Table 14 shows that firms 2, 12, 17, 23, 26 and 41 have the lowest values, indicating that these are the ones where the social dimension is less representative. Companies 4, 9, 11 and 46 have the highest values representing the companies that are most relevant to the social dimension. It is possible to obtain the sub-index of social sustainability for the entire supply chain by adding the sub-indices of each individual company.

Analyzing the environmental sub-index for companies in Table 15 it appears that firms 1, 27, 38 and 39 have the lowest values (and thus can be seen as least important) in the environmental dimension. Companies 22 and 37 have the highest values and thus are relatively most important in the environmental dimension. The sub-index of environmental sustainability for the entire chain can be obtained by adding the sub-indices for each individual company.

Once the sub-indices had been calculated by company, the overall sustainability index for the company was computed summing each sub-index (social sub-index + economic sub-index + environmental sub-index) (Table 16).

Table 16. Total sustainability index by company.

	Social Sub-Index	Economic Sub-Index	Environmental Sub-Index	Total Sustainability Index by Company
company 1	0.386	n.a.	1.23×10^{-9}	0.386
company 2	0.035	n.a.	n.a.	0.035
company 3	n.a.	n.a.	0.380	0.38
company 4	0.413	n.a.	0.362	0.776
company 5	0.199	n.a.	0.378	0.576
company 6	0.307	n.a.	0.380	0.687
company 7	0.096	n.a.	0.375	0.470
company 8	0.183	n.a.	0.358	0.541
company 9	0.494	n.a.	0.375	0.869
company 10	0.183	n.a.	0.366	0.549
company 11	0.486	n.a.	0.376	0.862
company 12	0.035	n.a.	n.a.	0.035
company 13	n.a.	n.a.	n.a.	n.a.
company 14	0.157	n.a.	0.337	0.494

Table 16. *Cont.*

	Social Sub-Index	Economic Sub-Index	Environmental Sub-Index	Total Sustainability Index by Company
company 15	0.108	n.a.	n.a.	0.108
company 16	n.a.	n.a.	0.005	0.005
company 17	0.046	n.a.	0.374	0.419
company 18	0.054	n.a.	n.a.	0.054
company 19	0.219	n.a.	0.380	0.599
company 20	0.328	n.a.	0.380	0.708
company 21	0.079	n.a.	0.380	0.459
company 22	0.125	n.a.	0.540	0.665
company 23	0.006	n.a.	0.380	0.385
company 24	0.143	n.a.	n.a.	0.143
company 25	n.a.	n.a.	n.a.	n.a.
company 26	0.050	n.a.	n.a.	0.050
company 27	0.178	n.a.	1.25×10^{-6}	0.178
company 28	0.355	n.a.	0.365	0.721
company 29	0.163	n.a.	0.278	0.441
company 30	n.a.	n.a.	n.a.	n.a.
company 31	0.080	n.a.	0.263	0.342
company 32	n.a.	n.a.	n.a.	n.a.
company 33	0.064	n.a.	n.a.	0.064
company 34	0.160	n.a.	0.380	0.540
company 35	0.256	n.a.	0.380	0.636
company 36	n.a.	n.a.	0.376	0.376
company 37	0.246	n.a.	0.585	0.831
company 38	0.070	n.a.	9.52×10^{-8}	0.070
company 39	0.097	n.a.	0.0001	0.097
company 40	0.311	n.a.	0.261	0.572
company 41	0.032	n.a.	0.380	0.412
company 42	0.152	n.a.	0.380	0.532
company 43	0.395	n.a.	0.005	0.400
company 44	0.269	n.a.	0.380	0.649
company 45	0.365	n.a.	0.368	0.730
company 46	0.407	n.a.	n.a.	0.407

Looking at the total index of sustainability by company in Table 16 it reveals that those companies that have the highest sustainability index are numbers 9, 11 and 37. These companies have a sustainability index closest to the maximum value of 1, showing that they are relatively the most sustainable. In contrast, the least important companies in terms of sustainability are numbers 27, 38 and 39 (scoring closest to 0).

To determine the behavior of the supply chain for each dimension (Table 17) the Equation (10) was used.

$$SCI_s = \frac{\sum_{j=1}^{n} (Ii)j}{n} \tag{10}$$

where $\sum_{j=1}^{n}(Ii)j$ represents the value of the sum of each sub-index, and *n* is the number of companies in the supply chain under study.

Table 17. Behavior of the supply chain for each dimension.

	$\sum_{j=1}^{n}(Ii)j$	***n***	$SCI_s = \frac{\sum_{j=1}^{n}(Ii)j}{n}$
Sub-index			
Social	7.731	46	0.168
Environmental	10.523	46	0.229
Economic	n.a.	n.a.	n.a.

Analyzing the behavior of the supply chain for each dimension (Table 17) it could be stated that the social sub-index is the least important with a value of 0.168 (closest to 0) and the environmental sub-index is most important with a value of 0.229 (closest to 1).

Again using the Excel spreadsheet, the sustainability index for the supply chain was calculated using the following function:

$$I_{C\_SUSTSC} = f\,(W_{i1} \times SCI_{i1}, W_{i2} \times SCI_{i2}, W_{i3} \times SCI_{i3}) \quad (11)$$

where SCI_i is the value retrieved from Table 17 which relates to the behavior of the supply chain for each dimension, and W_i is the weight of each reporting indicator.

Table 18 shows the sustainability index for the supply chain. While the environmental dimension is more sustainable (with a value of 0.048) and the social dimension is less sustainable (with a value of 0.022) both values represent low levels of sustainability. In total a value of 0.070 was obtained, which shows that this index has a low level of sustainability; it can be concluded therefore that the environmental and social dimensions are both priority areas for changing certain behaviors with the aim of becoming supply chains more sustainable and thus also more competitive. However, due to the lack of economic data and constraints in obtaining responses to the questionnaire, which are essential for determining the weights of dimensions, only a partial conclusion can be drawn, requiring a more thorough analysis. However, given that the weights obtained for the economic indicators were the highest values, it can be assumed that this would be the factor of greatest relevance to the sustainability of the supply chain.

Table 18. Index of sustainability to the supply chain.

Sub-index	SCI_i	W_i	I_{C_SUSTSC}
Social	0.168	0.13	0.022
Environmental	0.229	0.21	0.048
Economic	n.a.	0.66	n.a.
Total			**0.070**

4. Conclusions

Sustainability presents a new purpose and an attractive and strategic issue, not only at a national level, but also for individual organizations and supply chains. Sustainability refers to the management of the three associated dimensions: economic, social and environmental.

In this study the construction of a sustainability index is proposed that consists of five stages. In the first stage, the selection of sustainability indicators is performed by choosing indicators that contribute to the evaluation of each sustainability dimension. The second stage uses the AHP method and a questionnaire was prepared for professionals and academics for determining the weights for each indicator. Once the level of importance for each indicator is determined, the third stage associated to the normalization of indicators is performed using the minimum–maximum method. The fourth stage derives from the application of the linear additive aggregation method. Finally, as part of the construction of the index it is possible to obtain an index by company, a sub-index for each sustainability dimension and an index of overall sustainability by company and supply chain.

The suggested sustainability index was then tested in a real case study. The application of the suggested index in this case study made possible to conclude that there is a low level of sustainability and more focus needs to be given to the social and environmental dimensions to affect future changes in behavior. However, due to the lack of economic data and constraints in obtaining responses to the questionnaire, which are essential for determining the weights of dimensions, only a partial conclusion can be drawn, requiring a more detailed analysis.

The proposed framework is easy to use by professionals from the automotive industry and understandable, representing also an important contribution for supporting managers in decision-makings related to sustainability issues. Moreover a set of indicators reflecting the social, economic and environmental dimensions of sustainability is suggested which could be deployed by SC' managers to make their supply chains more sustainable. In addition the application of the proposed framework could encourage SC managers to discuss on why they consider some sustainability indicators more important for the sustainability of their supply chains, but in some cases, they do not work on their improvement. This framework makes also easier to determine whether the efforts of individual companies are effective in improving sustainability of supply chains.

This method allows an assessment of the sustainability of the supply chain and, at the same time, the opportunity to improve business performance The proposed integration could represent a best solution to achieve the sustainability in line with the Theory of Industrial Ecology [66]. In this context, the theory of Industrial Ecology represents a powerful analytical tool for describing the flows of material and energy that connect business and the natural world. According to this theory exists a continuous loop between materials and energy flowing between natural and industrial systems in three stages. First, natural materials are extracted from the earth and converted into raw materials and mechanical energy. Second, these raw materials and energy flows are worked into useable and saleable products. Third, resulting products are distributed, consumed or used, and disposed of by consumers. All three of these stages produce waste that becomes pollution. In sum, the focus of analysis is the interconnected processes of raw material extraction, the production of goods, the use of those goods, and the management of the resulting wastes [67] reflecting also a supply chain perspective.

As a result, managers can adjust company behavior in accordance with the level of sustainability reached in the index and improve their economic, social and environmental performance. The supply chain sustainability index can help managers improve competitiveness and accountability for their own company and the sector, reflecting stakeholders' expectations. In addition, it enables a benchmarking analysis to be performed by checking the best and worst performances of the companies within the supply chain, while at the same time makes possible to rank companies attending to their economic, social and environmental behavior.

Limitations of this study include the lack of responses from academics and professionals for determining the weights of indicators and the lack of data for indicators associated to economic dimension.

As a suggestion for future research, this index could be applied to other supply chains, thus helping verify the potential of this tool. The proposed index could also be used to evaluate interactions between parallel supply chains. It is also important to conduct benchmarking analysis, and analysis of supply chains belonging to the same sector or to sectors less concerned with sustainability issues. Moreover, it will be interesting to perform the same approach however involving other players of the automotive supply chain in the weighting of the sustainability indicators.

Acknowledgments

This research is supported by the Center for Mechanical and Aerospace Science and Technologies (C-MAST) of the Portuguese Foundation for Science and Technologies (FCT).

Author Contributions

Miguel F. Salvado was responsible for the literature review and for writing the first draft of the manuscript. Susana G. Azevedo worked on the design of the study and also the suggested sustainability index. João C. O. Matias was responsible for methodological issues and was also involved in the preparation of the manuscript for its submission. Luís M. Ferreira was responsible for data collection and analysis and interpretation of the results.

Conflicts of Interest

The authors declare no conflict of interest.

References

1. Singh, R.K.; Murty, H.R.; Gupta, S.K. An overview of sustainability assessment methodologies. *Ecol. Indic.* **2012**, *15*, 281–299.
2. Seuring, S.; Muller, M. From a literature review to a conceptual framework for sustainable supply chain management. *J. Clean. Prod.* **2008**, *16*, 1699–1710.
3. Costanza, R.; Patten, B.C. Defining and predicting sustainability. *Ecol. Econ.* **1995**, *15*, 193–196.
4. Pinar, M.; Cruciani, C.; Giove, S.; Sostero, M. *Constructing the FEEM Sustainability Index: A Choquet-Integral Application*; Fondazione Eni Enrico Mattei: Venice, Italy, 2013.
5. World Commission on Environment and Development (WCED). *Our Common Future*; Oxford Paperbacks: New York, NY, USA, 1987.

6. Taticchi, P.; Carbone, P.; Albino, V. *Corporate Sustainability*; Springer: Berlin, Germany, 2013.
7. Winter, M.; Knemeyer, A.M. Exploring the integration of sustainability and supply chain management: Current state and opportunities for future inquiry. *Int. J. Phys. Distrib. Logist. Manag.* **2013**, *43*, 18–38.
8. Linton, J.D.; Klassen, R.; Jayaraman, V. Sustainable supply chains: An introduction. *J. Oper. Manag.* **2007**, *25*, 1075–1082.
9. Bithas K.P.; Christofakis, M. Environmentally sustainable cities: Critical review and operational conditions. *Sustain. Dev.* **2006**, *14*, 177–189.
10. Fischer, J.; Manning, A.D.; Steffen, W. Mind the sustainability gap. *Trends Ecol. Evol.* **2007**, *22*, 321–624.
11. Goodland, R.; Daly, H. Environmental Sustainability: Universal and Non-Negotiable. *Ecol. Appl.* **1996**, *6*, 1002–1017.
12. Martin, J.P. The Social Dimensions of Sustainable Development. In Proceedings of the European Social Agenda and EU International Partners, Brussels, Belgium, 20–21 November 2001; p. 94.
13. Moldan, B.; Janouskova, S.; Hák, T. How to understand and measure environmental sustainability: Indicators and targets. *Ecol. Indic.* **2011**, *17*, 4–13.
14. Mckenzie, S. *Social Sustainability: Towards Some Definitions*; Hawke Research Institute Working Paper Series 27; Hawke Research Institute: Adelaide, Australia, 2004.
15. Morelli, J. Environmental Sustainability: A Definition for Environmental Professionals. *J. Environ. Sustain.* **2011**, *1*, 19–27.
16. Rumelt, R.P. *Strategy, Structure, and Economic Performance*; Harvard University Press: Cambridge, MA, USA, 1974.
17. Hicks, J.R. *Value and Capital*; Clarendon: Oxford, UK, 1946.
18. Delai, I.; Takahashi, S. Sustainability measurement system: A reference model proposal. *Soc. Responsib. J.* **2011**, *7*, 438–471.
19. Commission on Sustainability Development. Indicators of Sustainable Development: Guidelines and Methodologies. Available online: http://www.un.org/esa/sustdev/csd.htm (accessed on 12 June 2014).
20. Global Reporting Initiative (GRI). Sustainability Reporting Guidelines. Available online: http://www.globalreportinginitiative.org (accessed on 14 July 2014).
21. Jones, S. Notes of the University of Sydney Pacioli Society: Sustainability reporting in Australia: An empirical overview. *Abacus* **2005**, *41*, 211–216.
22. Dow Jones Sustainability Indexes (DJSI). *Dow Jones Sustainability World Index Guide*; RobecoSAM AG: Zurich, Switzerland, 2013.
23. Wang, L. A methodology of Sustainability, Accountability and Management for Industrial Enterprises. Master's Thesis, Faculty of Graduate School, the State University of New York at Buffalo, Buffalo, NY, USA, 2005.
24. Elkington, J. *Cannibals with Forks: The Triple Bottom Line of the 21st Century Business*; Capstone: Oxford, UK, 1997; p. 402.
25. Willard, B. *The Sustainability Advantage: Seven Business Case Benefits of a Triple Bottom Line*; New Society: Gabriola Island, BC, Canada, 2002.

26. Slaper, T.; Hall, T. *The Triple Bottom Line: What Is It and How Does It Work?* Indiana University Kelley School of Business, Indiana Business Research Center: Bloomington, IN, USA, 2011.
27. ETHOS. Indicadores ETHOS para Negócios Sustentáveis e Responsáveis. Available online: http://www.ethos.org.br (accessed on 24 June 2014). (In Portuguese)
28. Frischknecht, R.; Jungbluth, N.; Althaus, H.J.; Bauer, C., Doka, G.; Dones, R.; Hellweg, S.; Hischier, R.; Humbert, S.; Margni, M.; *et al*. *Implementation of Life Cycle Impact Assessment Methods*; Ecoinvent Report No. 3, v2.0; Swiss Centre for Life Cycle Inventories: Dübendorf, Switzerland, 2007.
29. ECOINVENT. Data Quality Guidelines for the Ecoinvent Database Version 3. Available online: http://www.ecoinvent.org (accessed on 10 April 2014).
30. International Organization for Standardization (ISO). *Environmental Management—Environmental Performance Evaluation—Guidelines*; ISO 14031:2013; ISO: Geneva, Switzerland, 2013.
31. Yang, C.L.; Lin, S.P.; Sheu, C. Mediated effect of environment management on manufacturing competitiveness: An empirical study. *Int. J. Prod. Econ.* **2010**, *123*, 210–220.
32. López, M.V.; Garcia, A.; Rodriguez, L. Sustainable Development and Corporate Performance: A Study Based on the Dow Jones Sustainability Index. *J. Bus. Ethics* **2007**, *75*, 285–300.
33. KPMG. Corporate Sustainability: A Progress Report. Available online: http://www.kpmg.com/Global/en/IssuesAndInsights/ArticlesPublications/Documents/corporate-sustainability-v2.pdf (accessed on 3 September 2014).
34. Clift, R. Metrics for supply chain sustainability. *Clean Technol. Environ. Policy* **2003**, *5*, 240–247.
35. Touslfas, G.T.; Pappis, C.P. A model for supply chains environmental performance analysis and decision making. *J. Clean. Prod.* **2008**, *16*, 1647–1657.
36. Sikdar, S.K. Sustainable development and sustainability metrics. *Am. Inst. Chem. Eng. J.* **2003**, *49*, 1928–1932.
37. Searcy, C.; Karapetrovic, S.; McCartney, D. Designing sustainable development indicators: Analysis for a case utility. *Measur. Bus. Excell.* **2005**, *9*, 33–41.
38. Bossel, H. *Indicators for Sustainable Development: Theory, Method, Applications*; International Institute for Sustainable Development: Winnipeg, MB, Canada, 1999; p. 124.
39. McCool, S.; Stankey, G. Representing the future: A framework for evaluating the utility of indicators in the search for sustainable forest management. In *Criteria and Indicators for Sustainable Forest Management*; Raison, R.J., Brown, A.G., Flinn, D.W., Eds.; CAB International: Wallingford, UK, 2001; pp. 93–109.
40. Maclaren, V.W. Urban sustainability reporting. *J. Am. Plan. Assoc.* **1996**, *62*, 184–202.
41. Mccool, S.F.; Stankey, G.H. Indicators of Sustainability: Challenges and Opportunities at the Interface of Science and Policy. *Environ. Manag.* **2004**, *33*, 294–305.
42. Veleva, V.; Ellenbecker, M. Indicators of sustainable production: Framework and methodology. *J. Clean. Prod.* **2001**, *9*, 519–549.
43. Krajnc, D.; Glavic, P. Indicators of sustainable development. *Clean Technol. Environ. Policy* **2003**, *5*, 279–288.
44. Azapagic, A. Developing a framework for sustainable development indicators for the mining and minerals industry. *J. Clean. Prod.* **2004**, *12*, 639–662.

45. Krajnc, D.; Glavic, P. A model for integrated assessment of sustainable development. *Resour. Conserv. Recycl.* **2005**, *43*, 189–208.
46. Labuschagne, C.; Brent, A.C.; van Erck, R.P.G. Assessing the sustainability performance of industries. *J. Clean. Prod.* **2005**, *13*, 373–385.
47. Singh, R.K.; Murty, H.R.; Gupta, S.K.; Dikshit, A.K. An overview of sustainability assessment methodologies. *Ecol. Indic.* **2009**, *9*, 189–212.
48. Dowse, J. Making CR measurement meaningful to the rest of the business. *Corp. Responsib. Manag.* **2005**, *1*, 14–21.
49. Keeble, J.J.; Topiol, S.; Berkely, S. Using indicators to measure sustainability performance at a corporate and project level. *J. Bus. Ethics* **2003**, *44*, 149–158.
50. Seuring, S.A.; Koplin, J.; Behrens, T.; Schneidewind, U. Sustainability assessment in the German detergent industry: From stakeholder involvement to sustainability indicators. *Sustain. Dev.* **2003**, *11*, 199–212.
51. Welford, R.; Young, W.; Itterhus, B. Towards sustainable production and consumption: A literature review and conceptual framework for the service sector. *Eco-Manag. Audit.* **1998**, *5*, 38–56.
52. Szekely, F.; Knirsch, M. Responsible leadership and corporate social responsibility: Metrics for sustainable performance. *Eur. Manag. J.* **2005**, *23*, 628–647.
53. Zhou, L.; Tokos, H.; Krajnc, D.; Yang, Y. Sustainability performance evaluation in industry by composite sustainability index. *Clean Technol. Environ. Policy* **2012**, *14*, 789–803.
54. Al-Barqawi, H.; Zayed, T. Infrastructure Management: Integrated AHP/ANN Model to Evaluate Municipal Water Mains Performance. *J. Infrastruct. Syst.* **2008**, *14*, 305–318.
55. Kumar, S.; Parashar, N.; Haleem, A. Analytical hierarchy process applied to vendor selection problem: Small scale, medium scale and large scale industries. *Bus. Intell. J.* **2009**, *2*, 355–362.
56. Hassan, M.; Saman, M.; Sharif, S.; Omar, B. An Integrated MA-AHP Approach for Selecting the Highest Sustainability Index of a New Product. *Procedia—Soc. Behav. Sci.* **2012**, *57*, 236–242.
57. Nardo, M.; Saisana, M.; Saltelli, A.; Tarantola, S. *Tools for Composite Indicators Building*; European Commission: Brussels, Belgium, 2005.
58. Zhou, P.; Ang, B.; Poh, K. Comparing aggregating methods for constructing the composite environmental index: An objective measure. *Ecol. Econ.* **2006**, *3*, 305–311.
59. Farmer, T.A. Testing the robustness of multi-attribute utility theory in an applied setting. *Decis. Sci.* **1987**, *18*, 178–193.
60. Pettigrew, A.M. Longitudinal field research on change: Theory and practice. *Organ. Sci.* **1990**, *1*, 267–292.
61. Seuring, S. Case Study research in supply chains: An outline and three examples. In *Research Methodologies in Supply Chain Management*; Kotzab, H., Seuring, S., Muller, M., Reiner, G., Eds.; Springer: Berlin, Germany, 2005; pp. 235–250.
62. Azevedo, S.G.; Govindan, K.; Carvalho, H.; Cruz-Machado, V. An integrated model to assess the leanness and agility of the automotive industry. *Resour. Conserv. Recycl.* **2012**, *66*, 85–94.
63. Muerza, V.D.; Arcocha, E.L.; Moreno-Jiménez, J.M. The multicriteria selection of products in technological diversification strategies: An application to the Spanish automotive industry based on AHP. *Prod. Plan. Control* **2013**, *25*, 715–728.

64. Byun, D.-H. The AHP approach for selecting an automobile purchase model. *Inf. Manag.* **2001**, *38*, 289–297.
65. Coyle, G. *The Analytic Hierarchy Process (AHP)*; Pearson Education Limited: New York, NY, USA, 2004.
66. Ioppolo, G.; Cucurachi, S.; Salomone, R.; Saija, G.; Ciraolo, L. Industrial Ecology and Environmental Lean Management: Lights and Shadows. *Sustainability* **2014**, *6*, 6362–6376.
67. Friedman, R. When you find yourself in a hole, stop digging. *J. Ind. Ecol*. **2000**, *3*, 15–19.