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Corporate sustainable performance assessment based on fuzzy logic

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ABSTRACT

Creativity leads to society's development and is a fundamental factor associated organizational innovative process. Although innovation has an important influence on consumption behavior this is in conflict with the sustainability principles. Nowadays, sustainability has become a critical issue for corporations' development, because they interact with their environment, and become affected by it. An analysis of this interaction allows the assessment of the influencing factors on corporate sustainable performance. These results are useful to all stakeholders' decision making processes. The purpose of this paper is to propose a suitable methodology in order to improve the corporate sustainability management. To achieve the research results, the research design is based on fuzzy logic, in order to assess the corporate sustainable performance of a representative European automotive company ranked in the top 10 worldwide by Forbes in 2017. The research takes into account the influence of corporate environmental performance and corporate financial performance on the corporate sustainable performance. The research methods are based on principal component analysis, in order to identify the new corporate environmental performance and corporate financial performance components and the fuzzy logic to assess their influence on the corporate sustainable performance. Research results indicate that the fuzzy model represents a suitable tool to provide a comprehensive analysis on the corporate sustainable performance based on environmental and financial components. The link between corporate environmental performance and corporate financial performance is an innovative approach that uses linguistic variables and linguistic rules to provide quantitative measures of corporate sustainable performance.

1. Introduction

Creativity leads to societies development (Berman and Korsten, 2010; Hennessey and Amabile, 2010) and is used to obtain original and feasible solutions for current and complex, and multi-level problems (Lubart, 2001; Anderson et al., 2014). As an intangible concept, creativity is applicable to any domain concerning forms of production (for example a theory, a method) (De Lucia et al., 2016).

Creativity could be defined as the “ability to come up with new surprising and valuable ideas or artefacts” and it could be transferred throughout organizations and society when it has produced something novel and appropriate that involves knowledge (De Lucia et al., 2016). Creativity integrates different but interconnected elements (Sternberg, 2006; Siqueira and Pitassi, 2016), such as: knowledge (Kurtzberg and Amabile, 2001), intellectual abilities (Runco and Acar, 2012; Sternberg, 2006), thinking styles (O'Hara and Sternberg, 2001; Runco and Acar, 2012), motivation (Kurtzberg and Amabile, 2001; O'Hara and Sternberg, 2001), personality (Tierney and Farmer, 2002; Shalley et al., 2004), and environment (Shalley et al., 2004).

Creative thinking determines the evolution of the intellectual abilities and the use of creative practices favors the effectiveness of a continuous knowledge construction to help society (De Lucia et al., 2016). Creativity is not equivalent to innovation, because it could lead to different manifestations which cannot be associated to market activities (Lane and Lop, 2015). However creativity and innovation are integrated in the same complex process (Anderson et al., 2014).

Creativity gives an active support to the individual innovative behavior (Yuan and Woodman, 2010) and therefore is the fundamental factor associated organizational innovative process (Amabile, 1996). Based on the Schumpeterian model, creativity is the precursor of innovation mechanisms, because creative ideas lead to innovation that contributes to the organizational knowledge translated into a new business organization (Fischer et al., 2001).

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Within an organization, creativity is considered as the seed of innovation when creative ideas are successfully implemented (Joo et al., 2013; De Lucia et al., 2016). In this case, creativity is not a sufficient condition to determine innovation. This fact is emphasized by the innovations dependence on the discovery that knowledge domains form a vast 'space' (De Lucia et al., 2016).

Innovation is a dynamic process which through a recursive mechanism actively supports new knowledge, useful to enhance new creative ideas that bring more innovation in the field (Sarooghi et al., 2015; De Lucia et al., 2016). Innovative approaches may contribute to reaching sustainability goals and for this it is necessary to reduce the inequality gap across and within nations and generations (De Lucia et al., 2016).

Business representatives and academic scholars are intensively promoting the idea that currently there is a transition phase from the knowledge based economy to the innovation based economy (Istrate et al., 2017; Luca et al., 2018). The actual economic development model does not create optimal solutions to solve different problems and the new sustainable development models should generate an optimal balance in obtaining welfare (Bolis et al., 2017). In this case, a formalized categorization of the innovative business model is represented by 'innovation for sustainability' (Bocken et al., 2014; De Lucia et al., 2016).

Seen as a creativity outcome, innovation could have divergent objectives from sustainability (Siqueira and Pitassi, 2016). Thus, innovation has an important influence on consumption behavior (Teece et al., 1997) which is relatively in conflict with the sustainability principles (Schapke and Rauschmayer, 2014). The conflicting objectives of these two concepts led to a complex shift in business logic (Schapke and Rauschmayer, 2014; Gorge et al., 2015), and the assessment of innovation for sustainability, seen as an outcome of creativity, implies new processes or new methods, which could be used in business practices (OECD, 2005).

The correlation between creativity and sustainability is sustained by two concepts: (a) innovation - driven by the research associated with ecological behavior, and (b) education for sustainable development - driven by continuous improvement of organizational environmental knowledge (De Lucia et al., 2016).

The literature presents a gap in understanding this correlation between creativity and sustainability. This limited understanding regarding this correlation is generated by the controversial perception on the concepts. "Creativity [...] calls for novel insights and non-traditional perspectives of [...] organizational life" (Andersen and Kragh, 2013).

The sustainable development issue is comprehensive analyzed in the literature, but with the risk to be unclear from its practical fundament. Hence it's very difficult to propose viable actions for sustainability, since there is no consensus as to an approach in the literature (Hopwood et al., 2005; Bolis et al., 2014, 2017). Therefore, decision making processes are the most important element towards achieving a more sustainable orientation. In order to adapt to this sustainable paradigm and to obtain a cleaner production, organizations need to re-adapt the decision making process to ecological principals (Bolis et al., 2017).

Adams et al. (2015) noted that the sustainability principles are a new path for corporate development. Even if the literature contributes to innovative practical actions, the sustainability principles remains open to debate (Siqueira and Pitassi, 2016).

In the automotive industry, sustainable development is a very important issue. Corporations in this industry must comply with a mix of environmental, financial and social complex requirements and also be competitive (Zhu et al., 2007; Schoggl et al., 2017).

According to the current requirements, corporations must be socially responsible in order to improve competitiveness and obtain financial success (Moneva and Ortas, 2010). Corporations can't maximize profits without taking into consideration the legal, ethical and environmental issues (Freeman, 2008; Wood, 2008; Moneva and Ortas, 2010). Corporations should also understand their role and environmental impact on the society and must voluntarily provide reliable data about their financial and environmental performance (Crowther et al., 2008).

Sustainability assessment plays a crucial role in organization development due to the following reasons (Phillis and Kouikoglou, 2009): (i) the population is more open to environmental goods; (ii) the environmental and financial performance improvement should imply an efficient production process; (iii) the corporate strategic decisions must be based on a solid sustainability analysis; (iv) the local and national policies integrate sustainable development principles.

The main objective of this paper is to develop and test an innovative and efficient quantitative tool in order to assess the company's sustainability performance. In essence this tool has as its central core fuzzy logic and advanced statistical methods. This research assesses the corporate sustainable performance of a representative European automotive company ranked in the top 10 worldwide by Forbes in 2017. The assessment is based on principal component analysis (PCA), statistical method and fuzzy logic, and includes the two fundamental dimensions of corporate sustainable performance: (i) corporate environmental performance (*CEP*) and (ii) corporate financial performance (*CFP*).

This research will provide useful information to top management decision makers in order to manage properly environmental issues and also to evaluate their contribution to corporate success.

The structure of this paper is as follows. Section 2 presents an overview related to the corporate sustainable performance assessment and its pillars. Section 3 summarizes the research design. Section 4 includes the research results and discussions based on our automotive study case. Section 5 presents the study conclusions and underline the most important research contributions.

2. Corporate sustainable performance assessment

Sustainability has become a critical issue for today's world and for the future of tomorrow (Herghiligiu and Robu, 2017; Hutchins and Sutherland, 2008; Bottani et al., 2017); a part of business communities worldwide (Antolín-López et al., 2016). Corporations interact with their environment, physical, biological and social, they affect it and become affected by it. It is quite natural that organizations play an important role in the sustainability of a region or a country (Phillis and Davis, 2009).

The approach to the sustainability issue by private and public organizations can be considered as a consensual solution of stakeholders who are involved in business decision-making process (Mukherjee et al., 2016; Engert and Baumgartner, 2016), taking into account the synergy between enhancing ecological resilience (Planet) (A), people (B), and profit (C).

Corporations were encouraged by United Nations (UN) members' governments to adopt the principles of sustainable development in their corporate governance (Labuschagne et al., 2005; Rio Declaration on Environment and Development, 1992). The use of these principles leads corporations to achieve some objectives regarding environment protection, social equity and economic prosperity (Bansal, 2005). The result of achieving these objectives is reflected through transparency in reporting sustainable development (Heemskerk et al., 2002).

An analysis of this type of information enables the sustainable performance assessment (Labuschagne et al., 2005; Visser, 2002), as well as the extent to which the social and environmental elements reported by the companies to be useful to all stakeholders decision making processes. In the last decades, the concept of sustainable development has, progressively, changed the traditional organizational managerial approach of maximizing shareholders' value by taking into account new variables such as environmental protection, social welfare or human rights (Moneva et al., 2007; Moneva and Ortas, 2010).

Hayward et al. (2013) present that a "majority of 93% of CEOs worldwide sees sustainability as important to the future success of their business, while only 38% believe they can accurately quantify the value of their sustainability initiatives" (Mass et al., 2016). Therefore it could be observed that from its definition core (WCED, 1987) and through the economic, environmental and social perspectives (Dyllick and Hockerts, 2002; Goldman and Gorham, 2006; Bottani et al., 2017), the sustainability concept is a very important business success factor.

There are mixed views in the literature as to whether there is a correlation between corporate sustainability and financial performance. Orlitzky et al. (2003) concluded that "corporate virtue in the form of social responsibility and, to a lesser extent, environmental responsibility is likely to pay off". Oxford University researchers reviewed 190 academic studies regarding corporate sustainability, found that Environmental, Social and Corporate Governance (ESG) performance "result in better operational results, lower costs of capital, and improved stock price performance" (Clark et al., 2017). Clarkson et al. (2011) found that companies that reduced negative environmental impact (polluting emissions) performed better financially (cash flow, leverage and growth); therefore environmental responsibility is good for business (Esty and Cort, 2017).

However other studies argue that the relation between sustainability and financial performance is mixed or even absent (Esty and Cort, 2017). Therefore to enhance a company's profitability starting from various environmental initiatives is hard (Vogel, 2005); also to see sustainability as a driver for innovation is a "formidable task" (Marcus, 2015).

A "lack of controls and clarity over causal connections" can be seen in the literature because "the existing studies leave doubt as to whether more sustainable companies create financial value - or whether more financially valuable companies invest more in sustainability" (Esty and Cort, 2017). Regarding these empirical studies, various results exist that (1) research which finds a statistically significant correlation between sustainability and corporate performance and (2) research which does not take into account various elements of sustainability (Esty and Cort, 2017).

2.1. Corporate sustainability dimensions

Antolín-López et al. (2016) mention that the diversity of instruments associated with corporate sustainable assessment and the lack of knowledge on this topic "create complexity and confusion for academics and practitioners" leaving it open to debate; also no consensus has been reached on which sub-dimensions must be considered relevant when measuring the three dimensions of corporate sustainability (economic, social and environmental).

Scholars agree that corporate sustainability integrates three dimensions (economic, social and environmental) or in other words the 3Ps associated with business (Profit, People, Planet) or the "triple bottom line" (Amini and Bienstock, 2014).

It's also very important to mention that in general the instruments associated with corporate sustainable assessment focus more on environmental and social dimensions than on the economic dimension (Antolín-López et al., 2016; UN SDGs, 2015). Hence, ISO 26000 does not integrate economic metrics in a clear manner; on the other hand the Global Reporting Initiative (GRI) includes only several very general economic indicators (Hahn and Kuhnen, 2013).

A general review from the literature that presents various accepted "elements" of corporate sustainability (economic, social and environmental) can be seen in Table 1.

According to some scholars, the research regarding the relation between corporate environmental performance (*CEP*) and corporate financial performance (*CFP*) is debatable (Filbeck and Gorman, 2004; Moneva et al., 2007; Qi et al., 2014). Causality between *CEP* and *CEF* is primarily due to the various methodologies used for evaluating these constructs (Moneva and Ortas, 2010). The results of different studies concerning this correlation between *CEP* and *CFP* are still contradictory (Albertini, 2013) and very complex (Horvathova, 2010).

However most research on this relation between corporate environmental performance (CEP) and corporate financial performance (CFP) indicates that they are positively connected (Wu, 2006; Van Beurder and Gossling, 2008; Moneva and Ortas, 2010).

2.2. Corporate sustainability metrics

Currently there are proposed many separate indicators for corporate sustainability metrics that include environmental, social and corporate governance (ESG) dimensions, but the debate over the link between sustainability and business success its far from over. In the table below (Table 2) is a sample of ESG and Sustainability Metrics but it's not an exhaustive list.

The diversity of sustainability metrics considered to be relevant by companies is presented in various corporate sustainability reports. Tonello (2012) following a broad analysis of Canadian

Table 1
General corporate sustainability dimensions.
Source: Synthesis developed by Antolín-López et al. (2016) based on: Figge et al. (2002), Bansal (2005), Kolk et al. (2010), Kinder, Lydenberg and Domini (KLD), Dow Jones Sustainability Index (DJSI), United Nations Global Compact (UNGC), ISO 26000, Global Reporting Initiative (GRI) and B-Corporation (B-Corp).

	Sub-dimensions
Economic/dimension 1	Profit generation
	Efficiency
	Supplier relations
	Marketing practices
	Innovation
	Risk & crisis management
	Employee compensation
	Government relations
	Ethics in management
Social/dimension 2	Employee programs
	Occupational health & safety
	Human rights
	Philanthropy
	Volunteerism
	Local commitment
	Bottom of pyramid (BoP)
	Product responsibility
	Quality Management
	Consumer relations management
	Sustainable consumption
Environmental/dimension 3	Energy conservation
	Materials management
	Water issues
	Waste management
	Climate change
	Pollution
	Biodiversity
	Product stewardship
	Environmental management systems
	Distribution and transportation
	Green suppliers
	Environmental reporting
	Environmental compliance
	Environmental risk

Table 2
ESG and sustainability Metrics.
Source: Esty and Cort(2017).

Metrics	Product/Source
"Six Social Themes (Nutrition, Disease Treatment, Sanitation, Affordable Real Estate, SME Finance, Education) and five environmental themes (Alternate Energy, Energy Efficiency, Green Building, Sustainable Water, Pollution Prevention)".	Sustainable Impact Metrics/MSCI ESG, 2016a
"Includes metrics across three dimensions: Sustainable Impact (to measure fund exposure to companies that address core environmental & social challenges); Values Alignment (to screen funds for investments that align with ethical, religious or political values); and Risk (to understand fund exposure to ESG-related risks)".	ESG Fund/MSCI ESG, 2016b
"Includes 80 Exposure Metrics (business segment and geographic risk exposure" and "129 Management Metrics (based on policies, programs, & performance data)".	ESG Rating/MSCI ESG, 2016c
"Includes a comprehensive range of data on fossil fuel reserves, carbon emissions and sector application".	Carbon Solutions/MSCI ESG, 2015
"Over 120 Environmental, social and governance indicators keyed to the Global Reporting Initiative list of performance indicators".	ESG Disclosure Scores/Bloomberg Professional (2016)
"Includes "over 70 Key Performance Indicators" in three categories: Environmental (Resource Use, Emissions, Innovation); Social (Community, Workforce, Human Rights, Product Responsibility); and Governance (Management, Shareholders, CSR Strategy)".	ESG Data/Thomson Reuters (2017)

companies found 585 different indicators of sustainability performance and that "the companies had very divergent views as to what indicators constituted the core measures of sustainability" (Esty and Cort, 2017).

Regarding corporate sustainability metrics, Esty and Cort (2017) state that (1) while mandatory metrics of performance in sustainability continue to grow, the majority of material issues remain voluntary resulting in gaps and inconsistencies" and also (2) "much more focus needs to be given to what really matters in terms of environmental impacts – and the structure of metrics needs to re-geared to reflect this materiality analysis".

Generally it could be said that sustainability metrics have evolved and have increased substantially. The current approach focuses on relative measures and focus on relationships (Stewart, 2008). However this topic is very important for companies because "anybody pursuing sustainable development as a corporate goal will sooner or later face questions about the metrics used to operationalize sustainability" (Schaltegger and Burritt, 2010; Garcia et al., 2016).

In the last decades, corporate sustainability received particular attention from academics and practitioner scholars. However scholars such as Chelli and Gendron (2013) or Maas and Reniers (2014) argue that corporate sustainability measurement "remain underexplored despite its prominence in the business arena". In the literature very few clear attempts exist of approaches related to corporate sustainability measurement (Krajnc and Glavic, 2005; Searcy and Elkhawas, 2012) and those that exist focus on industries, cities or regions, analyzing mainly a single dimension of corporate sustainability, namely environmental sustainability.

The most used instruments associated with corporate sustainability assessment in the literature by the specialists Kinder, Lydenberg and Domini (KLD), Morgan Stanley Capital International (MSCI), Dow Jones Sustainability Index (DJSI), United Nations Global Compact (UNGC), ISO 26000, Global Reporting Initiative (GRI) and B-Corporation (B-Corp), are described in the table below (Table 3).

3. Research design

In the literature the models used to assess and compare different aspects of sustainability development are the quantitative models (Todorov and Marinova, 2011; Bottani et al., 2017) that addresses economic models (Faucheux et al., 1996), simulation models (Boulanger and Brechet, 2005), policy models (O'Doherty et al., 2007), and fuzzy logic models (Andriantiatsaholiniaina et al., 2004).

The most extensive metrics identified in the literature, as being associated to sustainability assessment were a number of 2555 unique indicators (Ahi and Searcy, 2015). Other scholar (Tajbakhsh and Hassini, 2015) design a data envelopment analysis model in order to assess a process associated to sustainability. The model was applied on two organizations from manufacturing and service sector. Mota et al. (2015) present a mathematical programming model that focus on the same process as Tajbakhsh and Hassini (2015), but its model integrates the economic, environmental and social pillar of sustainability. In addition Chen and Andresen (2014) operationalize their model by integrating the analytic hierarchy process (AHP). Phillis and Kouikoglou (2009) and Andriantiatsaholiniaina et al. (2004) applied fuzzy logic in the sustainability assessment through an original model called SAFE; the model was used to assess different countries sustainability level (Bottani et al., 2017).

Due to the complexity of sustainability corporate performance, the evaluation process has some limitations (Bolis et al., 2017). This limitations are associated to classical and quantitative models used in decision making process (Martinez-alier et al., 1998; Cortner, 2000; Hertin et al., 2009; Hezri and Hasan, 2004; Garrity, 2012; Maiorano and Savan, 2015), and to complexities of sustainable development phenomenon (Rammel and Bergh, 2003; Nooteboom and Teisman, 2003; Foxon et al., 2013).

To fill this literature gap, the purpose of this research is to assess the corporate sustainable performance (*CORSUS*) based on corporate environmental performance (*CEP*) and corporate financial performance (*CFP*) dimensions. In order to measure these two main dimensions, in the study we considered some relevant indicators (financial and environmental) that were reported by a representative European automotive company ranked in 2017 by Forbes in top 10 worldwide. This indicators were introduced in principal components analysis (*PCA*) in order to estimate the standardized scores for *CEP* and *CFP*. The research design model is presented in Fig. 1.

Following, this two components were considered in the proposed fuzzy model to assess their influence on the CORSUS.

3.1. Indicators of CEP and CEF

In the case of corporate environmental performance (*CEP*) dimension, the literature presents the following representative indicators:

(1) *Water consumption* (*WaC*) - (m^3 thousands) is a measure of the company's impact on water resources. If less water is used to make a given amount of product, more water is available for humans and other species to use (McElroy and

Table 3
Corporate sustainability measurement.
Source: Antolín-López et al.,(2016).

Instrument/Source	Purpose
Figge et al., 2002	Integration in the organizational general management of social and environmental dimension
Bansal (2005)	Identification of items that are associated to Corporate Sustainable Development
Kolk et al., 2010	Presents metrics for corporate sustainability dimensions
Kinder, Lydenberg and Domini (KLD) – owned by MSCI	Presents metrics and management tools in order to "integrate corporate sustainability factors in investment decisions"
Dow Jones Sustainability Index (DJSI)	Development of a corporate sustainability performance assessment index for the largest Dow Jones companies
United Nations Global Compact (UNGC)	Development of a global governance code for corporate sustainability
ISO 26000	Presents a standard scheme for companies in order to develop and implement a Corporate social responsibility practices
Global Reporting Initiative (GRI)	Presents a standardized system in order to report to all stakeholders that information's associated to corporate sustainability
B-Corporation (B-Corp)	Presents a framework/certification scheme for companies in order add various benefits to shareholders and to society

Therefore this research direction associated with corporate sustainable assessment "remains in an explorative stage" (Antolín-López et al., 2016).

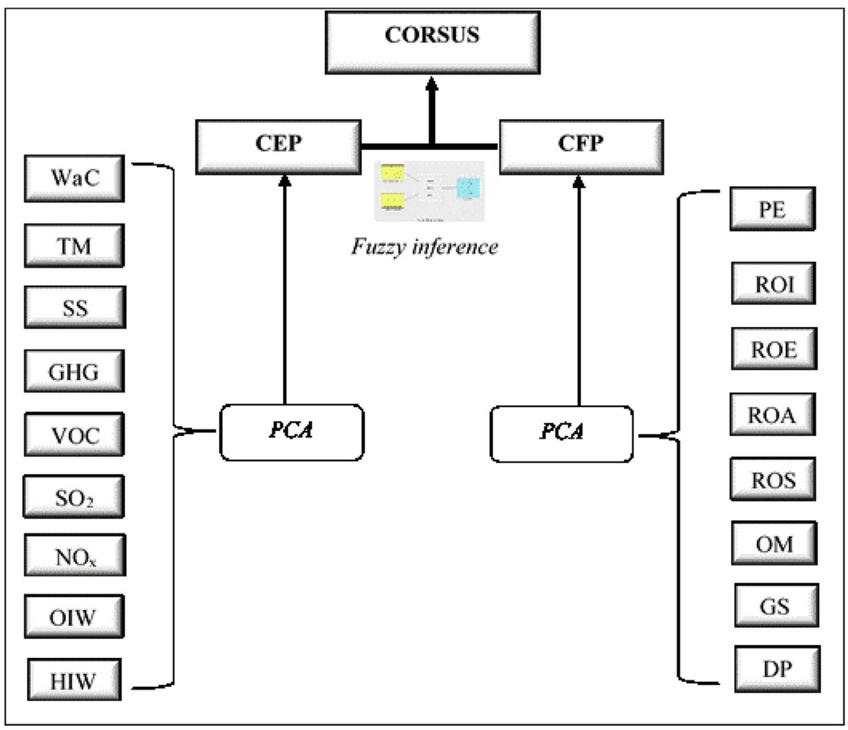

Fig. 1. The conceptual framework for developing a fuzzy-PCA model to support the corporate sustainable performance based on environmental and financial corporate dimensions.

van Engelen, 2012; Semmens et al., 2014; Ahi and Searcy, 2015; MSCI ESG, 2016a; Bottani et al., 2017; OICA, 2018); lower water use is better, so we set the upper target level to the industry average $L_W = 5.2\ m^3$ of water per unit product and the lower unsustainable value to the maximum over all companies, $U_W = 10\ m^3$ (Semmens et al., 2014);

(2) Liquid discharges: *Toxic metals (TM)* and *Suspended solids (SS)* - data on pollutant flows are based on measurements of effluents after they have been treated in the plants and before they are discharged to the outside. Discharges from some plants may subsequently be treated in municipal treatment plants (Ansari et al., 2013; Ahi and Searcy, 2015; OICA, 2018).

TM quantity represents the sum of the flow of toxic metals discharged, weighted by a toxicity coefficient. This quantity, expressed in tons per year, is calculated as follows: Toxic metals = 5 flows (Ni + Cu)+10 flows (Pb + As)+1 flow (Cr + Zn)+50 flows (Hg + Cd) (Ansari et al., 2013). Subjectively we can consider that upper target level to the industry average $L_{TM} = 0.002$ kg/year per unit and the lower unsustainable value to be the maximum $U_{TM} = 0.005$ kg/year per unit.

The quantity of *SS* represents the average daily flow of suspended solids discharged, expressed in tons per year. Lower discharges is better. Subjectively we can consider that upper target level to the industry average $L_{SS} = 0.1$ kg/year per unit and the lower unsustainable value to the maximum $U_{SS} = 0.5$ kg/year per unit (Ansari et al., 2013).

(3) *Greenhouse gas* (GHG) discharges include the direct and indirect GHG emissions and are expressed in metric tons of carbon dioxide equivalent. Emissions from the following sources were included: combustion of fossil fuels; fuel consumption during testing of engines; fork-lift trucks using compressed natural gas or propane (Ki-Hoon and In-Mo, 2011; Ahi and Searcy, 2015; MSCI ESG, 2015; OICA, 2018). *GHG* is assumed that lower is better and that any value below

a certain threshold is sustainable (Ki-Hoon and In-Mo, 2011), i.e., its normalized value is one. The threshold is set at $T_{GHG} = 0.2$ tons CO_2 equivalent per car produced. The upper bound at which sustainability is zero is the maximum value over all years for all companies. This value is $U_{GHG} = 0.5$ tons CO_2 vehicle produced. These emissions make up more than 95% of the GHG emissions produced by the automotive manufacture.

(4) *Volatile organic compound (VOC)* - The atmospheric emissions of volatile organic compounds (*VOC*) included in the data are the emissions produced when bodywork is painted (body assembly plants). The application of paint on bumpers and on parts and accessories is not taken into account (Byung Ro Kim, 2011; Andriantiatsaholiniaina et al., 2004; OICA, 2018). *VOC* corresponds to the tons of emissions per m^2 of painted vehicle surface. The consolidated ratio for the Group corresponds to the total *VOC* emissions generated by the body assembly plants divided by the total of the painted surfaces. Subjectively we can consider that upper target level to the industry average $L_{VOC} = 3$ kg/year per unit and the lower unsustainable value to the maximum $U_{ss} = 5$ kg/year per unit (Byung Ro Kim, 2011).

(5) *Sulfur dioxide and nitrogen oxides* (SO_2 and NO_x). The atmospheric emissions of and included in the data correspond to emissions produced by the burning of fossil fuels at all sites, excluding transport to the site (Semmens et al., 2014; MSCI ESG, 2015; OICA, 2018). Subjectively we can consider that upper target level to the industry average $L_{VOC} = 0.002$ kg/year per unit and the lower unsustainable value to the maximum $U_{ss} = 0.005$ kg/year per unit.

(6) *Ordinary industrial waste* (tons per unit produced) is the mass of solid waste that is dumped by the company into a landfill, rather than reused or recycled in some manner (Antolín-López et al., 2016; OICA, 2018). A lower amount of waste dumped is better for the environment due to less pollution of the land and greater amount of land available to the ecosystem for other purposes (farming, animal habitat, etc.). Less waste is also an economic benefit, since companies that produce less waste will spend less money on raw materials, run a lower risk of environmental fines and penalties and have less land and waste removal costs. As previously, the average value $T_{OIW} = 0{,}2$ t/unit is considered to be the threshold for sustainability and the maximum $U_{OIW} = 0{,}5$ t/unit produced as the smallest undesirable value (Sharma et al., 2016; Pislaru and Trandabat, 2012).

(7) *Hazardous industrial waste* (kg per unit produced) generated by the company harms the ecosystem because that waste must be treated or dumped (Andriantiatsaholiniaina et al., 2004; Phillis and Davis, 2009; Kouikoglou and Phillis, 2011; OICA, 2018). The less hazardous waste the company produces, the more sustainable it is. Suppose that any level of waste production below $T_{HIW} = 10$ kg/unit (industry average) is sustainable with value one, with sustainability decreasing linearly to the maximum value $U_{HW} = 30$ kg/unit (Pislaru and Trandabat, 2012).

In the case of corporate financial performance (*CFP*) dimension Moneva and Ortas (2010) present two literature models: (i) a model that integrates market-based measures like: stock performance and market return share price – a model used to analyze the financial impact of various environmental events (Luo and Bhattacharya, 2006; Barnett and Salomon, 2006); (ii) a model that integrates accounting-based measures as: profitability, returns on assets, asset turnover and growth proxies – model that reflect the organization's internal efficiency (Peinado-Vara, 2006; He et al., 2007).

In the literature exist different opinions regarding the selections of the indicators that characterizes the CFP (Wood and Jones (1995) quoted by Albertini, 2013). Nevertheless the most common indicators are: return on assets (ROA), profit margin, return on equity (ROE) [relative], and cash-flow and operating profits [absolute] (Moneva and Ortas, 2010). Many studies present three subdivisions of CFP (Albertini, 2013), as follows:

(1) *market-based* (investor returns) as price-earnings ratio (*PE*), associated with the firm's market performance; *Price-earnings* (PE) ratio is used to compare the current market price of the stock with quality of the corporate earnings and a high value of this ratio could indicate the excitement of investors over the results obtained by the company (Bragg, 2007). Low values of this ration indicate that investors don't have a favorable appreciation on the company's earnings.

(2) *accounting-based* (accounting returns) as: return on equity (*ROE*) is calculated as a ratio between net income and own equity and it is used to assess the company's performance by paying dividends to the shareholders proportional to the amount of equity that has been made available to the company (Jaba et al., 2017); return on assets (*ROA*) is calculated as a ratio between the operating income and operating assets, measures the company's efficiency in using its assets on order to obtain future economic benefits (Jaba et al., 2017); return on sales (*ROS*) describes the company's operational efficiency and is computed as a ratio between gross margin and total sales (Bragg, 2007). This indicators is used to determine the profitability of a product or service that is sale by the company (Bragg, 2007); return on investment (ROI) is used to measure the efficiency of the investments in the assets of the company, based on the gains that are obtained taking into consideration the costs of capital (Ichsani and Suhardi, 2015);

(3) *organizational measures* as operating margin (*OM*) (for measuring employees productivity) is calculated as a ratio between operating income and net sales (reduced by the investment income) and measures efficiency of the company's operating activity (Bragg, 2007); growth in sales (*GS*) (for measuring costumers satisfaction) is the difference between the previous and current annual sales, divided by previous annual sales and measures the performance of sales due to client's satisfaction or consumer loyalty (Cao and Li, 2015); days payables (*DP*) (for measuring the relation efficiency with its suppliers) (Harrison and Wicks, 2013) measures the days that a company takes to pay its suppliers and is calculated as a ratio between accounts payables and total purchases per day. High values of this indicator reveal that the company could not pay its suppliers in time due to insufficient cash (Bragg, 2007).

3.2. Normalization of CEP and CFP indicators

Each environmental and financial indicator must be passed through a filter that normalizes their values in [0,1] (zero - lowest level of sustainability and one - highest level of sustainability) in order to allow the use of PCA and fuzzy computations.

If the value of a basic indicator is x, its target an interval $[a_i, A_i]$, its minimum value b_i and its maximum value B_i, then its normalized value y is as in equation (1) (Phillis and Kouikoglou, 2009):

$$y = \begin{cases} \frac{x-b_i}{a_i-b_i}, b_i \le x \le a_i \\ 1, \quad a_i \le x \le A_i \\ \frac{B_i-x}{B_i-A_i}, A_i \le x \le B_i \end{cases} \quad (1)$$

The maximum and minimum values are provide by a set of collected data from the field of interest.

Fig. 2 shows the normalization of basic indicator y where x represent the indicator value for the sustainability variables that are assessed.

3.3. The use of PCA to estimate CEP and CFP scores

PCA is a multivariate statistical method that is used for data reduction and for obtaining new latent variables (Jaba and Robu, 2011; James et al., 2014; Robu and Istrate, 2015). In this case we started from the environmental and financial indicators proposed in Fig. 1, to obtain the new latent variables *CEP* and *CEF*, as dimensions of corporate sustainable performance.

The initial variables were include in PCA to obtain the scores for the proposed *CEP* and *CFP* dimensions. Using PCA with IBM SPSS 22.0, the scores for *CEP* and *CFP* were estimated by including the initial environmental and financial indicators in the following equations:

$$CEP = \beta_1 \cdot WaC + \beta_2 \cdot TM + \beta_3 \cdot SS + \beta_4 \cdot GHG + \beta_5 \cdot VOC + \beta_6 \cdot SO_2 + \beta_7 \cdot NO_X + \beta_8 \cdot OIW + \beta_9 \cdot HIW \quad (2)$$

$$CFP = \delta_1 \cdot PE + \delta_2 \cdot ROI + \delta_3 \cdot ROE + \delta_4 \cdot ROA + \delta_5 \cdot ROS + \delta_6 \cdot OM + \delta_7 \cdot GS + \delta_8 \cdot DP \quad (3)$$

The estimated scores for *CEP* and *CFP* have the following statistical distributions: $CEP \sim N(0;1)$ and $CFP \sim N(0;1)$, and their values (minimum, maximum, quartiles 1, 2 and 3) were considered for determination of fuzzy sets.

3.4. The fuzzy logic approach

Fuzzy logic operates with incomplete truth and the final result may be totally true or totally untrue (Arabacioglu, 2010). Therefore in the literature it could be observed the fact that scholars design various fuzzy logic structure to solve the curse of dimensionality (Fayaz et al., 2017).

Fuzzy logic offers scientific tools to emulate human thinking in order to model a system without comprehensive computation using both quantitative and qualitative data (Negnevitsky, 2005). The computations are made by words, and knowledge is defined by language rules (for example IF-THEN).

A fuzzy set is a set whose elements have degrees of membership. The fuzzy set was introduced by Lotfi A. Zadeh in 1965 (Zadeh, 1965) as an extension of the classical notion of sets and can be applied in many fields of human activity. Fuzzy sets determines "how much" the element belongs to the set (Doskočil and Radek, 2015). Essentially, fuzzy logic measures the certainty or uncertainty of how much the element belongs to the set (Doskočil et al., 2009).

A fuzzy set can be simply defined as a set with fuzzy boundaries. Consequently a fuzzy rule can be defined as a conditional statement in the form (Zadeh, 1973): IF x is A THEN y is B, where x and y are linguistic variables; A and B are linguistic values determined by fuzzy sets on the universe of discourses X and Y, respectively.

Linguistic variable introduced by Zadeh (1973) represent a fundamental concept of fuzzy logic. A linguistic variable is a variable "whose values are words or sentences in a natural or artificial language" (Zadeh, 1973). Accurately, a linguistic variable is a fuzzy partition of a physical X range in areas that eventually overlap. Each area is represented with a fuzzy set in X named linguistic value (Phillis and Kouikoglou, 2009).

In the field of corporate performance assessment, the sustainable decision-making process involve complex and imprecise parameters with a high degree of uncertainty due to deficient understanding of the supporting issues. The dynamics of any socio-ecological system cannot be described by traditional mathematics because of its intrinsic difficulty and vagueness. This is one of the reasons why, it is more adequate to use fuzzy logic to assess it (Phillis et al., 2010).

Fuzzy systems offer opportunities to model environmental processes for which only a linguistic description is available; non-fuzzy techniques cannot handle the imprecision and vagueness of semantic aspects which are inherent to linguistic uncertainty (Ascough II et al., 2008).

4. Results and discussions

The main results of our study consist in presentation of descriptive statistics associated to the *CEP* and *CFP* dimensions that were included in PCA, of fuzzy sets and fuzzy rules, performing the fuzzy inference and fuzzy system assessment.

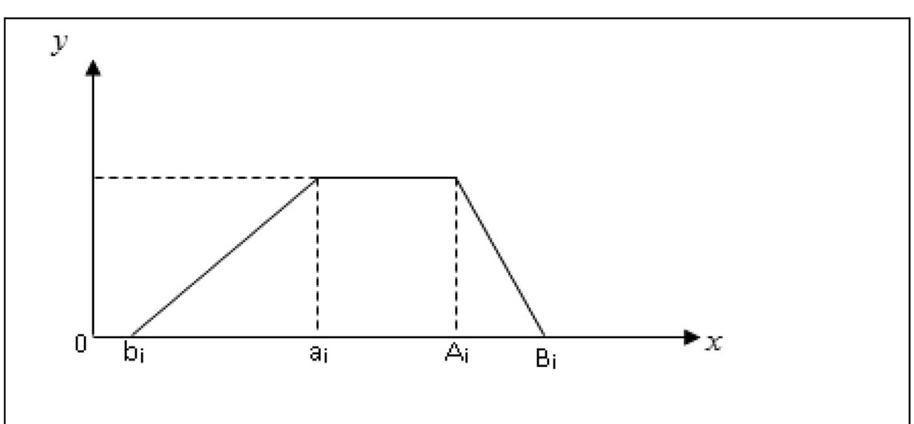

Fig. 2. Normalization of basic indicator y.
Source: Phillis and Kouikoglou (2009)..

4.1. Descriptive for CEP and CFP indicators

In our study case, data for the indicators that determines *CEP* and *CFP* scores in PCA was collected from available public statements of automotive manufacturer (see Tables 4–7).

In Table 5 are presented the environmental basic indicators used by the model in order to assess the corporate environmental performance. The raw data can be found in the annual registration document of the car manufacturer from 2007 until 2016. Basic indicators come in a variety of scales and units. Lower values mean better corporate sustainability performance for some indicators but worse performance for others. In order to be able to compare the indicators and to facilitate analysis, the data are normalized on a 0–1 scale, using equation (1). The value 0 means the least desirable score and the value 1 the most desirable indicator values, which are determined from literature. Corresponding normalized values for the environmental and financial performance indicators are presented in Tables 6 and 7.

In Table 7 there are presented the values and the normalized values of the financial indicators include in *PCA*. To have comparability and to be introduced in PCA analysis (based on equation (2) and (3)) and in fuzzy system, the normalized values were obtained by equation (1).

Based on the estimates of the parameters for equation (2) and (3) that are obtained in PCA the new equations for CEP and CFP scores are the following:

$$CEP = 0{,}153 \cdot WaC + 0{,}129\ TM + 0{,}160 \cdot SS - 0{,}111 \cdot GHG + 0{,}120 \cdot VOC + 0{,}169 \cdot SO_2 + 0{,}201 \cdot NO_X + 0{,}158 \cdot OIW + 0{,}161 \cdot HIW \tag{4}$$

$$CFP = 0{,}025\ PE + 0{,}176 \cdot ROI + 0{,}194 \cdot ROE + 0{,}194 \cdot ROA + 0{,}179 \cdot ROS + 0{,}185 \cdot OM + 0{,}172\ gs + 0{,}058 \cdot DP \tag{5}$$

The new values of *CEP* and *CFP* that are obtained using the values from Tables 6 and 7 in equations (4) and (5) are inputs in fuzzy sets.

In Table 8 there are presented the descriptive statistics for *CFP* and *CEP*, variables that were introduced in PCA. Low values of *CFP* indicates a poor corporate financial performance and high values of *CFP* indicates a high degree of corporate financial performance. In contrary, low values of *CEP* indicates a high degree of corporate environmental performance, and high values of *CEP* indicates a low degree of corporate environmental performance.

Table 4
The group annual unit production.
Source: Annual Report - Registration Document, automotive manufacture, 2007–2016.

Year	Vehicle production (units)
2007	2.485.039
2008	2.382.243
2009	2.309.188
2010	2.625.796
2011	2.722.062
2012	2.550.286
2013	2.523.237
2014	2.571.185
2015	2.843.353
2016	3.131.495

Based on equation (1), normalized values for environmental and financial performance indicators (Tables 5–7) are computed depending of number of vehicle manufactured every year (Table 4). The year 2017 was not included in the analysis because the corresponding data for the financial indicators were not published, in accordance with the legal requirements.

4.2. Determination of fuzzy sets

The first step is to take the crisp inputs *CEP* (corporate environmental performance) and *CFP* (corporate financial performance) and to establish the degree to which these inputs belong to each of the appropriate fuzzy sets. The crisp input represent a numerical value limited to the universe of discourse. Fuzzification represent the computation whereby the normalized value of basic indicator is turned into a linguistic variable from a crisp value (as a precise value).

Each linguistic variable is present in a number of fuzzy sets. For our case the linguistic variable of *CEP* (corporate environmental performance) and *CFP* (corporate financial performance) indicators has five fuzzy sets with linguistic values such: *very bad (VB), bad (B), average (A), good (G) and very good (VG)* as presented in Fig. 3 (Pislaru and Trandabat, 2012).

In order to represent *CORSUS* (corporate sustainability) a bigger number of fuzzy sets should be used because components *CEP* (corporate environmental performance) and *CFP* (corporate financial performance) which compose *CORSUS*, each have five linguistic rules and so generate 5^2, 25 different combinations.

To determine how many fuzzy set must be attributed to the final indicator *CORSUS*, positive weights α and β must be assigned representing the relative importance respectively of *CEP* and *CFP* in the calculation of *CORSUS*. We also assign the integer values from 0 to 4 to the five linguistic values, such that 0 is assigned to *VB*, 1 is assigned to *B*, 2 is assigned to *A*, 3 is assigned to *G*, and 4 is assigned to *VG*. Consequently, to each pair of weights (*CEP*, *CFP*) we assign an index *CORSUS* for the linguistic value of the overall sustainability, where

$$CORSUS = \alpha CEP + \beta CFP \tag{6}$$

The minimum value of *CORSUS is* $0\alpha + 0\beta = 0$ and the maximum value is $4\alpha + 4\beta$ (see Table 8). In order to keep a balance between the environmental and financial dimensions of sustainability the hypothesis $\alpha = \beta$ is applied.

CORSUS becomes an integer between 0 and 8, and the output system (corporate sustainability) must have at least nine fuzzy sets in order to aggregate *CEP* and *CFP* more precisely. These fuzzy sets are: *extremely low* (EL = 0), *very low* (VL = 1), *low* (L = 2), *moderately low* (ML = 3), *average* (A = 4), *moderately high* (MH = 5), *high* (H = 6), *very high* (VH = 7), and *extremely high* (EH = 8) as presented in Fig. 4 (Phillis and Davis, 2009).

4.3. Determination of fuzzy rules

In order to obtain fuzzy rules an expert opinion is required to describe how the problem can be solved based on previously described fuzzy sets. Basically, this step consists in taking fuzzified inputs and apply them to the antecedents of the fuzzy rules. There are two inputs (*CEP* and *CFP*) and one output variable (*CORSUS*) in our study case. The rule base for *CORSUS* is obtained from equation (4) and are presented in Table 9.

If a given fuzzy rules has multiple antecedents, the fuzzy operator (AND or OR) is used to obtained a single number that represents the result of the antecedent evaluation. This value (the truth value) is then applied to the consequent membership function.

4.4. Fuzzy inference performing

Fuzzy inference can be defined as a process of mapping from given input to an output, using the theory of fuzzy sets (Negnevitsky, 2005). Once the fuzzy sets and fuzzy rules were defined they must be encoded and in this way a fuzzy system was

Table 5
Basic indicators for the environmental performance dimension.
Source: own processing based on annual environmental statements of automotive manufacturer.

Year	Water usage	Discharges in Water		Discharges in Air				Waste disposal	
		Suspended Solids	Toxic Metals	Volatile Organic Compounds	Greenhouse gases	Atmospheric emissions		Ordinary Industrial Waste	Hazardous Industrial Waste
						SO_2	NO_x		
units	m^3 thousands	tons	tons	tons	teqCO_2	tons	tons	tons	tons
2007	13495.9	443.15	14.6	12221.6	671431.8	135.9	643.8	854204.2	73719.7
2008	11516.5	486	13.9	9835.0	615374.7	106.3	544.2	785597.4	60239.3
2009	10681.6	497.5	14.4	13532.38	1190657.9	94.0	512.9	738464.7	50936.1
2010	10690.1	496.4	12.4	13532.38	1251517.9	35.8	596.5	905383.3	54531.0
2011	11972.3	408	11.7	13895.44	1191009.2	12.0	505.8	877219.3	65092.7
2012	11538.6	386.6	8.9	14221.93	1193243.6	11.6	513.2	839044.4	57840.8
2013	11391.2	418.7	8.3	11044	1224965.4	15.8	534.3	845275.2	57774.6
2014	10746	379.7	12.2	10424	1174065	8.8	469.4	839599	60785
2015	11840	375	12.3	11021	1230159	10.8	528.6	892354	59924
2016	12635	400.6	14.2	11948.1	1214428	9.8	595.1	944240	66152

Table 6
Corresponding normalized values for the environmental performance indicators
Source: own processing based on indicators from Table 5 computed with equation (1).

Year	Water usage	Discharges in Water		Discharges in Air				Waste disposal	
		Suspended Solids	Toxic Metals	Volatile Organic Compounds;	Greenhouse gases	Atmospheric emissions		Ordinary Industrial Waste	Hazardous Industrial Waste
						SO_2	NO_x		
2007	0.952	0.804	0.225	0.041	0.766	0	0.205	0.521	0.017
2008	1	0.740	0.233	0.436	0.806	0	0.358	0.567	0.236
2009	1	0.711	0.153	0	0	0	0.389	0.601	0.397
2010	1	0.777	0.456	0	0.078	0	0.364	0.517	0.462
2011	1	0.875	0.540	0	0.208	0.197	0.571	0.592	0.304
2012	1	0.871	0.702	0	0.107	0.150	0.494	0.570	0.366
2013	1	0.835	0.742	0.312	0.048	0	0.441	0.550	0.355
2014	1	0.881	0.451	0.473	0.145	0.526	0.587	0.578	0.318
2015	1	0.920	0.535	0.562	0.225	0.401	0.570	0.621	0.446
2016	1	0.930	0.493	0.592	0.374	0.624	0.550	0.662	0.444

Table 7
Normalized values for the financial performance indicators
Source: own processing based on annual financial statements of automotive manufacturer and computed with equation (1).

Indicator	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
PE	16,50	10,90	18,60	15,50	13,70	15,00	18,60	18,60	19,00	20,30
PE normalized	0,60	0,00	0,82	0,49	0,30	0,44	0,82	0,82	0,86	1,00
ROE (%)	12,62	2,82	−17,89	17,90	9,03	7,33	2,49	7,99	10,76	11,64
ROE normalized	0,85	0,58	0,00	1,00	0,75	0,70	0,57	0,72	0,80	0,83
ROA (%)	3,90	0,87	−4,89	5,10	2,93	2,39	0,78	2,41	3,28	3,55
ROA normalized	0,88	0,58	0,00	1,00	0,78	0,73	0,57	0,73	0,82	0,84
ROS (%)	20,00	18,10	17,10	19,30	18,50	17,40	17,90	18,90	20,40	21,40
ROS normalized	0,67	0,23	0,00	0,51	0,33	0,07	0,19	0,42	0,77	1,00
ROI (%)	13,06	3,66	−10,55	13,86	7,60	3,46	1,32	3,70	4,95	5,05
ROI normalized	0,97	0,58	0,00	1,00	0,74	0,57	0,49	0,58	0,63	0,64
OM (%)	3,00	−0,30	−2,80	1,60	2,90	0,30	−0,10	2,70	4,80	6,40
OM normalized	0,63	0,27	0,00	0,48	0,62	0,34	0,29	0,60	0,83	1,00
GS (%)	−2,04	−7,11	−10,49	15,60	9,38	−3,19	−0,82	0,30	10,41	13,05
GS normalized	0,32	0,13	0,00	1,00	0,76	0,28	0,37	0,41	0,80	0,90
DP days	87,57	80,45	74,04	71,18	65,89	68,31	69,12	72,68	77,77	80,82
DP normalized	1,00	0,67	0,38	0,24	0,00	0,11	0,15	0,31	0,55	0,69

obtained. For fuzzy inference accomplishment the aggregation of the rule outputs and defuzzification must be performed. Defuzzification combines the membership grades of the fuzzy output into a single numerical value and represents the last step in the fuzzy inference process. Aggregation is the process of unification of the outputs of all rules. Basically, the membership functions of all rule consequents are combined into a single fuzzy set so the output is one fuzzy set for each output variable.

Because the final output of a fuzzy system has to be a crisp number a defuzification process must be performed. So, the input for the defuzification process will be the aggregate output fuzzy set and the output is a single number.

Finally in order to obtain a crisp value for CORSUS, several defuzzification methods can be used such as: centroid, bisector of area, height defuzzification (Sivanandam et al., 2007). The Centroid technique method was chosen because is probably one of the most popular and reflects reality quite accurately (Cox, 1999). For the inference, it was used the MATLAB Fuzzy Logic Toolbox because it

Table 8
Descriptive statistics for *CFP*, *CEP* and *CORSUS*
Source: own processing in SPSS 22.0

Statistics		CFP	CEP
Mean		0,0000	0,0000
Median		0,1418	0,2106
Std. Deviation		1,0000	1,0000
Minimum		−2,1616	−2,0540
Maximum		1,1445	1,2998
Percentile	62	**0,6294**	**0,3103**

generally provides complete environments for building and testing fuzzy systems and very friendly graphical user interfaces.

The most common and used fuzzy inference techniques are the Mamdani and Sugeno methods. Due to the fact that ability to capture expert knowledge in fuzzy rules the Mamdani method is widely accepted in fuzzy expert systems. The Sugeno method performs well with optimization problems, making it suitable for dynamic nonlinear systems (Mamdani and Assilian, 1975; Kaur and Verma, 2015).

The company's sustainability performance indicators from Tables 6 and 7 were input in the PCA procedure returning the scores for *CEP* and *CFP* which in turn represent input in the graphical interface of the fuzzy inference tool (see Fig. 5).

Fig. 5 presents the crisp output value for *CORSUS* indicator obtained by defuzzification of fuzzy sets representing *CEP* and *CFP*. The fuzzy inference technique used is so-called Mamdani method (Mamdani and Assilian, 1975).

These values were subject of fuzzification, achieving a membership value for each linguistic judgment according to the scales presented in Fig. 3. Overall, the fuzzy numbers and linguistic judgments obtained for the *CEP* and *CFP* and the related membership degree was used to aggregate them, according to Fig. 6. The

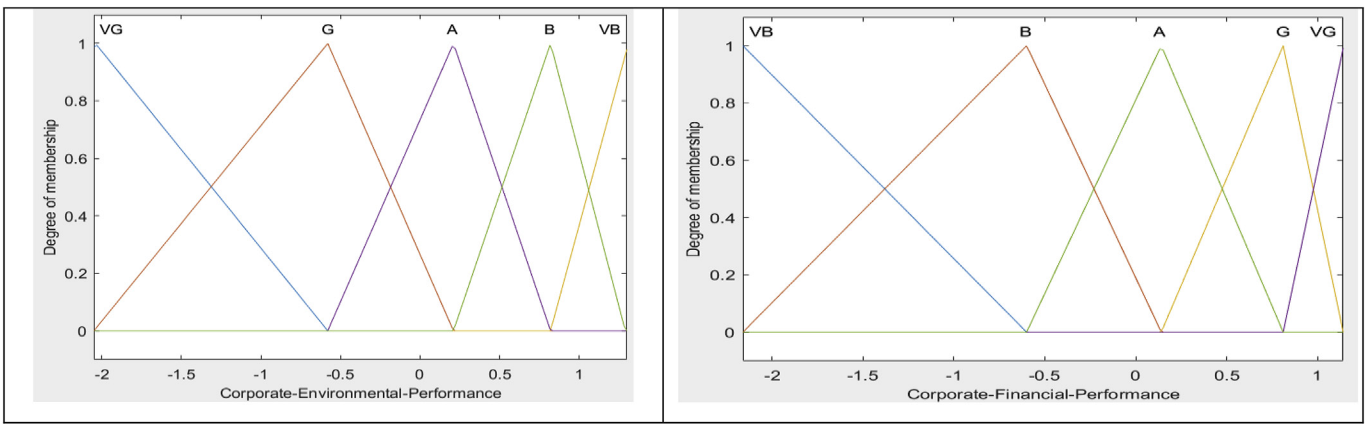

Fig. 3. Membership functions for CEP and CFP indicators.

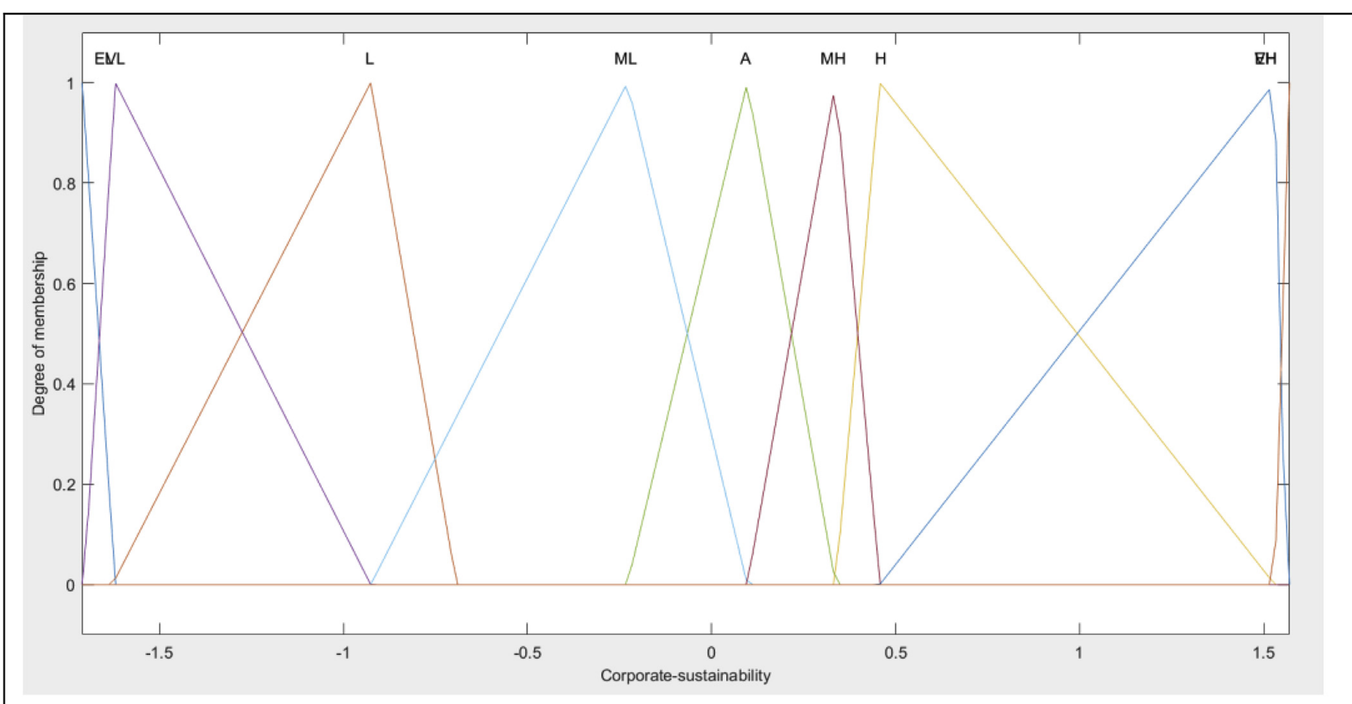

Fig. 4. Membership functions for CORSUS sustainability indicator.

Table 9
Rule base for CORSUS indicator.
Source: own processing.

Rule	IF CEP is	and CFP is	then CORSUS is
R1	VB (0)	VB (0)	EL (0)
R2	VB (0)	B (1)	VL (1)
R3	VB (0)	A (2)	L (2)
R4	VB (0)	G (3)	ML (3)
R5	VB (0)	VG (4)	A (4)
R6	B (1)	VB (0)	VL (1)
R7	B (1)	B (1)	L (2)
R8	B (1)	A (2)	ML (3)
R9	B (1)	G (3)	A (4)
R10	B (1)	VG (4)	MH (5)
R11	A (2)	VB (0)	L (2)
R12	A (2)	B (1)	ML (3)
R13	A (2)	A (2)	A (4)
R14	A (2)	G (3)	MH (5)
R15	A (2)	VG (4)	H (6)
R16	G (3)	VB (0)	ML (3)
R17	G (3)	B (1)	A (4)
R18	G (3)	A (2)	MH (5)
R19	G (3)	G (3)	H (6)
R20	G (3)	VG (4)	VH (7)
R21	VG (4)	VB (0)	A (4)
R22	VG (4)	B (1)	MH (5)
R23	VG (4)	A (2)	H (6)
R24	VG (4)	G (3)	VH (7)
R25	VG (4)	VG (4)	EH (8)

fuzzy system returned the overall output presented in Fig. 6.

The fuzzy rules, their ranges as described above and the final output CORSUS, is presented in Fig. 6. The rule evaluation consist in considering fuzzified inputs and apply them to the antecedents of the fuzzy rules. If the antecedent of a rule has more than one part, the fuzzy operator (AND or OR) is applied to obtain one number that represents the result of the rule antecedent. This number is then applied to the consequent membership function (Zadeh, 1973).

To evaluate the disjunction of the rule antecedents AND fuzzy operator was used. Anyway the AND operator can be easily customized for particular cases. For instance, the MATLAB Fuzzy Logic Toolbox supports two AND methods: *min* and the product, *prod*. In the literature there are proposed and applied several approaches to perform AND and OR fuzzy operators (Cox, 1999) and as expected different methods lead to different results. After performing different simulation with our fuzzy system, we concluded that fuzzy operator AND responds better to the requirements of the issue.

The distribution of the values of *CEP* and *CFP*, estimated by using the *PCA* method, can be seen in Fig. 6. The CORSUS score is determined by the sum between *CEP* and *CEF*: 62% of *CEP* (for an average value 0.310) cumulated with 62% of *CEF* (for an average value 0.629) determine a score of 0.0612 for CORSUS. This value corresponds to a corporate sustainable performance degree lower than 50% for the automotive manufacturer. From PCA, the descriptive statistics of *CORSUS* are: mean = 0, median = 0,0972, minimum = −1,705, maximum = 1,5682.

4.5. Evaluation and fuzzy system tuning

Regarding to company's sustainability assessment Phillis and Davis (2009) presented a multi-stage fuzzy logic model with the main objective to evaluate the corporation's sustainability. Sabaghi et al. (2016) also develop a model that could asses product or process sustainability through fuzzy AHP coupled with the formula of Shannon's entropy. Other scholars designed a model that uses fuzzy logic in order to evaluate corporate sustainability level; the model was applied in two case studies (Kouikoglou and Phillis, 2011; Bottani et al., 2017).

The literature concerning the use of sustainability assessment tools in automotive industry identify a gap. Through this various assessment tools, such as Life Cycle Assessment [LCA] - based

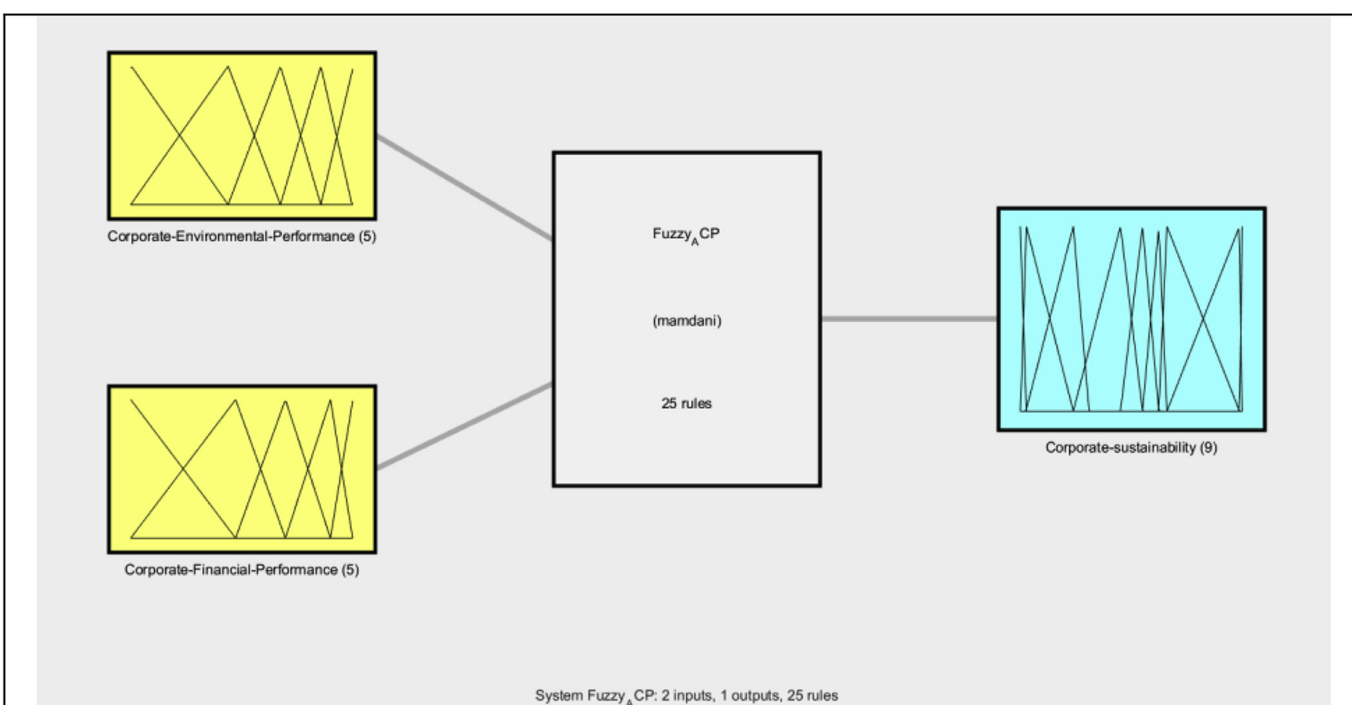

Fig. 5. Fuzzy system for CORSUS assessment.

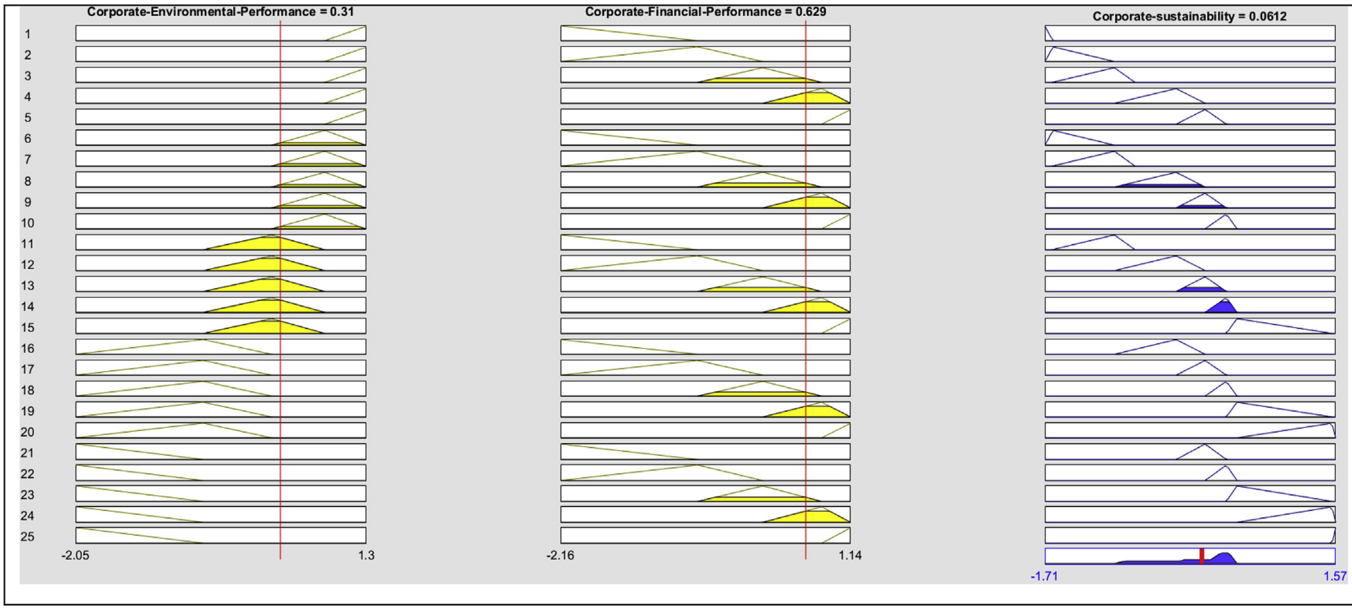

Fig. 6. Presentation of the fuzzy rule base for CEP and CFP aggregation and defuzzification.

decision support tool (Mayyas et al., 2012), LCA inventory (Ostad-Ahmad-Ghorabi and Collado-Ruiz, 2011) or eco-design tool based on fuzzy logic (Herva et al., 2012), only few are appropriate to be used by the managers from this industry (Schoggl et al., 2017).

Most of the studies that assess sustainability based on fuzzy logic address it in macro-systems level (Igarashi et al., 2013; Lin et al., 2015; Bohringer and Jochem, 2007). The exhaustive evaluation of corporate sustainability remains debatable (Bottani et al., 2017).

In our model, the last and the most difficult task was tune the fuzzy system in order to assess and observe if the system fulfill the requirements underlined at the beginning. The fuzzy Logic Toolbox can generate a surface in order to help the user to analyze the system's performance.

Fig. 7 represents three-dimensional plots for two input (*CEP* and *CFP*) and one output (*CORSUS*) system. The distribution of the estimates of *CORSUS* based on environmental and financial performance is presented in Fig. 7.

The fuzzy Logic toolbox can generate a three dimensional output surface by varying any two of the inputs and keeping other inputs constant. Thus can be observed the performance of the system: blue areas are associated to low level or corporate sustainability determined by high values of *CEP* (meaning a poor environmental performance) and low values of *CFP* (meaning a poor financial performance); opposite, yellow areas are associated to high level or corporate sustainability determined by low values of *CEP* (meaning a good environmental performance) and high values of *CFP* (meaning a good financial performance).

The proposed model also consider relevant in its first design stage two important issues noted by Kim et al. (2014). Hence the model takes into consideration all the limits presented before in prior literature and comprises key indicators transformed in commensurable units with the objective to integrate them in a single measure in order to generate a robust corporate sustainability assessment – in regard to commensurability issue. A performant corporate sustainability level requires good results associated to indicators because they cannot hide deficiencies of policies or processes - in regard to fungibility issue (Escrig-Olmedo et al., 2015).

5. Conclusions

The problem of corporate sustainability assessment becomes one of specifying priorities among basic indicators and designing appropriate policies that will guarantee corporate market success. The link between environmental and financial performance determines a significant impact on corporate sustainability, pointing out the importance of practical aspects of this topic (Wagner, 2005).

Even after fifty years of research on corporate sustainability development (*CSD*) and corporate financial performance (*CFP*) there are still inconsistencies (Margolis and Walsh, 2007). Hence scholars in different empirical studies conclude that the relation between *CFP* and corporate sustainability are: (i) a positive one (Orlitzky et al., 2003), a negative one (Brammer et al., 2006), neutral or non-significant (McWilliams and Siegel, 2001), mixed (Barnett and Salomon, 2012), a various causal directions (Scholtens, 2008). This very different research results (assessing the relation between *CFP* and *CSD*) are a consequence associated to vagueness and inconsistencies in the measurements construct (Van Beurden and Gossling, 2008; Callan and Thomas, 2009).

In our paper, based on PCA there were estimated the values of *CEP* and *CEF*, new dimensions that were considered as inputs for corporate sustainable assessment using fuzzy logic. This approach requires an appropriate fuzzy system design in order to assess properly the dimensionality of corporate sustainability performance. The research objectives is to obtain the determinant of CORSUS (using PCA) and to perform the fuzzy inference.

Our model, represents an attempt to provide a quite comprehensive description and assessment of the corporate sustainability based on environmental and financial dimensions. The work subjects attention to the link between the *CEP* and *CFP*, and their influence on the *CORSUS*, which is an innovative approach as regards the literature in the field. Using linguistic variables and linguistic rules, the model provides quantitative measures of corporate sustainability (*CORSUS*).

The model has several very important advantages. Firstly, the proposed model architecture reduces the total number of rules, because it uses just two dimensions (*CEP* and *CFP*) and due to the minimum number of membership functions that have been set. The

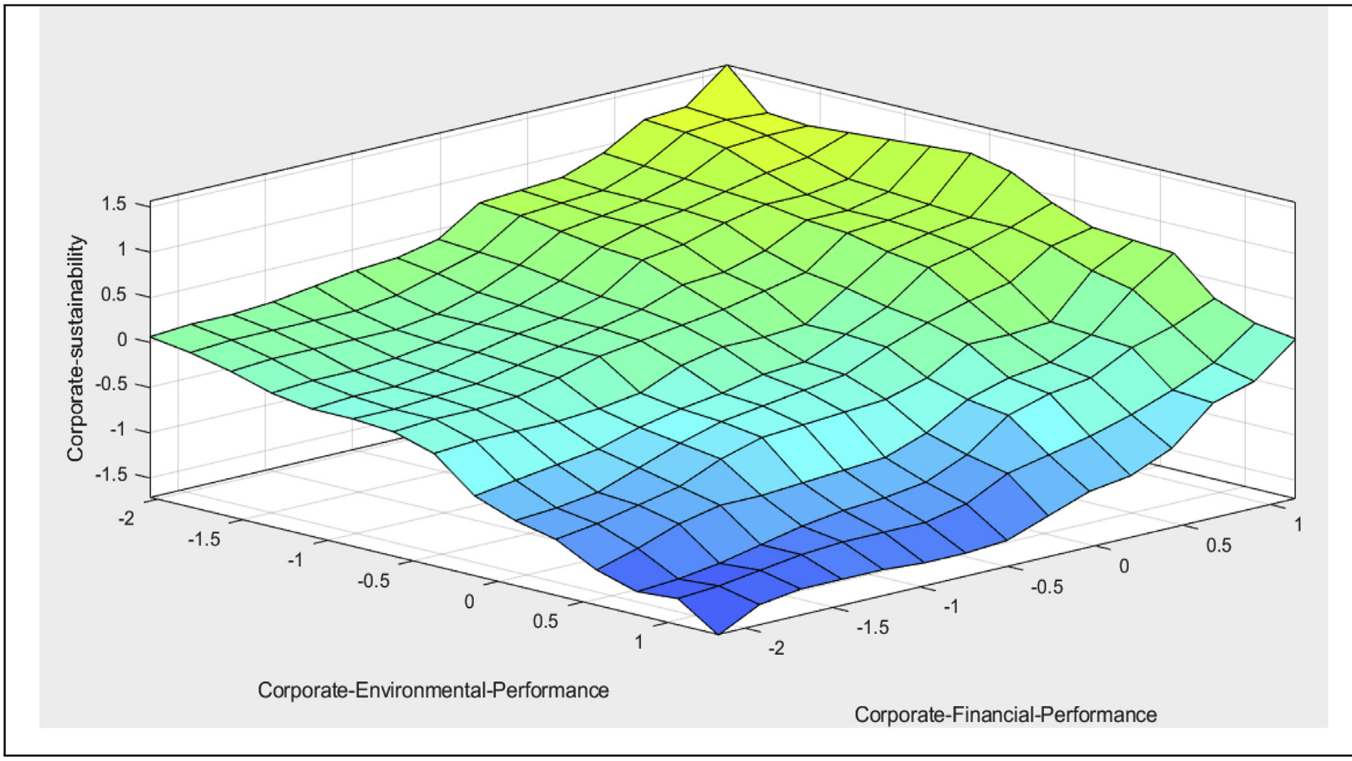

Fig. 7. The representation of CORSUS based on fuzzy-PCA model.

"rules reduction is important because the curse of dimensionality damaged the transparency and interpretation as it is very tough to understand and justify hundreds or thousands of fuzzy rules. As a consequence of the curse of dimensionality often rules are over fitted which damages the generalizability of fuzzy systems" (Fayaz et al., 2017).

Second, using a large number of rules in a conventional fuzzy system it's a challenge and very difficult and has a negative impact on the system performance. Therefore a reduced number of parameters associated to the model mathematical algorithm is desirable. The proposed model hence has integrated in its design/logic architecture the concept of parameter reduction.

Third, the input data needed to fulfill the requirements for conventional fuzzy system is exponential. In order to diminish the associated errors that could generates time loss and uncertainty, the proposed model reduce in an efficient manner the data set required to operate the system.

Fourth, in the fuzzy logic design rule specification is very important (Fayaz et al., 2017). Therefore the proposed model integrates knowledge from the field to set the rules, in order to perform an appropriate corporate analysis associated to a sustainable behavior.

There is no claim that this research can accurately assess corporate sustainability performance, the model being subject to improvement by adding new parameters or by setting boundaries in which the core indicators should be within or by including other fuzzy sets. The research limits are determined by using in the analysis of a single automotive manufacturer. Another limit is represented by the absence of data for some environmental indicators, data that weren't disclosed by the automotive manufacturer.

Further, the model provides new insights of corporate sustainability, and it may serve as a practical tool in decision making process and policy design for companies. The approach plays a more important role as the system allows a sensitivity analysis determining the effect of a change on system performance. In this case, further research directions propose the use of hierarchical fuzzy and neuro–fuzzy approach to assess the corporate sustainable performance of the EU automotive manufacturers.

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