Ranking of Responsible Automotive Manufacturers according to Sustainability reports using PROMETHEE and VIKOR methods

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Abstract

Industrial activities and road transportation are the main contributors to air quality degradation and resource depletion. The automotive sector, which is one of the main players of the manufacturing industry and the supplier of road transport demand, is considered one of the most prominent symbols of pollution. Therefore, the issue of sustainability in the automotive industry is critical as it poses a wide range of challenges and negative externalities on the environment and society. This study aims to present a list of responsible consumption and production dimensions in line with the 12th United Nations Sustainable Development Goal and to rank the auto and auto part manufacturers in the Fortune Global 250. We used content analysis and text mining to identify 13 dimensions underlying responsible consumption and production. We then weighted each dimension according to the preferences of the experts using Delphi and the Analytical Hierarchy Process. After examining the dimensions in the sustainability reports of the selected companies, we ranked them using the PROMETHEE and VIKOR techniques. We also showed the robustness of the rankings.

Keywords: Automotive industry, sustainability, responsible production, responsible consumption

1. Introduction

For the last decades, the world has been going through challenging times and signaled climate change, pollution, decrease in biodiversity, dramatic increase in wastes, decrease in clean water sources, and many more issues that threaten life in the world. However, on the other side the consumption, which consumes limited resources, continues to increase day by day globally. Therefore, a global partnership was established in 1992 with the participation of more than 178 countries to improve human life, protect the environment, and promote sustainable development. In 2015, this committee prepared the 2030 Sustainable Development Agenda, which mainly included 17 Sustainable Development Goals (SDGs) at the United Nations (UN) Sustainable Development Summit in New York. Many thematic issues, from human rights to the environment, and even to urbanization, have been addressed based on these SDGs. [1,2] Moreover, the European Commission has even proposed to increase the European Union's target of reducing greenhouse gas (GHG) emissions by 55% below 1990 levels by 2030, aiming to keep global temperature rise below 2°C. [3]

Motor vehicles and parts manufacturing causing more environmental impact (GHG emission, acidification, mineral and organic resources, etc.) than the production of any other good, even more than livestock farming [4], because of consuming various sources and materials such as steel, rubber, glass, paints, plastics and many more. Although the automobile industry has put forward great effort to reduce CO2 emissions and waste per car produced by 30% and 13%, respectively since 2008[5], their importance is still viable for a sustainable future. For this reason, motor vehicle and part manufacturers need to adopt a more responsible consumption and production approach for the future of the world, as well as being competitive in the automotive sector. Thus, this study aims to develop a comprehensive list of responsible consumption and production (RC&P) criteria specifically to the automotive industry in accordance with the 12th target of SDG. Next, the other purpose of this study is to provide a comparison of automobile manufacturers according to their inclusion of (RC&P) goals in their sustainability reports.

The automotive industry attracts a lot of attention in the academic community both with the job opportunities it creates, with other production areas that it has strengthened, and with a large share that it contributes to the world economy alone. Vehicle manufacturing [6], modeling approach[7], components[8], materials[9], and future vehicles[10] are some of the popular topics regarding auto industry. Because the auto industry is considered as one of the most evident symbols of pollution[11], in the literature, the issue of sustainability has not been overlooked, either. There exists a growing body of work on the sustainable automotive industry which focuses on different areas of sustainability. One stream of the research focuses on the selection of recycled, renewable, non-toxic, and low energy content materials in the automotive industry[11,12,13] because the selection of sustainable materials is an important strategy for decreasing the negative environmental impacts of automotive products. Another stream of research provides eco-design solutions for automobiles[14,15]. Designing for sustainable automobiles includes the topics of design for manufacturing[16], design for recyclability[17] , design for durability[18] , design for energy efficiency[17], and design for end-of-life[18] . Sustainable product design performances of the automotive companies with two-stage network data envelopment analysis was compared [20]. In their analysis, they considered cubic inch displacement, rated horsepower, compression ratio and axle ratio as inputs, hydro-carbon, carbon oxide, carbon dioxide, and nitrogen oxide emissions as outputs. The results of the analysis presented that innovative design decisions including product reengineering can enhance better vehicle manufacturing that leads to better environmental performances.

The outstanding area regarding the sustainable automotive industry is product life assessment[11,21,22,23,24] where the environmental impacts of an automobile and its parts are analyzed from the pre-manufacturing stage to its end of life stage. Schmidt and Taylor [25] implemented Product Sustainability Index, which was proposed by Ford of Europe, to compare five models of Ford. The index includes eight indicators such as life cycle global warming potential, sustainable materials, safety, life cycle of cost ownership. Salvado et al. [26] proposed a sustainability index to automotive manufacturers for assessing their both overall and sub-indexes of social, environmental, and economic. The index involves metrics obtained from the literature and existing indexes such as ISO 14031, Dow Jones Sustainability Index, and Global Reporting Initiative. After determining the metric weights by Analytical Hierarchy Process (AHP), they compared the sustainability performances of 46 car parts manufacturers located in the supply chain network of an automotive in Portuguese using the proposed index. However, the authors highlighted that there is a discrepancy in the comparisons due to the difficulties in collecting data. Jasiński et al. [23] proposed a comprehensive sustainability index for automotive manufacturers. The index consists of very detailed 27 metrics, which were obtained from a comprehensive literature review, that consider the entire life cycle of an automobile.

1.1 Gaps in the literature and the contributions of the study

Although there are studies that propose sustainability assessment criteria in the literature, it seems that there is no consensus among them on which criteria are critical and which framework should be used as a standard. Second, the previous studies focused on developing a comprehensive index with detailed metrics that encompass sustainability's triple bottom line for automobile manufacturers. However, they had difficulties to compute the manufacturers' index because of the difficulties to access or collect data, which of some might be considered confidential by the companies. Additionally, neither study used a detailed analysis for evaluating global auto-manufacturers' views on sustainability from their statements. Although one of the previous studies attempted to rank auto-part manufacturers of a car producer according to an index, the study did not use an advanced quantitative technique for comparisons and the scope was limited to a single auto manufacturer and one country.

To fill the gaps in the literature, this study aims at contributing to the extant literature by introducing the current sustainability rankings of the best global automotive companies with the help of multi-criteria decision-making methods (MCDMs). At a practical level, this ranking is intended to aid managers by offering an opportunity to evaluate themselves and their competitors in the framework of RC&P criteria defined by the UN. Thus, unlike previous studies, we took the UN's 12th sustainable development goal of RC&P as a basis to develop criteria suitable for the automotive industry. This study provides evidence-based insights to answer the following questions.

- What are the highlighted factors or main dimensions of RC&P responsible consumption and production of the UN's 12th SDG?

- What might be the weight of each factor or dimension to assess an automaker's stance against the UN's 12th SDG?
- How much do the automakers emphasize the main dimensions of being a responsible consumer and producer?
- What is the ranking of global auto manufacturers according to their stance against the UN's 12th SDG?

The contributions of this study are threefold. First, we identified the underlying dimensions of the RC&P goal of the UN using content analysis for developing a framework. Second, we determined the importance of each dimension according to experts' choices using a quantitative decision-making method. Third, using content analysis, we presented how much each automaker emphasizes the dimensions of the RC&P goal according to its sustainability report. Finally, we ranked global automakers according to their stance against the proposed framework, using two different quantitative techniques to gain various insights.

This study consists of three sections. In the next section, the proposed integrated model and the analysis results of the applied methods are given in detail, step by step. The last section presents the concluding discussions and remarks about the study.

2. Proposed Model for Outranking Responsible Producer

The conceptual framework of the methodology adopted in this study to answer the predefined research questions is shown in Figure 1. In the first step, we analyzed the content of the UN's report describing the UNSDG's RC&P goal using the NVivo 11 Plus software. Additionally, we reviewed previous studies to extract dimensions suitable to the RC&P goal. In the second step, we held a focus group discussion with experts to collect data to determine the importance of each dimension using the Analytical Hierarchy Process technique so that we could assess the automakers' view of the RC&P goal in the next steps. The third step aims to analyze the content of the sustainability reports of auto or auto part manufacturers that were in the top 250 in 2019's Global Fortune 500 companies list. To this end, we performed a text mining to extract the frequencies of each predefined dimension of the RC&P goal in sustainability reports. Next, we applied two of the well-known multi-criteria decision-making techniques, PROMETHEE II and VIKOR, to rank the identified producers according to their stance against the RC&P goal. Finally, we performed a sensitivity analysis on predetermined weights to investigate the robustness of the ranking.

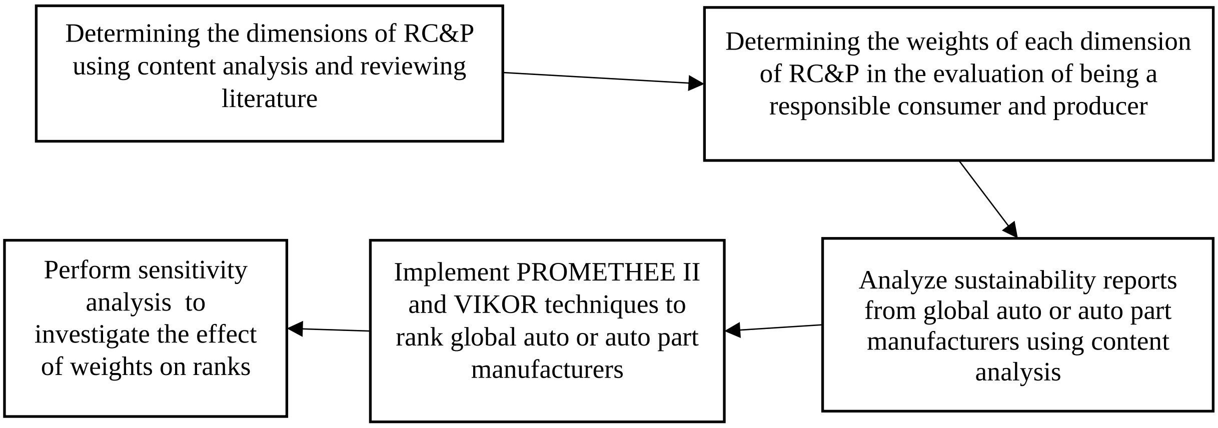

Figure 1. The adopted research methodology.

2.1. Main Dimensions of Responsible Consumption and Production

According to United Nations[1], SDG 12 on Responsible Consumption and Production (RC&P) is simply defined as “doing more and better with less”. It is also described as “decoupling economic growth from environmental degradation, increasing resource efficiency and promoting sustainable lifestyles”. United Nations[1] defined several targets under the RC&P goal such as minimizing wasteful consumption during production, adopting environmental decisions, improving the social impacts of production. Thus, this goal encourages manufacturing companies to adopt sustainable practices and reflect them into their sustainability reports.

For our analysis, we have extracted documents and texts related to the RC&P goal from the United Nations[1] and its links. After creating a single document, we analyzed the most frequently used words and concepts in the document with the “word frequency query option” of the NVivo 11 Plus software. In the analysis, the minimum word length was set to four to exclude words such as “a”, “an”, “by”, or “per”. “Stemmed word grouping” was selected as the grouping option to group all the roots of a particular word together and count them as one. For example, while the word sustainable counts on its own, it also includes roots such as sustain, sustainability, sustainably, and sustained. After obtaining the most frequently used words such as sustainability, consumption, production, waste, material, reduction, and environment, irrelevant words such as “taking” and “countries” were eliminated. A text search query was then applied to each of the most frequently quoted words and their synonyms in the document to explore their context, as words alone are not sufficient to reflect the dimensions of the RC&P target. The word tree option of the text search query showed all the words used at the beginning and end of each of the most frequently quoted words. Thus, meaningful and relevant expressions such as “reduce waste”, “hazardous waste”, “waste generation”, and “wasteful consumption” were identified and defined as dimensions of the RC&P goal. The dimensions determined from the UN reports are listed in Table 1 with equivalent expressions and designated as UNSDG 12. Additionally, we reviewed previous studies on the RC&P goal to determine if we could add different dimensions. As seen in Table 1, determined four additional dimensions such as repair, remanufacturing, disassembly, GHG emission with their equivalent expressions. In conclusion, we identified 13 key dimensions of the RC&P goal in UN reports and literature. These dimensions are briefly explained as follows.

Table 1. The similar phrases to the selected criteria

Code	Dimension	Equivalent expression	Reference
F1	responsible consumption	sustainable consumption, responsible sourcing	UNSDG 12, Ozturkoglu [27]
F2	responsible production	sustainable production	UNSDG 12; Abdul-Rashid[28]
F3	over-consumption	wasteful consumption	UNSDG 12
F4	hazardous waste	-	UNSDG 12
F5	waste reduction	reduced waste, decreased waste, waste minimization, zero waste	UNSDG 12
F6	material footprint	material consumption	UNSDG 12
F7	waste management	waste generation, waste disposal, waste product	UNSDG 12
F8	recycling	-	UNSDG 12
F9	reuse	-	UNSDG 12
F10	repair	-	King[29]; Pathak& Saha[30]; Bracquené[26] ; Weetman[32]
F11	remanufacturing	-	Matsumoto[33]; Xiong[34]; Hazen[35] ; Gunasekara[36] ; Singhal[37]
F12	disassembly	dismantle	Smith&Chen[77]; Liu[38]
F13	GHG emission	emission, greenhouse gas, (low) carbon, footprint	Meinshausen[39]; Mora[40]; Makan & Heyns[41]

Responsible production: Responsible production is a policy that adapts the view of doing more and better with less. It is a term used to express material selection sustainably, assess the product life cycle and adapt eco-design practices while taking into consideration the health and wellness of the employees and societies[11].

Remanufacturing: Remanufacturing adds new and better functionality to a used product and restores it to a new condition [33]. Remanufacturing helps to reduce waste formation significantly, in addition, benefits the use of scarce resources. It is a proven sustainable product recovery strategy that returns used products to their original state with minimum waste of material and energy[36]. Therefore, remanufacturing is attracting growing attention in the improvement of the circular economy[35] because it is lengthening the life cycle of items and increasing the economic, environmental, and social benefits[37]. For example, it is consumed 85% less energy in remanufacturing compared to the energy consumed for manufacturing new items [35].

Disassembly: Disassembly is the first stage of a product, component or a material recovering process. It is the process of replacing the obsolete part/s with new one/s instead of destroying the product when it is realized that the end of its life has come [42]. The aim here is to impact the end-of-life of product by prolonging its life, maintenance, and to improve service quality[42]. Both cost savings and sustainable use of resources are achieved through the disassembly[25],[43].

After disassembly, it is decided which stage of recovering process (repair or recycle) will be applied to the old used parts.

Recycle: Recycling is the process of turning the materials into new products, which would otherwise be thrown away as trash [17]. While preventing the waste of potentially useful materials, it also reduces some scarce raw material consumption [83]. Firms can significantly reduce raw material usage costs with recycling. It is more common than repair or remanufacturing[29].

Reuse: Reuse is the action of using an item again, whether for its main purpose or to fulfill a different function. It gives a product with value a second life, but not the same way with recycling. Previously used items are reused without reprocessing. It is aimed at optimum production by utilizing reduced natural resources, producing minimum pollutions, emissions, and wastes[44]. This feature contributes to the economy and then to the environment by reusing the materials obtained by disassembly stage.

Repair: Repairing is a vital component in the circular economy, which helps extend the life cycle of products[32]. Simply, it is the correction of faults in a product. However, it is depending on the user's decision about whether to repair, pass on or throw away [29]. It is a process for conserving scarce resources and involves less work content than remanufacturing and reconditioning [31]. In the repair process, the damaged parts and products are included in the manufacturing process again therefore less energy is needed and all material and assembly are kept [29].

Responsible consumption: It is a form of consumption that has a less negative impact or a more positive impact on the environment, society, the self, and other beings[45]. The adaption and development of this understanding contribute to sustainable development. In the literature, it is observed that responsible consumption highlights several types of consumption patterns, such as; ethical consumption[46], socially responsible consumption[47], and green consumption [48. The individual consumer is the focal point in those consumption patterns[49], and the study patterns show us that responsible consumption is handled mainly through consumption behavior and attitude lens. However, as responsible consumption is about careless and mindless mass consumption [49], in this study the concept is handled from the point of production, which is also partly related to over-consumption and material footprint.

Over-consumption: It is defined as the excessive use of goods and services resulting from different reasons. The primary condition for sustainability is to use scarce resources as sparingly as possible [50]. With excessive consumption, serious damage is caused to both the environment and the economy. It is observed that there is a serious correlation between economic growth and excessive consumption [51]. Therefore, production, which is the most important pillar of economic growth, must seriously address the issue of over-consumption.

Material footprint: The term material footprint is mostly used to describe resource utilization throughout the life cycle of products, services, activities, and consumers at the micro-level [52]. A material footprint is a consumption-based indicator of resource use for a product in the entire production process. A total material footprint is the sum of the material footprint for biomass, fossil fuels, metal ores, and non-metal ores [1]. To be a responsible producer and consumer, it is necessary to keep the footprint as low as possible.

Hazardous waste: Wastes are categorized as hazardous if they have at least one oxidation, reactivity, or flammability property [53]. Hazardous waste generation is an unavoidable outcome of the production activities in the industry. Discarded materials may lead to a potential hazard to human health, environment, and safety when inappropriately treated and managed [54]. Therefore, hazardous waste management is a major concern especially for governments and international organizations. In order to minimize and manage hazardous wastes, the regulatory institutions develop political frameworks, create a legal order, invest in disposal infrastructure and technologies, and encourage the manufacturers to create hazardous waste management networks [55]. Hazardous waste is processed in-house of the plant or handed over to specialized agencies for treatment in accordance with the legal regulations of the country the plant is located in [56].

Zero waste: Zero waste includes a set of principles focus on waste prevention by means of refuse, reduce, reuse, rot, and recovery of all materials without burning them or discharging to landfills, oceans, or incinerators. However, it is more than the reuse or recycle. Zero waste focuses on restructuring manufacturing systems to prevent waste. Therefore, it is more a guideline for systematically and continually working towards preventing wastes [57].

Waste management: Waste management involves strategies, tactics and directions to convert a linear economy model to a circular one [58], Regenerating, recycling, restoring, and conversion are the main actions that are handled within the waste management policy. Life cycle approach and environmental footprints are mostly used to set more quantifiable objectives and to measure the outcomes.

Greenhouse gas emission: Climate action plans of UNSDG coincide with the activities of SDG 12. The specific target of climate action goal is to become climate-neutral by 2050. 23% of 2019 global GHG emissions primarily came from manufacturing activities [59]. Therefore, GHG emission is a vital indicator of responsible production [17].

2.2 Determining the importance of the dimensions

The weighting of the criteria plays a critical role in ranking alternatives in Multi-Criteria Decision Making (MCDM) process. In general, criterion weights could be determined by subjective, objective, or by their combination. Subjective weighting is the most commonly used method in determining criterion weights according to the preferences of experts using techniques such as Delphi[60] and Analytic Hierarchy Process (AHP)[61]. Subjective weights are based on selection of qualified experts with extensive practical or theoretical experience.

A group of seven experts was selected, mostly from industry and academia, with at least 5 years of experience in the automotive industry, sustainability or operations management. Table 2 shows their profiles. For confidentiality reasons, the names and companies of the experts are not specified. The list of dimensions, their definitions, the purpose of the focus group study, and Saaty[61]'s 7-point comparison scale were sent to the experts via e-mail. An online meeting was then held to discuss the importance of the dimensions. After each expert's five-minute introductory talk on dimensions, the experts shared pairwise comparisons in blind forms, one pair at a time, under the authors' direction. When the threshold criterion for consensus, which was defined as 75% agreement (at least 5 agreements out of seven experts in this study [62], was reached, the experts were directed to compare the next pair until all comparisons are done. Throughout the comparisons, the experts were reminded of the reasoning behind the comparisons and the completed comparisons were shared to reduce inconsistency. After all comparisons are obtained, the AHP procedure was applied to determine the subjective weights given in Table 3 as the initial AHP weights. The pairwise comparison matrix obtained at the end of consensus is given in Table A1 in the appendix. The consistency ratio of the comparison matrix is 0.03; hence, it is acceptable as it is less than 0.1.

Table 2. The profile of the experts.

Expert	**Academia/ Industry**	**Field of Study/Area**	**Institution**	**Years of Experience**	**Current Role**
#1	Academia	Production and Operations Management	Private University	17	Associate Professor
#2	Academia	Production and Operations Management	Private University	18	Associate Professor
#3	Academia	Sustainable Operations Management	Private University	18	Professor
#4	Industry	Industrial Engineer	Nation-wide big-sized manufacturing company of steel auto parts	6	Procurement Engineer
#5	Industry	Industrial Engineer	Internationally owned big-sized manufacturing company of wheels	25	Marketing Director
#6	Industry	Industrial Engineer	Nation-wide big-sized manufacturing company of auto parts	21	Director of Production and Procurement
#7	Industry	Industrial Engineer	Internationally owned big-sized manufacturing company of auto parts producer	12	Supplier relationship manager

Table 3. The percentage weights of dimensions obtained by the experts' preferences.

	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13
AHP weights	8.0	14.8	3.4	14.8	14.8	4.1	6.0	2.3	2.3	1.3	1.3	4.2	22.7

As seen in Table 3, GHG emission (F13), responsible production (F2), hazardous waste (F4), and waste reduction (F5), which make up 67% of the total weight, are the four most critical dimensions of RC&P goal. On the other hand, it is surprising that recycling, reuse, repair and remanufacturing, despite being heavily mentioned in the UN reports, has an insignificant impact on the decision with an average weight of 1.8% according to the experts' preferences. After a discussing these four criteria with experts, they suggested that we present these as a single criterion as 4R (hereafter coded as F14) because of their strong ties to the circular economy concept.

2.3. Analyzing sustainability reports of the auto or auto parts makers

According to the United Nations [1], 93% of the world's 250 largest companies develop sustainability reports. As multinational large companies provide references for other companies, our analysis focused on the Motor Vehicle and Parts manufacturers, which were among the top 250 companies in the 2019 Global Fortune 500 companies list. In recent years, the sustainable production problems caused by the inability to balance the three dimensions of sustainability in the automotive industry is the reason why we focus only on automotive in this list [11]. This industry operates in a highly competitive market that appeals to the end consumer, and therefore economic focuses such as market shares and profitability ratios come to the fore [23]. Accordingly, there are 16 Motor Vehicle and Parts manufacturers located in the list. These companies are listed in Table 4. We then downloaded their recent sustainability reports from the company websites. A total of 16 companies' 2007-page sustainability reports were examined. Table 4 provides the details of the reports, the origins and the ranking of the companies in the list. About half of the companies originate in Germany and Japan, while others are scattered in the USA, China, South Korea and France.

Table 4. Motor vehicle and parts producers in the 2019 Global Fortune Top 250 companies list.

Manufacturers	Rank	Report Year	Number of pages	Country
Volkswagen	9	2018	108	Germany
Toyota Motor	10	2019	120	Japan
Daimler	18	2018	128	Germany
Ford Motor	30	2019	52	USA
General Motors	32	2018	196	USA
Honda Motor	34	2019	169	Japan
BMW	53	2018	126	Germany
Nissan Motor	66	2019	324	Japan
Bosch	77	2018	77	Germany
Dongfeng Motor Group	82	2018	75	China
Hyundai Motor	94	2019	127	South Korea
Peugeot	96	2018	308	France
Continental	205	2018	44	Germany
Zhejiang Geely Holding Group	220	2018	49	China
Kia Motors	227	2018	54	South Korea
Denso	230	2019	50	Japan

To answer the third research question, we performed text mining to extract the frequencies of the dimensions of the RC&P goal given in Table 4 in the sustainability reports of the companies. For this purpose, we developed Java code using a library provided by Apache Tika[1]. We then

[1] "The Apache Tika™ toolkit detects and extracts metadata and text from over a thousand different file types (such as PPT, XLS, and PDF). All of these file types can be parsed through a single interface, making Tika useful for search engine indexing, content analysis, translation, and much more" (source: http://tika.apache.org/index.html, accessed November 5, 2016).

counted the number of occurrences of the dimensions, their equivalences and synonyms with their roots to determine to what extent a company emphasized each dimension. Table 5 shows the aggregated total number of mentions of each dimension in companies' reports.

Table 5. Frequency of each dimension

Manufacturers	**F1**	**F2**	**F3**	**F4**	**F5**	**F6**	**F7**	**F8**	**F9**	**F10**	**F11**	**F12**	**F13**	**Total**
BMW	2	0	0	4	1	0	1	40	3	2	0	4	272	329
Bosch	0	0	0	0	1	0	0	1	0	0	0	0	60	62
Continental	0	0	0	1	0	0	8	30	5	1	0	0	53	98
Daimler	1	2	0	0	0	1	1	29	7	4	4	0	206	255
Denso	0	0	0	0	0	0	0	1	0	2	0	0	36	39
Dongfeng Motor G.	0	0	0	22	0	0	9	8	3	1	0	0	133	176
Ford Motor	18	1	0	1	14	0	3	41	7	0	1	4	218	308
General Motors	4	1	0	9	1	0	3	31	18	23	0	1	297	388
Honda Motor	1	0	0	1	0	0	6	45	10	5	0	1	198	267
Hyundai Motor	1	0	0	0	2	0	2	31	6	11	0	1	132	186
Kia Motors	1	0	0	1	0	1	3	47	7	9	0	19	169	257
Nissan Motor	0	0	0	1	2	0	14	72	30	5	8	5	340	477
Peugeot	2	0	0	34	4	4	26	196	60	41	32	27	767	1193
Toyota Motor	1	2	0	0	1	0	5	124	31	13	6	37	296	516
Volkswagen	0	0	0	12	0	0	10	20	5	0	0	0	207	254
Zhejiang Geely H.	0	0	0	10	0	0	2	32	6	1	0	2	83	136
Total	31	6	0	96	26	6	93	748	198	118	51	101	3467	4941
Average	1.9	0.4	0.0	6.0	1.6	0.4	5.8	46.8	12.4	7.4	3.2	6.3	216.7	1.9
Standard deviation	4.4	0.7	0.0	9.7	3.5	1.0	6.7	49.4	15.8	10.9	8.1	11.2	173.7	
Coefficient of variation	2.3	1.9	-	1.6	2.1	2.7	1.2	1.1	1.3	1.5	2.5	1.8	0.8	

As seen in Table 5, on average, GHG emissions (F13) and recycling (F8) are the most frequently mentioned dimensions in companies' reports. Other commonly emphasized concepts were reuse, repair, disassembly, and waste management. It is seen that this result is compatible with the results we obtained from analyzing United Nations[1] reports. It is surprising to see that over-consumption (F3) dimension is not included in any company's report. In addition, Peugeot emerged as the company that highlights each dimension the most on the list.

We also analyzed the top ten dimensions highlighted in countries based on the average number of mentions per company of the same country. Table 6 shows the ranking of countries according to the average mention. Meanwhile, these countries are among the top 10 countries with the highest share in total global manufacturing output [63]. As can be seen in Table 6, France ranked number one by most of the dimensions while China ranks last for half of the dimensions. It is also surprising that Germany ranks among the last three countries in all dimensions.

Table 6. Top ten dimension of each country

Rank	Dimensions	Average mention	Country Rank					
			France	USA	Japan	South Korea	Germany	China
1	GHG emission	276.7	1	2	3	5	4	6
2	recycling	62.6	1	4	2	3	5	6
3	reuse	17.5	1	3	2	4	6	5
4	repair	11.9	1	2	4	3	5	6
5	hazardous waste	9.9	1	3	5	5	4	2
6	disassembly	8.7	1	4	2	3	6	5
7	waste management	7.9	1	5	2	6	4	3
8	remanufacturing	6.1	1	4	2	5	3	5
9	responsible consumption	2.5	2	1	5	3	4	6
10	Waste reduction	2.3	2	1	4	3	5	6

2.4 Ranking auto and auto parts manufacturers

As known that there is no single perfect method that is suitable for any multi-criteria decision-making (MCDM) problem [64]. For the last fifty years, large number of MCDM techniques have been proposed in the literature such as Analytic Hierarchy Process (AHP), VIKOR (VlseKriterijumska Optimizacija I Kompromisno Resenje), Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), ELECTRE, PROMETHEE (Preference Ranking Organization Method for Enrichment Evaluations), COPRAS (Complex Proportional Assessment). There are also very recently introduced techniques such as SPOTIS (Stable Preference Ordering Towards Ideal Solution) by [65], SIMUS (Sequential Interactive Model of Urban Systems by [66], COMET (Characteristic Objects Method) by [67]. The MCDM techniques can be divided into two categories based on the aggregate performances of variants as aggregation to a single criterion (American school) and aggregation by using the outranking relationship (European school)[68]. In this study, we applied PROMETHEE and VIKOR to determine the rankings of selected auto and auto parts manufacturers. We selected PROMETHEE, which is one of the European school-based methods, because it presents a full and quantitative ranking unlike the other methods in the same [69]. We also selected VIKOR method, which is one of the American school-based methods, because it was shown that VIKOR produces less correlated rankings than methods such as TOPSIS, PROMETHEE II, and COPRAS[69]. Thus, whereas PROMETHEE calculates ‘‘net outranking flows’’, VIKOR evaluates ‘‘closeness to the ideal’’ as an aggregating (utility) function to decide whether one alternative dominates the other alternatives[70]. Therefore, the use of these techniques aims to provide comprehensive and comparable rankings at the end of the application.

As seen in Table 5, the word count of some dimensions varies considerably between alternatives. For instance, Denso, Zhejiang Geely, Hyundai, Continental, and Peugeot have mentioned “recycling (F8)” in 1, 32, 31, 30, and 196 times, respectively. The average and standard deviation of mentions of F8 are 46.8 and 49.4, respectively; therefore, the coefficient of variation, which is the standard deviation divided by the average and indicates the level of variation, is 1.1, indicating a moderate variation. Accordingly, could we say Zhejiang Geely is superior to Hyundai and Continental although their mentions are very close to each other? We think that it is difficult to say because the maximum and minimum number of mentions are 196 and 1, respectively. Therefore, we decided to use a 5-point scale to normalize the frequencies in Table 5 to very low (1), low (2), medium (3), high (4), and very high (5). The intervals of the scales are equal to each other and calculated according to the minimum and maximum of the number of mentions of each dimension. Also, if a company's report does not specify a dimension, we give a score of 0, meaning "not available". Table 7 shows the corresponding scale values for each dimension and alternative. Dimensions F8 to F11 are not located in Table 7 since it was suggested by experts in section 2.2 that dimensions F8 to F11 can be represented by F4 as 4R. Therefore, we calculated the scale values of F14 considering the total number of mentions of the four relevant dimensions. We also added their weights given in Table 3, so the weight of F14 was determined as 7.2%. F3 is not included in Table 7 as it is not mentioned in any company report. Therefore, the weight of F3, given in Table 3, is evenly distributed over the other dimensions including F14. Thus, the concluding final AHP weights used to rank companies are given in Table 7. Accordingly, we implemented PROMETHEE and VIKOR techniques using the data given in Table 7 in the following sections.

Table 7. The density of the highlighted criteria in the companies' reports.

Manufacturers	F1	F2	F4	F5	F6	F7	F12	F13	F14
BMW	1	0	1	1	0	1	1	2	1
Bosch	0	0	0	1	0	0	0	1	1
Continental	0	0	1	0	0	2	0	1	1
Daimler	1	2	0	0	1	1	0	2	1
Denso	0	0	0	0	0	0	0	1	1
Dongfeng	0	0	4	0	0	2	0	1	1
Ford	5	1	1	5	0	1	1	2	1
General Motors	1	1	2	1	0	1	1	3	2
Honda	1	0	1	0	0	1	1	2	1
Hyundai	1	0	0	1	0	1	1	1	1
Kia	1	0	1	0	1	1	3	2	1
Nissan	0	0	1	1	0	3	1	3	2
Peugeot	1	0	5	2	4	5	4	5	5
Toyota	1	2	0	1	0	1	5	3	3
Volkswagen	0	0	2	0	0	2	0	2	1
Zhejiang	0	0	2	0	0	1	1	1	1
Final AHP weights	8.4	15.2	15.2	15.2	4.5	6.4	4.6	23.0	7.5

0: Not available, 1: very low, 2: low, 3: medium, 4: high, and 5: very high

2.4.1 Ranking with PROMETHEE

PROMETHEE was developed by Brans [71] and extended by Brans and Vicke [72] and Brans [73]. This technique is one of the preference function-based MCDM techniques that offers six types of utility (preference) functions. Using an appropriate preference function for each criterion, PROMETHEE calculates the ‘‘net outranking flow’’ which is the difference between leaving flows, which indicate how dominant one alternative is over the others, and entering flows, which express how much the alternative is dominated by the others. According to net outranking flows, PROMETHEE II provides complete preorder while PROMETHEE I provide partial preorder. Therefore, we chose to implement PROMETHEE II in this study using the following procedure developed by Brans [73].

Step 1. Determine the weights of n criteria $(w_1, w_2, w_3, \ldots, w_n)$ and calculate the outcomes x_{ij} of each alternative i $(i = 1, .., m)$ for all criterion j.

Step 2. Determine the preference function $P_j(i, i')$ from the six function types for each criterion that indicates

- The alternatives i and i' are indifferent if $P_j(i, i') = 0$;
- The alternative i is weakly preferred over the alternative i' if $P_j(i, i') \sim 0$;
- The alternative i is strongly preferred over the alternative i' if $PP_j(i, i') \sim 1$;
- The alternative i is strictly preferred over the alternative i' if $P_j(i, i') = 1$.

P is defined through a function of $H(d)$ where d is the difference between the outcomes of two alternatives a and b; $d = f(i) - f(i') = x_{ij} - x_{i'j}$. Hence,

$$H(d) = \begin{Bmatrix} P_j(i, i'), & d \geq 0 \\ P_j(i, i'), & d \leq 0 \end{Bmatrix}$$

Step 3. Calculate aggregate preference function $\pi(i, i') = \sum_{j=1}^{n} \left[w_j \times P_j(i, i') \right] / \sum_{j=1}^{n} w_j$.

Step 4. Calculate the leaving (or positive) flow $\phi^+(i)$, the entering (or negative) flow $\phi^-(i)$, and the net flow $\phi(i)$ of the alternative i.

$\phi^+(i) = \dfrac{1}{m-1} \sum_{i=1}^{m} \pi(i, i')$ and $\phi^-(i) = \dfrac{1}{m-1} \sum_{i=1}^{m} \pi(i', i)$ where $i \neq i'$

$\phi(i) = \phi^+(i) - \phi^-(i)$

Step 5. Rank all the alternatives according to their $\phi(i)$. The greater the $\phi(i)$ values the superior is the alternative in PROMETHEE II. Hence, the best alternative is the one that has the highest $\phi(i)$.

- The alternative i outranks the alternative i', if $\Phi(i) > \Phi(i')$.
- The alternatives i and i' are indifferent if $\Phi(i) = \Phi(i')$.

We used Visual-PROMETHEE software powered by GAIA analysis to implement the PROMETHEE II method. Of the six preference functions described by Brans [73], we used the "usual preference function" because of its suitability for equidistant scales. The usual preference function is described in Figure 2. When the PROMETHEE steps were implemented using the final AHP weights given in Table 8, the leaving, entering and net flows for each company were obtained as in Table 9. The producers were also ranked in descending order of net flows in the table. According to the complete comparison using PROMETHEE II, Peugeot appears to be the most responsible manufacturer followed by General Motors and Toyota.

$$H(d) = \begin{cases} 0, & d \leq 0 \\ 1, & d > 0 \end{cases}$$

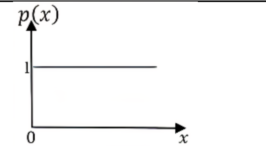

Figure 2. The usual preference function used in the PROMETHEE method.

Table 8. Entering, leaving and net flows and the ranks according to AHP weights

Rank	Manufacturers	$\phi(i)$	$\phi^+(i)$	$\phi^-(i)$	Rank	Manufacturers	$\phi(i)$	$\phi^+(i)$	$\phi^-(i)$
1	Peugeot	0.73	0.79	0.06	9	Volkswagen	-0.07	0.25	0.32
2	GM	0.49	0.62	0.13	10	Honda	-0.09	0.21	0.30
3	Toyota	0.38	0.57	0.19	11	Dongfeng	-0.21	0.19	0.40
4	Ford	0.34	0.53	0.19	12	Hyundai	-0.24	0.15	0.39
5	Nissan	0.24	0.45	0.21	13	Zhejiang	-0.27	0.14	0.41
6	BMW	0.05	0.29	0.24	14	Continental	-0.35	0.10	0.44
7	Daimler	-0.01	0.32	0.33	15	Bosch	-0.41	0.08	0.50
8	Kia	-0.02	0.27	0.29	16	Denso	-0.56	0.00	0.56

In addition to the complete ranking in Table 8, Figure 3 presents partial rankings of the manufacturers. While BMW is favored over Daimler in the complete ranking, it is in fact incomparable when partial rankings are considered because $\phi^+(\text{BMW}) < \phi^+(\text{Daimler})$ and $\phi^-(\text{BMW}) < \phi^-(\text{Daimler})$. Similarly, Daimler and Volkswagen, Dongfeng and Hyundai, Volkswagen and Honda, Kia and Daimler are also incomparable (see Figure 3 for details). The partial rankings also confirm that the first five ranked manufacturers obtained by the complete ranking outperform the others.

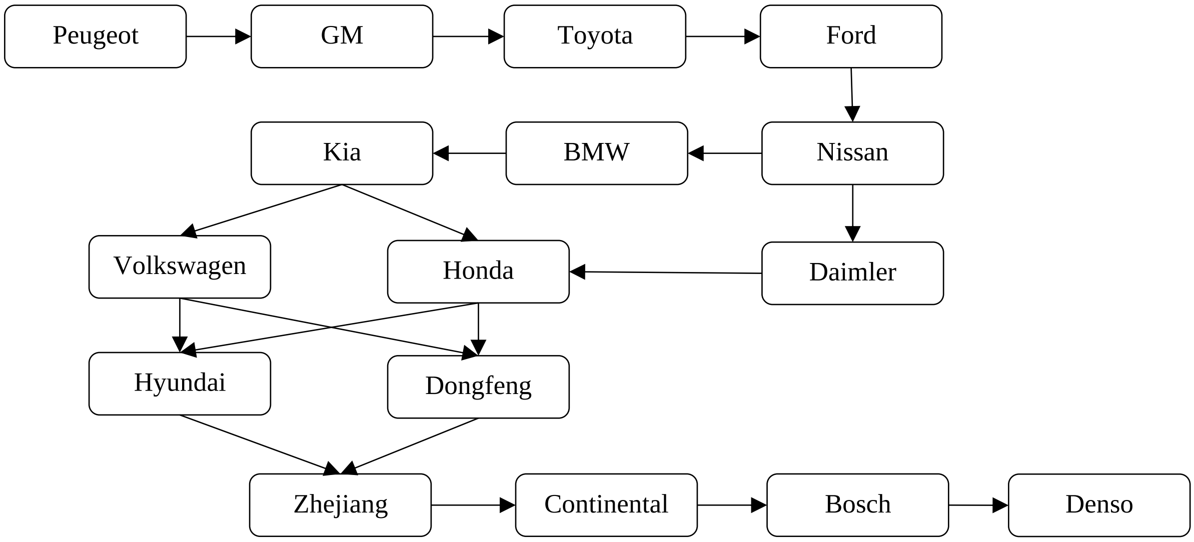

Figure 3. Partial ranking of the producers using PROMETHEE I and AHP weights. The arcs indicate superiority on the connected network.

2.4.2. Ranking with VIKOR

VIKOR was first mentioned by Opricovic [74], but was first developed by Opricovic and Tzeng [70] as a useful compromise ranking technique to be implemented within MCDM. Compromise solutions can be developed according to negotiation between the maximum group utility of the majority and a minimum individual regret of the opponent [70]. Unlike PROMETHEE, VIKOR is preferred when decision-makers do not know how to express their preferences. We adopted the following procedure developed by Opricovic and Tzeng [70] to implement VIKOR in our study.

Step 1. Determine normalized outcomes $f_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}}$ for each alternative i and criterion j.

Step 2. Determine the worst and the best values of the normalized values as f_j^- and f_j^* each criterion j, respectively. $f_j^* = \max_i f_{ij}$, $f_j^- = \min_i f_{ij}$ when the criterion is beneficial, otherwise vice versa.

Step 3. Calculate the utility matrix $U \in u_{ij} = (f_j^* - f_{ij})/(f_j^* - f_j^-)$. Then calculate utility S_i and the regret R_i measures for each alternative using w_j weights.

$S_i = \sum_{j=1}^{n} w_j u_{ij}, \ R_i = \max_i [w_j u_{ij}]$.

Step 4. Calculate Q_i as the integrated VIKOR index for each alternative i.

$Q_i = v(S_i - S^*) / (S^- - S^*) + (1 - v)(R_j - R^*)/(R^- - R^*)$, where $S^* = \min_i S_i$, $S^- = \max_i S_i$, $R^* = \min_i R_i$, $R^- = \max_i R_i$, v and (1- v) are the strategy (negotiation) weights of the maximum group utility and the individual regret measures.

Step 5. Rank alternatives sorting Q_i in ascending order such that the lower the Q_i the better the alternative i.

Step 6. If the following two conditions are satisfied, the alternative i that has the lowest Q_i, called a^1, is the best as a compromise solution.

i) Acceptable advantage: $Q(a^2) - Q(a^1) \geq DQ$, where a^2 is the alternative at the second position from the best and $DQ = 1/(n-1)$.

ii) Acceptable stability in decision making: The alternative a^1 must be the best when alternatives are ranked in ascending orders of R_i and/or S_i.

Step 7. If any of the conditions given in Step 6 is not satisfied, then the compromise solution consists of alternatives a^1 and a^2 when only the condition (ii) is not satisfied; or $a^1, a^2, \ldots. a^m$ when the condition (i) is not satisfied where $Q(a^m) - Q(a^1) \leq DQ$.

After applying the procedure of the VIKOR method with the final AHP weights given in Table 7, we calculated the positive-ideal (f_i^*) and negative-ideal (f_i^-) solutions for each dimension as in Table 9. The positive ideal solutions also indicate the most preferred responsible manufacturer where the relevant dimension is the only dimension considered. For example, when we consider waste reduction (F5) only, Ford is the most preferred. However, Toyota is the top manufacturer when the responsible production (F2) dimension is the only dimension considered. The utility matrix is obtained using the positive and negative ideal solutions as in the accompanying Table 10.

Table 9. The positive and negative ideal solutions based on AHP weights

	F1	F2	F4	F5	F6	F7	F12	F13	F14
f_i^*	0.87	0.63	0.65	0.85	0.94	0.67	0.66	0.55	0.68
	Ford	Toyota	Peugeot	Ford	Peugeot	Peugeot	Toyota	Peugeot	Peugeot
f_i^-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.14

We then calculated utility and regret measures in order to develop compromise solutions with a consensus where v is 0.5 [70]. Table 11 presents these measures with their Q_i values. Accordingly, the rankings of the manufacturers are obtained when Q_i is sorted in ascending order. Thus, the VIKOR results also confirm the rankings obtained by the PROMETHEE method.

Table 10. The utility matrix of the VIKOR method using AHP weights.

Manufacturers	F1	F2	F4	F5	F6	F7	F12	F13	F14
BMW	0.07	0.15	0.12	0.12	0.05	0.05	0.04	0.17	0.08
Bosch	0.08	0.15	0.15	0.12	0.05	0.06	0.05	0.23	0.08
Continental	0.08	0.15	0.12	0.15	0.05	0.04	0.05	0.23	0.08
Daimler	0.07	0.00	0.15	0.15	0.03	0.05	0.05	0.17	0.08
Denso	0.08	0.15	0.15	0.15	0.05	0.06	0.05	0.23	0.08

Dongfeng	0.08	0.15	0.03	0.15	0.05	0.04	0.05	0.23	0.08
Ford	0.00	0.08	0.12	0.00	0.05	0.05	0.04	0.17	0.08
General Motors	0.07	0.08	0.09	0.12	0.05	0.05	0.04	0.12	0.06
Honda	0.07	0.15	0.12	0.15	0.05	0.05	0.04	0.17	0.08
Hyundai	0.07	0.15	0.15	0.12	0.05	0.05	0.04	0.23	0.08
Kia	0.07	0.15	0.12	0.15	0.03	0.05	0.02	0.17	0.08
Nissan	0.08	0.15	0.12	0.12	0.05	0.03	0.04	0.12	0.06
Peugeot	0.07	0.15	0.00	0.09	0.00	0.00	0.01	0.00	0.00
Toyota	0.07	0.00	0.15	0.12	0.05	0.05	0.00	0.12	0.04
Volkswagen	0.08	0.15	0.09	0.15	0.05	0.04	0.05	0.17	0.08
Zhejiang	0.08	0.15	0.09	0.15	0.05	0.05	0.04	0.23	0.08

Table 11. The utility and regret measures with the rankings according to the final AHP weights.

Rank	Manufacturer	Q_i	S_i	R_i	Rank	Manufacturer	Q_i	S_i	R_i
1	Peugeot	0.14	0.32	0.15	9	Volkswagen	0.63	0.86	0.17
2	GM	0.25	0.66	0.12	10	Honda	0.64	0.87	0.17
3	Toyota	0.34	0.59	0.15	11	Dongfeng	0.89	0.85	0.23
4	Ford	0.42	0.58	0.17	12	Zhejiang	0.94	0.92	0.23
5	Nissan	0.46	0.76	0.15	13	Hyundai	0.95	0.93	0.23
6	Daimler	0.55	0.75	0.17	14	Continental	0.96	0.94	0.23
7	BMW	0.62	0.84	0.17	15	Bosch	0.98	0.97	0.23
8	Kia	0.62	0.84	0.17	16	Denso	1.00	1.00	0.23

2.5 Sensitivity Analysis

A change in ranking is usually expected due to change in weights or method. For example, the ranking may change when the preference function changes in the PROMETHEE method. In addition, the ranking obtained by the VIKOR method may also change, especially when the strategy (negotiation) parameter v changes because it produces compromise solutions using utility and regret measures. Therefore, we performed a sensitivity analysis to examine possible changes in rankings relative to changes in parameters.

First, we performed stability analysis, which gives weight interval for each dimension in which the current complete ranking remains unchanged. Table 12 presents the stability intervals of the dimensions' weights for the PROMETHEE II ranking given in Table 8. For example, the ranking given in Table 11 for PROMETHEE remains unchanged even if we assign a weight of 3.47% to 15.73% to the 4R (F14) dimension (note that the predetermined weight is 0.075). As seen in Figure 4, the Visual PROMETHEE software also visualizes the effect of weight changes in the 4R dimension on the rankings. In the figure, the bar on the horizontal axis represents the stability interval. As seen in the figure, although there is a change in the position of the top five manufacturers, their names do not change when the weight of the 4R changes.

Visual PROMETHEE software also allows us to change dimension weights and examine the effect on rankings in an interactive way called “walking weight analysis”. In this analysis, we changed the weight of a dimension from 0.0 to 1.0 in 0.1 steps. As the weight of one-dimension increases, the weights of the other dimensions decrease in proportion to their basis weights. Therefore, we performed 9x10=90 trials to see the changes in the rankings. For the results of the complete walking weight analysis, you can visit the following private video link (https://youtu.be/Oo6KsUka4Ic).

Table 12. Stability intervals of dimension weights (%) in PROMETHEE method. LB and UB indicate lower and upper bounds of the intervals.

	F1	F2	F4	F5	F6	F7	F12	F13	F14
LB	6.22	14.74	13.65	13.04	0.00	4.18	9.90	16.42	3.47
UB	10.07	19.61	15.95	17.73	10.40	12.01	5.04	33.16	15.73

We also investigate the effect of changing strategy parameters on the rankings obtained by the VIKOR method. For this, we increased the value of v from 0.1 to 0.9 in 0.1 steps. Figure 5 demonstrates the changes in the rankings obtained by the VIKOR method given in Table 11. As seen in the figure, when v changes, only the positions of the top five companies change. The biggest change occurs in General Motors’ position such that it is placed 1st when $0.1 \leq v \leq 0.3$, 2nd when $0.4 \leq v \leq 0.7$, and 4th when $0.8 \leq v \leq 1.0$. On the contrary, as v increases, Ford’s position increases from the 5th to the 3rd place. Based on the sensitivity analysis results, we can conclude that the VIKOR rankings are quite robust to varying v.

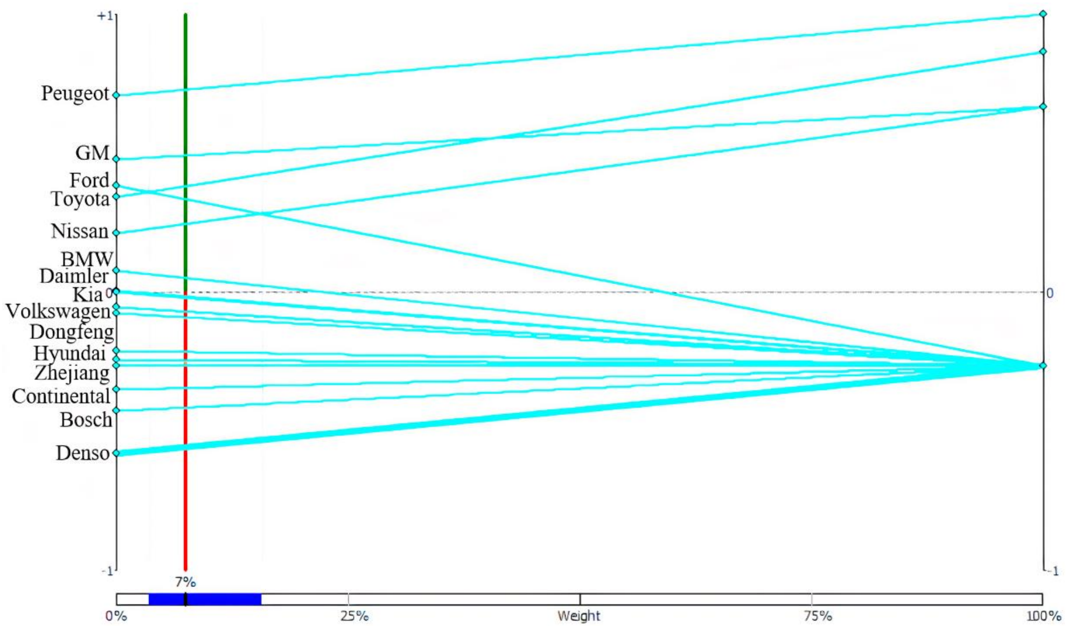

Figure 4. Visual stability intervals of the criterion 4R in PROMETHEE analysis with AHP weights.

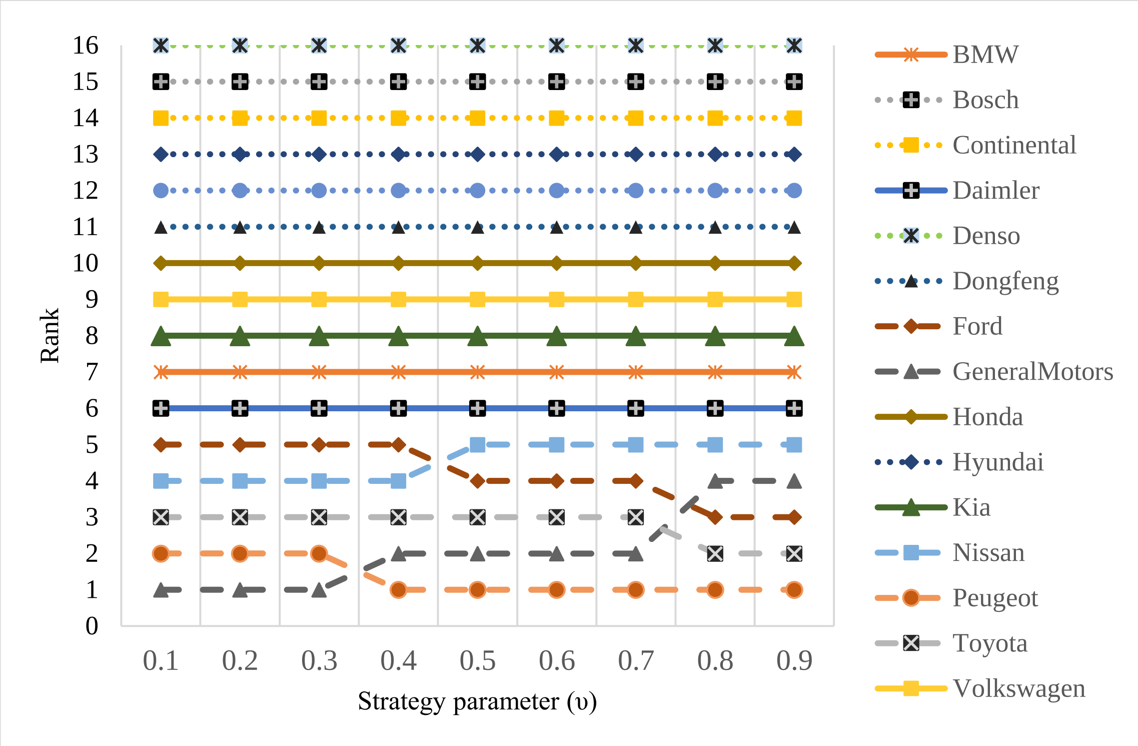

Figure 5. The impact of strategy parameter on the rankings given by the VIKOR with AHP weights.

3. Conclusion and Discussion

The auto and auto parts manufacturing industry, one of the driving forces of the global economy, has devastating effects on the planet as it depends on the natural environment and the use of resources. The UN's 12th goal for sustainable development, which deals with responsible consumption and production, also encourages automotive manufacturers to adopt sustainable practices. In this study, the main aim is to provide a comparison of automobile manufacturers according to their inclusion of the responsible consumption and production (RC&P) goal in their sustainability reports. First, we identified the underlying dimensions of the RC&P goal of the UN using content analysis for developing a framework with the using NVIVO 11 software. Second, we determined the importance of each dimension according to experts' choices using Delphi and Analytic Hierarchy Process (AHP) methods. Third, using content analysis, we presented how much each automaker emphasizes the dimensions of the RC&P goal according to its sustainability reports. Finally, using the PROMETHEE II and VIKOR techniques, we ranked global automakers according to their stance against the proposed RC&P dimensions. When manufacturers are ranked using both PROMETHEE II and VIKOR, we see that the top five companies are Peugeot, General Motors, Toyota, Ford, and Nissan, respectively. As a final step, we showed how sensitivity analyzes are used to assess the robustness of the rankings. The results showed that the VIKOR rankings appear to be quite robust against varying v while PROMETHEE rankings are somewhat robust against the varying weights of the dimensions.

As a summary of the analyzes applied meticulously and in detail, according to the statements in the sustainability reports, we can say that a decision-maker will see that Peugeot has the strongest stance against the UN's goal of responsible consumption and production, while Continental, Bosch, and Denso are the weakest .

One of the steps taken in line with the main purpose of this study is to determine how much RC&P dimensions are mentioned in company sustainability reports. According to the results of content analysis, GHG emission is the most frequently mentioned dimension in the company reports. In parallel with this result, when we examine the weight of each criterion on the total impact with AHP based on expert opinions, we see that the most critical criterion is greenhouse gas emission (23%). This finding may be due to the characteristics of the automotive industry and the characteristics of the automotive companies listed in the study. Industrial activities and road transport are the second and third economic sectors with the largest contributors to greenhouse gas emissions[75] (the first being energy) and the automotive industry is related to both industrial activities and road transportation. Therefore, we can say that the automotive industry contributes to both production-based and consumption-based greenhouse gas emissions (by producing parts and vehicles for use by end-users in road transport). For this reason, it is not surprising that automotive companies mention greenhouse gas emissions in their sustainability reports and expert opinions on the importance of greenhouse gas emissions. In addition, the home countries of the 16 companies listed in our survey are the main sources of greenhouse gas emissions worldwide. Except for France (20th); China (1st), USA (2nd), Japan (5th), Germany (6th), and South Korea (8th) are among the top 10 greenhouse gas emitters that contribute more than two-thirds of global emissions [81]. For several years, global agreements such as the United Nations Framework Convention on Climate Change, the Kyoto Protocol, and the Paris Agreement have introduced an international framework aimed at reducing greenhouse gas emissions. All countries of origin of the companies listed in our study are parties to these agreements and develop their climate change policies according to these agreements. Therefore, we can conclude that the manufacturers in our study, as vital contributors to their national economies, have formed their sustainability strategies mainly around greenhouse gas emissions in parallel with government policies.

3.1. Theoretical and Managerial Implications

The theoretical contributions of this study to the literature are threefold. First, several calls have been made by both academics and international organizations about the need for concrete sustainability performance measurement tools [11]. This study contributed to the literature by conceptualizing the sustainability assessment of the companies as a decision-making problem. The research conducted delivers a holistic framework for assessing responsible manufacturers and represents a sustainability assessment evident rather than discussing only the managerial benefits. In addition, this study, which has a quantitative research feature by using more than one analytical method, also contributes to the general qualitative tendency of the studies conducted in this field [23]. Second, a responsible production framework was developed based on UNSDG Goal 12. This framework includes three main categories namely; production, consumption, and environment. Under these categories, we determined 13 non-complex, simple dimensions which differ from the previous studies. For example, Lowell Center for Sustainable Production (LCSP) has developed nine guiding principles to promote a better understanding of sustainable production among companies. The environmental principles include ecologically sound production, recycling, waste reduction, less material usage, and hazardous waste reduction. Gavrilescu[76] proposed indicators of waste treatment, waste dilution, and reducing hazardous or toxic constituents for cleaner production. Veleva & Ellenbecker[77] have developed core indicators of sustainable production, and environmental indicators include the principles of energy and material usage reduction, waste reduction, GHG emissions, and recycling. In addition to the above-mentioned indicators, our study added responsible consumption, remanufacturing, disassembly, reuse, repair, overconsumption, and waste management criteria to the framework of environmentally sound responsible production. Thirdly, basing the content of the study on the sustainable production goal of the UN also contributes to the automotive literature. The vast majority of studies in the sustainable automotive field in the literature are concerned with the product life cycle assessment[23].

This research has managerial implications as well. Sustainability reports play an important role in influencing both investor decisions and relationships and the preferences of customers. In this study, we ranked the leading automotive companies according to the sustainable production content by comparing each other. Thus, we offered managers the opportunity to evaluate both their own companies and competitors which will help them to develop strategies to position themselves at a more competitive level. We mentioned here the sustainability issue also as a competitive tool because a growing body of evidence shows that customers are willing to pay more for sustainable products[78] and the most desirable job seekers are attracted to companies with sustainable practices[79]. It is also a well-known fact that one of the factors that investors consider before investing in firms is sustainability disclosures. This study ranked the automotive companies according to their responsible stance against responsible consumption and production, which all show that the best responsible automotive companies are Peugeot, General Motors, Toyota, Ford, and Nissan. In addition, the UN calls on all companies operating in the global economy to comply with the sustainability goals they have set and reflect them into their sustainability reports. As a second managerial contribution, we offered holistic content regarding responsible production and consumption goal of the UN to all production companies. Thus, they can use the determined dimensions while designing sustainable consumption and production policies and reflect them in their reports by taking advantage of the ease of measurement and application control.

3.2. Limitations and future research

This study suffered several limitations. First, while the contents of the other objectives have the potential to change the results of the analyses, this study focuses on only one goal of the SDGs, which is responsible consumption and production. Subsequent studies can follow the same research process of the current study by adding and examining more or all SDGs to reveal the level of commitment of manufacturing companies to the UNSDGs. Another limitation derives from the content of the 12th goal of SDGs. Content analysis results of this goal revealed only the environmental aspects of sustainability. For example, GHG emissions recycling, and reuse criteria are generally handled under the environmental heading of sustainability. Unlike environmental indicators, social and economic issues do not receive attention in existing dimensions. Therefore, future studies can extend our study by addressing also social (i.e. human rights strategy) and economic (circular economy strategy) aspects of sustainability in the production industry. The third limitation of this study is examining the self-reported sustainability disclosures of the companies which have the potential to raise concerns about the objectivity of companies' claims. Because the companies have the potential to disseminate green information to cover up their environmental harm and selectively disclose information to obtain a green premium, which is defined as greenwashing.

Based on the results obtained rather than the limitation of the study, in the upcoming studies, we strongly recommend examining the relationship between the economic performance of companies and sustainable production activities. Because, while compliance was observed between the sustainability rankings set out in this study and the Fortune Global 250 that was created by considering the revenues of the companies, it was determined that there was a conflict in some positions. For example, according to the revenue ranking in the Fortune list, Volkswagen ranks 1st and Peugeot ranked 12th, whereas according to the sustainability ranking of this study, Volkswagen ranked 13th and Peugeot took the first position. On the contrary, it is seen that GM, Toyota and Ford companies are among the top 5 in both revenue and sustainability rankings, while Denso is the last in both rankings. In future studies on this subject, we recommend that studies be carried out to include economic determinants as well as sustainability indicators in the ranking of the best local and/or global companies. Besides, additional MCDM techniques can be used to rank the producers, their rankings can be compared with in-depth analysis using various weighting techniques with a large set of simulated attributes as Paradowski[80] did.

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APPENDIX

Table A1. Pairwise comparison matrix with consensus.

	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13
F1	1.0	0.3	3.0	0.3	0.3	3.0	1.0	5.0	5.0	7.0	7.0	3.0	0.3
F2	3.0	1.0	5.0	1.0	1.0	5.0	3.0	7.0	7.0	9.0	9.0	5.0	0.3
F3	0.3	0.2	1.0	0.2	0.2	1.0	0.5	2.0	2.0	3.0	3.0	1.0	0.2
F4	3.0	1.0	5.0	1.0	1.0	5.0	3.0	7.0	7.0	9.0	9.0	5.0	0.3
F5	3.0	1.0	5.0	1.0	1.0	5.0	3.0	7.0	7.0	9.0	9.0	5.0	0.3
F6	0.3	0.2	1.0	0.2	0.2	1.0	0.3	3.0	3.0	5.0	5.0	1.0	0.1
F7	1.0	0.3	2.0	0.3	0.3	3.0	1.0	3.0	3.0	4.0	4.0	2.0	0.2
F8	0.2	0.1	0.5	0.1	0.1	0.3	0.3	1.0	1.0	3.0	3.0	0.3	0.1
F9	0.2	0.1	0.5	0.1	0.1	0.3	0.3	1.0	1.0	3.0	3.0	0.3	0.1
F10	0.1	0.1	0.3	0.1	0.1	0.2	0.3	0.3	0.3	1.0	1.0	0.2	0.1
F11	0.1	0.1	0.3	0.1	0.1	0.2	0.3	0.3	0.3	1.0	1.0	0.2	0.1
F12	0.3	0.2	1.0	0.2	0.2	1.0	0.5	3.0	3.0	5.0	5.0	1.0	0.1
F13	0.3	3.0	6.0	3.0	3.0	7.0	5.0	7.0	7.0	9.0	9.0	7.0	1.0