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company performance measurement with environmental concerns

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Abstract

Purpose - Current literature presents limited measurement methods of quantifying manufacturers' performance with environmental concerns. The purpose of this paper is to construct a company performance index for benchmarking motor vehicle manufacturers with environmental concerns.

Design/methodology/approach – Methods of constructing the index include regression analysis, a modified linear method for normalizing variables and a geometric mean for aggregating variables into a single index I_{MVM} (index for motor vehicle manufacturers). A case study is conducted in twelve motor vehicle manufacturers from 2008 to 2017. A sensitivity analysis with the simple additive weighting method is performed to analyze how different aggregation methods affect the final value. The index I_{MVM} is assessed through a benchmark with three existing indices.

Findings – Three realistic considerations are identified from motor vehicle manufacturers (MVMs), based on which proper and transparent methods are chosen to construct the I_{MVM}. The construction of the index I_{MVM} has been assessed through a benchmark against the methodologies of three other indices. The results indicate that the new measurement is feasible and effective for MVMs to measure their company performance from an environmental perspective.

Research implications – The construction of the index I_{MVM} can support policymakers with accurate statistics for decision making. As a response to current imperative climate policies, this paper raises awareness of CO_2 emissions in vehicles' production. For statistical organizations and stakeholders in the investment world, this paper provides available and reliable statistics for trend analysis of different MVMs.

Originality/value - A new method is designed for constructing a company performance index for motor vehicle manufacturers. Three environmental variables are identified based on literature, their environmental impact as well as their data availability from public documents. A ranking by manufacturer with environmental concerns is generated. This index can contribute with available statistics and useful insights for decision making.

Keywords Performance measure, Composite indicator, Environmental measure, Motor vehicle manufacturer

Paper type Research paper

1. Introduction

In 2017, there were 97,302,534 motor vehicles produced globally in a single year (Organization of Motor Vehicle Manufacturers, 2018). The motor vehicle manufacturing sector is one of the world's largest economic sectors by revenue. Nevertheless, this sector has a negative impact on climate change. As a response to reducing climate change, several programs such as the European Union Emissions Trading System (EU ETS) and the Paris Agreement have been launched. A few highly greenhouse gas (GHG) emitting sectors have been announced in publicly available reports with detailed statistical disclosure. However, the motor vehicle manufacturing sector was not documented with sufficient information.

Motor vehicle manufacturers are expected to take a long-term view in contributing to sustainable development rather than exclusively focusing on profitability. In other words, company performance should be multidimensional and include environmental measures. To quantify the multidimensional concept, performance analysts use composite indicators. A composite indicator (CI) may be defined as an index "formed when individual indicators are compiled on the basis of an underlying model of the multidimensional concept" (Glossary of Statistical Terms, OECD). The index can be used to summarize complex issues, in view of supporting decision-makers (Saltelli, 2007). Constructing CIs (or indices) involves methods for selecting variables, weighting variables, normalizing measures to make them comparable, aggregating variables into one single index and conducting the post-analysis on CIs (or indices).

The construction of indices cannot be directly generalized from one sector to another sector. In other words, variables as well as their weights vary from one sector to another. For instance, in the aviation sector, the water vapor in aircraft engine exhaust is a big player in global environmental issues. However, in the motor vehicle sector, the water vapor is mostly benign as an emission. Therefore, it is necessary for airlines to report the negative impact of the water vapor on the environment while it is of no concern for motor vehicle manufacturers to take water vapor into account in their reporting.

A research gap is found in the field of company performance and management. That is, current efforts haven't provided a rigorous index for quantifying motor vehicle manufacturers' performance with environmental concerns. To narrow the gap, this paper aims to construct a company performance index I_{MVM}. "MVM" is short for motor vehicle manufacturers. The main research question arises as how to construct the I_{MVM}? This research question can be broken down into three sub-questions as follows.

1) What methods can be used to construct the index for motor vehicle manufacturers?
2) What variables can be identified in terms of environment-related issues for motor vehicle manufacturers?
3) Can the index be used as a statistic to generate a rank by manufacturer from an environmental perspective?

To answer the research questions, the remaining part of this paper is organized as follows. Section 2 presents studies with related CIs. Section 3 presents the development of the I_{MVM} in five phases. It consists of the methods for selecting variables, weighting variables, normalizing variables and aggregating variables into a single index $I_{MVM.}$ Section 4 conducts a multiple case study in twelve motor vehicle manufacturers over the fiscal years (FYs) 2008 to 2017. A sensitivity analysis is conducted to validate the robustness of the $I_{MVM.}$ Section 5 provides a discussion about the outcome of the I_{MVM}. The ranking by manufacturer is generated based on the I_{MVM} value. Finally, the last section provides concluding remarks, limitations and three recommendations for further research.

2. Company performance measurement

2.1 Company performance measures

There are several financial measures such as "return on assets" (Hagel III et al., 2010) and "cash flow return on investment" (Aust, 2010) which were regarded as "the best way" to measure company performance. Besides, multiple measures such as the combination of "market to book value", "company size" and "return on capital" (Adeneye and Ahmed, 2015) were employed as company performance measures.

Based on the stakeholder theory (Freeman, 2004), manufacturers should take into account the concerns of various stakeholders. For public manufacturers, generally, stakeholders consist of customers, shareholders, investors, communities, business partners, non-governmental organizations, non-profit organizations (NPOs) and employees. Increasingly, customers are becoming more knowledgeable about the products' environmental impact. NPOs, such as Greenpeace in the Netherlands, take inventive actions for reducing resource overconsumption and they take action against companies that damage the environment.

As to the investment world, there has been a change in thinking from avoiding companies that have a negative impact on the environment to investing in companies that have positive environmental policies. As one of the first international asset management companies, Robeco together with RobecoSAM published "The Big Book of SI" in 2018. Here "SI" is short for sustainability investing which indicates investors take environmental protection to a high level by making it tangible and measurable. It is important to include environmental measures for company performance measurement.

The motor vehicle manufacturing sector is one of the most resource-intensive sectors and has a huge impact on the environment. For motor vehicle manufacturers, environmental impacts can be measured in terms of resource consumption, emissions or environmental damage (Hahn et al., 2010). As one of the leading motor vehicle manufacturers, Audi AG has adopted specific indicators to measure environmental impact reduction in production since 2011. The indicators are the average change (on a per-unit basis) of carbon dioxide (CO2) emissions, energy, freshwater, organic solvents, wastewater and waste (Audi AG, 2018). Bayerische Motoren Werke AG has focused on five aspects in terms of the improvement in resource consumption and emissions from vehicle production since 2006, namely, energy consumption, CO2 emissions, and waste for disposal, water consumption, process wastewater and solvent emissions (BMW Group, 2018).

2.2 Company performance indices for motor vehicle manufacturers (MVMs)

For building a composite indicator, there are ten steps in the checklist including a theoretical framework, data selection, imputation of missing data, multivariate analysis, normalization, weighting and aggregation, uncertainty and sensitivity analysis, back to the data, links to other indicators, visualization of the results (European Commission, 2008). There are various kinds of techniques during each step, and each technique has its own pros and cons. It's crucial to understand the methods and their assumptions for constructing indices. If indices are properly conceived, they can work as an effective statistical tool for users to benchmark the multidimensional performance. Otherwise, the outcome derived from the indices gets controversial. In this study, there is a focus on motor vehicle manufacturers that primarily design and manufacture motor vehicles including passenger cars, commercial vehicles, buses and coaches. For motor vehicle manufacturers, several indices such as Dow Jones Sustainability Indies World, Newsweek Green Rankings and the Automobile Manufacturer Industry Scorecard by Moody's Corporation have been proposed for measuring company performance.

2.2.1 Dow Jones Sustainability Indices World

The World Index, or the Dow Jones Sustainability Indices (DJSI) World, first published in 1999, comprises global sustainability leaders as identified by RobecoSAM. It represents the top 10% of companies based on factors from environmental, social and governance developments. Its methodology for automobile companies is listed in Table 1. As can be seen, there are three dimensions totally with 24 criteria. The environmental factors include operational eco-efficiency, low carbon strategy, environmental reporting, climate strategy, product stewardship and environmental policy & management systems. The weights of the 24 criteria were provided by RobecoSAM.

Insert Table 1 here

2.2.2 Newsweek Green Rankings

Green Rankings 2017 is one of the most recognized environmental performance assessments of the world's largest publicly traded companies (Newsweek, 2018). This ranking was produced by the magazine Newsweek in partnership with Corporate Knights. The Global 500 from Green Rankings consists of an assessment of the 500 largest publicly-traded companies in the world by revenue. Based on the data from Bloomberg, FactSet, Thomson Reuters and the Carbon Disclosure Project, the environmental metrics and their corresponding scoring weights are designed as shown in table 2. Nineteen motor vehicle companies were included in GLOBAL 500 2017, with the ranking range from 16th to 366th.

Insert Table 2 here

2.2.3 Automobile Manufacturer Industry Scorecard

In 2017, Moody's Investors Service developed a scorecard as the methodology for rating companies that are primarily engaged in the design and manufacture of passenger vehicles. The factors and their corresponding weights are listed in table 3. Its methodology includes a scorecard which is a relatively simple reference tool that can be used in most cases to explain the factors that are generally most important in assigning ratings to issuers in the motor vehicle manufacture sector. All factors are financial measures except the "trend in Global Unit Share over Three Years" which is forward-looking. However, this forward-looking measure brings a shortcoming, namely, key rating assumptions related to unanticipated changes such as general financial market conditions and industry competition can cause the rating to be incorrect.

Insert Table 3 here

2.3 Six limitations from the indices

Despite that the three indices are currently well accepted, there are five shortcomings as follows.

1) Not all indices take into account environmental concerns. For instance, the Automobile Manufacturer Industry Scorecard by Moody's Corporation doesn't take environmental variables into account.
2) Not all indices are designed especially for motor vehicle manufacturers. For instance, the Global 500 from Newsweek Green Rankings is based on the same methodology (with the same criteria) for multiple industry sectors.
3) There are some studies involving experts 'scoring as variables' weighting method, but don't tackle the uncertainty and subjectivity inherent in weighting variables. For instance, methodologies for the DJSI World and the Automobile Manufacturer Industry Scorecard involve questionnaires to get weights. However, a step of handling the subjectivity of respondents is missing.
4) The majority of the indices keep the importance levels/weights of variables/factors/measures approximated, fixed or totally the same for all companies. This is not applicable in reality because actual importance levels/weights of variables may vary substantially. Besides, companies in different application sectors may value the variables differently.
5) None of the indices provides a post-analysis on the indices with different methodologies. This missing step makes the indices short of robustness.

2.4 Principles of developing a method for constructing the index I_{MVM}

The purpose of this paper is to construct the index I_{MVM} which can overcome the five shortcomings above. Five principles are listed in order to develop a method for constructing the I_{MVM} as follows. Based on the five principles, a method for constructing the index I_{MVM} will be designed. After the index is ready, we will benchmark the index I_{MVM} with the three indices in section 5.1.

1) Especially for motor vehicle manufacturers. According to the International Standard Industrial Classification of All Economic Activities (4th Reversion), the manufacture of motor vehicles (code 2910) includes manufacture of passenger cars, manufacture of

commercial vehicles (vans, lorries, over-the-road tractors for semi-trailers), manufacture of buses and coaches, and so on. Therefore, motor vehicles in this paper refer to passenger cars, commercial vehicles, buses, and coaches. Accordingly, motor vehicle manufacturers in this paper refer to manufacturers that are primarily engaged in the design and manufacture of motor vehicles.

2) Exclusively with quantitative variables
3) Including variables with respect to environmental issues
4) With measurability based on publicly available data
5) With transparency about methods of normalizing variables, aggregating variables and conducting the post-analysis on the index I_{MVM}.

3 A design for I_{MVM} by five phases

The design for constructing the index I_{MVM} consists of five phases. During phase I, develop a conceptual framework of company performance with variables and their measures. During phase II to phase IV, construct I_{MVM} using regression analysis for weighting variables, a linear procedure based on min-max normalization for normalizing variables, and a geometric mean for aggregating individual variables into a multiplicative index. During phase V, a sensitivity analysis is used to analyze the robustness of I_{MVM}.

The five phases are illustrated in figure 1. In order to choose proper methods of constructing I_{MVM}, three realistic considerations are identified in phase III and IV. The considerations are obtained from literature and the public available reports of manufacturers.

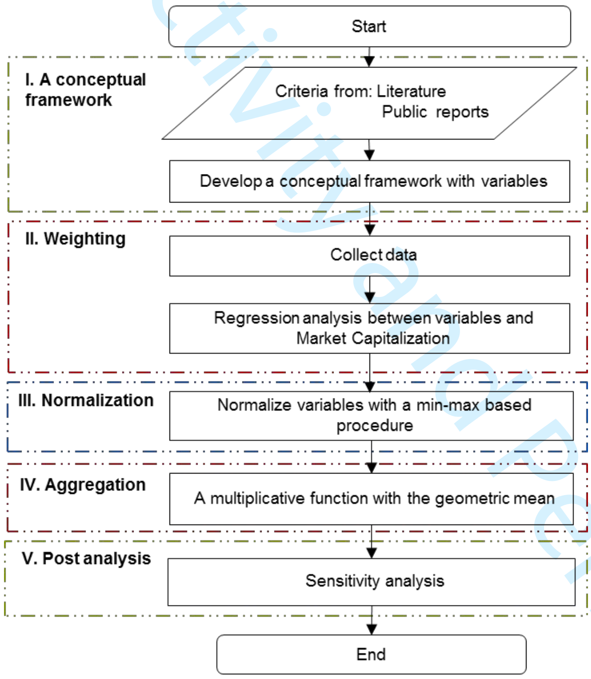


Fig. 1 A design for I_{MVM} in this paper

3.1 Phase I - A conceptual framework for company performance measurement

3.1.1 Selecting environmental variables

Environmental impacts can be measured in terms of resource consumption, emissions or environmental damage ((Hahn et al., 2010). Manufacturers such as Audi AG have adopted environmental measures including the average change (on a per-unit basis) of carbon dioxide (CO_2) emissions, energy, fresh water, organic solvents, wastewater and waste. Nevertheless, three variables are taken into account including 1) water consumption, 2) energy consumption and 3) CO_2 emissions. The reasons why the three variables are chosen are as follows.

1) Vehicle production requires a large volume of water, usually through in-house parts production and painting operations. However, access to affordable water has been identified as one of the most important issues at risk through companies' activities. Water

consumption can be regarded as an indicator of the company's impact on water resources (Harik et al., 2015).

2) The increasing use of energy-saving techniques is a recent trend in motor vehicle manufacture. Nevertheless, motor vehicle manufacturing consumes a large volume of energy during the production process (Afgan et al., 2000).
3) CO_2 emissions contribute around 70% of the whole global greenhouse gas (GHG) which leads to severe consequences such as global warming.
4) In general, the three variables are available data while others are not. Data of the three variables can be collected individually from public documents. Note that this paper doesn't analyze the relationship among the three variables.

Water consumption: this figure is made up of freshwater consumption internal catchment, and freshwater consumption externally sourced (including rainwater used, groundwater, and surface water from lakes, rivers, and ocean). For manufacturers which don't report direct water consumption data such as Nissan Motor Company, this figure can be measured by the difference between the amount of water intake (or water input or water withdraw) and water discharge.

The unit cubic meter (m3) is used for water consumption because 1) it is a base unit from the International System of Units and 2) many manufacturers such as Audi AG report water resource data in this unit. Water consumption on a per- unit (auto vehicles produced) basis is adopted as a measure, namely water consumption per vehicle produced. The calculation of this variable is in Equation (3.1), where "N" is for the production volume, "i" is for the manufacturer and "Ni" is for the volume of auto vehicles produced from the manufacturer "i".

$$\text{Water consumption per vehicle produced}[m^3/\#] = \frac{\text{Water consumption}\left[m^3\right]}{N_i\left[\#\right]} = \frac{\text{Water input}\left[m^3\right] - \text{Water discharge}\left[m^3\right]}{N_i\left[\#\right]} \quad (3.1)$$

Energy consumption: energy consumption (Dwyer et al., 2009) on a per-unit (auto vehicles produced) is adopted as a variable, namely energy consumption per vehicle produced. This figure of energy consumption is made up of electricity, heat, natural gas and heating oil consumption from vehicle production minus combined heat and power losses. Megawatt-hours (MWh) is used for water consumption because 1) watt is a derived unit from the International System of Units and 2) many manufacturers such as General Motors report energy resource data in MWh. The calculation of this variable is in Equation (3.2).

$$\text{Energy consumption per vehicle produced}[MWh/\#] = \frac{\text{Energy consumption}\left[MWh\right]}{N_i\left[\#\right]}$$

(3.2)

CO_2 emissions: CO_2 emissions on a per-unit (auto vehicles produced) are adopted as a measure. This figure of CO_2 emissions is made up of direct CO_2 emissions through the combustion of fuel oil at manufacturing plants (Scope 1) and indirect CO_2 emissions through a company's use of electricity and heat consumption (Scope 2 emissions). Manufacturers report the emissions-related data in multiple units. For instance, G does it in metric ton, A does it in ton and K does it in kilogram. Metric ton (t) is adopted as the unit for CO_2 emissions considering 1) metric ton is a unit accepted for use with International System of Units, 2) many manufacturers report emissions data in this unit and 3) this unit is used in the world's biggest carbon market, namely EU ETS. The calculation of this variable is in Equation (3.2).

$$CO_2 \text{ emissions per vehicle produced}[t/\#] = \frac{CO_2 \text{ emissions}\left[t\right]}{N_i\left[\#\right]} \quad (3.3)$$

3.1.2 A conceptual framework for company performance measurement

Company performance is a multidimensional and complex concept. It would be impractical to refer to all relevant corporate behavior factors for motor vehicle manufacturers. Within a company, there are three primary outcomes analyzed: market performance, financial performance, and shareholder value performance (in some cases, production capability performance may be analyzed). In this paper, the concept of company performance is analyzed by referring to four main sources as follows: 1) Company stability performance in terms of business continuity, company conception and company configuration (Beelaerts van Blokland et al., 2012), 2) company performance measures from an inventory perspective (Zeng and Beelaerts van Blokland, 2018) and company environmental protection measures (Zeng et al., 2018), 3) annual reports from motor vehicle manufacturers including financial reports, sustainability reports, environmental reports and corporate social responsibility reports, 4) ISO 14031 guidelines which are applicable to all companies regardless of their application sectors, 5) G4 Guidelines from Global Reporting Initiative.

Accordingly, a conceptual framework of company performance for motor vehicle manufacturers is developed in table 4. It consists of six dimensions with eight variables. Each variable is denoted with its impact direction, where impact "+" denotes the variable which satisfies "the larger its value is, the better the result gets" and "-" denotes the variable which satisfies "the smaller its value is, the better the result gets ". Measures on a per-employee basis are used for V3 and V4. Here, the term "Employee" refers to any person who is regularly employed by the company or consolidated subsidiaries or affiliated companies worldwide at a salary and is enrolled in the active employment rolls of the company or a subsidiary. It excludes part-time employees or apprentices. In this paper, the absolute value of the data for R&D expenditure and the data for the cost of goods sold (COGS) is used. For the variable Inventory Turnover, in this paper, it belongs to the category "the larger value it has, the better the impact is" since generally a high inventory turnover typically means a manufacturer is selling goods very quickly and that there is demand for their products.

Insert Table 4 here

3.2 Phase II - Regression analysis for weighting variables

As a determinant of firm performance (Kuncová et al., 2016), firm size has three proxies: total sales, total assets and market capitalization (Dang et al., 2018). Market capitalization is a more appealing measure, since 1) it is a market-oriented and forward-looking measure of size and economic relevance for a company (Bryan, 2007) and 2) it is calculated by multiplying a company's shares outstanding by the current market price of one share, which means it isn't subject to managers' influence on profit figures and investment decisions. Market capitalization is used as a proxy of company size for manufacturers, with the calculation in Equation (3.4). "n_{MS}" represents the number of a company's outstanding shares, and "SP_t" for the current share price of a single share.

$$\text{Market Capitalization}[\$] = n_{MS}[\#] * SP_t[\$] \tag{3.4}$$

This paper excludes scoring methods which rely on experts' opinions for weighting variables. As a statistical-based technique, regression analysis is commonly used in the phase of selecting variables and in the phase of weighting. To elicit the weights, we use multiple linear regression analysis with market capitalization as an endogenous variable. The importance levels (w) of the variables are generated upon the coefficients between the eight variables and the variable "market capitalization". The normalized value of the standardized coefficients works as the importance level set w=(w_{V1}, w_{V2}, w_{V3}, w_{V5}, w_{V6}, w_{V7}, w_{V8}), where $\sum w_i$=1.

3.3 Phase III - Normalizing variables

Before aggregating those variables into a single index, a normalization phase should be done to transfer variables with different measurement units into dimensionless variables. Originally, the min-max algorithm transforms the data set into the range [0,1] by Equation (3.5). The notation and its content are listed in table 5. Equation (3.5) is modified into Equation (3.6) due to two realistic considerations as follows.

1) There are two different categories of impact for the eight variables. For instance, the variable profit per employee satisfies "the larger its value is, the better the result gets" while the variable energy consumption per vehicle produced satisfies "the smaller its value is, the better the result gets ". Therefore, there are two functions for the two categories respectively.
2) There are variables that have negative values. For instance, the variable profit per employee in FY2008 in Audi AG was $76,477, while it was negative $121,280 for General Motors. In this case, the value from Equation (3.5) is inapplicable for aggregations such as power functions. In order to be able to adopt potential aggregations in the following phase, the Equation (3.6) is developed. The value by Equation (3.6) is qualified as a base number in power functions.

Therefore, for all variables, the higher normalized value a manufacturer has the better performance a manufacturer has in terms of the variable. For instance, the variable CO_2 emissions consumption per vehicle produced belongs to the impact "-". Its value should be normalized by the second function in Equation (3.6). Afterward, the higher its normalized value a manufacturer has, the better the performance in terms of CO_2 emissions reduction the company has.

$$x^* = \frac{x - \min x}{\max x - \min x}$$

(3.5)

$$x^{*t}_{ij} = \begin{cases} \dfrac{x^t_{ij}}{\max\limits_i x^t_{ij}} + 2, \; for \quad impact\,"+" \\ \dfrac{\min\limits_i x^t_{ij}}{x^t_{ij}} + 2, \; for \quad impact\,"-" \end{cases}$$

(3.6)

Insert Table 5 here

3.4 Phase IV - Aggregating variables

Following the phases of weighting variables and normalizing variables, an aggregation phase needs to be conducted to integrate those individual indicators into a single index. Weighted geometric aggregation is a commonly used aggregation method which entails partial compensability. Here, "compensability" can be understood in this way: weighted geometric mean can better reflect a situation when a shortage in one variable limits the result and cannot be compensated by other variables. For example, in this paper, despite the huge profit of some manufacturers, if the normalized value for energy consumption is very low, the final I_{MVM} index probably will get very low as well. Its function is in Equation (3.7), where x_i is the value of variable i, w_i is the weight of variable i, $\sum_i^n w_i$ is the sum of the weights $w_1, w_2, \dots, w_n$.

An aggregation function based on the weighted geometric mean is developed in Equation (3.8) due to the third realistic consideration as follows. A complete compensability between the eight variables is not desirable (European Commission, 2008). For instance, we disagree that high cash flows from operating activities can compensate for a loss of available water. In Equation (3.8), x^{*t}_{ij} works as the unfixed base of a power function while w_{ij} works as an exponent. There are three steps for calculating this multiplicative function: 1) denote x^{*t}_{ij} as the unfixed base of a power function, 2) denote the weights w_{ij} as an exponent to the variable j in manufacturer i, and 3) multiply these values raising from power functions.

$$\bar{x} = \left(\prod_{i=1}^{n} x_i^{wi} \right)^{\frac{1}{\sum_{i=1}^{n} wi}} = \exp\left(\frac{\sum_{i=1}^{n} wi \ln x_i}{\sum_{i=1}^{n} wi} \right)$$

(3.7)

$$I_{MVM}{}_i^t = f\left[x_{ij}^{*t}, w_{ij}\right] = \prod_{j=1}^{m} x^{*t}_{ij}{}^{w_{ij}} \quad (3.8)$$

3.5 Phase V – Conducting the post-analysis on the index I_{MVM}

A sensitivity analysis is an integral part of model development and involves an analytical examination of input parameters to aid in model validation (Hamby, 1995). Here, a sensitivity analysis is performed in order to gauge the robustness and increasing the transparency of the IMVM. With this phase, it can be determined how the variation in the I_{MVM} is connected quantitatively to different sources of variation. Normally the impacts of variables weights are used for sensitivity analysis (Li and Zhao, 2016). However, the variation in the IMVM stays the same in terms of the impact on variables' weights because of the nature of the multiplicative functions in Equation (3.8).

Therefore, with methods for weighting and normalizing variables unchanged, we analyze how the different aggregation methods affect the final value. Simple additive weighting (SAW, also known as a weighted linear combination) is widely used in practice due to its ease of understanding for non-experts (Zhou et al., 2006). In this paper, SAW is used during the post-analysis phase.

4 Implementing the design for I_{MVM}

4.1 Case sampling

From phase II to phase V, data sets with real figures are required to demonstrate the applicability of the method developed in section 3. According to the scope of motor vehicle manufacturers as well as the five principles in section 2.3, manufacturers are sampled by three steps as follows.

1) Include manufacturers that rank top 15 by motor vehicle production volume.
2) Exclude non- listed manufacturers.
3) Exclude manufacturers which do not provide the required data for variables V_1-V_8 with a ten-year time span.

The International Organization of Motor Vehicle Manufacturers (OICA) is the world association of the national automobile industry federations. Founded in 1919 in Paris, OICA is committed to the global harmonization of safety, environmental standards, and fuel efficiency, and this organization represents the common interests of the global auto industry. The World Motor Vehicle Production Ranking of Manufacturers by OICA is referred to. The top 15 motor vehicle manufacturers are selected. Because up till now this ranking statistic by manufacturer in FY2017 has not been released, the statistics in FY2015 and FY2016 are referred to identify the top 15 manufacturers. The information in terms of the three steps is shown in table 6. The sampling process resulted in twelve eligible MVMs, including A, B, C, D, E, F, G, H, I, J, K, and L. MVMs including M, N and O were excluded due to insufficient information of their environmental performance.

Insert Table 6 here

4.2 Data collection

No existing dataset is available for all eight variables over ten or more than ten FYs, so data is collected from multiple sources: 1) Annual reports from motor vehicle manufacturers including financial reports, sustainability reports, environmental reports and corporate social responsibility reports and 2) professional websites for stock market information. The time span is a ten-year period from FY2008 to FY2017. In order to make the data comparative, the currency is all adjusted to US dollars. As explained in section 3.1.1, the units of the three environmental variables have been unified as follows.

1) The unit of water consumption has been unified into cubic meters (m^3). Eleven out of twelve MVMs report data in m^3 while C in ton. 1.0 ton of water = 1.0160469 metric ton of water = 1.0160469 m^3 of water.
2) The unit of energy consumption has been unified into megawatt hour (MWh). Seven manufacturers report data in megawatt hour while manufacturer A and manufacturer H

in gigajoule, manufacturer E in kilowatt hour, manufacturer G in terajoule, manufacturer K in gigawatt hour. 1.0 kilowatt hour = 1.0×10^{-6} gigawatt hour= 1.0×10^{-3} megawatt hour. 1.0 terajoules = 1.0×10^{3} gigajoule = 277.7778 to megawatt hour.

3) The unit of CO_2 emissions has been unified into metric ton (t). Ten out of twelve manufacturers report data in metric ton while manufacturer A and manufacturer H in ton. 1.0 ton of CO_2 emissions = 1.0160469 metric ton of CO_2 emissions.

4.3 Weighing the variables

A dataset with non-missing values from twelve manufacturers over ten FYs (2008-2017) is built, including the variables V_1, V_2, V_3, V_4, V_5, V_6, V_7, V_8 and market capitalization. This paper intends to include all eight variables for constructing the I_{MVM}. Multiple linear regression analysis is used with the "Enter" method. The confidence interval is set up as 95%. The value from standardized coefficients is used. An example is given using the data from manufacturer A by four steps.

1) Perform a regression analysis in order to get the standardized coefficients in table 7.
2) Get their absolute value as (0.152,0.293,0.178,0.03,0.398,0.484,0.297,0.056).
3) Sum up the value as 0.152+0.293+0.178+0.03+0.398+0.484+0.297+0.056 = 1.888.
4) Get a new set as (0.152/1.888,0.293/1.888,0.178/1.888,0.03/1.888, 0.398/1.888, 0.484/1.888,0.297/1.888,0.056/1.888)=(0.08,0.155,0.094,0.016,0.211,0.256,0.157,0.03.

This new set was used as the importance levels (w) of the eight variables for A, namely, $w=(w_{V1}, w_{V2}, w_{V3}, w_{V5}, w_{V6}, w_{V7}, w_{V8})$ = (0.08, 0.155, 0.094, 0.016, 0.211, 0.256, 0.157, 0.03). Therefore, the multiplicative function of company performance for A is generated as follows.

$$I_{MVM}{}^{t}_{Toyota} = f\left[x^{*t}_{j}, w_j\right] = \prod_{j=1}^{8} x^{*t}_{j}{}^{w_j} = x^{*t}_{V1}{}^{0.08} * x^{*t}_{V2}{}^{0.155} * x^{*t}_{V3}{}^{0.094} * x^{*t}_{V4}{}^{0.016} * x^{*t}_{V5}{}^{0.211} * x^{*t}_{V6}{}^{0.256} * x^{*t}_{V7}{}^{0.157} * x^{*t}_{V8}{}^{0.03}$$

Insert Table 7 here

Similar calculations have been applied to the other eleven manufacturers, and the importance levels are listed in table 8.

Insert Table 8 here

4.4 Normalizing and aggregating the variables

The normalized value for the eight variables is calculated with Equation (3.5). Accordingly, the value of the index I_{MVM} can be calculated with Equation (3.7). The normalized value of variables and the I_{MVM} value in FY2008 are shown in table 9.

Insert Table 9 here

Similar calculations have been applied into the data in other FYs. Finally, the I_{MVM} value (the value of company performance for motor vehicle manufacturers) over ten FYs is obtained in table 10.

Insert Table 10 here

4.5 Sensitivity analysis

With methods for weighting and normalizing variables unchanged, how the different aggregation methods affect the final value is analyzed. In other words, a set of value is calculated with methods including the regression analysis, the linear normalization procedure in Equation (3.5) and the SAW approach. This set of value is shown in table 11.

Insert Table 11 here

To gauge the robustness of the company performance index I_{MVM}, Pearson's correlation test (2-tailed) was used to compare the set of I_{MVM} values with the set of values from the methods including SAW. The test indicates whether or not there is a correlation between the two sets of values calculated from different aggregation methods (other methods unchanged). Therefore, the null hypothesis and the alternative hypothesis are as follows.

H_0 There is no correlation between the values computed from different aggregation methods.

H_1 There is a positive correlation between the values computed from different aggregation methods.

As shown in table 12, for manufacturers A, B, D, E, F, G, H, I, J and L, the correlation coefficients were all close to 1.0. Besides, the P values of these tests were all smaller than 0.05 at the 0.05 level (2-tailed) or smaller than 0.01 at the 0.01 level (2-tailed). For the ten manufacturers, the values computed from I_{MVM} have a high positive correlation with the values from the method with the commonly used SAW technique. Despite that there were weak correlations in C and K, the average correlation coefficient of the twelve manufacturers was 0.892 (close to 1.0) and the average P-value was 0.001. Therefore, the null hypothesis H_0 was rejected at the significance level α =0.05 for the tests which indicates a high positive correlation between the two sets of values.

Insert Table 12 here

4.6 Sub conclusion

With three realistic considerations, the index I_{MVM} (the company performance index for motor vehicle manufacturers) was transparently constructed. In general, the sensitivity analysis indicates the outcome from the I_{MVM} has a very strong correlation with the outcome with SAW as an aggregation method. SAW is widely used in practice because of its ease of understanding for users. However, it asks for an assumption of preference independence which exists if and only if variables are mutually preferentially independent (Podvezko, 2011). Here arises the advantage of the rigorous design of I_{MVM} which doesn't involve that unrealistic assumption.

5 Discussions

As mentioned in section 2.3, the index I_{MVM} will be benchmarked with the three indices after constructing the index I_{MVM}. Therefore, in section 5.1, a benchmark is made between the I_{MVM} and the indices including the DJSI World, Newsweek Green Rankings and the Automobile Manufacturer Industry Scorecard by Moody's Corporation. Based on the I_{MVM} value, a ranking by motor vehicle manufacturer is generated in section 5.2. In order to introduce the environmental impact on rankings, section 5.3 presents the ranking $R_{exc.env}$ which stands for the ranking by manufacturer excluding environmental measures. Afterward, section 5.4 presents a comparison on the ranking R based on the I_{MVM} value and the ranking $R_{exc.env}$ based on the value excluding environmental variables. There are manufacturers which had improved rankings from $R_{exc.env}$ to R due to the contribution from their environmental performance. Section 5.5 provides a discussion on their environmental performance in terms of water consumption, energy consumption and CO_2 emissions in FY2017 as well as their targets in the near future. In section 5.6, this paper raises awareness of CO_2 emissions in vehicles' production.

5.1 Benchmark with other indices

To benchmark the index I_{MVM} with the DJSI World, Newsweek Green Rankings and the Automobile Manufacturer Industry Scorecard by Moody's Corporation, we list seven items as follows.

1) The index takes into account environmental concerns.
2) The index is designed especially for motor vehicle manufacturers (rather than for multiple industry sectors).
3) The index tackles the uncertainty and subjectivity inherent in weighting variables if the experts' scoring method is used as the weighting method.
4) The index makes the variables' weights adjustable for different manufacturers rather than fix the weights of variables the same for all manufacturers.
5) All of the variables in the index can be measurable based on publicly available data.
6) The index is constructed with clear methods for normalizing variables and aggregating variables.

7) The index is transparent with a post-analysis phase.

A benchmark between I_{MVM} and the three indices is presented in table 13. As mentioned in section 2.3, the three indices are currently well accepted. However, there are five shortcomings which make the three indices incapable to satisfy all benchmark items. The development of the index I_{MVM} doesn't involve subjective scoring methods, so the third benchmark item is not applicable for I_{MVM}. In conclusion, the index I_{MVM} satisfies all six applicable benchmark items while the three indices are incapable to satisfy their applicable benchmark items.

Insert Table 13 here

5.2 The ranking R by manufacturer based on I_{MVM}

5.2.1 The ranking R by manufacturer based on I_{MVM} value over FY 2008-FY 2017

The I_{MVM} value is the value takes into account the three environmental variables. Based on the index $I_{MVM,}$ it is possible to generate a ranking R by manufacturer with environmental concerns. The ranking R by manufacturer during FY2008 to FY2017 is presented in table 14.

The rankings varied over the ten FYs. Generally, manufacturer B ranks the top among the twelve manufacturers, except in FY 2009 and in FY2017 it ranked the second. Manufacturer A ranked either the second or the third, except in FY2011, in FY2012 and in FY2016 it ranked 4th. Manufacturer L usually ranked the third, 4th or 5th, except in FY2011 and in FY2012 it ranked the second. Manufacturer H usually ranked either 8th or 9th, except in FY2014 and in FY2017 it ranked 6th. Manufacturer K usually ranked the last among the twelve manufacturers, except in FY2008, in FY2009 and in FY2012, it ranked 10th, 11th and 11th respectively.

Insert Table 14 here

5.2.2 Motivation to compare the ranking R with a ranking excluding environmental measures ($R_{exc.env}$)

Currently, there are several rankings by manufacturer without environmental concerns. For instance, OICA refers to the production volume as the only criterion to rank "the 15 largest manufacturers". Manufacturer C ranked 3rd based on OICA ranking in FY2016 while this manufacturer ranked 11th based on the I_{MVM} value in this paper. One reason for the big ranking difference is that the index I_{MVM} takes into account environmental concerns while other rankings such as the one from OICA don't. Manufacturers have to pay attention to sustainable development rather than exclusively focusing on profitability. Therefore, they have to be aware of CO_2 emissions in vehicles' production. In order to introduce the environmental impact on rankings, section 5.3 presents the ranking R' by manufacturer excluding environmental measures.

5.3 The ranking $R_{exc.env}$ by manufacturer based on the value excluding environmental measures

This section presents the final value of company performance excluding the three environmental variables, namely V_6, V_7 and V_8. The five variables (V_1-V_5) are weighted with regression analysis, normalized the five variables with Equation (3.5) and aggregated the five variables with Equation (3.7). Based on the final value of company performance, table 15 lists the ranking $R_{exc.env}$ for each manufacturer during FY2008 to FY2017.

Generally, manufacturer H ranked the top among the twelve manufacturers, except in FY2013, in FY2015, in FY2016 and in FY2017 it ranked the second respectively. Manufacturer D ranked either the first or the second among the twelve manufacturers, except in FY2008 and in FY2009 it ranked the last and 8th respectively. Manufacturer J usually ranked either the third or 4th, except in FY2008 and in FY2012 it ranked the second and 5th respectively. In contrast, manufacturer K usually ranked the last among the twelve manufacturers, except in FY2008 it ranked 11th. The similar situation happened to manufacturer F which usually ranked 11th among the twelve manufacturers, except in FY2008 and in FY2009 it ranked 9th and 10th respectively. Manufacturer E ranked 10th among the twelve manufacturers, except for in FY2009 it ranked 11th. Manufacturer L usually ranked 9th among all manufacturers, except in both FY2008 and in FY2011 it ranked 8th.

Insert Table 15 here

5.4 Comparison between the ranking $R_{exc.env}$ and the ranking R in FY2017

$R_{exc.env}$ stands for the ranking based on the company performance value excluding environmental measures. R stands for the ranking based on the I_{MVM} value which takes environmental concerns into account. As shown in table 16, there are three ranking trends from $R_{exc.env}$ to R. 1). The trend "↗" denotes the manufacturer which has an improved ranking from $R_{exc.env}$ to R. 2). The trend "↘" denotes the manufacturer which has a drop in rankings from $R_{exc.env}$ to R. 3). The trend "--" denotes the manufacturer which keeps an unchanged ranking. Manufacturers including C, G, H and J were with a decrease in rankings. Manufacturers including D, E, I and K had unchanged rankings no matter based on the ranking $R_{exc.env}$ and the ranking R.

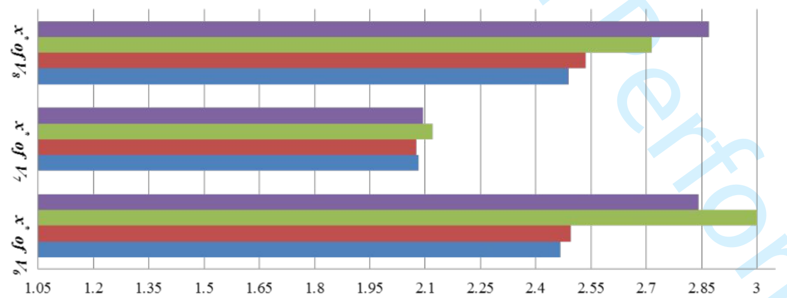
Insert Table 16 about here

As shown in table 16, manufacturer B ranked 7th without environmental concerns. Once the three environmental variables were taken into account, manufacturer B improved its ranking to 2nd. For manufacturer A, the ranking improved from 6th to 3rd. For manufacturer L, the ranking improved from 9th to 4th, and for manufacturer F, the ranking improved from 11th to 9th. All four manufacturers had an increase in rankings due to the contribution of their environmental performance.

5.5 The environmental performance of manufacturers with an increase in rankings

As introduced above, section 5.5 focuses on the environmental performance of the manufacturers which had improved rankings from $R_{exc.env}$ to R in FY 2017. There are four manufacturers including A, B, F and L. According to the multiplicative function $I_{MVM} = f\left[x^*, w\right]$, the environmental performance is up to the normalized value (x^*) and the weights (w) of variable V_6, V_7 and V_8. The x^* was obtained with the linear method in Equation (3.6) and the w was obtained by the regression analysis in section 4.3. Both of the two values were based on the raw value of variable V_6, V_7 and V_8.

However, it is not practical to put all their raw data into one figure. For instance, the raw data for V_3 Profit per employee can be over 1,000,000 while the raw data for V_8 CO_2 emissions per vehicle produced can be less than 5.0. Therefore, instead of the absolute values of the variable V_6, V_7 and V_8, their normalized values are used.



	Normalized value (x*) of V6 Water consumption per vehicle produced	Normalized value (x*) of V7 Energy consumption per vehicle produced	Normalized value (x*) of V8 CO2 emissions per vehicle produced
L	2.842342342	2.09375627	2.870621825
F	3	2.121101848	2.713909897
B	2.494708995	2.076774002	2.53516484
A	2.4675	2.082759705	2.488182834

Fig.2 The normalized value (x^*) of environmental variables for the manufacturers with an increase in rankings

The normalized value (x^*) of variables V_6, V_7 and V_8 for the four manufacturers is presented in figure 2. As explained in section 3.3, the higher the normalized value of the variable V_6, V_7 or V_8 a company has, the better performance in terms of water conservation, energy conservation or CO_2 emissions reduction the company has.

5.5.1 The environmental performance in terms of water consumption

As seen in figure 2, manufacturer F had the highest x^* of V_6 as 3.000. In FY2017, manufacturer F reduced water consumed per vehicle produced by 16.2% compared to the level of FY2010. The x^* of V_6 was 2.842 for manufacturer L. Manufacturer L reduced water consumed per vehicle produced by 1.3% to 2.22 (m^3/#) in FY2017 compared to the level of FY2016. Manufacturer L targets to achieve a reduction of 45% by FY2020 compared to the level of FY2006.

The x^* of V_6 was 2.495 for manufacturer B. Manufacturer B has set up a membrane bioreactor which could turn wastewater into hygienically safe industrial water by three stages. This will help manufacturer B realize its target of a one-third reduction in the amount of water required in production. The x^* of V_6 was 2.468 for manufacturer A. Manufacturer A's approach to water conservation consists of "a comprehensive reduction in the amount of water used, and water purification and returning it to the earth". Manufacturer A has implemented "rainwater collection and filtering to increase the recycling rate".

5.5.2 The environmental performance in terms of energy consumption

As seen in figure 2, the x^* of V_7 was 2.121 for manufacturer F. Manufacturer F engages in a variety of energy-saving activities in the manufacturing process. The total energy consumption of manufacturer F's global production sites accounted for 8.462 million MWh in FY2017, a reduction of 6.4% compared to the level of FY2016. The x^* of V_7 was 2.094 for manufacturer BMW. In FY2017, manufacturer L launched a digitalization project in the area of energy consumption. Energy consumption per vehicle produced was 2.17 (MWh /#) in FY2017. Compared to the level of FY2006, manufacturer L has achieved a reduction of 36.5%. This manufacturer targets to achieve a reduction of 45% by FY2020. The x^* of V_7 was 2.077 for manufacturer B. Manufacturer B concentrates on generating energy from renewable sources. Energy consumption amounted to 2,924,694 MWh in FY2017 compared to 2,867,015MWh in FY2016. This is mainly due to operation of the new plant in Mexico and lower production output by the European production sites.

5.5.3 The environmental performance in terms of CO_2 Emissions

The x^* of V_8 was 2.871 for manufacturer L. Manufacturer L has the plan to move towards carbon-free production. As a key driver of electric mobility, manufacturer L increased the share of electric vehicles in its product portfolio and delivered 103,080 electric vehicles FY2017. In Europe, L sources its electricity free of CO_2. The x^* of V_8 was 2.714 for manufacturer F. Manufacturer F aims to achieve zero-emission production. From FY2010 to FY2017, manufacturer F globally sold more than 320,000 units of the LEAF, a zero-emission vehicle. In FY2017, manufacturer F had a reduction of 31% on CO_2 emissions per vehicle produced compared to the level of FY2005. Manufacturer F targets to reduce CO_2 emissions from new vehicles by 90% based on FY2000 levels by FY2050.

The x^* V_8 was 2.525 for manufacturer B. Manufacturer B aims to be a leader in electric cars which can reduce carbon footprint. In April 2017, manufacturer B's new all-electric concept vehicle, the e-tron Sportback, made its debut. Manufacturer B sets a target that one in three manufacturer B's cars sold by 2025 can be an electric model. The x^* V_8 was 2.488 for manufacturer A. In its New Vehicle Zero CO_2 Emissions Challenge, manufacturer A has set the target of a 90% CO_2 emissions reduction in new vehicles by FY2050 compared to the level of FY 2010.

5.6 Raising awareness of CO_2 emissions in vehicles' production

As a global response to climate change, several organizations such as the European Environmental Agency have been launched. Accordingly, several plans with specific targets have been made. In April 2018, the revised EU ETS Directive entered into force. As an ambitious reform during its fourth trading period (2021-2030), EU ETS aims to facilitate a 43% GHG emissions reduction from EU ETS sectors by 2030 (European Commission, 2018). This target is in line with its commitments under the Paris Agreement. For new lorries, in November 2018, the European Parliament set a target with a 35% GHG emissions reduction by 2030 (European

Parliament, 2018). Although European automakers, as well as the European Automobile Manufacturers Association, have raised objections, they have to follow the plans with aggressive targets. For motor vehicle manufacturers, it is essential to create a bigger market share of zero-emission or low emission vehicles. According to the "cap and trade" principle of EU ETS, holders will be rewarded if they actively reduce carbon emissions to certain amounts during their production. Otherwise, they will be fined if they generated excessive carbon emissions.

Therefore, manufacturers have to get aware of the potential risks such as the bills due to excessive carbon emissions and carbon tax. Manufacturers with a decrease in rankings such as manufacturer G and manufacturer H should take it serious especially if their normalized values of CO_2 emission were below the average level. Manufacturers with an increase in rankings need to raise awareness as well even though they had improved rankings. For instance, the normalized value of CO_2 emissions for manufacturer A and manufacturer B was 2.525 and 2.488 respectively. The value was below average level (2.638), which suggests that manufacturer A and manufacturer B should make an effort on reducing their CO_2 emissions. Manufacturer B aims to develop its roster of electrified vehicles to include over 20 models, so that the manufacturer can reach a target of 800,000 annual sales of electrified vehicles by 2025. This indicates manufacturer B may have better performance regarding its environmental protection with less CO_2 emissions. Manufacturer A aims to achieve zero CO_2 emissions at all plants by 2050 and has introduced low-CO_2 production technologies into the vehicle manufacturing process. This indicates that manufacturer A may have more competitive environmental performance in the following years.

6 Contributions

6.1 Implications for research

This paper has contributed to the performance measurement literature with a new design of company performance index I_{MVM}. In order to design the index, five principles have been listed as follows: 1) especially for motor vehicle manufacturers, 2) exclusively with quantitative variables, 3) including variables with respect to environmental issues, 4) with measurability based on publicly available data and 5) with transparency in the methods of constructing $I_{MVM.}$

The conceptual framework of company performance is new including three environmental variables. In order to choose proper methods for normalizing variables and for aggregating variables, three realistic considerations have been identified as follows: 1) there are two different categories of impact for the eight variables, 2) there are variables which have with negative values and 3) a complete compensability between the eight variables is not desirable. A modified linear method has been developed for normalizing the variables based on min-max methods.

6.2 Implications for industry

Based on the index I_{MVM}, a ranking by motor vehicle manufacturer with environmental concerns can be generated. The environmental impact on rankings has been introduced with a comparison on the ranking based on the I_{MVM} value and the ranking based on the value excluding environmental measures. As a response to current imperative climate policies, this paper raises awareness of CO_2 emissions in vehicles' production.

The developed approach for measuring the environmental performance is practically relevant for MVMs with regards to reducing energy consumption, water consumption and CO_2 emissions during vehicles' production. The data generated in this paper is helpful for MVMs to get aware of the potential risks due to excessive carbon emissions fines and carbon tax bills. "the entry price of € 10 per tonne from 2021 is much too low, the price will stabilize on the market and can then rise to €120 to 130 per ton, which many people demand." says the influential German economist Jens Südekum (FD, 2019). Better environmental performance is beneficial for MVMs with lower production costs as well as with a high reputation for sustainable development. In addition, better environmental performance can also get more support from organizations that take inventive actions for reducing resource overconsumption such as Greenpeace in the Netherlands.

The case study in twelve MVMs has practical relevance with regards to providing available and reliable statistics to statistical organizations such as the International Organization of Motor Vehicle Manufacturers and the European Environment Agency. Statistics generated in this research can be integrated as a modular into the big statistic network in the organization for the historical performance analysis (during FY2008 to FY2017) of different MVMs.

Data generated in this paper has practical relevance with stakeholders in the investment world such as asset management organizations. As to the investment world, there has been a change in thinking from avoiding companies that have a negative impact on the environment to investing in companies that have positive environmental policies. For sustainability-themed investments, the data helps the stakeholders identify the MVMs that are with positive environmental policies.

The investigation of current problems during CIs' construction has a practical impact on data analysts in both academia and industry. In order to construct effective CIs, data analysts have to adopt rigorous techniques taking into account restrictions from the specific utilized industry. The approach developed for delivering an index I_{MVM} has practical relevance for setting up realistic restrictions for MVMs.

7 Conclusions

For ranking motor vehicle manufacturers, users can refer to individual variables as well as indices such as the DJSI World index. However, sufficient statistics haven't been found when it comes to company performance measurement with environmental concerns for motor vehicle manufacturers. Therefore, the purpose of this paper is to construct a company performance index I_{MVM} for motor vehicle manufacturers with environmental concerns. The research question arises as how to construct the index I_{MVM}.

A design by five phases has been developed for the index I_{MVM}. Proper methods have been used to identify variables and to analyse the data. A conceptual framework with three environmental variables has been identified. A ranking by manufacturer with environmental concerns has been generated with a case study in twelve motor vehicle manufacturers. These efforts have answered the research question. This paper is concluded by indicating two limitations in this paper and four recommendations for further research.

7.1 Limitations in this paper

Despite the rigorous methods and transparent implementation, there are two main limitations in this paper. The first limitation is that the case sampling process only involved the top 15 manufacturers based on production volume from OICA. The sampling process results in twelve eligible motor vehicle manufacturers. Some influential manufacturers such as Ashok Leyland, PACCAR Inc., and the Mitsubishi Group are missing. The second limitation is that the sensitivity analysis only referred to the impact on different aggregation methods. The simple additive weighting approach is used as the only comparison method. A sensitivity analysis of how the different weighting methods and/or normalization methods affect the final value is missing.

7.2 Recommendations for further research

For MVMs, it is essential to create a bigger market share of zero-emission or low emission vehicles. This is in line with the principle of EU ETS as well as other environmental policies. In order to avoid potential risks such as the carbon tax bills, MVMs have to get aware of their actual performance. Consistent and transparent data is encouraged to be released on periodic (not only on a yearly basis but also in shorter periods of time) reports by manufacturers. The time-series data of the performance from an environmental perspective can be added to manufacturers' reports. With this data as a benchmark metric, manufacturers will feel motivated to achieve a balanced combination between their economic performance and environmental performance.

It can be interesting to perform a comparison study on the performance in sub-sectors of the motor vehicle manufacturing sector. In terms of the primary type of business, the automobile and light-duty motor vehicle manufacturing sector can be characterized as in the Business-to-Customer market segment. The heavy-duty truck manufacturing sector can be characterized as in the Business-to-Business market segment. There may be some correlation between the performances in the two sectors.

Currently, several tools are being adopted to rank or rate companies. However, the majority involves a third party who can collect the data, make the comparison and provide feedback but all on a confidential basis (Managing Innovation, 2019). Generally, the tools only target at top companies that means that not every MVM is qualified to be included. Further research can be done on developing a measurement tool using SQL, JavaScript and Preprocessor Hypertext. The tool can be accessible and practical for any MVM to measure and benchmark its performance against the best in class in this sector. It can aid managers to make suitable decisions for continuous improvement.

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Table 1 The Dow Jones Sustainability World Methodology for automobile companies
(Source: RobecoSAM Corporate Sustainability Assessment 2018)

Industry Group	Industry	Dimension	Criterion	Weight (%)
Automobiles & Components	AUT Automobiles	Economic Dimension	Corporate Governance	9
			Codes of Business Conduct	6
			Supply Chain Management	4
			Innovation Management	4
			Risk & Crisis Management	3
			Materiality	3
			Brand Management	2
			Customer Relationship Management	2
			Product Quality and Recall Management	2
			Tax Strategy	1
			Policy Influence	1
		Environmental Dimension	Operational Eco-Efficiency	8
			Low Carbon Strategy	6
			Environmental Reporting	6
			Climate Strategy	5
			Product Stewardship	3
			Environmental Policy & Management Systems	3
		Social Dimension	Occupational Health and Safety	6
			Talent Attraction & Retention	6
			Human Capital Development	6
			Social Reporting	5
			Corporate Citizenship and Philanthropy	3
			Labor Practice Indicators	3
			Human Rights	3

Table 2 Matrices and weights from Green Rankings Global 500
(source Newsweek Green Rankings)

Matric	Weight (%)	Matric	Weight (%)
Combined energy productivity	15	Green revenue percent range	20
Combined GHG productivity	15	Sustainability pay link	10
Combined water productivity	15	Sustainability board committee	5
Combined waste productivity	15	Audited environmental metric	5

Table 3 Automobile Manufacturer Industry Scorecard
(source Moody's Investors Service)

Rating Factors	Weight (%)	Sub-factors	Weight (%)
Business Profile	40	Trend in Global Unit Share Over Three Years	10
		Market Position and Product Breadth/Strength	30
Profitability and Efficiency	20	EBITA Margin	20
Leverage and Coverage	30	Debt / EBITDA	10
		(Cash + Marketable Securities) / Debt	5
		RCF / Debt	5
		FCF / Debt	5
		EBITA / Interest Expense	5
Financial Policy	10	Financial Policy	10
Total	100	Total	100

Table 4 The conceptual framework of company performance for auto vehicle manufactures

Dimension	Variable (category)	Impact	Function/Measure[Unit]	Source
Competitive Performance	V_1 Market share	+	V_{1i}= N_i[#]/ $\sum_{i=1}^{n} N_i$ [#], "n" for the number of manufacturers	Tseng et al., 2009
Financial performance	V_2 Cash flow margin	+	V_{2i}= Cash flows from operating activities [$]/NS[$],"NS" for net sales	Ibarra, 2009
Manufacturing capability	V_3 Profit per Employee	+	V_{3i}=Profit [$]/Employee [#]	Bryan, 2007, Beelaerts van Blokland et al., 2012
Innovation capability	V_4 R&D expenditure per employee	+	V_{4i}= R&D Expenditure [$]/Employee[#]	Beelaerts van Blokland et al., 2018
Inventory performance	V_5 Inventory turnover	+	V_{5i}= $COGS_t$/[0.5*(I_t+I_{t-1})], "I" for inventory size	Zeng and Beelaerts van Blokland, 2018
Environmental performance	V_6 Water consumption per vehicle produced	-	Equation (3.1) [m^3/#]	Harik et al., 2015, ISO 14031
	V_7 Energy consumption per vehicle produced	-	Equation (3.2) [MWh/#]	G4—EN3 Power consumption within the organization
	V_8 CO_2 emissions per vehicle produced	-	Equation (3.3) [t/#]	Zeng et al., 2018, G4—EN15 and G4—EN16 Direct and Indirect GHG emissions

Table 5 Basic notations and their content

No.	Notation	Content
1	t	The fiscal year, $t=0,1,\ldots,T$
2	i	The motor vehicle manufacturers, $i=1,2,\ldots,n$
3	I_{MVMi}^t	The company performance index for motor vehicle manufacturer i in t
4	j	The individual variables, $j=1,2,\ldots,m$
5	x_{ij}^t	The value of variable j for manufacturer i in t
6	$x^*{}_{ij}^t$	The normalized value of x_{ij}^t, $x^*{}_{ij}^t \in (0,3]$
7	w_{ij}	The weight of variable j for manufacturer i, $w_{ij} \in (0,1)$, and $\sum w_i=1$
8	$\max_i x_{ij}^t$	Within manufacturer i, the maximum value of variable j in t
9	$\max_i x_{ij}^t$	Within manufacturer i, the minimum value of variable j in t

Table 6 Sample manufacturers

Rank	Manufacturer	Production in FY2015	Production in FY2016	Data availability
		SUM 90,297,736	SUM 94,771,814	
1	A	10,083,831	10,213,486	YES
2	B	9,872,424	10,126,281	YES
3	C	7,988,479	7,889,538	YES
4	D	7,484,452	7,793,066	YES
5	E	6,393,305	6,429,485	YES
6	F	5,170,074	5,556,241	YES
7	G	4,543,838	4,999,266	YES
8	H	4,865,233	4,681,457	YES
9	I	3,032,652	3,373,278	YES
10	J	2,982,035	3,152,787	YES
11	M	3,034,081	2,945,295	NO
12	N	2,260,579	2,566,793	NO
13	K	2,134,645	2,526,450	YES
14	L	2,279,503	2,359,756	YES
15	O	1,540,133	1,715,871	NO

Table 7 Coefficients summary and importance levels for manufacturer A

Coefficients[a]					Importance level (*w*)
Model		Unstandardized Coefficients		Standardized Coefficients	
		B	Std. Error	Beta	
1	(Constant)	757627.482	358657.448		
	V_1	-575036.949	753897.287	-0.152	0.080
	V_2	185753.499	183545.411	0.293	0.155
	V_3	0.182	0.463	0.178	0.094
	V_4	-0.582	6.176	-0.030	0.016
	V_5	12000.682	7842.252	0.398	0.211
	V_6	-28219.560	15474.354	-0.484	0.256
	V_7	-111274.883	108095.606	-0.297	0.157
	V_8	-29504.894	227525.446	-0.056	0.030
a. Dependent Variable: Market Capitalization					

Table 8 Importance levels of variables for eleven manufacturers

Manufacturer	V_1	V_2	V_3	V_4	V_5	V_6	V_7	V_8
B	0.060	0.154	0.056	0.279	0.002	0.230	0.055	0.163
C	0.062	0.101	0.268	0.194	0.021	0.004	0.123	0.227
D	0.018	0.189	0.304	0.107	0.125	0.004	0.078	0.176
E	0.120	0.015	0.127	0.089	0.047	0.037	0.266	0.299
F	0.035	0.029	0.124	0.128	0.052	0.131	0.366	0.135
G	0.062	0.101	0.268	0.194	0.021	0.004	0.123	0.227
H	0.082	0.228	0.099	0.069	0.288	0.101	0.023	0.109
I	0.119	0.113	0.105	0.037	0.266	0.145	0.033	0.182
J	0.154	0.079	0.235	0.104	0.169	0.097	0.087	0.074
K	0.026	0.016	0.118	0.102	0.015	0.217	0.349	0.157
L	0.087	0.184	0.199	0.031	0.010	0.241	0.214	0.033

Table 9 The normalized value of variables and the I_{MVM} value in FY2008

x^* / Manufacturer	V_1	V_2	V_3	V_4	V_5	V_6	V_7	V_8	I_{MVM}^{2008}
A	3.000	2.377	1.810	2.546	2.743	2.316	2.277	2.152	2.396
B	2.111	2.621	3.000	3.000	2.584	2.426	2.313	2.629	2.640
C	2.301	2.000	2.406	2.425	2.247	2.196	2.175	2.187	2.275
D	2.897	1.604	0.414	2.634	2.767	2.234	2.278	2.112	1.310
E	2.585	1.578	1.401	2.691	3.000	2.215	2.200	2.112	2.151
F	2.368	2.517	1.883	2.568	2.569	2.164	2.313	2.194	2.269
G	2.424	2.188	2.138	2.600	2.404	3.000	3.000	3.000	2.535
H	2.478	2.032	2.201	2.268	2.293	2.186	2.129	2.215	2.209
I	2.252	1.942	2.030	2.385	2.382	2.236	2.318	2.530	2.276
J	2.360	2.002	2.050	2.271	2.393	2.317	2.399	2.426	2.252
K	2.235	2.082	2.182	2.435	2.231	2.171	2.142	2.070	2.172
L	2.156	3.000	2.064	2.756	2.439	2.470	2.254	2.149	2.388

Table 10 The I_{MVM} value for twelve manufacturers over FY2009 to FY2017

I_{MVM} / Manufacturer	I_{MVM}^{2009}	I_{MVM}^{2010}	I_{MVM}^{2011}	I_{MVM}^{2012}	I_{MVM}^{2013}	I_{MVM}^{2014}	I_{MVM}^{2015}	I_{MVM}^{2016}	I_{MVM}^{2017}
A	2.505	2.646	2.489	2.545	2.659	2.637	2.663	2.591	2.583
B	2.646	2.902	2.893	2.868	2.837	2.868	2.746	3.003	2.626
C	2.462	2.588	2.481	2.449	2.510	2.457	2.505	2.410	2.403
D	2.021	2.406	2.406	2.434	2.459	2.401	2.562	2.630	2.636
E	2.220	2.447	2.450	2.442	2.421	2.385	2.532	2.485	2.447
F	2.365	2.534	2.523	2.604	2.611	2.517	2.716	2.647	2.462
G	2.668	2.428	2.311	2.362	2.338	2.317	2.356	2.413	2.463
H	2.275	2.396	2.379	2.402	2.396	2.407	2.413	2.414	2.542
I	2.341	2.377	2.379	2.378	2.379	2.401	2.457	2.468	2.555
J	2.280	2.375	2.333	2.262	2.263	2.271	2.386	2.465	2.500
K	2.131	2.320	2.303	2.289	2.254	2.231	2.315	2.389	2.296
L	2.416	2.642	2.684	2.649	2.599	2.557	2.585	2.558	2.558

Table 11 The value of company performance with the SAW approach as an aggregation method

FY / Manufacturer	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
A	2416	4.541	4.879	4.739	4.695	4.763	4.791	4.661	4.609	4.692
B	4.752	4.784	5.392	5.351	5.193	5.109	5.228	4.856	6.066	4.795
C	4.471	4.757	5.030	4.927	4.815	4.856	4.844	4.893	5.156	5.054
D	3.897	4.321	4.912	4.891	4.809	4.813	4.805	4.942	5.564	5.087
E	4.361	4.452	4.901	4.886	4.812	4.748	4.748	4.886	5.286	4.751
F	4.290	4.458	4.683	4.686	5.358	5.369	5.265	5.470	5.742	5.586
G	5.553	5.675	4.685	4.534	4.571	4.517	4.533	4.559	4.937	5.443
H	4.278	4.385	4.733	4.688	4.750	4.704	4.774	4.762	4.326	5.429
I	4.340	4.446	4.737	4.666	4.548	4.522	4.594	4.630	4.794	5.267
J	4.446	4.522	4.848	4.817	4.511	4.489	4.533	4.645	5.145	5.035
K	4.091	4.050	4.369	4.343	4.268	4.176	4.188	4.274	4.681	5.467
L	4.477	4.545	5.124	5.161	4.951	4.832	4.848	4.834	4.797	5.141

Table 12 The summary of Pearson correlation coefficient

Manufacturer	Correlation coefficient R	Sig. (2-tailed)	Significant (YES/NO)	Manufacturer	Correlation coefficient R	Sig. (2-tailed)	Significant (YES/NO)
A	0.742*	0.140	YES	G	0.919**	0.000	YES
B	0.919**	0.000	YES	H	0.835**	0.003	YES
C	0.516	0.127	NO	I	0.902**	0.000	YES
D	0.912**	0.000	YES	J	0.930**	0.000	YES
E	0.847**	0.002	YES	K	0.494	0.147	NO
F	0.760*	0.011	YES	L	0.866**	0.001	YES
Average of the twelve manufacturers					0.892**	0.001	YES
* Correlation is significant at the 0.05 level (2-tailed) ** Correlation is significant at the 0.01 level (2-tailed)							

Table 13 A benchmark: I_{MVM} against other indices

Benchmark Item	DJSI World	Newsweek Green Rankings	Automobile Manufacturer Industry Scorecard	I_{MVM}
1)With environmental concerns	√	√	×	√
2)Especially for motor vehicle manufacturers	√	×	√	√
3)Tackle the subjectivity inherent in weighting variables	×	N.A.	×	N.A.
4)With weights adjustable for different manufacturers	×	√	×	√
5)With variables measurable based on public available data	×	√	×	√
6)With clear normalizing and aggregating methods	√	√	√	√
7)With clear post-analysis phase	×	×	×	√
Note: "√" means the index satisfies the item, "×" means the index dissatisfies the item and "N.A." means the item is not applicable for this index.				

Table 14 The ranking R by manufacturer with environmental concerns

FY / Manufacturer	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
A	3	3	2	4	4	2	2	3	4	3
B	1	2	1	1	1	1	1	1	1	2
C	6	4	4	5	5	5	5	7	11	11
D	12	12	8	7	7	6	7	5	3	1
E	11	10	6	6	6	7	9	6	6	10
F	7	6	5	3	3	3	4	2	2	9
G	2	1	7	11	10	10	10	11	10	8
H	9	9	9	8	8	8	6	9	9	6
I	5	7	10	9	10	9	8	8	7	5
J	8	8	11	10	12	11	11	10	8	7
K	10	11	12	12	11	12	12	12	12	12
L	4	5	3	2	2	4	3	4	5	4

Table 15 The ranking $R_{exc.env}$ by manufacturer excluding environmental measures

FY / Manufacturer	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
A	7	7	7	9	8	6	7	5	7	6
B	3	5	6	5	4	4	4	6	6	7
C	4	2	3	3	3	5	5	7	8	8
D	12	8	2	2	2	1	2	1	1	1
E	10	11	10	10	10	10	10	10	10	10
F	9	10	11	11	11	11	11	11	11	11
G	5	4	5	6	6	7	8	8	4	4
H	1	1	1	1	1	2	1	2	2	2
I	6	6	8	7	7	8	6	4	5	5
J	2	3	4	4	5	3	3	3	3	3
K	11	12	12	12	12	12	12	12	12	12
L	8	9	9	8	9	9	9	9	9	9

Table 16 Differences between the two rankings in FY2017

Ranking / Manufacturer	$R_{exc.env}$	R	Trend	Ranking / Manufacturer	$R_{exc.env}$	R	Trend
A	6	3	↗	G	4	8	↘
B	7	2	↗	H	2	6	↘
C	8	11	↘	I	5	5	--
D	1	1	--	J	3	7	↘
E	10	10	--	K	12	12	--
F	11	9	↗	L	9	4	↗

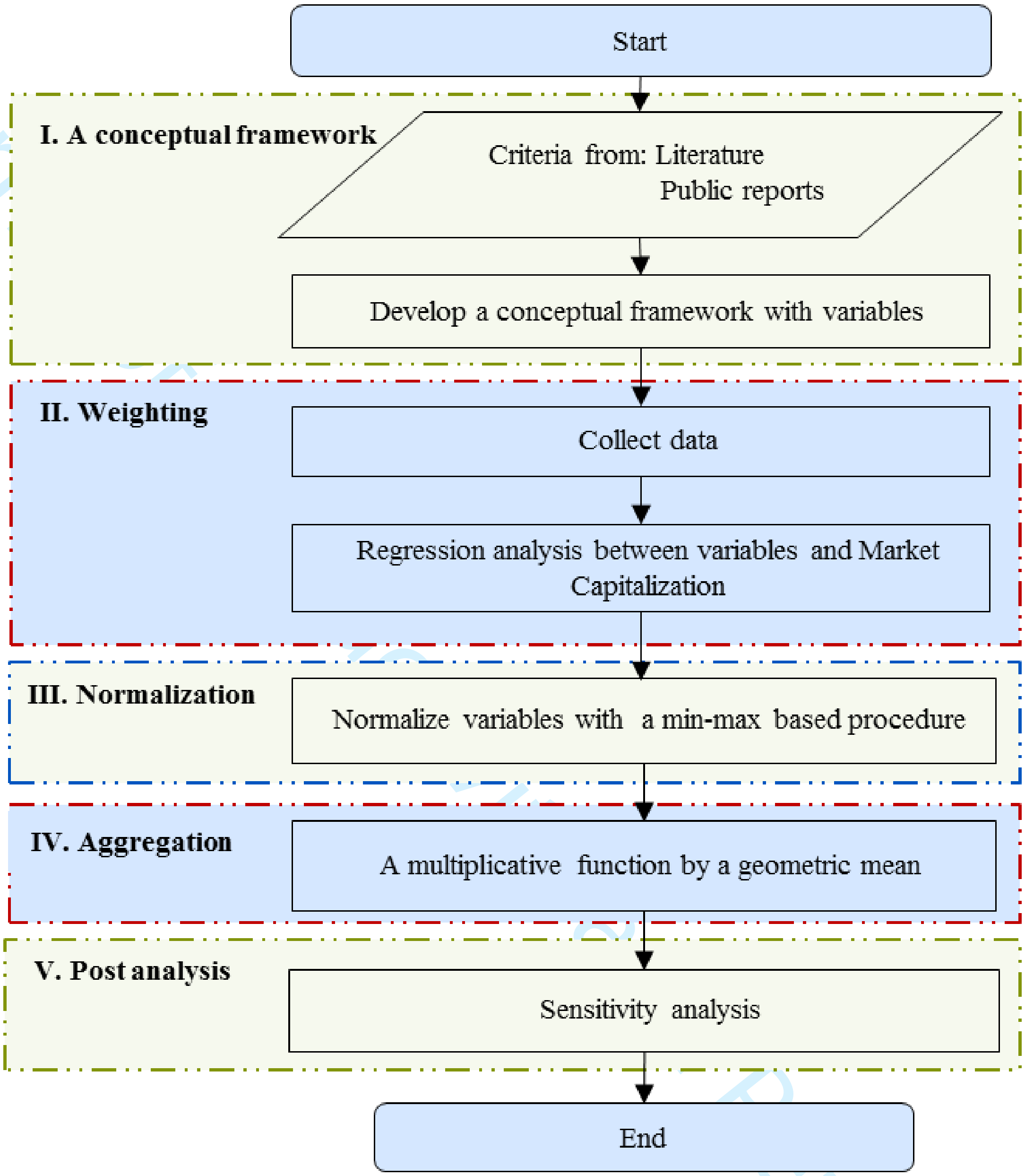
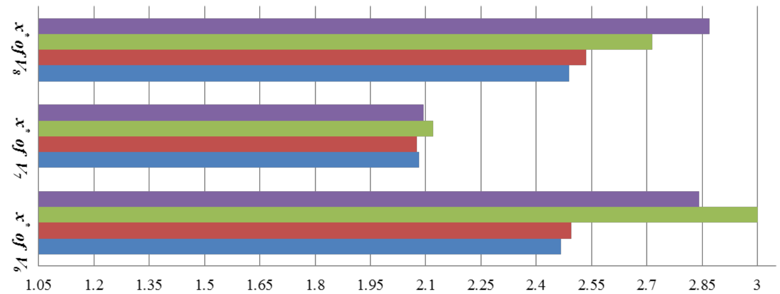


Figure 1 A design for I_{MVM} in this paper



	Normalized value (x*) of V6 Water consumption per vehicle produced	Normalized value (x*) of V7 Energy consumption per vehicle produced	Normalized value (x*) of V8 CO2 emissions per vehicle produced
L	2.842342342	2.09375627	2.870621825
F	3	2.121101848	2.713909897
B	2.494708995	2.076774002	2.53516484
A	2.4675	2.082759705	2.488182834

Fig.2 The normalized value (x^*) of environmental variables for the manufacturers with an increase in rankings