Methodology for Corporate Sustainability Quantification: a Case Study on a Car Rental Company

Enrico Orani
enrico.orani@tecnico.ulisboa.pt

Instituto Superior Técnico, Universidade de Lisboa, Portugal

December 2021

Abstract

Corporate sustainability is a relatively new concept that has been claiming always more interest due to the significant possibilities it may bring into the industrial sector. But how is corporate sustainability calculated? This research aimed at developing an easy and reliable framework to measure the sustainability performance of a car rental company. The framework is composed of two sections, one is dedicated to the sustainability measurements, with a consequent analysis of the results through the Life Cycle Sustainability Analysis method (LCSA). The second one concentrates on the interconnections of the results obtained from the LCSA using alternatively three different Multi-criteria Decision Analysis methods (MCDA), the Multi-attribute Value Theory (MAVT), Analytic Hierarchy Process (AHP) and a methodology developed in this work called Sustainability Function method. The results showed that the LCSA can be applied to service companies with some modifications, and that the framework can present results in a form easy to understand also for non-experts. Furthermore, this methodology represents an interesting possibility for experts and decision-makers to better define the share that each aspect of sustainability has on the final score, an issue found in most research regarding this topic. In fact, the measurement of sustainability in the corporate sector is one of the current hot topics, and it is found to be in the interest of stakeholders, shareholders and society. The corporate sustainability field is constantly growing, and this work provides insights on how to measure it and defines a potentially reliable framework for its quantification.
Keywords: Corporate Sustainability Quantification, Life-cycle Sustainability Analysis, Multi-criteria Decision Analysis, Triple bottom line.

1. Introduction

In an era of environmental damage, social and economical crises, companies of all sectors are trying to define a new system of thinking that include sustainability into the business core. This concept is called corporate sustainability, and finds essence in the application of the triple bottom line (TBL), hence the simultaneous application of environmental, economic and social aspects. Research focuses not only in the calculation of these features them-self, but also in the interconnection of the TBL, in order to define a proper sustainability performance quantification, able to benchmark companies over this new indicator, and compare its different aspects. In this work a car rental company was selected to perform a sustinability analysis. The framework proposed includes the calculation of the three aspects separately through the use of the Life Cycle Sustinability Analysis method, paired with Multi-criteria Decision Analysis for the interconnection and evaluation. This work aims to build the basis for a new methodology to quantify sustainability for companies of the same sector/subsector.

2. Case study

The selected company for the sustainability quantification analysis is a car rental company located in Sassari, Italy. The company counts a total of three employees and presents a fleet of 52 vehicles, which comprehend standard auto vehicle for passengers, refrigerated cell trucks, vans, mini-vans, electric vehicles and one minibus. It owns a shed used both to allocate the vehicles, operate maintenance, recharge the electric vehicles and host the offices for the personal and other companies. The building also presents a photovoltaic (PV) system of 120 kW on the rooftop, which account for most of the electricity consumed by all the services. The electricity produced in advance is not curtailed but sold to the network of the city. Inside the private property of the building, the cleaning and disinfection of the cars is operated, with water furnished by the city provider. The maintenance of the cars in case of engine problems are generally taken by a third party. The company already started introducing sustainability measure inside its core business, leaving the electricity production to the PV and by sustaining a transition to electric vehicles EV, which has now reached the number of 10 cars. The building is also endowed of three charging stations, which can be used both for the owned EV and for private owner of electric cars.

3. Methodology for the LCSA

The methodology was developed throughout the advancement of the thesis and defines a clear way to calculate the sustainability performances of a company. Initially the Life cycle sustainability analysis is performed. Since the chosen company provides a service, the LCSA is implemented using an adaptation of the UNEP/SETAC framework, which defines the guidelines for the LCSA of products. Since the chosen company provides services, the framework was slightly adapted to it, by introducing in the system boundaries, where possible, not only the manufacturing of products, but also the usage. Goal and scope, system boundaries, system function and functional unit are defined based on the requirements of the company and on the data gathered. Then, the E-LCA and LCC were performed using the database provided by Ecoinvent [1], while the S-LCA used the PSILCA database [4]. For this reason the S-LCA was performed separately from the other two aspects. In the life cycle inventory analysis each flow of the system was defined, together with the assumptions. Each flow was modified based on the available data and on the characteristic of the company. For example the life cycle impact of the vehicles was reduces considering the average life-spam of vehicles, since the company normally uses vehicles for 4 to 5 years and not for their entire life. While the E-LCA and LCC where performed considering manufacturing, usage and end of life, the S-LCA only took into account the manufacturing. This decision was taken since the local impact, being the company small, and counting only three employee, was considered negligible with respect to the global one. The life cycle impact assessment for the E-LCA and LCC was performed using the method developed by Goedkoop et al. (ReCiPe) [7], it provides harmonized characterization factors at midpoint and endpoint levels (endpoints were used). In the S-LCA the method developed in PSLICA by Greenlab [8] was used. A total of 13 indexes have been selected, 8 from the E-LCA (Fine Particulate Matter Formation (FPMF), Water Consumption (WC), Carcinogenic Toxicity (HCT), Marine Eco-toxicity (ME), Global Warming (GW), Ozone Formation (OF), Terrestrial Acidification (TA)) divided in environmental and damage to the human health, 1 from the LCC (Net-cost) and 4 from the S-LCA (Certified Environmental Management Systems (CEMS), Contribution of the Sector to Economic Development (CSED),Promoting Social Responsibility (PSR), Fair Salary (FS)). The total amount of units of measurements are 7, the DALY for the Human Health (HH) impact, and species.yr for the Environment, both in the E-LCA. Net-cost for the LCC and the 4 different medium risk units for the S-LCA, each one referred to an index.

Once the system was built the program OpenLCA [3] was used to perform all the flows and the impact assessments. Through the variation of the input flows the various cases for the company have been studied, the results will be shown in section (5).

4. Methodology for the MAVT

4.1. MAVT

The Multi-criteria Decision Analysis was performed through three main methodologies. Initially the Multi-attribute Value theory was used. The MAVT method final objective is the creation of an integrated function able to represent the decision maker's preferential system. The function is built as follows:

$$V(a) = F(V_1(a_1), ..., (V_1(a_1)) \tag{1}$$

where a_j is a vector of the evaluation criteria, $V_j(a_j)$ is the score associated to all the values a_j can assume. The final objective of MAVT is the definition of a set of functions V, which summed up (sum is the most used method, used in DECENS) after weighting, will have an optimal solution that can be identified. Below, the formula of the final objective function is as follows:

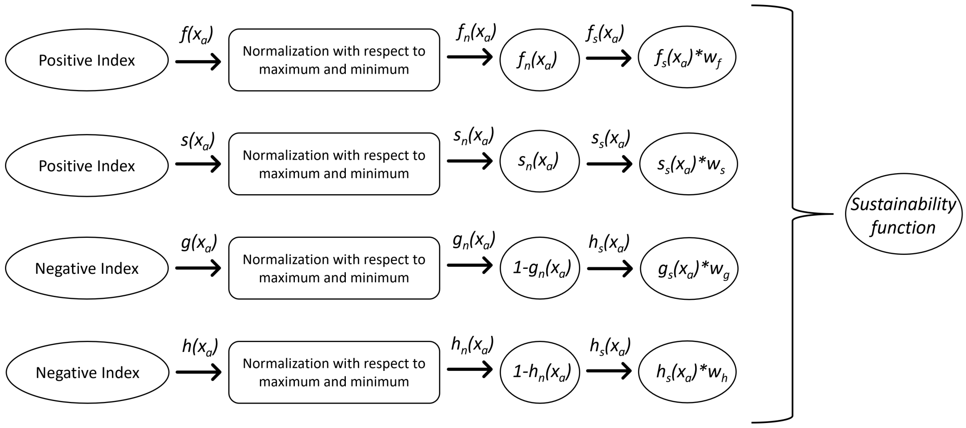
$$V(a) = w_1V_1(a_1) + ... + w_mV_m(a_m) \tag{2}$$

as can be seen, each function $V_j(a_j)$ is multiplied by a weight bigger than 0, and the the sum of the weights is equal to 1. This methodology gives the total power to the decision-maker to select the weights of the case. This method was chosen between the MCDA methodologies because it enables the creation of functions to establish how the final score of the company sustainability varies, modifying the weights. This function is highly important to understand the dependency the final score has on the weights given to the three different aspects, or to each one of the indexes that define the product systems [6].

4.2. AHP

The analytic hierarchy process is a method created by Saaty et al. [9] in 1980. It is founded on the pairwise comparison between criteria, and it presents a different additive model with respect to equation (2), but with a different weight and decision matrix calculation. This method creates a matrix nxn,

Figure 1: Block scheme of the MATLAB code for the sustainability function creation



where each criterion is pairwise compared to the other. In the pairwise comparison, if one criterion takes the values s, the respective one will get the value $1/s$. The weight to the criterion that can be assigned goes from 1 to nine, meaning the respective one will range from 1 to 1/9. Then the matrices are created, and the values for the weights and the functions can be used. The AHP model is based on the assumption that judges are better at taking relative than absolute decision, differently than in the MAVT method. This only expresses a different method for the weight system definition. Weights found with AHP can then be applied to the MAVT model, to create a sensitivity analysis for a better weight definition. The integration of both methodologies will be explained in section (8).

4.3. MATLAB Code

This unit is introduced to explain a possible alternative for the visualization of the interconnection of the impact assessment's results. The MATLAB code presents a similar framework to the MAVT method, but with a different final visualization of the data and range selection. The system's framework has an inverse development with respect to the MAVT system, since it starts from the indexes' functions, and ends with the creation of the sustainability quantification function.

The code starts with the definition of functions related to each of the indexes. Functions can be created interpolating points, or just by finding the equation of a straight line passing for two points, as in this case study since the indexes increase linearly with the variation of the vehicle's category percentages. Each indicator will have two functions, one for the diesel and one for the electric vehicles. The idea is to divide the two functions in 100 points, and sum them following the system shown in the equation (3).

$$\begin{cases} 0 \leq D \leq 100; \\ 0 \leq EV \leq 100; \\ D + EV = 100. \end{cases} \quad (3)$$

This defines a representation of the indicator measure when varying the composition of the fleet of cars. This process is repeated for each index. Subsequently, all the functions with the same unit of measurement are summed up, so the final value is obtained. Now four functions have been created, one for each of the units of measurements ($DALY$, $species.yr$, $Net - cost$, $medium\ risk\ hour$). The workflow, once the functions are in the system, is presented in Fig.(1). Then, each function is normalized with respect to the maximum and minimum. Now scores are assigned to each of the points defined previously. As discussed before, indexes can be positive or negative in the sustainability quantification, so the maximum can represent the optimal level, or vice versa for the minimum. Two are the possibilities:

- Maximum: the score will be equal to the values assigned to the normalized function;
- Mnimum: the score will be equal to 1 minus the values assigned to the normalized function.

Next, a weight is applied to the four functions. Once the Functions are normalized and weighted, they can be summed up to obtain the final function that express the sustainability of the company. The function is denominated as "*Sustainability function*", and it will range from 0 to 1. The interesting aspect of this visualization is the possibility to understand how far the analyzed company is to the optimal system, and how the sustainability varies for every slight change in the fleet composition.

This methodology differently from the MAVT and AHP methods does not give any insights on how to model the weights in the analysis, but MAVT and AHP from their side are not able to represent in a clear and easy way the sustainability trend for the company, being two complementary approaches. Furthermore, this method is easily scalable for case studies that present more variables and indicators. Of course, increasing the variables, the iterations will increase exponentially, so variables need to be chosen carefully.

5. LCSA Results

As anticipated the results of the LCSA were first analysed separately. The aim of this section is to show the effects changes of scenarios have on the chosen indexes of the sustainability quantification. This helps to understand where are the main flaws in the system, in order to support future decision-making. For the LCSA and LCC the analysed categories where the following:

- Equally Distributed Vehicle Categories-Grid (EDVC-G): Electric cars are charged through the regional grid. Vehicles' categories are equally distributed;
- Equally Distributed Vehicle Categories-Photovoltaic (EDVC-P): Electric cars are charged through the photovoltaic plant on the roof. Vehicles' categories are equally distributed;
- Current Distribution of Vehicle Categories-Photovoltaic (RDVC-P): Electric cars are charged through the photovoltaic plant on the roof. Vehicles' categories are distributed following the real share of the company.

In the case of S-LCA only the manufacturing is considered, there is no distinction for the charging phase. The analysis will be carried addressing the two following scenarios.

- Equally Distributed Vehicle Categories (EDVC): Vehicles categories are equally distributed;
- Current Distribution Vehicle Categories (RDVC): Vehicles categories are distributed following the real share of the company.

5.1. E-LCA

In Fig(2) the total impacts of the E-LCA in terms of $DALY$ and $species.yr$ are shown. As can be noted, the first two cases mainly differ only for the impact of the electric category of vehicles. In fact, the one with PV production shows an interesting decrease in impact for all the indexes. This result was quite expected since the PV production apart from the initial phase of manufacturing of the panels and structures does not produce emissions. By looking at the first two scenarios, it is easy to see how the EV category with PV production is the one that less arms the HH and the eco-system. It is interesting to see how also the petrol category has a really low impact in both human health and environment, but this can be mainly explained by the fact that petrol vehicles have been selected as cars of small size, the one used by the company. This has effects on both the manufacturing of the cars and emission during their life-cycle. Further, EV charged by PV remains the best option. Unfortunately, as of now it would be not possible the complete substitution of internal combustion engine cars with EV since a good share of diesel vehicles is composed by vans and refrigerator trucks, categories of vehicles that have not been launched in the EV market. For the E-LCA the two most impacting categories where the HCT and the GW. OpenLCA gives the possibility to dig into the roots of what created the indexes, so each environmental impact was analysed in all its components. The HCT is mainly connected to the vehicle manufacturing, in fact looking at the first two cases of the HCT indicator, all categories showed similar values, and the EV does not change much. In this case the company can only choose vehicles that present a lower impact in terms of car manufacturing, but it will not do anything significant inside the company management to diminish the impact.

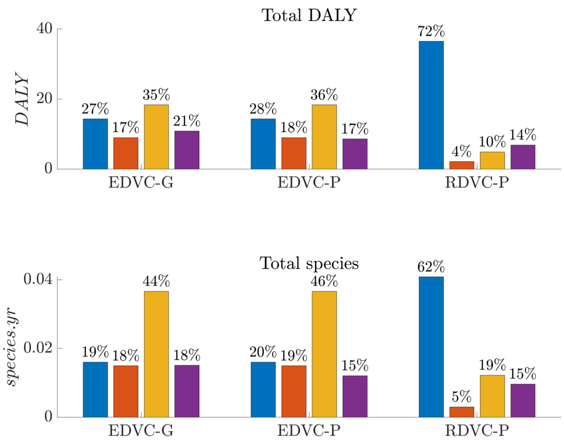


Figure 2: Total impact values comparison (Blue=Diesel, Orange=Petrol, Yellow=Refrigerator truck, Purple=Electric vehicle)

Regarding GW diesel cars and refrigerator trucks are the two categories that contribute the most to the impact. Refrigerator trucks have higher impact both in the production of the vehicles and in the consumption, but this is mainly given by their bigger size. Petrol cars instead have the smallest contribution between internal engines, this is given by the use of petrol as fuel, but also to the smallest size of the vehicles used by the company. The average construction of the vehicle glider takes about three times the construction of the power-train of the internal combustion engine ICE, but the interesting result is that the construction of the whole vehicle normally takes only 1/5 of the total consumption of the life-cycle impact of the car. The same cannot be said for the electric cars which have a much higher percentage since the vehicle usage takes much less in terms of everyday consumption. EVs have manufacturing emission similar to ICE cars, but in this case the battery takes about 46% of the total vehicle construction emissions. Less relevant in the life-cycle of the vehicle are the maintenance and the road maintenance/construction. This aspects are more relevant for bigger companies. Furthermore, in general it can be said that diesel vehicles tend to contribute more to the global warming impact category, while EV much less in the case of PV production. For the global warming there is a reduction of impact of 87.4% in the electricity supply.

Also for the environmental impacts two are the most relevant indicators. The first one is the (ME), which in this case is higher for the EV. The reason why, is that it is strictly connected to the manufacture of the battery, which takes almost 60% of the total share of the impact. In fact, batteries do have a bad impact on the marine eco-toxicity, but many are the possibilities to reduce it as shown by Aichberger et al. [2]. Nevertheless, this would not be a task for the company lesse, but for the battery manufacturer. The remaining share of the impact is due to the manufacturing of the vehicles. The other relevant indicator is the global warming index, which as for the HH impact presents a much lower value for the EV with PV production. Here, as in the previous case the share is mostly dependent on the fuel used by the vehicles, in fact the trucks and diesel cars have the highest impact.

5.2. LCC

The LCC was performed with the use of only one indicator, the final results of the three cases are shown in Fig.(3). As explained before the impact calculated for this aspect of the sustainability assessment is the Net-cost [5]. This indicator helps us understand which are the categories that are more costly, which one can be cut or improved under an economical perspective. It is strictly connected to the E-LCA, in fact the flows used are the same. By looking at the first two cases of Fig.(3) it is easy to see that similarly as for the E-LCA aspect, the change in supply of energy has an incredible impact on the cost assessment. In fact, looking at the results more in-deep, the price of the electricity supply has 1/5 of the cost of the electricity from the grid. This has an incredible impact on the final overall price, which would be even more relevant with a higher number of electric vehicles. Nonetheless, fuels such as diesel and petrol have similar prices to the electricity supply. Furthermore, there is a big cost difference between the battery production and the manufacturing of the internal combustion engine. In fact, the former results in costing nearly 25% less. As expected again, the manufacturing and usage of the refrigerator trucks and small size petrol cars represents the two extremes of the calculation. The first one being vehicles of large size with the addition of cold rooms and refrigerants, and the former being vehicles of smaller size.

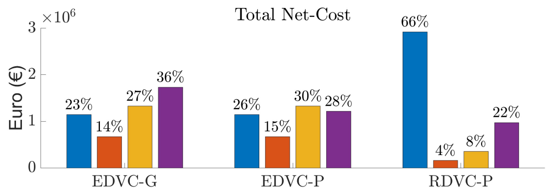


Figure 3: Total net-cost (Blue=Diesel, Orange=Petrol, Yellow=Refrigerator truck, Purple=Electric vehicle)

Having now a closer look to the present status of the company, as can be seen from the difference in total net cost, the company does not present a good level of economical sustainability, even though the transition to EV has already started.

5.3. S-LCA

The social aspect of the sustainability was analyzed using four indicators, which were considered as the most significant for the car rental company service, and the ones better able to describe the social sustainability conditions with the available data. As previously explained, the social assessments tend to be expressed with more qualitative than quantitative measures. For this reason, the results in this section will be analyzed based only over the composition of the fleet of cars for the company, and by analyzing only the two main relevant categories: EV and diesel cars, for each indicator separately. In Fig.(4) medium risk quantities for each of the four indexes selected. From the four graph it is easy to to notice how the EV do have a stronger impact than ICE in terms of social impacts, both positive and negative. In most cases the main differences are relative to the production of the battery.

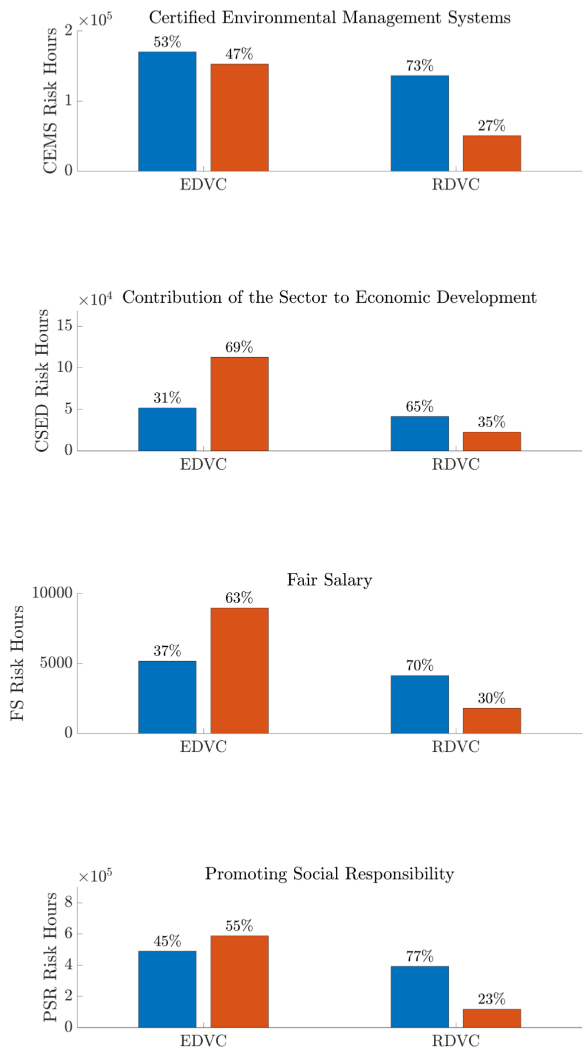


Figure 4: Social indexes comparison (Blue=Diesel, Orange=Electric vehicle)

For example, taking into account the indicator Certified Environmental Management Systems, about 65% of the total share of the impact is taken by the battery manufacturing. This shows us how the manufacturing of batteries, which due to the use of more polluting materials, results in less EMS, even if slightly. In fact, the manufacturing of the vehicles' parts for EV and ICE takes about the same share for the two categories. Nonetheless, for the second indicator considered, Contribution to the Sector Economic Development, the highest share of the contribution is the manufacturing of the vehicles parts of the electric vehicle, that include the electric motor. Different behavior is found for the Fair Salary indicator. This highlights the salaries in the electric car manufacturing in France result in being less fair than the ICE vehicle manufacturing in Germany, with a significant gap between the two. Lastly, the Promoting Social Responsibility indices presents a similar trend as the previous one, with the manufacturing of the EV parts that takes the highest share with 44%. Then the manufacturing of the ICE vehicles with 38%, and then the storage battery manufacturing with the lowest share, of about 18%. This indicator defines a negative impact, so diesel vehicles are the ones that mostly engage the promotion of social responsibility. This in deep analysis of the results can be applied to the current situation by shifting the purchasing of car to the more socially sustainable, but also by extending the research to different categories of vehicle in order to expand the decision-making process to other typologies of cars. This assessment can also help the manufacturer to improve or eliminate flows that decrease the social sustainability in their car manufacturing process.

6. Framework results presentation

This section is dedicated to the description of the results obtained from the interconnection of the three pillars of sustainability.

6.1. Multi-criteria decision analysis results

The multi attribute value theory method was used in the framework to model the weighting scale and to obtain a final score for the company. It allows the user to select an initial set of weights for each of the criteria and monitor the trend of the score based on a sensitivity analysis on the weights.

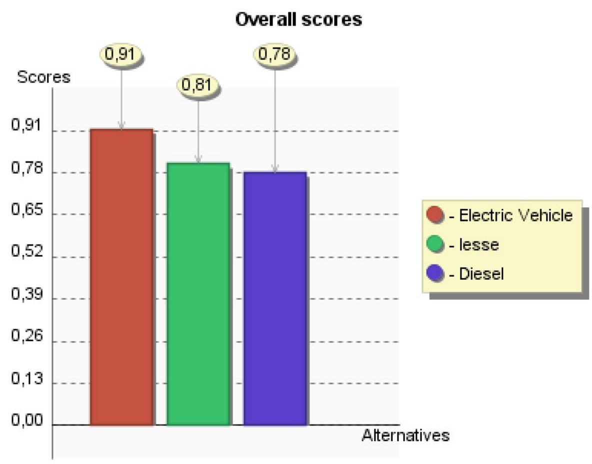


Figure 5: Overall score using the MAVT method, scenario with equal share for each car category

The initial case presented the same share of weights distributed to each criterion. This baseline case is used to understand how the model would behave if environmental, economic and social aspects were valued as equal. The score trend represented by this initial case can be seen in Fig.(5). The red bar represents the score of the company if it was composed 100% by EV, the purple bar if it would be 100% diesel and the green bar the current composition of the fleet of Iesse, which is

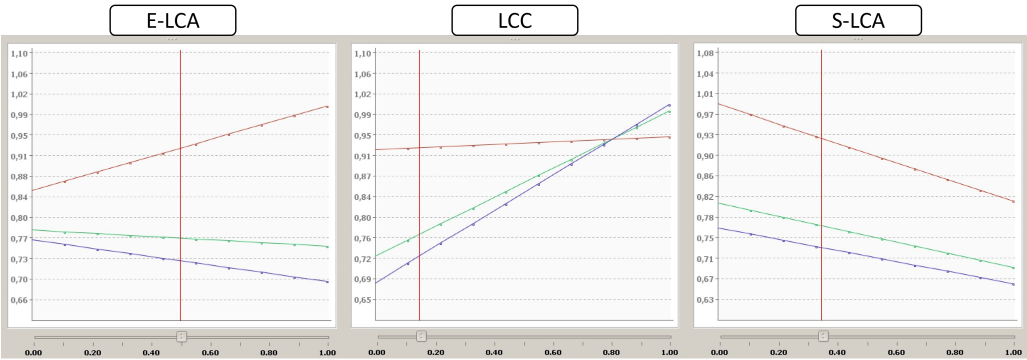


Figure 6: Weight SA using the MAVT method, scenario adapted to case study (x-axis=% vehicles share) (y-axis=score)

made by 20% EV and 80% diesel. It is possible to see that the electric vehicle alimented by PV has higher score respect to the diesel. This will mean that in general the values of the EV are closer to the optimum maximum or minimum depending on the indicator. The value of the company instead stands in between the two values, much closer to the diesel given the composition. The behavior of the variation of the score by changing the percentages was found to be linear and oscillating between the two maximum and minimum scores.

Having now a closer look to the current case study, since the weaker aspect in terms of data and indexes is the life-cycle costing, the assumption that the LCC has a lower impact on the sustainability assessment can be taken. Furthermore, even though the S-LCA was performed with an acceptable set of data and the chosen indexes represent the social aspect with a good approximation, only the global aspect was considered, not taking into account the impact on the local community. Considering these assumptions, the value assigned to the weights of the E-LCA, LCC and S-LCA are 0.5, 0.15 and 0.35 respectively.

On the new case, a sensitivity analysis (SA) based on this weighting scale is performed. The SA is shown in the three graphs represented in Fig.(6). The graphs are representing the variation of the E-LCA weight, LCC weight and S-LCA weight respectively. The x-axis represents the variation of the weight, from 0 to 1; The y-axis is referred to the sustainability score.

Analyzing the three graphs of Fig.(6) and looking at the slope of the three curves, it can be noticed that EVs and Diesel vehicles have opposite behavior for the environmental and economic aspects, while socially do not differ much. In fact, considering both the extreme cases of the E-LCA and LCC, it can be seen how in the first image scores tend to diverge, while in the second one to converge. This was expected, since environmentally EV performs better than diesel, and vice versa for the economic aspect. Socially instead the tow score behave nearly equally, in fact the slope is nearly the same.

The program also allows to edit weights internally for the E-LCA, LCC and S-LCA. Obviously, the variations in these cases of the score functions will be less significant with respect to the three aspects weight variation, but it still may be important for a more precise final solution. In this case study, the unit of measurement are only four, “$DALY$”, “$species.yr$”, “$Euros$” and “$mediumrisk$”, and the only two belonging to the same category are the first two, since the “$medium\ risk$” has been factorized with the PSILCA impact assessment [4, 8]. For this reason, the current case study does not require a sensitive analysis of the units of measurements, but the study can be applied also to assessments with different units inside the same sustainability aspect.

It can be noticed how the score of the company stands in between the two lines (green line). This behavior was expected, in fact the results of the LCSA analysis vary linearly with the variation of the composition of car fleet as previously explained. Of course, the company function with respect to the score will be closer to the diesel one. The more the percentage of EV increases, the more the company's function will get closer to the it, hence improve its score. This analysis may be an interesting framework for experts to be followed. It could help to better define weights in sustainability analysis. This method represents an easy and clear way to show how scores behave when depending on weights.

6.2. Analytic Hierarchy Process Results

The AHP can be used in this framework as an alternative method to calculate the weights. In this section the assumptions of the second case used in section (4) will be assessed. The decision table is presented in Fig.(7). The weights assigned after this pairwise comparison are 0.558, 0.122 and 0.319 to the E-LCA, LCC and S-LCA respectively.

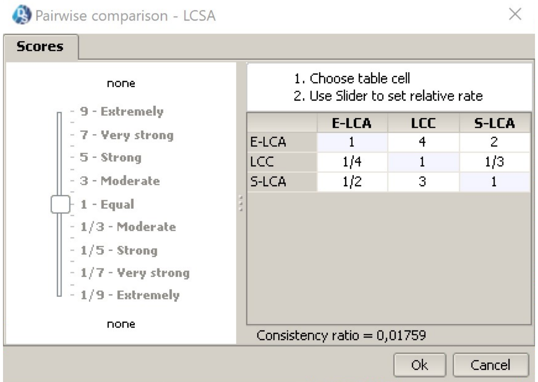


Figure 7: Weight calculation using the AHP method, scenario adapted to case study

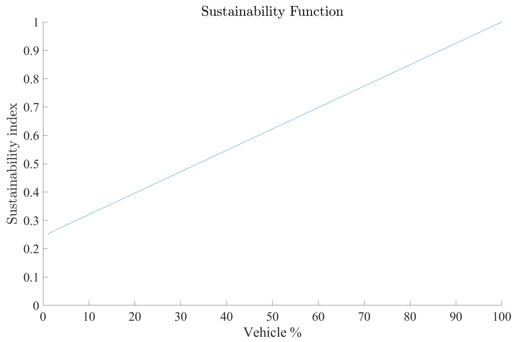


Figure 8: Sustainability function representation of the company's case study

Shown in figure Fig.(7) the values chosen to reflect the assumption made are represented. It is important to highlight that this is just a simple case where the weights are assigned only to the three aspect of the sustainability, but to develop a more precise system of weighting, the same pairwise comparison should be applied to each flows in the system, specially for the S-LCA aspects, that as previously explained, present less quantitative measurements. Applying these weights to the MAVT method then a sensitivity analysis can be applied again to perform a more accurate study on the weights.

7. Sustainability function calculation & results

The MATLAB code represents a different approach for the visualization of the final score for the sustainability quantification. The main differences between this methodology and the previously mentioned ones, are the flexibility and clearness since it was developed based on the final objective of the Iesse case study. This gave the possibility to create a model to represent the value of the sustainability performance as a function dependent to the variation in category's car share. The behavior of the company sustainability, as expected is represented by a straight line (given the previously explained linearity dependence on the indexes in section (4)). The same behavior was found using the MAVT method in section (4), but a different weighting range was applied (different maximum/minimum values). In fact, in DECENS the score increased linearly with the increase of EV share, drawing an imaginary straight line. This shows that the program behave correctly for the current case. The sustainability function of the case study is shown in Fig.(8).

It is important also to highlight that the current work is dependent on the company information. The case study was selected to monitor the behavior of the framework in the real world. This model would be interesting if implemented for a more complex case study that presents a nonlinear distribution of the data. In the former case, the optimum may be found anywhere along the sustainability function, presenting a more complex result to be found. Furthermore, in the Iesse case study, because of the lack of data, and to make the overall calculation easier, only two variables (EV and Diesel) were defined. On the contrary, a case study with more variables would create a calculation with a significant number of iterations. This would define a much more difficult solution to be found, making the program highly valuable for the sustainability calculation.

To show the intended outcome, a system with four indicator represented by four piece-wise functions randomly assembled was created, the first two seeking to find the maximum, and the other two the minimum. The number of variables is kept constant, and it reflect the same situation of the case study (the variability of the car category's share for the company). The result is presented in Fig.(9). As can be noticed the sustainability function is irregular and presents two maximums. The function reflects the sustainability of the company, showing for each percentage of cars, which is the performance value. For example, in this random case two maximum points with nearly the same values are observed. If the company finds itself at a value of 20%, and seek to optimize its sustainability, the most convenient choice is to move to the closest maximum, since moving to the further one would create nearly the same improvements, but with much more effort.

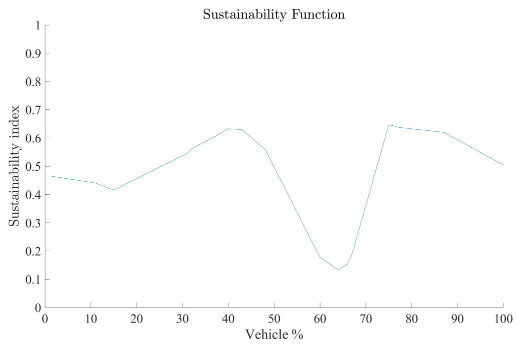


Figure 9: Sustainability function representation of test case

The last example explains the value of this framework in the decision-making of the company, by showing in a simple way how and where to direct future investments.

8. Suggested framework for the weight calculation

In this section a general framework for the interconnection of the three sustainability aspects will be explained. The method can comprehend all three methodologies described in the previous sections of this chapter. The sequence of chronological steps is presented in Fig.(10). The bold arrows represent mandatory choices, dashed arrows represent choices that can have more than one possibility. The method is iterative and should be repeated until the optimal solution is found.

1. Calculation of the LCSA impacts;
2. The first method to be used is the MAVT methodology. Once the results are implemented into the system, the score functions relative to the weights are created by the program (DECENS), and the first evaluations are implemented in the system weight selection.
3. This step is composed of two possibilities: the first one is the use of the AHP method to define a more relative judgment on the weights, taking into consideration the assumptions and insight found in step n°2. The second possibility is the direct use of the MATLAB code for the development of the sustainability function using the weighting scale obtained in step n°2.
4. The process is repeated iteratively until the optimal solution is found.

9. Discussion & perspectives

Throughout this work, a framework for the weighting selection in sustainability analysis was created. This article presented the example on a real-world case study of the business built by Iesse, with only two variables. This decision, was taken to well describe the framework through a non-complex case study. The same approach that has been used for the optimum composition of the fleet of vehicles, can be applied to different aspects of the company. For example, an analysis of the steps, products and wastes for the car cleaning process, or the rental spaces offered by the company, that would take into account the energy used for the air conditioning, the comfort of the employee etc. The more information is furnished, the more the sustainability analysis will be complete. For this to be possible further digitalization is essential to keep track of data, and commitment and transparency of the company would be even more crucial.

Furthermore, even more interesting is the possibility to apply the same framework, following well defined criteria and parameters to companies belonging to the same sector/sub-sector, but with different sizes. This, would allow the creation of a benchmark. Once this stage has been reached, defining the sustainability performance of companies will not be as difficult as it is now. The only requirement will be to provide the data to the system to automatically obtain the sustainability and rank the company with respect to others. This will help stakeholders, public and private investors in selecting companies based on a new fundamental parameter, the sustainability performance. The interests of stakeholders and companies into a sustainability performance label is positively dualistic, since the first one positively impacts the other.

Moreover, the analysis of the provided data from many companies of the same sector/sub-sector, by defining better performing companies and by detecting how far is the company from the optimal solution, will be able to give insights on where to improve, limit or delete given processes of the business model, helping managers for future decision-making. Another booster for companies to carry sustainability studies is the significance it has reached to public viewers.

Lastly, the most important outcome would be the overall improvements at a macro-level in the field of CS. From one side, the huge impact of the corporate sector would be positively reduced. From the other the introduction of sustainability would have incredible indirect benefits. Firstly by defining guidelines for for everyone to follow. Secondly for individuals, by instructing and boosting workers to be more sustainable in their every-day life. In fact, this issue touches all of us, and small actions taken by everyone could bring massive changes.

10. Limitations & further studies

This work presented the definition of a general sectoral framework for the corporate sustainability quantification of a service company. It merged two major methodologies, LCSA for the sustainability quantification and MCDA for the results intercon-

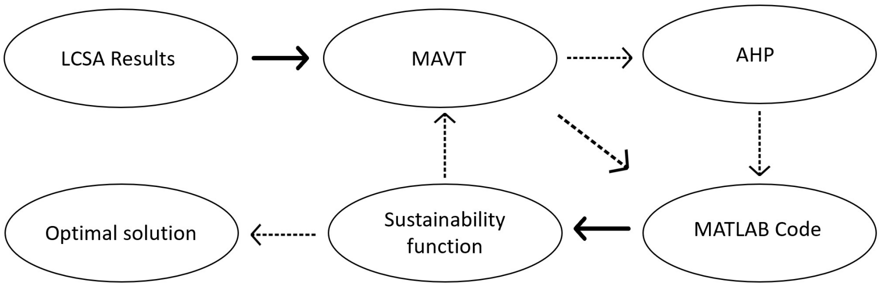


Figure 10: Work-flow of the framework for the weight decision-making process

nection. While the former one can be considered as quite mature, LCSA is still under development. The reason why, is that it is composed of three aspects that reflect different ways and units of measurements. The LCA which has reached maturity and reliability, LCC that has improved a lot in past years and S-LCA which is under constant development. For the current case:

- E-LCA was provided with almost all the data required for its calculation;
- LCC difficulties instead were found mainly in the lack of data furnished by the company, that did not allow the calculation of more precise indexes;
- S-LCA found its difficulties in the lack of data in the vehicles industry for a more precise calculation of the indexes.

Furthermore, LCSA is a framework that is primarily used to assess products and not services. The lack of literature on this topic required the adaptation of this methodology to a sustainability quantification of a service, being one of the first of its kind. Another limitation related to the lack of data, is that sustainability has not entered yet the corporate sector, for this reason it is difficult to find companies able to provide data for a complete benchmark creation. These issues are relevant for the interconnection of the results and for the creation of a more reliable sustainability performance score. The possibility to address the quantification using different examples would make the final result more consistent. Then, to apply the framework it is fundamental to gather experts, who need to discuss deeply the different aspects of sustainability in order to be able to perform a good measurement. Furthermore, because of the lack of data the framework was not applied to the maximum of its capabilities.

As predicted, the limitations are a great deal to be overcome, and in some cases may still need time, such as for example the digitalization of companies or the improvement of databases. Nevertheless, some ideas may be helpful for the application of the developed framework in future research. For example, an interesting possibility could be the use of machine learning to simulate sustainability measures and create an initial benchmark. Even more interesting would be the possibility to use companies of different sizes but from same sectors/sub-sectors and simulate measures from other companies to fill the gaps, following the increasing trend of the real-world companies selected, by using a number generator with mean standard deviation. This would help defining a sustainability benchmark that can variate its range together with the size of the company. Future research could focus on the application of the proposed machine learning method to fill the gaps dictated by the lack of data, the not yet completed digitalization of companies, and test the methodology on different sectors and gather experts of the three aspects of sustainability to better define the weights system.

References

[1] Ecoinvent.

[2] C. Aichberger and G. Jungmeier. Environmental life cycle impacts of automotive batteries based on a literature review. *Energies*, 13(23):6345, December.

[3] C. d. N. Andreas Ciroth. Openlca manual. June.

[4] F. E. Andreas Ciroth. Database version 1 documentation. March.

[5] A. Ciroth. Life cycle costing and calculation of value added in openlca. March.

[6] DECERNS. Decerns user manual.

[7] M. Goedkoop, R. Heijungs, and M. Huijbregts. Report i: Characterisation. page 133.

[8] K. Maister. Database version 3 documentation. page 124.

[9] S. TL. The analytic hierarchy process.