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Multi-Criteria Assessment of Taxi Transport Services for Public Procurement: Case Study for Bacau City

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Abstract: LCA methodology is often used in public procurement decision making. The European Commission introduced Life Cycle Costing (LCC) in 2014 to support this methodology. LCCs take into account costs incurred during a service, work or product's lifetime. Application management techniques of LCC offer a better awareness of the factors that influence the resources and costs in the case of procurements. The identification of the factors that influence the costs is the main key of the LCC tool. In such a way, the life cycle management is focused on efficient purchasing. The awareness levels of the LCC criteria influence the cost and will also highlight other aspects of existing products that could benefit from the involvement of life cycle management. Taxi transport services (as an alternative to public transportation) are a sector of the economy with a good income when acquisitions are properly carried out. When the acquisitions are analyzed, governmental and local regularizations should be taken into account. Today, cities, as well as small towns, look forward to improving the quality of life of the citizens and reducing pollution. The acquisitions of buses/cars for public use must be carried out with respect to the required performance of the cars. On the one hand, the municipality should be in line with the European Commission's policy; on the other hand, it should be in line with the state's public procurement requirements. An acquisition must also be reasonable in terms of price, lifetime, environmental impact, circular economy and meeting citizens' needs. The goal of this paper was to analyze the acquisition of cars for taxi services from the perspective of public procurements. The study was performed with the help of the Taxi LAL company from Bacau County. The LCC techniques were applied to identify the most "acceptable" as well as the most "profitable" choices for taxi services. For a better understanding of the problem, within the present paper the mechanism of cost assessment for a product modernization was exemplified.

Keywords: energy efficiency; public procurement; LCC tools; innovative technologies; taxi service

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1. Introduction

In the context of societal sustainable development, especially after car crises such as Volkswagen and Honda, improving awareness can be considered significant. The manufacturing sector (as a part of technology) aims to estimate not only production costs but also how much a product will generate value. There are other costs in each stage of the economic chain that influence the product life cycle.

The transport services in the metropolitan area are the subject of discussion when it comes to sustainable environment for citizens [1–8]. On the one hand, the municipality should face the European Commission policy and, on the other hand, it should answer to the requirements of state public procurement [9]. Moreover, it has to be reasonable from the perspective of price, operating time, environment impact, circular economy and meeting citizens' needs (Figure 1) [2,3].

There are different approaches to this subject. One of the biggest European cities, London, has a tax that is applied to "Congestion Charging and the London Low Emission Zone (LEZ) Schemes" [10]. The daily charge is GBP 15 if you pay in advance or on the same day or GBP 17.50 if it is paid by midnight of the third day after travel [10].

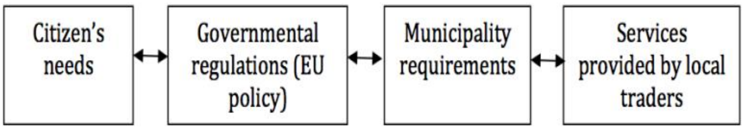


Figure 1. Procurement regulation scheme [2,3].

Another strategy has been applied in Amsterdam. This city uses only electric vehicles for public services. In 2011, the first electric taxi service was launched: Taxi Electric [11,12]. Moreover, starting in October 2014, all taxi journeys from Schiphol Airport are made in electric cars (the Tesla Model S). A new subsidy scheme was introduced in 2011 in Amsterdam to stimulate the users of corporate cars (high mileage) to switch to electric ones [11,12].

Each municipality of the member state defines their own strategies for environmental and citizens' needs in accordance with European Commission (EC) regulations.

The methodologies proposed by the EC for sustainability assessment are the Life Cycle Assessment (LCA) or the Life Cycle Costing (LCC) tools. These tools consider improvements of energy efficiency as a whole. Energy efficiency is considered at all stages: design, construction, management of construction, acquisition of equipment that consumes energy and the purchase of electricity [13].

The project "The European Platform of Life Cycle Assessment" that was launched by the European Commission provides the LCA for environment sustainability [14,15]. A lot of companies and business associations, as well as industries, already use the life cycle approach. The industry started to increasingly use LCAs to reduce the overall environmental issues during the entire life cycles of services and goods. As mentioned in the "Communication on Integrated Product Policy", the European Commission concluded that, currently, the LCA provides the "best framework" for assessing potential impacts of products on the environment [14–16].

LCA methodology is often used in the decision making of public purchasing: "The benefit of LCA is that it provides a single tool that is able to provide insights into upstream and downstream trade-offs associated with environmental pressures, human health, and the consumption of resources" [14–18]. To support the methodology, in 2014, the European Commission introduced the Life Cycle Costing (LCC) tool. The LCC assumes the costs incurred during the lifetime of the service, work or product [19]):

- Purchase price and other costs (insurance, installation, etc.);
- Operating costs (fuel consumption, water use, lubricant and maintenance);
- End-of-life costs (decommissioning or disposal).

Companies, as well as public bodies, include LCA or LCC criteria for procurements or for defining public environmental objectives. These actions lead to "win-win" potential savings and new green products or services [20].

It should be emphasized that, generally, energy efficient products and services have a high price. Basically, the consumers focus on the purchase price, without taking into account the maintenance costs throughout the life of the product [21]. A statistical analysis of data from seven European countries shows that the costs do not increase but rather decrease, if the goods and services that respect EU rules on Energy Efficient Public Procurement are used [22,23]. Three targets are proposed to achieve by 2020 according to 20-20-20 targets [13] that involve the circular economy, renewable energy sources and combatting climate change:

- A 20% reduction compared with 1990 greenhouse gas emissions;
- A 20% planned consumption of energy to come from renewable energy sources;
- A 20% reduction in primary energy use by improving energy efficiency.

The integration of aspects related to improving energy efficiency consists of making investments, maintenance, other expenses regarding equipment that use energy and services related to energy supply [2–5].

There is no one model that can be followed or recommended, but there are some common criteria drawn from the European regulations that are used in the public strategies that are projected on public procurement [2–5,24].

2. Main Criteria for Vehicles for Public Use

When we discuss the structure of costs, we must not forget that there are many costs associated with various stages and activities. From this perspective, we highlight the following types of costs: the initial cost (buy, procurement, transport, putting into operating), fuel cost, operating (maintenance and repair), replacement costs, residual value (resale, costs for reconditioning operations, transfer) and financial expenses (interest payments).

If we consider the whole life of a product, in the context of circular economy, we can make the following considerations on costs [25]:

- The costs of acquisitions are made between the decision to start the acquisition and the entry of goods or services into operational use;
- The operational costs are those that are incurred during the operating lifetime of the product or service;
- The end-of-life costs are associated with the removal, replacement or termination of the product or service. Sometimes, the cost of disposal may be negative because the product may have a resale value.

The costs during the life cycle are added to all types of identified costs during the year for each alternative (amounts and discounts). To reduce this huge amount of energy consumption, it is necessary to set key criteria, even in the tendering process.

For reducing energy in the manufacturing process of vehicles, there is an opportunity to consider vehicles made from recycled/bio-materials. Renault has this type of strategy, the RENAULT Eco^2 [26]. The Eco^2 assumes that up to 95% of the car content is used at the end of its life. At least 5% of the total plastic contained in the vehicle comes from recycled plastics. Moreover, the CO_2 emissions are below 120 g/km. Of course, there are enough car manufacturing companies that use recycled materials or have a strategy in "go green".

The Renault example was chosen because of the impact on the environment in Romania, as well as the number of cars in use. The Dacia Group is a part of the Renault company and has a plant in Mioveni, Arges County. According to Generali Ensurance, up to 34.5% of sold cars at the end of 2021 [26–28] are Dacia and 6.1% are Renault. This underlines two important achievements: a large part of vehicles that are on Romanian roads are sustainable from the perspective of CO_2 emissions and, from the angle of the life cycle approach, 95% are used. This is a big change in the map of cars in Romania with help from the "Rabla Program" that has the goal of renewing the cars parked in Romania.

The use of regenerated lubricant oil or environmentally friendly types of oil (low rolling resistance) can also increase energy efficiency. Eco-driving systems and information systems should be implemented in the vehicles to give instructions for an energy-efficient driving style [29].

The structure of the article addressed issues related to the procurement of taxi services and the LCC criteria. The aim of this paper was to analyze the purchase of cars for taxi services from the perspective of public procurement. The study was conducted with the help of the Taxi LAL company in Bacau County.

3. Taxi Service in Bacau

The paper discussed the procurement issues of the taxi service. There are eight companies that provide taxi services in the Bacau area. They cover 98 villages (39.6% of the country) for a population of 144,307 citizens and 250,000 persons in the metropolitan area (2021) [30,31]. The average distance between villages is 15.7 km.

Bacau ranks 16th in the ranking of polluted cities in our country. Romania ranks first in terms of PM10—a dust particle harmful to our health—pollution at the European level. The number of cars in Bacau county increased last year by about 6%. The county's vehicle fleet increased from 225,145 vehicles to 238,151 by the end of 2021 (up 5.7%) and the number of car-license holders increased from 240,990 to 248,038 by the end of 2021.

According to the data presented above, and due to the fact that it is not possible to intervene on the purchase of cars by the population, the local administration of the city of Bacau has shown interest in the public purchase of less polluting cars.

For the study one of the biggest taxi companies in the Bacau area was chosen: TAXI LAL [32]. The company has 200 cars in use daily. The company holds 150 cars and has contracts with 50 independent drivers who use the logistics, Internet application and call center of the company. The data from the research were made available to the local administration of Bacau.

Some data on the topic of taxi service are provided in Table 1 for the city of Bucharest and Bacau [33,34].

Table 1. Taxi service data.

Criteria	Bucharest	Bacau
LPG users	60%	65%
Price per km	RON 2.29 *	RON 1.99 *
LPG expenses per day	RON 50.00 *	RON 45.00 *
Daily distance	150 km	130 km
Working hours	14 h	10 h

* EUR 1 = RON 4.9.

As can be seen in Table 1, the use of Liquid Petroleum Gas (LPG) instead of gasoline or diesel has a major percentage in the domain of taxi services. The drivers and owners who choose to redesign the engine look for advantages such as a low price for fuel and engines that is considered green fuel because of the low rate of CO_2 emissions. Disadvantages exist too; an engine overhaul is required every 10.000 km and the consumption of fuel increases. In this context, the LCA or LCC tools should be designed to make the predictions with respect to LPG. On the other hand, in Romania, cars are usually sold with a gasoline or diesel engine and reconfiguration of the car is the responsibility of the owners, along with the price.

This study focused on the configuration of cars in concordance with the public procurement requirements and LCA and LCC methodologies, as well as sustainability.

The municipality of Bacau city has released 992 taxi licenses per year since 2017 and has the intention to change this by the end of 2025. The methodology of selection includes the following criteria:

- The car age;
- Emission standard EURO 6/5/4;
- The internal volume of the car;
- The experience of driver (years);
- The safety of the clients.
- Other features (including LPG, air quality, etc.).

As we can see, the emissions and the energy/fuel type are taken into consideration. According to "The energy consumption of the EU-27 countries partitioned in sectors", the transport sector is the biggest part of the entire energy consumption. Therefore, energy efficiency is very important in this sector [25]. Moreover, the companies choose the vehicles with reduced consumption as well as cheap maintenance. LPG meets these requirements.

4. Model and Methodology Research

The objectives of the study were:

- To analyze the request of the local administration to carry out a study to identify solutions for reducing pollution during the LCA of cars from public procurement;

- To identify some of the cars that contribute to environmental pollution during the LCA;
- Comparative analysis of the results obtained and their interpretation.

The study was conducted under the following hypotheses:

- The constitution of the research group only from cars belonging to local taxi companies in the city of Bacau;
- Other cars from public procurement (buses, public administration service cars, etc.) would not be studied.

Research methods and techniques:

- Conversation: via this method, the authors communicated with representatives of the local public administration, taxi firms and car dealers;
- Interviews with leaders of public administration and taxi firms;
- The questionnaire: this tri-modal tool was distributed to 200 car drivers;
- Analysis of the products studied in the LCA stages: this method obtained data on reliability, consumption and environmental pollution caused by the cars;
- Statistical/mathematical methods: the results obtained were processed using statistical/mathematical methods, analytical tables, histograms and diagrams.

The model and methodology research focused on the LCC criteria, the SMART SPP project and the LCC-CO_2 tool and the main features of the LCC-CO_2 tool and the life cycle phases.

4.1. LCC Criteria

Energy efficiency is defined as the percentage of total energy for a machine or equipment that is used for useful activity and not unnecessarily wasted as heat. It means to use less energy (input) and to provide the same level of performance for products and services (outgoing). For example, a compact fluorescent bulb uses 80% less energy than an incandescent bulb to produce the same amount of light.

Acquisitions (public) that are energy efficient can positively influence the market by savings, stimulating sustainable business and addressing ecological and moral behavior [35–37].

Life Cycle Cost (LCC) is a methodology that considers all life cycle costs of the product. This must determine the lowest cost of a product for an owner. The costs that are taken into account are: acquisition, installation, exploitation, maintenance, modernization and scrapping [16–18]. Life cycle cost analysis is useful when existing alternative solutions meet the same performance requirements but differ compared with initial costs and operating costs. The result of the analyses is to select the solution that maximizes results. The aim of Life Cycle Cost Assessment (LCCA) is "to estimate the total costs of the various possible products and to select the one that provides the lowest cost of owner, but also to the quality and functionality" [16,18,19]. The LCCA should be used at the beginning of the drafting process when the project designer still has the possibility of ensuring a reduction in Life Cycle Costs (LCC).

Naturally, after determining acquisition costs, it is necessary to evaluate them. The LCC techniques allow the evaluation of competing proposals based on the cost of life cycle. The LCC analysis is relevant in the case of service contracts and decisions on purchases of equipment.

Emission standards: The easiest approach to ensure good emission standards for purchased vehicles is to use the EURO standards. All new vehicles must currently meet the EURO V standards. These standards demand the criteria for EEV (Energy Efficient Vehicles) in the case of standard vehicles [19].

Production phase includes all processes for manufacturing the product. This includes resource extraction, production of all blanks, transport supply chain and assembly and commissioning of the final product.

Use: this stage of the life cycle includes all costs and CO_2 emissions, materials or services during the use of the product, such as costs for electricity, fuel and other supplies, training, maintenance and other services.

End of life/disposal: after the end of its operating time, the product starts its end of life and will be recycled and/or eliminated.

4.2. SMART SPP Project and LCC-CO_2 Tool

The tool was developed by Aure Adell (Ecoinstitut Barcelona, Barcelona, Spain), Dominik Seebach and Martin Möller (Öko-Institut, Berlin, Germany), with contributions from Philipp Tepper (ICLEI-Local Governments for Sustainability, Bonn, Germany), project coordinator in order to facilitate the calculation of the life cycle costs and significant emissions (CO_2) for various products and services and to help companies to make decisions about purchases. This tool was a part of the European project, SMART SPP, which introduced new and innovative technologies for to reducing CO_2 emissions and promoting the use of as many as possible energy efficient products [25,29,35].

Often, companies are reluctant to invest in the development of innovative technologies when there is uncertainty about the size of the market for the products based on these technologies.

The public authorities have the responsibility towards their communities to reduce CO_2 emissions of the products and services that they buy. Therefore, the request of public authorities regarding the energy consumption and innovative technologies has an important role in the development and integration of these technologies.

The main idea of SMART SPP was to promote sustainable innovation in the public purchasing of services or goods. In August 2011, the partners of the SMART SPP project (respectively, the Municipality of Cascais (Portugal), Eastern Shires Purchasing Organisation (UK), the city of Barcelona (Spain), the city of Kolding (Denmark) and Bromley (UK)) presented the practical character of sustainable innovation [18,25].

The tool can be used to evaluate two different but very close aspects, provided by the manufacturers, concerning innovative technologies with energy efficiency: life cycle costs and CO_2 emissions of different product options.

The tool can compare up to 15 different products. The instrument can be used for already owned products.

4.3. Main Features of LCC-CO_2 Tool

Life Cycle Costing (LCC) is one of the approaches. It is also called "whole life costs" (WLC). It counts and identifies the product costs through contracting and during the operation. Behind the acquisition costs, the LCC tool considers the operational costs (water, energy), maintenance, charges, resale value and scrapping costs [4,5,7,16,18,19].

An important role of the LCC tool is the emissions. The tool is designed to calculate the CO_2 emissions of products. The approach considers not only the emissions during the operation (usually caused by energy consumption) but also the embedded emissions, which are generated in the production process of the product. Moreover, it includes extraction of raw material, half-finished product, transportation, installation and removal.

One of the optional features that the tool can perform is to evaluate the tenders. It evaluates the offers and identifies the tender that is the most advantageous from the economic point of view. It requires setting the award criteria into the scheme.

4.4. Life Cycle Phases

The LCC-CO_2 tool is based on the calculation of the total life cycle for CO_2 emissions and calculations for the cost of each phase of the life cycle [4,5,7,25,29]; this means considering the whole life cycle of a product from production to scrapping. The following phases of the life cycle can be covered:

- Production: all relevant costs are included in the cost of purchase and installation;
- Use: all costs and CO_2 emissions, materials or services (taxes, insurance costs, etc.);
- End of life/disposal: the amount of residual and waste treatment costs (if any); the relevant CO_2 emissions should be included in embedded emissions [16,17,38].

5. Study Case

The case study focused on data entry to start the evaluation and product information from the CA (Contracting Authority).

5.1. Entering Data for Evaluation Start

TAXI LAL used the LCC tool to purchase cars for a taxi service. Originally, it considered purchasing only one car from a range of five medium–compact class cars, e.g., Volkswagen Golf, Opel Astra H, Skoda Fabia, Renault Megane and Dacia Logan (Table 2). First, the simulation costs were made for a single copy of each.

Table 2. Technical parameters for the five medium–compact class car models.

	Volkswagen Golf	Opel Astra H	Skoda Fabia	Renault Megane	Dacia Logan
Motorization	1.6 tdi	1.7 cdti	1.6 tdi	1.6 16v	1.2 mpi
Cylindrical capacity (cmc)	1598	1686	1598	1596	1149
Gearbox	6-speed	6-speed	5-speed	5-speed	5-speed
Horsepower/RPM	105/4000	110/4400	75/4000	110/6000	75/4000
Torque/RPM	250/2500	240/2300	195/2000	151/4250	107/2000
Urban consumption (L/100 km)	4.6	6.8	5.1	9	7.7
Extra urban consumption (L/100 km)	3.6	4.9	3.6	5.5	4.9
Mixed consumption (L/100 km)	4.2	5.9	4.2	6.8	5.9
CO_2 emissions (g/km)	99	139	109	157	137
Fuel tank capacity (L)	50	55	45	60	50

When the current situation was evaluated, all departments of budgetary entity with responsibilities (for energy costs, waste disposal, etc.) were involved. The simulation could be conducted by applying two different approaches:

- The contracting authority must complete certain basic data.
- The relevant cost that was provided by the suppliers or the cost scheme that the supplier used could be defined. In this case, the suppliers were asked to support the costs with details on the CO_2 emissions and other criteria that were used.

One of the important items to be introduced in the tool was the energy consumption and/or CO_2 emissions (Figure 2) associated with operation. These data could be required from the car dealer, procurer or energy officer. Usually, it was presented together with the car performance.

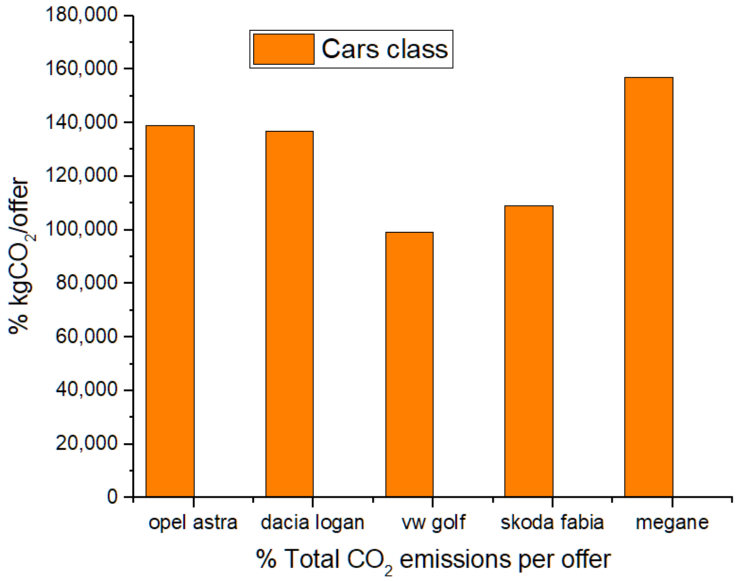


Figure 2. Total CO_2 emissions per offer.

The emissions (annual average) were calculated per unit as the Total Annual Emission per Unit (*TAEU*):

$$TAEU = \sum_{n=1}^{N} f_{En} * U_{rn} * Cn \quad (1)$$

where f_{En} is the emission factor, U_{rn} is the reference unit and N = 5 (number of cars). Reference units taken into consideration were operation hours (10 h), operation cycles (one) and kilometers (130 km). The consumption (*Cn*), which means energy consumption, was taken in liters (the tool can also use kW) per reference consumption unit (operation hours or km). These calculations were performed for all previously indicated operation modes and energy sources.

Moreover, the tool used the embedded emissions for calculations:

$$E_e = \sum_{n=1}^{N} (P_{en} + T_{en} + I_{en} + D_{en}) \quad (2)$$

where E_e is embedded emissions, P_{en} is emissions during the production, T_{en} is emissions during the transportation, I_{en} is emissions generated during the installation process and D_{en} is emissions generated during the disposal of the car.

The planning horizon in which the owners were interested was 10 years. It can be seen from Figure 3 that the tool could make predictions between 1 and 25 years. This term considered the time interval in which different offers were compared. The calculations of LCC and of CO_2 were made in the required interval. The products or solutions provided by the application had different values because the evaluated period was vital.

Another item required in the evaluation was the discount rate (nominal value). For simplicity, the country's interest rate (which included inflation) was used, i.e., 10%. In this case, it was necessary to also include the inflation rate of 3% to calculate the real discount rate. The value of the inflation rate was included in the LCC, where the discount rates and the interest rate (including inflation) were used to calculate the real discount rate.

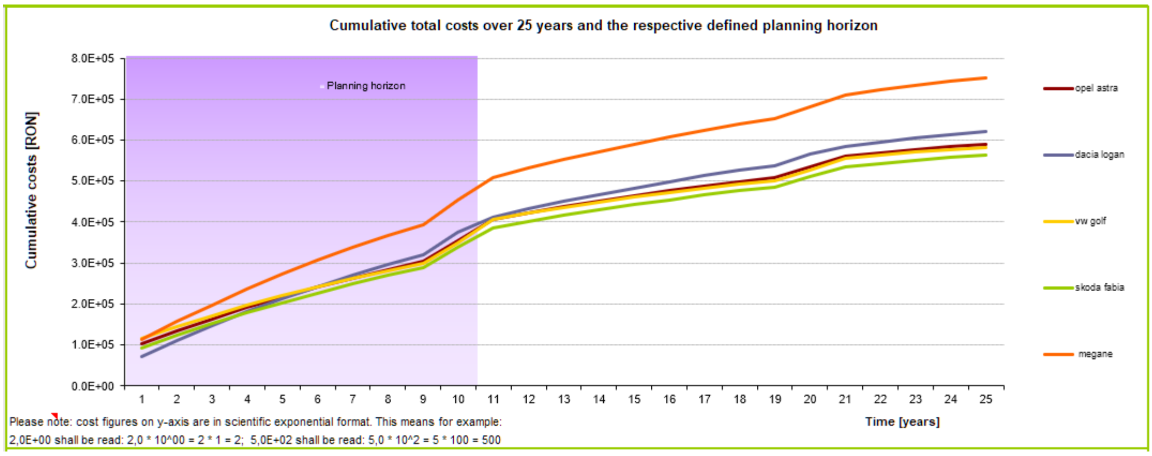
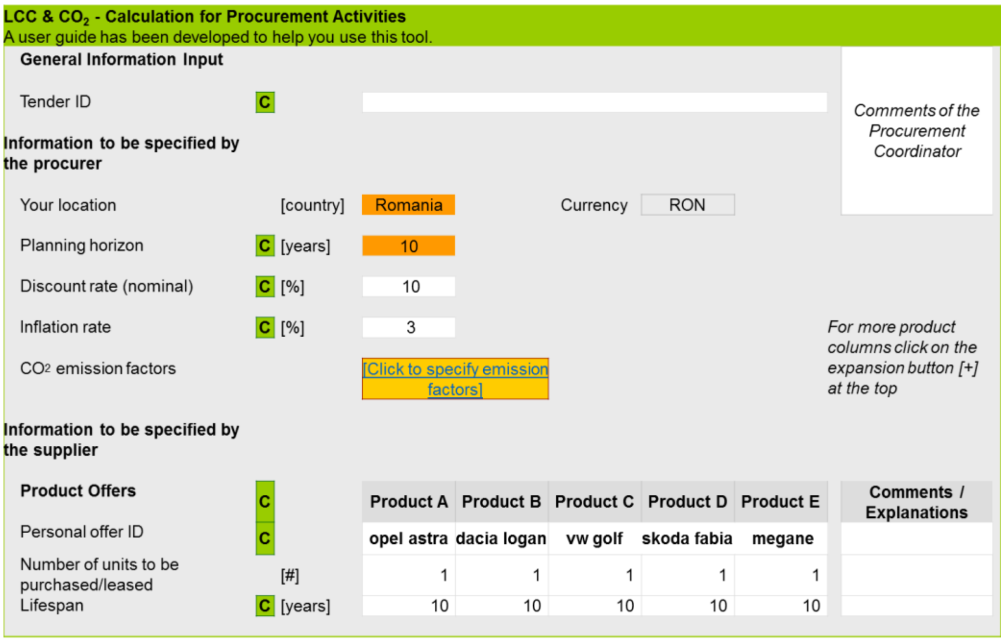


Figure 3. Planning horizon. (x—time in years, y—cumulative costs in RON).

The CO_2 emission factors were also used in the tool. It was required when certain fuels were used (gas, diesel, liquid gas and LPG). The instrument used these factors to calculate emissions during product use. It must be mentioned that CO_2 emission factors for different types of fuels served as starting points and could vary considerably from one country to another, depending on the usage mode of the product. In our study, the Gemisa and Defra lists were used, but a short list with only the most relevant fuels could also be used.

The first step was to introduce the general information for each of the bidders along with compulsory data to start the evaluation process (Figure 4) [25,29]. These data were entered using a form. Subsequently, data from that form were introduced in the tool.



LCC & CO_2 - Calculation for Procurement Activities
A user guide has been developed to help you use this tool.

General Information Input

Comments of the Procurement Coordinator

Tender ID	C							
Information to be specified by the procurer								
Your location		[country]	Romania		Currency	RON		
Planning horizon	C	[years]	10					
Discount rate (nominal)	C	[%]	10					
Inflation rate	C	[%]	3					
CO2 emission factors			[Click to specify emission factors]					
Information to be specified by the supplier								
Product Offers	C		**Product A**	**Product B**	**Product C**	**Product D**	**Product E**	**Comments / Explanations**
Personal offer ID	C		**opel astra**	**dacia logan**	**vw golf**	**skoda fabia**	**megane**	
Number of units to be purchased/leased		[#]	1	1	1	1	1	
Lifespan	C	[years]	10	10	10	10	10	

For more product columns click on the expansion button [+] at the top

Figure 4. Step 1: insert general information.

The next step was to calculate the life of the product. Sometimes, it could be difficult to estimate the lifetime, especially when the innovative products were assessed for which there was insufficient experience in terms of sustainability and behavior during their lifetime [39].

5.2. Information on the Product from CA (Contracting Authority)

This information should be required from the authority. The required information was: acquisition costs, initial costs that refer to one-off costs, energy costs, maintenance costs, annual taxes/commissions or other annual costs and the remanent value of the cost/the costs of the end of life. The results of the calculation were not influenced by the number of used units (Figure 5) [25,29].

	Life-cycle Costing (LCC) Information Input							
	Discount rate		[%]					
	Inflation rate		[%]					
Acquisition Costs				-				
	Purchase price		[RON/unit]	67.500,00	30.150,00	84.150,00	58.050,00	63.900,00
or	*Specify annual investment costs >>*	C		[Click to specify]	[Click to specify]	[Click to specify]	[Click to specify]	[Click to specify]
	Installation costs for all units	C	[RON]	1.000,00	1.000,00	1.000,00	1.000,00	1.000,00
	Initial one-off costs	C	[RON]	600,00	400,00	200,00	200,00	900,00
Operation Costs								
	Total operating costs per year		[RON/unit/year]	9.381,00	9.381,00	6.678,00	6.678,00	10.812,00
or	*Specify detailed operating costs >>*			[Click to specify]	[Click to specify]	[Click to specify]	[Click to specify]	[Click to specify]
Maintenance Costs								
	Total maintenance costs per year		[RON/unit/year]	2.800,00	2.700,00	3.000,00	3.000,00	2.900,00
or	*Specify detailed maintenance costs >>*			[Click to specify]	[Click to specify]	[Click to specify]	[Click to specify]	[Click to specify]
Other Costs								
	Annual taxes / fees / subsidies or other costs	C	[RON/unit/year]	1.310,00	930,00	1.053,00	1.053,00	1.053,00
Remnant Value / End-of-Life Costs								
	Remanent value / End-of-life-costs	C	[RON/unit]	3000,00	3000,00	3000,00	3000,00	3000,00

Figure 5. The main cost elements.

The acquisition costs consisted of: price/unit (including procurement taxes, if applicable) and the costs of installation that was given for the whole batch.

Initial one-off costs related to non-repeatable initial costs (such as environmental taxes, registration fee, training, communication, etc.). These costs excluded the purchase and installation costs. Normally, these costs were independent of the number of purchased units and the life of the product.

Installation costs were determined for the whole lot and were not calculated according to the number of units.

Initial costs referred to one-off costs. They were non-repeating and excluded the initial costs (such as registration fees, environmental taxes, communication, training, etc.). This implied that the costs of purchase and installation were excluded. Usually, the life of the product and the quantity of purchased units did not influence these costs.

The cumulative value of costs was defined and set in the GENERAL worksheet. They were especially detailed in the accessed OPERATION worksheet.

If we simulated high-mileage vehicles, in the case of different function modes, the tool automatically required the type of fuel. This criterium was important when the vehicle used different fuels or switched between heating and cooling (LPG in our case).

In the specification worksheet (OPERATION), a supplier (or Contracting Authority) could enter information for a maximum five different fuels or different ways of using the product.

It was important to check whether the cost of energy per unit (Euro/kWh) was in agreement with the energy unit. This parameter was entered automatically after the energy source was set.

Because gas was one of the products that determined the prices due to the petroleum rate, it came with the inflation rate in the case of long-term planning (Planning Horizon). The inflation rate contained specific tariff increases for electricity, water and different fuels (provided by national statistics). The energy consumption in terms of the reference unit was indicated in the tools.

The maintenance costs were introduced in the GENERAL worksheet as a single cumulative number. When maintenance costs were specified in the MAINTENANCE worksheet, bidders had to provide the following data: annual fixed rate for maintenance and spare parts (one to five). When the cost of spare parts was not provided in the annual budget, the sustainability of spare parts, as well as their price, had to be defined in order to determine the amount of spare parts during long-term planning (Planning Horizon).

The annual taxes/commissions or other annual costs reflected the taxes and other taxes or subsidies of the product during the year for the contracting authority. The vehicle registration taxes and other initial payments had to be included in the purchase price.

There were a few costs that arose from the life-end of the products, i.e., remnant value. They were included in Planning Horizon: (a) decommissioning that involved the elimination of the product in accordance with the regulations and (b) the use of the product. In this case, the product had a value.

Case (a) supposed that the product involved an additional cost, which could be added to the calculus of LCC. In our case (b), the owner could sell the product (Figure 5). The residual value would be earned by the owner after the sale. This residual value was dropped from the LCC calculation. The end-of-life costs (LCC) and residual value determined the disposal cost of the product or the residual price. This value was reflected in the tool as a negative or positive, respectively.

The general formula for *LCC* calculation in the tool was:

$$LCC = I + R_{epl} - R_{es} + E + W + OM\&R + O \tag{3}$$

In Equation (3), the sizes have the following meanings: *LCC* is total current value (PV) of the real exchange rate of the euro; I is current value of maintenance costs; R_{epl} is current values of replacement cost; R_{es} is actual values of residual values; E is actual values of energy costs; *W* is actual values of hydrological costs; *OM&R* is actual values for the cost of maintenance and costs; *O* is actual values of other costs.

The data that were used in this formula are presented in Table 2.

6. Results and Discussion

Results and discussions focused on specific CO_2 emissions and on tendering, evaluation and contracting, respectively.

6.1. Specific CO_2 Emissions

The most common CO_2 monitoring systems, as well as the public authorities' requirements and other institutions, only referred to emissions from energy consumption in the use phase [17]. The present study showed that the LCC tool allowed direct input of CO_2 emissions in the use phase in the GENERAL worksheet. The results from the five cars that were analyzed are presented in Figure 6.

	CO_2-specific Information Input						
	All figures you enter will be treated ***cumulatively***		**Product A**	**Product B**	**Product C**	**Product D**	**Product E**
	Total embedded emissions	[kg CO_2/]	0.14	0.14	0.99	0.11	0.16
or	*Specify detailed embedded emissions>>*		[Click to specify]	[Click to specify]	[Click to specify]	[Click to specify]	[Click to specify]
	Annual emissions: use phase	[kg CO_2/year/unit]	4200.0	4200.00	2970.00	3300.0	4800.0
	There of emissions from electricity supply	[kg CO_2/year/unit]	0.00	0.00	0.00	0.00	0.00
or	*Specify detailed annual emissions >>*		[Click to specify]	[Click to specify]	[Click to specify]	[Click to specify]	[Click to specify]

Figure 6. Specific CO_2 emissions.

Since the standards concerning the carbon emissions made a difference between the emissions during the combustion and emissions that were generated during fabrication (electricity production), results from the GENERAL worksheet (Figure 6) were compared with the carbon emission values during combustion, which corroborated with previous findings [14,16,33,36] on costs. The tool generated the required values for this item in a facile way. The data from Figures 2 and 4 showed the results of the CO_2_DIAGRAMS worksheet. The tool provided several eloquent graphics of great practical utility. The main formulas used numbers to calculate CO_2 emissions set out in the CO_2_FORMULAS worksheet.

It should be observed that, if it is desired to include the information on emissions embedded in the products, it must be checked whether all the values provided by suppliers are based on Life Cycle Assessment (LCA) procedures.

The final results were obtained after all variants were introduced. Thus, it was possible to compare the costs. The LCC key results, respectively, total costs per year and during the whole planning period are shown in Figure 7. The results presented in Figure 7 support previous studies [3,4,8,9,26,33,37] on costs.

LCC Results, in net present value

<< Click expansion buttons [+] on the left to show more results

Total cost in present net value [after 10 years] per offer	[RON]	354.624	375.317	348.704	339.137
Average annual costs per offer	[RON/year]	35.462	37.532	34.870	33.914
Total costs [after 25 years]	[RON]	590.443	620.892	582.675	563.995
Total costs per unit [after 10 years]	[RON/unit]	354.624	375.317	348.704	339.137
Annual cost per unit	[RON/unit/year]	35.462	37.532	34.870	33.914
Cost per unit [after 25 years]	[RON/unit]	590.443	620.892	582.675	563.995

LCC Detail Results

<< Click expansion buttons [+] on the left to show more results

Acquisition Costs					
Purchase costs [after 10 years]	[RON/unit]	67.500,00	30.150	84.150	58.050
Installation costs [after 10 years]	[RON/unit]	1.000	1.000	1.000	1.000
Initial one-off cost [after 10 years]	[RON/unit]	600	400	200	200
Acquisition costs [after 10 years]	[RON/unit]	69.100	31.550	85.350	59.250
ANNUAL AVERAGE AQUISITION COSTS	[RON/unit/year]	6.910	3.155	8.535	5.925
Operation Costs					
Operation costs [after 10 years]	[RON/unit]	181.869	243.869	157.068	173.602
Annual operation costs	[RON/unit/year]	18.187	24.387	15.707	17.360

Figure 7. LCC Results.

6.2. Tendering, Evaluation and Award of Contract

The worksheets of TENDERS-EVALUATION could also allow comparisons between different possible solutions and identification of the most advantageous solution from an economic point of view. The proposed solutions took into consideration both the LCC criteria and the CO_2 emissions.

The evaluation results are shown in a comparative table (Figure 8). The tool allowed the adaptation to the needs of the user.

Award Criteria	Product A	Product B	Product C	Product D	Product E
	Opel Astra	Dacia Logan	VW Golf	Skoda Fabia	Megane
LCC results [RON]	172.120	130.962	167.628	141.528	178.394
CO_2 results [kg CO_2]	42.000	42.000	29.701	33.000	48.000

Figure 8. Final evaluation of the offers.

The adjustment was made to include additional awarding criteria such as quality, aesthetics and other environmental criteria.

This flexibility allowed exporting the results for use in their own matrixes and systems' evaluation. It is also allowed the import of results from this instrument to other evaluation programs.

Checking of fulfilling mandatory technical specifications was performed by confirming with "yes" or "no".

Award criteria (including sub-criteria) took into account the maximum possible of points that were obtained by different offers for every criterion. The standard formula that was applied to assign points for award criteria was "arithmetic progression between the lowest score and the remaining offers". This formula was verified by the Court of Justice through its decision that was taken in the case of "Concordia" (Case 513/99, C 17 9. 2002, Concordia Bus Finland Oy Ab) [40].

The tool also provided the option to assign a monetary value to CO_2 emissions. In this case, the cost of CO_2 was included in LCC. After the final results were obtained, the owners of the TAXI LAL company decided to buy 10 vehicles: 5 WV Golf and 5 Sckoda Fabia. Morover, our research covered another five vehicles (Dacia Logan) that provided taxi services under the TAXI LAL brand. At the end of a 10-year period (Planning Horizon), the LCC results will be compared with the real cases, in line with the procurement policy of the city of Bacau.

7. Conclusions

The LCC and LCA approaches on vehicle procurement highlight the decision criteria that should be chosen in accordance with the European Commission directives.

The green approach to procurement, in the context of the circular economy concept, when the LCC tool is used in the procurement process, generates some savings. This is possible because of the holistic view of life cycle costs of the product or service, which includes not only the purchase price and fees during purchase and maintenance but also the related emissions.

The LCC makes savings for the procurers because of the possibility to choose the option that represents the best value throughout its entire life cycle. Moreover, the public procurements often specify only the economical items and a few environmental items, with respect to the country and EU regulations. In addition to considerations of price and appearance, there are a few performance indicators that can be derived from the public offer of the producer. These parameters, according to LCC purchasing, allow easy comparison of different brands and models of vehicles, regardless of the type of fuel used.

The results of the study were made available to the local administration of the City of Bacau, leading to an improved procurement process. The present calculation tool is a support that automatically calculates the most advantageous offer from an economic, environmental and circular economy point of view. The authors propose to continue the research and collaboration with the local public administration of Bacau in the future, taking into account other types of vehicles (buses, trucks, public administration service cars, etc.) in view of the circular economy and reducing environmental pollution.

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