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Sustainability of Urban Parks: Applicable Methodological Framework for a Simple Assessment

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Abstract: Urban parks play a pivotal role in fostering the development of sustainable and smart cities, encompassing multifaceted dimensions of environmental, social, and economic significance. To effectively manage these urban parks, it is imperative to undertake an in-depth investigation of their environmental, social, and economic conditions, as well as their level of sustainability. However, there is currently a lack of readily applicable methodologies that comprehensively measure these benefits and provide a sustainability rating for urban parks. In this study, we propose a valuable tool that employs effective and affordable measures for the daily management of these green spaces. Our methodology is rooted in the three pillars of sustainability: environmental, social, and economic. Within these pillars, we have defined 19 indicators and 50 criteria, enabling a comprehensive assessment of park sustainability. This methodology is developed through the characterization and systematic documentation of the park's day-to-day operations. To validate our methodology, we present a case study of Cárcamos Park, situated in the state of Guanajuato in Mexico, utilizing accurate operational data collected from January to December 2020. Through this real-life scenario, we demonstrate the high applicability and effectiveness of our methodology. The sustainability assessment of Cárcamos Park reveals a sustainability level of 57%, placing it within the medium sustainability range. Importantly, our methodology can also be incorporated during the design phase of new urban green spaces, offering flexibility and ease of application tailored to the unique characteristics of each park. Park managers can use our procedure and apply it to any park, evaluate their sustainability status and detect areas of opportunity. Our approach provides a comprehensive and practical tool for measuring and improving the sustainability of urban parks. Its simplicity and applicability make it accessible to anyone interested in creating a greener and more sustainable urban environment.

Keywords: sustainability; urban parks; green areas; sustainable cities

1. Introduction

The world is becoming increasingly urbanized [1]. Today, more than half of the global population lives in urban areas [2]. The urban share worldwide will rise from around one-third in 1950 to approximately two-thirds in 2050. Sustainable development depends on successfully managed urban growth to create sustainable cities in both developed and developing countries [3–5]. Currently, the development of sustainable cities has evolved into an indispensable reference point for balanced growth [6]. The sustainability of cities and their regeneration strategies principally focus on improving the cities' infrastructure and resilience of the urban environment [7,8]. Sustainable urban planning and the design of green infrastructures such as street trees, green roofs, and open green spaces like parks can contribute to reducing temperature and pollution in urban areas as well as creating habitats to protect biodiversity [9,10].

Urban parks are public places that provide essential ecosystem services, such as oxygen production, air and water purification [11], as well as noise and air filtering. Parks create a micro-climate and give space for biodiversity protection [12]. In addition, they provide social and psychological services and promote the well-being and education of citizens, which is relevant to the livability of cities [13,14].

People often associate urban parks with sustainability in cities. Nevertheless, despite the apparent benefits, the park's presence alone does not automatically imply a positive impact on the environment, society and economic viability. These spaces must offer specific characteristics that adapt to their location to provide tangible benefits [15]. Sustainable parks are different from traditional parks by three main points: 1) they are self-sufficient in terms of efficiency in resources like fertilizers and energy and water consumption to reduce maintenance costs; 2) they mitigate greenhouse gas emissions to reduce environmental challenges in cities since they provide sustainable benefits inside their limited boundaries, acting as "green lungs" in their communities, and 3) they provide habitat for native species [16]. The research of Vélez Restrepo [17] indicates that the contribution of parks, in terms of sustainability and resilience, takes into account the park's energy and water consumption as well as waste management.

A local sustainable management practice will have global impacts [18,19]. In order to raise sustainability in urban parks, an increased capacity of the responsible managers is essential [20]. Nevertheless those managers often lack sufficient skills, and tools to ensure that local green areas are more resilient to the challenges posed by global change [7].

Furthermore, urban green areas throughout the world frequently suffer from economic challenges and are not financially self-sufficient. Consequently, their maintenance and sustainable development is limited [21,22]. It is therefore essential to improve the management of the parks with practical strategies and tools; continuous collecting and monitoring of information on the condition of parks is fundamental to maintain environmental quality [23]. The high population density of the cities and limited recreation areas put a high pressure on parks and affect their sustainability. The challenge for urban park managers is to meet the needs of all visitors and still guarantee the sustainability and protection of park resources [24].

According to Dearden *et al.* [25] and Gavrilidis *et al.* [26], the proper management and protection of existing parks are more important than creating new parks. In the same way, the tools and strategies in park management are essential to reach and improve the goals and targets for present parks [27]. The parks must be designed considering the current and expected future climate and conditions [28]. However, cities lack information on the quantity and quality of urban parks; the existing data needs to be completed and more interrelated; a database with the parks managing information might improve its function [7].

To implement strategies for sustainability, the use of sustainability indicators is essential since they help to comprehensively measure green areas' functions. Sustainability indicators facilitate the assessment of the level of sustainability and the understanding of areas of opportunities for decision-makers, and environmental-policy-makers [23,29]. There are some presentations of methodologies to measure the sustainability of urban green areas, none of which we believe can provide a complete picture of sustainability. Social and economic elements are given little consideration. Cranz and Boland [16] consider five elements to define a park as sustainable: native plants, permeable surfaces, ecological restoration, green infrastructure, and resource self-sufficiency. They defined parks sustainability considering social and environmental elements like human and ecological health, environmental education and wildlife protection [16]. Nevertheless, they did neither consider the infrastructure and buildings installed within the park nor information on the park-employees or infrastructures including waste management like a waste collection center.

Ávila and Medina [30] address the sustainability from a socio-environmental perspective and Morales-Cerdas *et al.* [29] include environmental and socio-environmental aspects applying the following 11 environmental indicators: (1) Percentage of the area in which the protection surface was respected according to the regulations, (2) Percentage of native and exotic species in urban parks, (3) Number of trees per area (density), (4) Species structure, such as height of trees, (5) Diameter, (6) Number of trees planted in streets, (7) Number of trees planted in street pavements, (8) Number of trees planted in avenues, (9) Soil permeability, (10) Soil biotic index, (11) Potential of urban parks to host bird-life, for managing urban green areas to determine their environmental condition without considering the economic value. The socio-environmental perspective is very important since it relates the affecting components of visitors to conservation practices in public spaces. In addition to the participation and education of citizens and workers, we propose to include with equal weight the economic situation (economic pillar) as it may reflect efficiency in the use and consumption of resources leading to the economic self-sufficiency. Waste separation and recovering the value of the residues can generate financial resources that can be invested in the park to improve its operation.

Dizdaroglu [31], consider a more complete spectrum and note ten core sustainable design objectives of urban parks, which are: (1) providing green infrastructure, (2) creating a place for people of all ages, (3) building connected park systems within walking distance, (4) implementing water and energy conservation practices; (5) waste management; (6) promoting access to fresh, healthy, and low-cost food; (7) supporting and preserving biodiversity, (8) environmental education and stewardship through hands-on activities; (9) ensuring the long-term maintenance and management of the park, and (10) supporting disaster resilience; within which they describe theoretically the importance of sustainable park design and management as it broadens the scope of parks in the role of sustainable cities in helping to overcome environmental problems arising from urban sprawl.

In order to measure the degree of sustainability of universities and identify their areas of opportunity, one might use the UI Green Metric World University Ranking (Green Metrics) [32]. The Green Metrics is an initiative, launched by the University of Indonesia in 2010, that provides the result of an online survey regarding the current condition and policies related to green campuses and sustainability in universities worldwide. Green Metrics differs six criteria: Setting and Infrastructure, Energy and Climate Change, Waste, Water, Transportation, Education, and Research, with 51 indicators that focus on the objectives of sustainable universities. It is a simple guide to measuring and applying university sustainability. Nonetheless, nothing similar to Green Metric World University Ranking exists for parks [33].

Our methodology focuses on the integration of all components related to the operation of an urban park, which we believe is essential for a complete survey. To this end, we have developed a scalable, flexible, and replicable tool that enables the measurement of the sustainability of urban parks. Our methodology is designed to be reproducible, low-cost, and easy to implement by anyone using collected operational data from the park. Our objective is to obtain a sustainability grade for the park and to identify areas of opportunity for improvement. To achieve this, we have developed a method based on three dimensions of sustainability which we call pillars: environmental, social, and economic. These three pillars contain 50 criteria and 19 indicators that are used to characterize and gather information from day-to-day operations. By using our methodology, park managers can plan short-, medium-, and long-term environmental, social and financial actions while tracking their progress over time. Furthermore, our indicators can be used as a reference for designing new urban parks that are sustainable from the outset.

2. Methodology and sustainability scheme proposal

Our methodology corresponds to a quantitative analysis of park operation data, which seeks to draw a scalable, flexible, and replicable roadmap in other parks. This procedure consists in the creation of a database on the operation of the park, including environmental, economic and social aspects.

Pillars, indicators and criteria Our methodology is based on the three pillars of sustainability: environmental, economic, and social. For facilitating the data collection and analysis, the three pillars are divided into 19 indicators that consist of 50 criteria (the database) (see Figure 1). No matter the number of indicators or criteria, each pillar is evaluated equally, with one-third each. The highest

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sustainable value that an urban park can achieve is 100 %.

2.1. Indicators and criteria

The indicators represent a first differentiation of the pillars that represent specific groups or topics of the criteria see Figure 1. The criteria are the direct representation of the data record, collected and operated by the park management (see Section 2.2 and Tables 3–5).

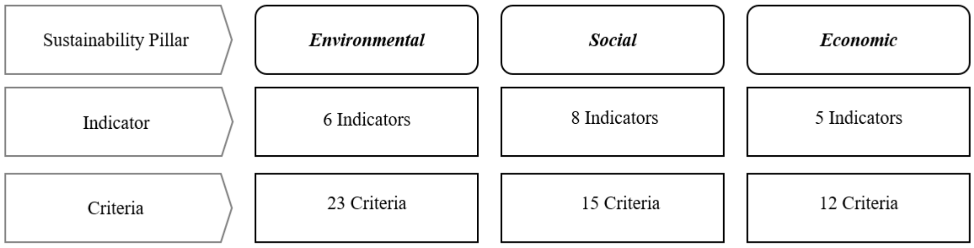

Figure 1. Sustainability scheme.

Criteria of the same category are joined to one indicator of 19 indicators in total. The Environmental Pillar consists of 6 indicators, 23 criteria (see Figure 1, Table 3). The Social Pillar consists of 8 indicators and 15 criteria (see Figure 1 and Table 4). Finally, the Economic Pillar has 5 indicators and 12 criteria (see Figure 1 and Table 5). The Social Pillar has the highest number of indicators (8). The Environmental Pillar has the highest number of Criteria (23). The Economic Pillar has the lowest number of Criteria (12) and the lowest number of Indicators (5).

2.2. Criteria and additional data

The criteria represent numerical information, collected by the park management on a day to day basis, that have a direct influence on the grade of sustainability. Some of this criteria (collected data) need additional data to be calculated (see Table 1). Those additional data do *not* have a direct impact on the level of sustainability. For example, the criterion (1) *Percentage of park employees that use car mobility to go to work*, is calculated from two additional data: 1.) the additional data *Number of park employees that use car mobility to go to work* and 2.) the additional data *Total number of persons* (see Figure 1 and Table 1).

The 18 additional data are only required to evaluate the criteria in the Environmental Pillar and the Economic Pillar. No additional data is required for the Social Pillar criteria (see Table 1).

Positive or negative Impact Criteria were determined to be of positive or negative impact in sense of sustainability. Positive impacts were highlighted with a plus sign (+) and negative impacts have been assigned a negative sign (-).

Internal and External Impacts (Dependencies) Each criterion was classified according to its internal or external dependency in order to reveal if the park management has a direct control on the value of the criterion (Internal) or if the criterion cannot be directly influenced by the park management (External). Impacts or dependencies of internal control, are criteria in which the park manager can intervene or modify, for example automatic irrigation. Those internal dependencies are marked with the letter (i+) if the impact is positive and (i-) if the impact is negative.

Table 1. Additional Data used for assessing certain Criteria (1,2,3,4,5) in the Indicators of the Environmental Pillar (E1, E2, E3, E4) and Economic Pillar (EC4).

No.	Additional Data	Indicator/Criteria
1	Total number of employees	E1/1
2	Number of employees that use car mobility to go to work	E1/1
3	Total surface of the park (m^2)	E2/1, E2/3
4	Total surface of green area (m^2)	E2/1
5	Total surface of constructed and sealed area (m^2)	E2/1
6	Total number of trees in the green area	E2/3, E2/4, E2/5
7	Number of native trees	E2/4
8	Number of healthy trees	E2/5
9	Volume of treated water (m^3)	E3/3
10	Volume of water used for irrigation (m^3)	E3/3
11	Number of total bulbs in the offices	E4/1, EC4/2, EC4/3
12	Number of LED bulbs in the offices	E4/1, EC4/2, EC4/3
13	Number of total bulbs in the green area	E4/2
14	Number of LED bulbs in the green area	E4/2
15	Total Energy consumption (kWh)	E4/3, E4/4, EC4/1
16	Energy produced by Renewable Energies	E4/3, EC4/4, EC4/1
17	Total number of electronic equipment	EC4/4
18	Number of electronic equipment that are less than five years old	EC4/4

Criteria of external dependencies are criteria where only external forces like the government can intervene or modify, and not the park management itself. For example the criterion "Presence of a lake (water body) inside the park", are marked with the letter (e+), since the decision of installing a lake is external and a lake has positive impact on sustainability (see Tables 3, 4, 5). The criterion "Number of park employees that use car mobility to go to work" was assigned with the impact "i-", since this criteria can be influenced internally by the park management (i, Internal) and has a negative (-) impact on sustainability (see Tables 3– 5).

Sustainability Degree The first step in achieving the sustainability degree is assigning the value for each criterion. Those values go from 0 to 100 points, being 100 the highest possible value. For a positive impact criterion (+), 100 is the best sustainability value. In the case of a negative impact criterion (-), 0 is the best value for a high sustainability assessment.

The weights of the indicator result from the average of the corresponding criteria values. Then the weights of the pillars are computed as the average of their indicator values. The final sustainability degree is calculated by averaging the values of all three pillar's, each pillar participating equally with one third.

According to the appraisal and evaluation strategies proposed by Dodgson *et al.* [34] (Chapter 2, pages 9-13). The decision making process that helped us to define the point range of the degrees of sustainability (see Table 2) was as follows: 1) Identifying objectives 2) Identifying options for achieving the objectives 3) Identifying the criteria to be used to compare the options 4) Analysis of the options 5) Making choices, and 6) Feedback [34].

Table 2. Degrees of Sustainability in Parks.

Point range	Sustainability
0-50	Low sustainability
51-79	Medium sustainability
80-100	High sustainability

The three sustainability levels and their point range are defined as: 1) Low sustainability for those with a total score between 0 and 50, 2) Medium sustainability with a score between 51 and 79, and 3) High sustainability for a score between 80 and 100 (see Table 2).

2.2.1. Criteria in the Environmental Pillar

The environmental Pillar contains 6 indicators 23 criteria (see Table 3).

The Sustainability Transport Indicator (E1) considers four different criteria; the value of this indicator consists of their average: Criterion (1) *Percentage of park employees that use car mobility to go to work* refers to the percentage of workers who come to the park with their own car that runs on fossil fuels. This percentage results from the two additional Data: *Total number of employees* and *Number of employees that use car mobility to go to work*. This resulting percentage equals the number of points for this criterion. Criterion (2) *Kilometers driven per day per employee to get to the park* refers to the distance between work and home that park employees must travel and includes only fossil fuel cars. The daily trips should be optimized and be a maximum of 7 km from home to work to accelerate the urban development solution and sustainable mobility [35]. Criterion (3) *Low-emission motorised transport* represents the possibility of reaching the park with a low-emission means of transport (e.g. public transport or organizing car sharing). The existence of a low-emission transport to the park leads to 100 points, the contrary leads to zero points. Criterion (4) *Bicycle infrastructure* refers to the availability of bicycles in the park to encourage their use as an alternative means of transportation. If bicycles are available inside the park: 100 points, if not, 0 points.

Green area and biodiversity Indicator (E2) considers the values of five criteria whose average leads to the indicator value: Criteria (1) *Percentage of green area* is determined using three additional data: the *Total surface of the park* and the *Total surface of green area* and *Total surface of constructed and sealed area* (see Table 1). The number of points available in this indicator is equal to the percentage of the green area of the park. Criterion (2) *Pollinator garden* evaluates if there is a pollinator garden inside the park. If the park counts with a pollinator garden, this equals 100 points, no pollinator garden equals 0 points. Criterion (3) *Number of trees per hectare* takes into account the recommendation of Forestal [36] of 625 trees per hectare in parks; the points that can be achieved for this criterion are a percentage of these recommended 625 trees. The value of criterion (4) *Percentage of native trees*, results from the percentage of native trees (calculated from two additional data: *Total number of trees* and the *Number of native trees*, see Table 1) from the recommended of 80% of native trees (and maximum 20% exotic trees), according to Sánchez and Artavia [37]. Criterion (5) *Percentage of healthy trees*, is calculated including the additional data of the *Total number of trees* and *Number of healthy trees* (see Table 1. The percentage of healthy trees in the park equals the score of this criterion. The average of all criteria leads to the value of this indicator.

Water conservation Indicator (E3) considers six criteria: Criterion (1) *Presence of a lake (water body) inside the park* scores 100 points if the park has a lake; no lake scores zero points. Criterion (2) *Automatic irrigation* scores 100 points if the park uses nutrient-rich water from the lake to irrigate green areas. Criterion (3) *Use of treated water for irrigation* leads to 100 points, if the park uses treated water for irrigation, regardless of where the water was treated, outside or inside the park. Criterion (4) *Percentage of water treated after use* refers to the percentage of irrigation water that was treated after being used in bathrooms or other facilities, etc. This percentage equals the number of points. Two additional data are necessary for this criterion: *Volume of treated water* and *Volume of water used for irrigation*. Criterion (5) *Rainwater harvesting systems* - the installation of a water capturing facility leads to 100 points; if the park lacks such a technology, zero points are awarded. Criterion (6) *Water-saving devices* considers the installation of water-saving technologies in bathrooms: its percentage equals the number of points.

Renewable energy and Energy efficiency Indicator (E4) considers four criteria. Additional data (11-16) are necessary to appraise the criteria of this indicator (see Table 1. Their average equals the value of this indicator: Criterion (1) *Percentage of LED lighting in the offices* refers to the percentage of LED lamps installed in the buildings equals the number of points. The total number of bulbs and the number of

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LED-bulbs installed in the buildings are the two criteria that lead to this value. Criterion (2) *Percentage of LED lighting in the green area* refers to the percentage of LED lamps installed in the green area equals the number of points (The Total number of bulbs and the number of LED-bulbs installed in the green areas are the two criteria that lead to this value). Criterion (3) *Clean energy generation* refers to the generation of green energy by renewable energies like solar or wind. Criterion (4) *Emission reductions from clean energy generation*; their present percentage leads to the number of points.

Waste management Indicator (E5) evaluates the management of residues inside the park, considers three criteria. The criterion (1) *Waste collection and separation service* indicates if the park offers a recycling center, where recyclable waste like paper, metal, glass, batteries or PET (Polyethylene terephthalate) are collected and separated. The presence of such a service leads to 100 points; the contrary equals zero points. Criterion (2) *Organic Waste management (composting)* leads to 100 points if the organic waste from the park is collected and composted. Criterion (3) *Recycling Program* leads to 100 points if there exists a recycling program that helps preventing waste and regulates its treatment in a sustainable way. No recycling program in the park would lead to zero points.

Sustainable building with certification (sustainability) Indicator (E6) includes one criterion, Criterion (1) *Sustainable building with green building certification*. If the park has a building, it must have a green building certificate, such as LEED, Passive House or BREEAM [38,39]. In order to get 100 points in this criteria, since a green building certificate guarantees the sustainability of the building [40]. No certificate leads to 0 points. If the park has no building, this indicator counts for 100 points. If the park has more than one building the percentage of buildings with green certificate equals the number of points.

2.2.2. Criteria in the Social Pillar

The Social Pillar holds 8 indicators and 15 criteria.

The exclusive maintenance staff Indicator (S1) takes into account on criterion: Criterion (1) *Exclusive maintenance staff* which refers to employees that take care and maintain the sustainable aspects of the park. At least one employee who takes care of the sustainable aspects inside the park, reflected by the three pillars (environmental, social and economic) leads to 100 points.

The environmental impact on society Indicator (S2) considers one criterion: Criterion (1) *Environmental education events* refers to environmental education events offered by the park, which should be at least twelve events per year or one per month. That means twelve events per year equals 100 points; 6 events lead to 50 points; no events lead to zero points.

Space for environmental education Indicator (S3) considers one criterion: Criterion (1) *Space to promote environmental education* refers to the existence of a dedicated space for environmental education activity. In order to achieve the highest score, the park has such an area available, which can be, for example, a botanical garden or a butterfly house.

Environmental education workshops Indicator (S4) takes into account six criteria, which are public information lectures or workshops on the most important environmental issues for everyone: Criterion (1) *Biodiversity workshops* includes talks and/or activities on biodiversity, Criterion (2) *Waste workshops* includes talks/activities on resources and residues, Criterion (3) *Air Quality workshops* includes talks and/or activities on air quality, Criterion (4) *Soil workshops* includes talks/workshops on the importance of the soil, Criterion (5) *Water workshops* represents talks and/or activities on water protection and Criterion (6) *Climate workshops* represents workshops on the importance of climate change. One talk and/or activity on a respective topic equals 100 points, no activity equals zero points. The average of all criteria leads to the value of the indicator.

Environmental policy for the use of green area Indicator (S5) considers the criterion (1) *Environmental policies for use of green area*. If the park counts with environmental policies like the visitors behaviour in an environmentally friendly way (avoiding single-use containers, or giving instructions on how to take care of flora and fauna inside the park), leads to 100 points. No established environmental policy leads to zero points.

The environmental management system in office Indicator (S6) consists of criterion (1) *Environmental management system in office*. If the park has implemented a program, this criterion obtains the maximum score of 100 points.

The accessible entrance indicator (S7) considers three criteria defining the accessibility of the park to all citizens. Criterion (1) *Free access (no entrance fee)* means that the access to the park is free and no entrance fee is charged. Criterion (2) *Open 7 days a week* means that the park opens every day (365 days/year), and Criterion (3) *Open at least 10 hours a day* considers that the park is available for the public for a minimum of 10 hours per day. Concluded, all three criteria would lead to 100 points if the criteria are not full-filled, zero pints for the respective criteria. Their average leads to the value of this indicator.

Sustainable building with certification (health) Indicator (S8) includes one Criterion (1) *Sustainable building for healthy living/working*. If the park has a building, it must have a Green building certificate, such as LEED, Passive House or BREEAM [38,39] in order to get 100 points in this criteria, since a green building certificate guarantees the healthy atmosphere inside the building [40]. No certificate leads to 0 points. If the park has no building, this indicator counts for 100 points. If the park has more than one building the percentage of buildings with Green certificate equals the number of points.

2.2.3. Criteria in the Economic Pillar

The Economic Pillar contains 5 indicators and 12 criteria which consider economic resources.

Economic resources generated from *Sale of waste Indicator* (EC1) considers two criteria of economic value: (1) *Sale of paper, carton, plastic, aluminium, iron, newspaper, electronic, tetra-pack, organic waste, glass.* Plastics refers to PET, since PET is economically the most important [41,42]. For each residue in the list, the park receives 10 points. If all waste types are sold, 100 points are achieved. Criterion (2) *Alkaline batteries* shows the importance of collecting alkaline batteries and guarantee their adequate recycling. Both criteria are of external impact, since the price of residues can not be influenced by the park management. The average of all criteria values leads to this indicator's value.

Charging fees indicator EC2 considers three criteria. Criterion (1), *Entrance fee*, indicates if the entrance to the park is free of charge. Criterion (2) *Workshop fee* indicates if the park can generate economic revenue by organizing and charging for workshops. Criterion (3) *Rent space fee* indicates if the park can generate economic revenue by charging for the rent of special areas inside the park. All three criteria lead to zero points if no fees are charged, since this would be an economic disadvantage.

Waste registration and collector control Indicator (EC3) considers two criteria: Criterion (1) *Waste registration* of collected and separated waste at the collection center, including the type of waste, the weight [kg], and the distance [m] from where they come from; the presence of a waste registration folder (analogue or digital) leads to 100 points; no continuous waste registration leads to zero points, and criterion (2) *Authorized waste collector*; the park obtains 100 points if the waste collector is legally authorized and counts with all necessary permits to manage recyclable waste. The average of both criteria leads to the indicator's value.

Energy efficiency indicator (EC4) considers four criteria: Criterion (1) *Clean energy generation* refers to economic savings through renewable energy generation like solar, wind, geothermic, biomass plant. The percentage of green energy generation leads to the number of points. Criterion (2) *Percentage of LED-illumination in offices*, refers to the percentage of high efficient illumination (LED) in the offices leads to the number of points. Criterion (3) *Percentage of LED-illumination in green area*, refers to the percentage of high efficient illumination (LED) in the green area leads to the corresponding number of points. Criterion (4) *Efficient electronic equipment (not older than 5 years)* means that recent energy efficient devices and equipment like pumps and computers, printers, and refrigerators, that are less than five years old, can lead to economic benefits; the percentage of the respective installations leads to the number of points. All criteria of this indicator need additional data (see Table 1 to determine the criteria of this indicator. The indicator's value represents the average of all criteria values.

Sustainable building with certification (efficiency) Indicator (EC5) includes one criterion: (1) *Sustainable building for energy efficiency and cost-savings*. If the park has a building, it must have a Green building certificate, such as LEED, Passive House or BREEAM [38,39] in order to get 100 points in this criteria, since a certificate guarantees cost savings through energy savings and cost efficiency [43]. No certificate leads to 0 points. If the park has no building, this indicator counts for 100 points. If the park has more than one building the percentage of buildings with Green certificate equals the number of points.

3. Results

In this Section, we present our methodology's application in the Cárcamos Park in the city of Leon, in the state of Guanajuato, in Mexico. First, we describe the park we used as a case study, then we explain the captured operational data. Finally, we show the sustainability values obtained for each criterion, indicator, and pillar, in addition to calculating the sustainable degree of this case study park. The outcome of the study identified the opportunities for improving the sustainability level of Cárcamos Park.

3.1. Case study Cárcamos Park, Mexico

In order to test the applicability of our methodology, we introduced the real operational and maintenance data from the Cárcamos Park to our data sheet. The Cárcamos Park is located in the City of León, in the state of Guanajuato in Mexico (see Figure 2). The Cárcamos Park has a total area of 116,074.99 m^2, of which the green area occupies 60% with 1,457 trees; the built-up area occupies 4%, and a lake occupies 36% of the surface area.

Cárcamos Park serves a dual purpose: it provides ample public green space and accommodates also buildings with government offices in the southern area of the park. The presence of government employees in the park has numerous benefits, particularly in terms of data collection and monitoring.

The government building inside the park spans two floors, which shelters a team of 20 employees who work weekdays from Monday to Friday. In addition to this, the park features an area dedicated to promoting environmental education and a collection center for citizens to drop off waste materials with a monetary value. These facilities are open every day of the year from 6:00 am to 8:00 pm, offering park visitors 14 hours of access per day. The park also employs a full-time maintenance worker to tend to the green space, while the government office staff stationed on-site split their duties between the botanical garden and the collection center.

We have carefully compiled all relevant operation data of the Cárcamos Park and summarized it in a comprehensive data sheet with 50 criteria and 18 additional data (see Table 1). In order to ensure a full understanding of the park's performance, we found it necessary to collect information over a one-year period spanning all seasons, including changing seasons and situations such as holiday seasons, rainy seasons and droughts. Thus, we incorporated all operational data from January to December 2020 to generate the database. Although the year 2020 was atypical, marked by the global SARS-COVID-2 pandemic, it provided an opportunity to evaluate the park's behavior from a baseline level. Additionally, with the reactivation of activities in August, the database facilitated an observation of the movements and changes in the park's operating parameters.

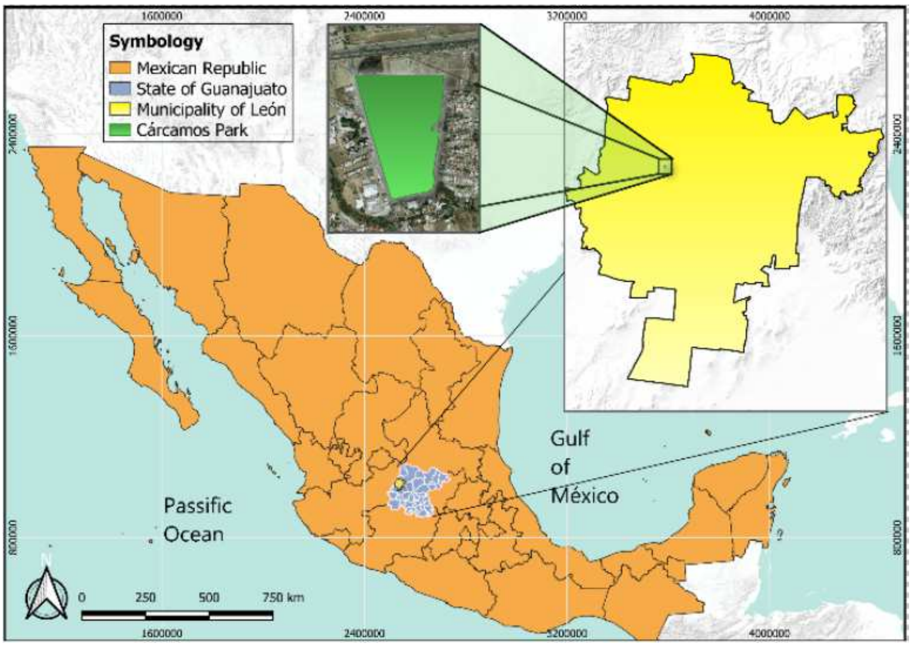

Figure 2. Location of Cárcamos Park in Mexico. Source: Own elaboration using QGis software and INEGI layers [44].

3.2. Sustainability Degree of the Case Study, Cárcamos Park, Mexico

This proposal presents the determination of the degree of sustainability assigned for Cárcamos Park in Mexico. It identifies the percentage of potential opportunities for enhancement for park sustainability (see Figures 3–5).

Once the database with information for each of the 50 criteria and 18 additional data of the Cárcamos Park was completed, we determined the values for the criteria. The weights for the indicators, and pillars of the Cárcamos Park resulted by summing the criteria´s values and taking their average (see Tables 3–6, and Figures 3–6). The Cárcamos Park resulted in a final degree of sustainability of 57.2%, which is classified as medium sustainable (see Table 2); Table 3 demonstrates the sustainability values of the criteria and indicators for the Environmental Pillar 47.7%, Table 4 for the Social Pillar with 75% and Table 5 for the Economic Pillar with 49% sustainability weight. Tables 3–5 also show the respective impact values and the Current Sustainable Park value of the Cárcamos Park. The *Current Park Value* of the indicator is generated from the average of the values of the respective criteria of each indicator.

The Parks improvement value is determined taking into account internal and external impacts. The park management only has an influence on the internal impacts (i), which is why these are included in the *Parks Improvement Value*. The park management has no direct influence the external impacts (e), which is why the values from Criteria with external impacts are not included in the *Parks Improvement Value*. In order to enhance this value, external sources from the park administration, like the municipal or federal government have to take action.

In the Environmental Pillar (see Table 3), the indicator with the lowest *Current Park Value* is *Sustainable building with green building certification* with 0%. The indicator with the highest *Current Park Value* is a *Renewable energy and Energy efficiency* with 96.5%. Non of the indicators reached the highest reachable value of 100. In the same Table 3, the *Parks Improvement Value* of the indicator *Sustainable building with certification (sustainability)* is zero (0) since it is of external impact, while the indicators *Renewable energy and Energy efficiency* and *Waste management* have a Parks Improvement Value of 100 respectively; both are of internal impact.

In the Social Pillar (see Table 4), the lowest indicators are *Environmental policies for the use of green area* with 0 % and *Sustainable building with certification (health)* also with 0 % . The other indicators all

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had a Current Park Value of 100 %: *Exclusive maintenance staff*, *Environmental impact on society*, *Space for environmental education*, *Environmental education workshop*, *Environmental management system in office* and *Accessible entrance* .

In the Economic Pillar (see Table 5), the lowest indicators are *Charging fees* and *Sustainable building with certification (efficiency)* both with 0%. The highest valued indicators are *Waste registration and collector control* with 100 % and *Energy efficiency* with 98 %.

A low sustainable value indicates a high area of opportunity. Considering that the pillar with the lowest sustainability level is the Environmental Pillar with 47.7%, we have identified the indicators with the greatest potential for improvement as follows: E1) *Sustainability transport*, (E2) *Green area and biodiversity* , (E3) *Water conservation* and (E6) *Sustainable building with certification (sustainability)*.

In second place, the Economic Pillar obtained a sustainability value of 49%. The indicators *Charging fees* (EC2) and *Sustainable building with certification (efficiency)* (EC5) have the lowest Current Park Value with 0% since the Cárcamos Park charges no fees (entrance, workshop or rent-space fees) and sustainable construction criteria are not applied. The other areas of opportunities are economic resources generated from the sale of waste (EC1). The park currently collects, separates and sells 11 types of recyclable materials without considering resale value.

The Social Pillar (see Table 4) with 75% resulted to be the pillar of highest sustainability. Here, the most significant areas of opportunity are *Environmental policies for the use of green area* (S5) and *Sustainable building with certification (health)* (S8) with 0% Current Park Value both, since the Cárcamos Park has no environmental policy in favor of green spaces, and the buildings have no green building certification.

The total sustainability value and the sustainability value obtained for each pillar for Cárcamos is shown in Figure 6. The total sustainability score is determined by summing the points earned by each of the three pillars. In this case study, the park received a sustainability value of 57.2%, indicating a medium level of sustainability with a potential for improvement up to 68.5.0%. The 31.5% that is missing for 100% sustainability is due to the external factors (e+ or e-) that the park administration itself cannot change. Only internal impacts (i+ or i-) are factored in the Parks Improvement Value since those can be influenced directly by the park management. Our results appraise a significant opportunity to enhance the sustainability of Cárcamos Park and provides a reference for park managers of Cárcamos parks, helping them in decision-making, prioritizing action implementation, and even justifying requests for economic resources (see Figure 6).

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Table 3. Sustainability Values: Environmental Pillar with its respective *Impact* (internal i or external e, positive + or negative -), *Current Park Value* (Recent Sustainability Value of the Cárcamos Park, Mexico) and *Parks Improvement Value* (Percentage of potential improvement considering only internal impacts that can be influenced by park managers).

Indicator (E1-E6) and Criteria (1, 2, ..., 6)	Impact	Current Park Value	Parks Improvement Value
E1: Sustainability transport		**8.8**	**50.0**
1 Percentage of park employees that use car mobility to go to work	i-	35.0	100.0
2 Kilometers driven per day per employee to get to the park	e-	0.0	0.0
3 Low-emission motorised transport	e+	0.0	0.0
4 Bicycle infrastructure	i+	0.0	100.0
E2: Green area and biodiversity		**64.4**	**92**
1 Percentage of green area	e+	60.0	60.0
2 Pollinator garden	i+	100.0	100.0
3 Trees per hectare	i+	20.2	100.0
4 Percentage of native trees	i+	54.6	100.0
5 Percentage of healthy trees	i+	87.3	100.0
E3: Water conservation		**33.3**	**66.6**
1 Presence of a lake (water body) inside the park	e+	100.0	100.0
2 Automatic irrigation	i+	100.0	100.0
3 Use of treated water for irrigation	e+	0.0	0.0
4 Percentage of water treated after use	e+	0.0	0.0
5 Rainwater harvesting systems	i+	0.0	100.0
6 Water-saving devices	i+	0.0	100.0
E4: Renewable energy and energy efficiency		**96.5**	**100.0**
1 Percentage of LED lighting in the offices	i+	92.0	100.0
2 Percentage of LED lighting in the green area	i+	100.0	100.0
3 Clean energy generation	i+	94.0	100.0
4 Emission reductions from clean energy generation	i+	100.0	100.0
E5: Waste management		**83.3**	**100.0**
1 Waste collection and separation service	i+	100.0	100.0
2 Organic waste management (composting)	i+	100.0	100.0
3 Recycling Program	i+	50.0	100.0
E6: Sustainable building with certification (sustainability)		**0.0**	**0.0**
1 Sustainable building with green building certification	e+	0.0	0.0
Total value of Environmental Pillar		**47.7**	**68.1**

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Table 4. Sustainability Values: Social Pillar with its respective *Impact* (internal i or external e)(positive impact + or negative impact -), *Current Park Value* (Recent Sustainability Value of the Cárcamos Park, Mexico) and *Parks Improvement Value* (Percentage of potential improvement considering only internal impacts that can be influenced by park managers).

Indicator (S1-S8) and Criteria (1, 2, ..., 6)	Impact	Current Park Value	Parks Improvement Value
S1: Exclusive maintenance staff		**100.0**	**100.0**
1 Exclusive maintenance staff	e+	100.0	100.0
S2: Environmental impact on society		**100.0**	**100.0**
1 Environmental education events	i+	100.0	100.0
S3: Space for environmental education		**100.0**	**100.0**
1 Space to promote environmental education	i+	100.0	100.0
S4: Environmental education workshop		**100.0**	**100.0**
1 Biodiversity workshops	i+	100.0	100.0
2 Waste workshops	i+	100.0	100.0
3 Air quality workshops	i+	100.0	100.0
4 Soil workshops	i+	100.0	100.0
5 Water workshops	i+	100.0	100.0
6 Climate change workshops	i+	100.0	100.0
S5: Environmental policies for the use of green area		**0.0**	**100.0**
1 Environmental policies for use of green area	i+	0.0	100.0
S6: Environmental management system in office		**100.0**	**100.0**
1 Environmental management system in office	i+	100.0	100.0
S7: Accessible entrance		**100.0**	**100.0**
1 Free access (no entrance fee)	e+	100.0	100.0
2 Open 7 days a week	e+	100.0	100.0
3 Open at least 10 hours per day	e+	100.0	100.0
S8: Sustainable building with certification (health)		**0.0**	**0.0**
1 Sustainable building for healthy living/working	e+	0.0	0.0
Total value of Social Pillar		**75**	**87.5**

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Table 5. Sustainability Values: Economic Pillar with its respective *Impact* (internal i or external e) (positive impact + or negative impact -), *Current Park Value* (Recent Sustainability Value of the Cárcamos Park, Mexico) and *Parks Improvement Value* (Percentage of potential improvement considering only internal impacts that can be influenced by park managers).

Indicator (EC1-EC5) and Criteria (1, ..., 4)	Impact	Current Park Value	Parks Improvement Value
EC1: Sale of waste		**45**	**50**
1 Sale of paper, carton, plastic, aluminium, iron, newspaper, electronic, tetra-pack, organic waste, glass	i+	90.0	100.0
2 Alkaline batteries	i+	0.0	100.0
EC2: Charging fees		**0.0**	**0.0**
1 Entrance fee	e+	0.0	0.0
2 Workshop fee	e+	0.0	0.0
3 Rent space fee	e+	0.0	0.0
EC3: Waste registration and collector control		**100.0**	**100.0**
1 Waste registration	i+	100.0	100.0
2 Authorised waste collector	i+	100.0	100.0
EC4: Energy efficiency		**98.0**	**100.0**
1 Clean energy generation	i+	100.0	100.0
2 Percentage of LED-illumination in offices	i+	92.0	100.0
3 Percentage of LED-illumination in green area	i+	100.0	100.0
4 Efficient electronic equipment (not older than 5 years)	i+	100.0	100.0
EC5: Sustainable building with certification (efficiency)		**0.0**	**0.0**
1 Sustainable building for energy efficiency and cost-savings	e+	0.0	0.0
Total value of Economic Pillar		**49**	**50**

Table 6. Sustainability value obtained per pillar for the Cárcamos Park: *Current Park Value* and *Parks Improvement Value* (Internal Criteria that can be changed by the park management).

Pillar	Current Park Value	Parks Improvement Value
Environmental Pillar	47.7	68.1
Social Pillar	75	87.5
Economic Pillar	49	50
Total value	**57.2**	**68.5**

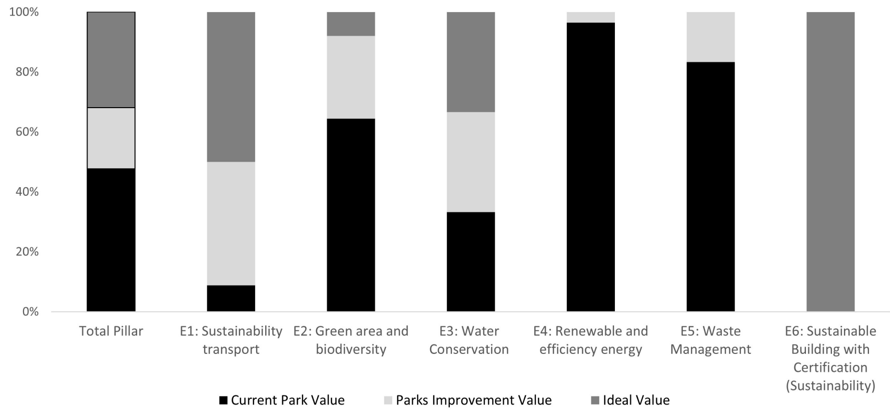

Figure 3. Environmental Pillar. Sustainability value obtained per indicator for the Cárcamos Park, Mexico. *Current Park Value* (Recent Sustainability Value of the Cárcamos Park, Mexico); *Parks Improvement Value* (Percentage of potential improvement considering only internal impacts that can be influenced by park managers); *Ideal Value* (100% sustainability).

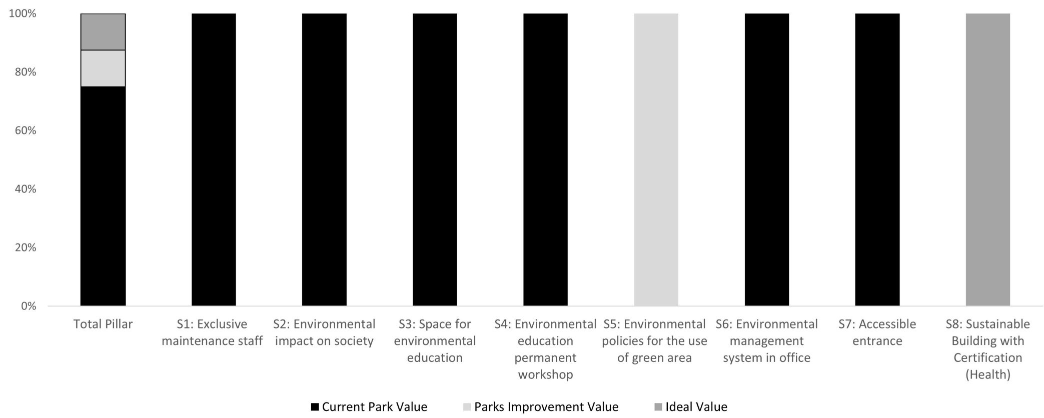

Figure 4. Social Pillar. Sustainability value obtained per indicator for the Cárcamos Park, Mexico. *Current Park Value* (Recent Sustainability Value of the Cárcamos Park, Mexico); *Parks Improvement Value* (Percentage of potential improvement considering only internal impacts that can be influenced by park managers); *Ideal Value* (100% sustainability).

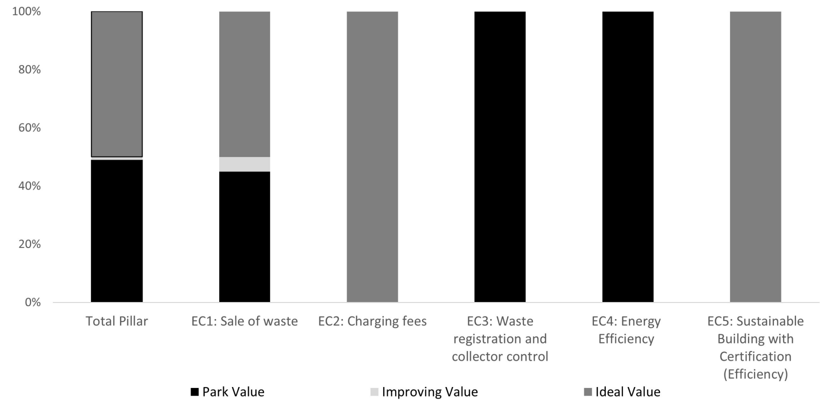

Figure 5. Economical Pillar. Sustainability value obtained per indicator for the Cárcamos Park, Mexico. *Current Park Value* (Recent Sustainability Value of the Cárcamos Park, Mexico); *Parks Improvement Value* (Percentage of potential improvement considering only internal impacts that can be influenced by park managers); *Ideal Value* (100% sustainability).

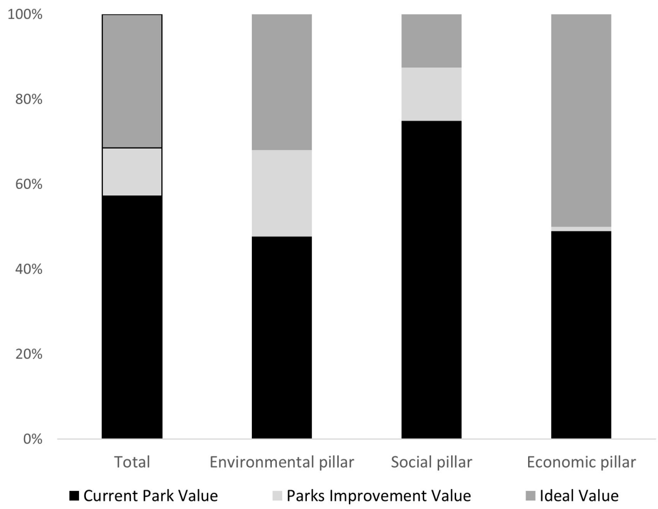

Figure 6. Total Sustainability value and individual sustainability values obtained per pillar for the Cárcamos Park, Mexico.

4. Discussion

Many studies evaluate the perception and satisfaction of urban parks and the experiences and emotions produced within these green spaces, considering the size of the park, the vegetation, convenience infrastructure, perception of natural scenery, conservation of equipment and nature, and the cleanliness of the environment [8,45,46]. While these studies focus mainly on visitor attraction and appreciation of nature, we think that it is equally important to consider parks' contribution to sustainability. Other authors have addressed the issue, attempting to establish the criteria necessary to strike a balance between the essential inputs to the operation of city parks and their benefits: Ávila and Medina [30] for example, analyze different perspectives based on the social-environmental aspects to develop sustainability without including the economic factors. Morales-Cerdas *et al.* [29] applied 11 environmental indicators for urban green areas to determine the environmental conditions as a tool for urban management, disregarding the importance of the park's economy.

Guerrero and Culós [47] applied six criteria that grouped ten indicators at two case study parks in Argentina. The requirements are: reference indicators (area covered by vegetation and sustainable human load), holistic indicators (ecological function and heritage index), cause and effect indicators

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(depredation of the urban park), projecting indicators (tourist demand and projected municipal investment in parks), risk and uncertainty indicators (natural vulnerability and heritage vulnerability), and control and management indicators (Integrated management of the park). Vélez Restrepo [17] shows a conceptual and analytical approach to the sustainability of urban parks and green areas and proposes the construction of a sustainability index based on three principles: 1) ecological functionality with one indicator, 2) economy and environmental management of resources with five indicators and 3) social functionality with three indicators. The main difference to our research is that Vélez Restrepo [17] only uses 9 indicators, which in our view are too abstract and superficial, making it almost impossible for park managers to use them to determine the park's sustainability index and to clearly identify its areas of opportunity.

Instead, our methodology takes into account three pillars: Environmental Pillar, Social Pillar and Economic Pillar, each being given equal importance as all three pillars play an important role in the management of parks. City parks are usually dependent on the governmental budget, which can be very limited. Undoubtedly, economic self-sufficiency can be achieved, for example, through the application of circular economy strategies: Stahel [48] or Geisendorf and Pietrulla [49]. We have included these strategies in our methodology and park managers can use it as a guide to become more sustainable not only from an environmental and social perspective, but also from a financial perspective. It is essential that progressive urban park management considers and maintains a balance between these three global pillars. This balance, embedded within an easy to apply proposal that guides through the necessary operational data represented by our operational criteria (and *additional data*), was not considered in the reviewed papers.

Our proposal includes 19 indicators and 50 criteria and 18 additional data representing easy to collect data from the park management (see Table 1). We include data that is not considered by other researchers:

1. The means of transport for employees must be taken into account. If employees come to the park by car, this has a negative effect on the sustainability index. If they arrive instead on foot, by bike or by public transport, the impact on sustainability would be positive.
2. We include waste management. We think it is vital that a sustainable park offers visitors a waste separation infrastructure and a waste collection center. Organic waste may end up in the compost serving as fertilizer for the parks greenery areas. Other waste like metal or PET can be sold and help to improve the parks economy.
3. A sustainable park needs environmental policies that give instructions for the use of green areas. Policies for saving water and energy are necessary and encourage the sustainable behavior of park visitors and employees and are beneficial for the sustainable development of the park ([50,51].
4. Another critical area of sustainability is energy efficiency. Here we must consider the use of a) Renewable energies such as sun, wind or biomass, and b) Illumination in the park, green spaces and offices. The energy consumption caused by the illumination is an important issue for a sustainable approach [52].
5. Our methodology includes the level of biodiversity as an indicator to define the sustainability of a park. The reason is that even small green spaces such as parks can include biodiversity if they provide water bodies (ponds or lakes) and green spaces nearby, creating a natural green space network [53].
6. We include the proportions of native and exotics species and their health conditions since local healthy species have to be favored [37]. Identifying tree species is a relatively easy task, that can be accomplished by an observant park employee as the trees remain visibly in place.
7. Our methodology also integrates the maintenance workforce and the environmental impact on society through environmental education, as well as the fact that city parks can help reduce crime in their sphere of influence [54].

8. Our proposal includes information on the space occupied by buildings or parking facilities which have a negative impact since they reduce the permeable area, increase waste generation, and raise energy consumption [55].
9. Our proposal includes the sustainability status of buildings inside the park. Buildings with a green building certification or rating tools lead to environmental, economic and social benefits, due to their sustainable construction materials and energy efficiency [39,43].
10. Our methodology considers the economic aspects separately from the social and environmental aspects, seeking economic self-sufficiency from the services that the park can provide to the citizens, not only by saving money efficiently but also by generating money from selling recyclable waste collected and separated at a collection center inside the park, offering workshops and renting space inside the park.

Sturiale and Scuderi [56] merge the economic and social aspects to "Eco-social". They consider the dimensions of sustainable development to contribute to promoting a governance model for the city called "eco-social-green". Certainly, the economic and the social aspects are strongly related in some points. For example Cárcamos park does not generate any economic resources from the visitors, since no fees are charged inside the park. For this reason, the Current Park Value generation of financial help from the *Charging fees* (EC2) is zero. It is essential to mention that for example a low entrance fee means, on the one hand, a low economic value but, on the other hand, a high social value, since access to the park is facilitated to everyone, regardless of their financial income and therefore favoring everyone's well-being. The same applies to fees charged for workshops or space offered by the park.

It must also be mentioned that the size of a park and its density of tree cover positively impact visitors' perception and promote more visits [45]. Larger urban parks receive more visitors than smaller parks, and the size is more important than the distance a park visitor has to travel to get to the park. The fact that larger parks attract more visitors, regardless of distance, could be detrimental to sustainability given emissions from traffic. Therefore, a minimum green surface area of the park, as well as the surrounding infrastructure, including the park's connection to public transport and bicycle lines, should be regarded [57].

In 2020 Cárcamos Park received an average of 171 visitors per day, considering only seven months after its opening because of the COVID-19 Pandemic. Our methodology does not include the number of visitors per day since the number itself is of little importance. More important is how those visitors get to the park without contaminating, what services (recycling center or educational programs) they use, and what they learn from their visit and their behaviour inside the park.

Urban parks help to conserve the local biodiversity and can be home to wildlife [58]. Besides the simple distinction between native and exotic plant species, our methodology does not include any distinction of wild animals such as birds, rodents, or amphibians which could be of interest for the sustainability of urban parks, as mentioned in [59]. The reason for this is that our methodology tries to be applicable for any park worker, and this distinction would involve a detailed biological research, elaborated by external experts, since animals move or hide and may be difficult to find or identify, especially when its about insects.

Dizdaroglu [31] considers healthy food as a indicator for sustainable parks. At this state, our methodology does not include the offer, consumption or promotion of healthy food, since our focus includes general sustainable data leading to the parks resilience. However this aspect might be considered and be included in the future.

During the analysis of the case study, potential avenues were identified to be developed and included in the database. A future method may include:

- more transport indicators, i.e., how visitors arrive at the park,
- the human carrying capacity, i.e., how many visitors the park can support to remain in balance.

This article presents a new methodology that is easy to apply by any park manager to parks of any size. The goal is to assign the grade of sustainability and show new ecologic, social and economic areas of opportunities of the park. This methodology is balanced as it gives equal weight to the three

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pillars of sustainability: environmental, economic, and social. Its application can identify the strengths and weaknesses of a park's sustainability. The method emerges from a detailed analysis of the park's operations and incorporates criteria and indicators that have allowed us to assign measurable values and measure sustainability quantitatively. This will facilitate park administrators making the right decisions in the future.

5. Conclusions

This article presents a low-cost and comprehensive methodology for efficiently and effectively measuring the sustainability of urban parks. It is based on three global pillars of sustainability to describe the overall conditions of the park: Environmental, Social, and Economic. Within these three pillars we defined 19 indicators with 50 criteria which allow the generation of an all-round database including the operational data of any urban park that is important for the definitions of its grade of sustainability. Our method allows to identify operational conditions or criteria as part of the operation, that can have a positive or negative impact on the sustainability of the park. Plain language and non-technical units for the required data allow any park manager to understand, complement and apply our methodology.

A park management that uses our methodology, has to collect the data for 50 operational criteria and 18 additional data; any responsible park employee creates a functional and usable database. This database is considered an essential and concrete tool that can be applied to any park. The applicability was proved by applying our methodology to Cárcamos Park in Leon, Mexico. This park, resulted in a final sustainability score of 57.2%, which is medium sustainability presented in the range 51% to 79%. A final score with less than 51% would mean low or no sustainability and more than 79% signifies high sustainability, see Table 2.

In a future step, the database can be automated so that users only upload the information, and the results are generated automatically in the form of diagrams and tables which enables easy comparison of the results of different parks. In the future, the methodology might be used in an Urban Park Ranking that is available on a digital platform, where directors of urban parks might upload their data. The platform will allow the comparison of the different results and the possibility of interaction between the participants will help to improve one's ranking.

The methodology presented here offers a simple and comprehensive approach to determine the sustainability level of urban parks by collecting all-encompassing comprehensive data. The results of the study demonstrate the validity of the method, as evidenced by its successful application to our case study, Cárcamos Park in Leon, Mexico. Therefore, the proposed approach serves as a reliable tool to assess the sustainability status of city parks, facilitating an understanding of their current state and identifying areas for improvement.

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Abbreviations

The following abbreviations are used in this manuscript:

Ex	Indicator of the Environmental Pillar, where x stands for the number of the particular indicator (E1-E6)
Sx	Indicator of the Social Pillar, where x stands for the number of the particular indicator (S1-S8)
ECx	Indicator of the Economic Pillar, where x stands for the number of the particular indicator (EC1-EC5)
e+	External dependency with positive impact
e-	External dependency with negative impact
i+	Internal dependency with positive impact
i-	Internal dependency with positive impact
LED	light emitting diode
PET	Polyethylene terephthalate
MDPI	Multidisciplinary Digital Publishing Institute
INEGI	National Institute of Statistic and Geography (Instituto Nacional de Estadística y Geografía)

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