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Abstract: The location of Electric Vehicle Charging Stations (EVCSs) is gaining significant importance as part of the conversion to a full-electric vehicle fleet. Positive or negative impacts can be generated mainly based on the quality of service offered to customers and operational efficiency, also potentially involving the electrical grid to which the EVCSs are connected. The EVCS location problem requires an in-depth and comprehensive analysis of geographical, market, urban planning, and operational aspects that can lead to several potential alternatives to be evaluated with respect to a defined number of features. This paper discusses the possible use of a multi-criteria decision-making approach, considering the differences between multi-objective decision making (MODM) and multi-attribute decision-making (MADM), to address the EVCS location problem. The conceptual evaluation leads to the conclusion that the MADM approach is more suitable than MODM for the specific problem. The identification of suitable attributes and related features is then carried out based on a systematic literature review. For each attribute, the relative importance of the features is obtained by considering the occurrence and the dedicated weights. The results provide the identification of the most used attributes and the categorization of the selected features to shape the proposed MADM framework for the location of the electric vehicle charging infrastructure.

Keywords: multi-attribute decision-making; criteria; attributes; features; electric vehicle; charging station; siting

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1. Introduction

The environmental commitment is leading towards the progressive reconversion of the vehicle fleet from conventional Internal Combustion Engines (ICEs) to Electric Vehicles (EVs). The need to reduce vehicle-related CO_2 emissions is forcing the acceleration of the electrification process of circulating vehicles. The benefits can be observed by reducing the global emissions due to transportation from 19% to 33% [1]. The electrification process relating to the vehicle fleet used for public transport is more incentivized and supported, and charging solutions can be designed on purpose and easily installed inside hubs and maintenance depots. However, the situation is different for private vehicles based on their unique concerns. The need for a widespread charging infrastructure strongly influences the EV diffusion level. To ensure e-mobility to take place and develop, the charging needs must be satisfied in every condition, assisting an increase in the EV market. For advancing EV diffusion, the charging infrastructure must be available in terms of capillary diffusion. An acceptable EV penetration is generally accompanied by a satisfactory penetration of EV charging infrastructure, thus enabling charging operations for EV owners and drivers [2].

Moreover, more widespread EV charging infrastructure helps reduce the anxiety drivers experience with respect to the EV driving distance range. Therefore, the location of Electric Vehicle Charging Stations (EVCSs) nowadays represents a constraint for the diffusion of EVs, but also an opportunity for market share and competitors. EVCS location may be considered as a technical problem, searching for the most appropriate solutions in grids with photovoltaic and battery storage systems, from distribution systems [3] to micro-grids [4]. Considering the spatial target of EV charging, specific solutions can be studied for different cases of residential communities [5], cities and urban areas [6,7], highways [8], and regional areas of a country [9]. The present work aims to consider the EVCS location problem as the main topic of interest and is based on an overview of the scientific literature. The location of EVCS infrastructures is addressed as a preliminary step to create and design a geo-localization tool that aims to select the eligible location among an initial set of alternatives for the installation of EVCSs for a Charging Point Operator (CPO). The methodological approach followed herein addresses the EVCS location problem from the multi-criteria decision-making (MCDM) point of view. In particular, this paper presents the following:

- The first novelty of this work consists of the conceptual categorization of the criteria, tailored to the EVCS location problem considered, based on the results actually available in the scientific literature regarding this subject. Starting with the categorization results and from the attributes that refer to each criterion, a numerical assessment regarding the importance of the attributes is performed, with the aim of identifying the most relevant attributes that can be considered to assist the decision maker in the choice of the most suitable EVCS location. The numerical assessment is shaped through the computation of appearances and weights for each study contribution considered, whose results are aggregated into two separate matrices. This method is exploited not only to quantify and evaluate the distribution of criteria in the literature, but also to extrapolate which attributes are predominantly considered, thus establishing a hierarchical order.
- The second novelty of this paper is the release of the ranking of the most relevant attributes, which can be considered as a basis for the implementation of EVCS location tools to guide the decision makers towards consistent attribute-driven choices. Moreover, this aims to constitute a standard framework of criteria to be implemented in the future for further research projects regarding the EVCS location problem. Therefore, a common basis can ensure direct comparisons between different solutions and approaches.
- The greatest challenge in the application of this approach is the need to deal with the highly fragmented and non-homogeneous background that is fundamentally related to the scopes and achievements expressed by each study contribution, together with the different focus points set by different authors on the types of attributes and the assignment of weights. Different points of view addressed in the literature, i.e., the cases seen from the perspective of stakeholders or policy-makers that are not always clearly stated, and a variable framework of criteria among the papers considered make the research context uneven. If not handled and addressed correctly, all these aspects can lead to meaningless final judgements.

The first aspect is the identification of the most suitable MCDM method to apply. The related discussion is presented in Section 2, underlining advantages and drawbacks of the different options and indicating the preferred solution. Then, based on a systematic literature review, the most recurring criteria are identified and rearranged to create the novel framework of the proposed criteria illustrated in Section 3. The new categorization is provided in Section 4 with a focus on the relative relationships and importance assigned within the literature references examined. Then main achievements of this study are summarized with the final conclusions. Figure 1 clarifies the process followed in the implementation of this paper.

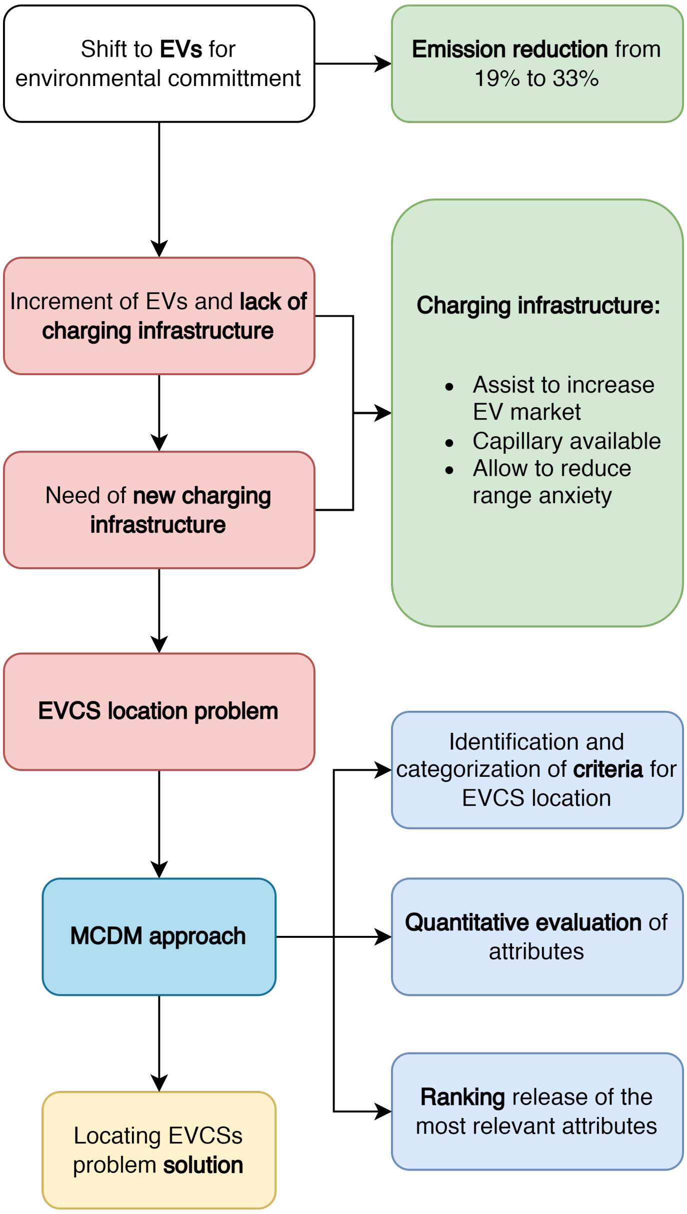


Figure 1. Locating EVCS problem roadmap.

2. Multi-Criteria Decision-Making Approaches

2.1. Overall View on Multi-Criteria Decision-Making

Multi-criteria decision-making problems have the general purpose of the identification of the preferred solution, which satisfies the decision maker's preferences. It is worth noting that in this conceptual framework, it is not possible to find an optimal solution, because this would imply that such a solution would present the best option in all the criteria considered and thus with no conflicts among them. Conversely, in the multi-criteria framework, this choice is made in the presence of conflicting information, which would lead to choosing a different solution depending on the prevalent feature considered. Hence, the choice of the preferred solution implies a comparison among different alternatives that can be either predetermined as the input of the problem or must be created from scratch by applying an appropriate methodology. This difference leads to the identification of two families of MCDM problems [10]:

- In the case of an initial set of a predefined number of alternatives, one has to "simply" select the most preferred one among those that compose an initial set; this case falls into a multi-attribute decision-making (MADM) problem.

- When MCDM methods are used to create the best solution (through, for example, an optimization method in a design process), the case falls into a multi-objective decision-making (MODM) problem.

Some common elements can be identified:

- Multiple attributes/objectives, representing the features that characterize the alternatives. In general terms, attributes/objectives can be called criteria. Relevant criteria must be adapted to the problem under analysis.
- Existence of conflict among the criteria. This means that no alternative is the best for all criteria.
- Different natures of the criteria: some of them can be numerical while some of them can be expressions (better, worse, higher, lower, and so on), which should eventually be translated into numerical terms. This aspect is much more relevant in MADM than in MODM, because the latter is usually based on a set of quantitative objectives and constraints rather than qualitative, as they better suit the design purpose.

Moreover, by definition, beyond the preferred and the optimal solutions, one can identify the following:

- *An ideal solution*: This is also called the *utopia point* and represents the solution characterized by the optimal values for all the objectives. This solution is unfeasible because of the conflicting nature of the criteria considered.
- *Non-dominated solutions*: These are also called *Pareto optimal* solutions. A solution α is non-dominated if and only if there is no other solution β improving at least one criterion with respect to the solution α without degrading at least another criterion. Being non-dominated is necessary (but not sufficient) for the preferred solution.
- *Satisfactory solutions*: Also called *compromise solutions*, these form a subset of the non-dominated solutions. They somehow exceed the acceptable level for all the criteria. The preferred solution is taken from this set of solutions.

The MCDM conceptual framework also allows us to include approaches based on decision theory: in this case, the criteria used to compare the alternatives are scenarios, and the application of decision theory approaches allows us to understand which alternative is more convenient. The scenarios are weighted with subjective weights or objective weights determined through the scenario occurrence probability or other mathematical elaborations based, for example, on the information entropy, or by combining subjective and objective weights [11]. The scenarios are built by including the potential evolution/modification of the boundary conditions (e.g., over a multi-year horizon) that can affect the values of attributes/objectives. Concerning the solution methods for MODM, depending on the nature of the problem and the variables involved, different approaches can be used, for example, as follows:

- *Multi-Objective Linear Programming* (MOLP): If the problem can be formulated in a linear optimization framework, the solution can be found by using linear programming, which guarantees convergence to the global optimum.
- *Evolutionary Multi-Objective Optimization* (EMO): when the computation times become prohibitive, the set of non-dominated solutions is approximated by using evolutionary algorithms that start with an initial set of solutions and improve these solutions iteratively until converging to a solution that becomes stable for a successive number of iterations.

2.2. Why Opt for Multi-Attribute Approaches?

The choice between MODM and MADM is essentially linked to the available information and the simulation approach, in particular, the presence of non-numerical attributes [12] and the identification of proper modelling approaches for social impact. In the presence of non-numerical attributes, the integration of the attributes within an optimization procedure is not straightforward: it is required to use proper scales to translate the non-numerical attributes into a quantitative numerical form. The evaluation of the impacts of some attributes (for example, the existence of a point of particular interest, such as malls or museums) may require complex simulation approaches referring to social aspects and human behaviour, which are only partially implementable and would require the creation of numerous customer profiles that can only be built with a large amount of detailed information.

In particular, the aspect of social simulation aspect constitutes the main obstacle to MODM implementation. Hence, the approach used by MADM essentially avoids providing a direct evaluation of the impact and allows for providing a relative comparison among different alternatives based on the available elements. For example, the presence of points of interest will not be evaluated by indicating the increase in number of accesses per hour, but instead, it will provide the information that the presence of a mall could impact much more than the presence of a museum because the use of cars is more common in the former case than in the latter one. Table 1 summarizes the elements to be considered when choosing the most appropriate approach, providing some brief notes for each element.

Table 1. Summary of MODM vs. MADM.

Characteristics	MODM	MADM	MADM Examples for EVCSs
Easy inclusion of non-numerical attributes	NO: A mathematical formulation is required	YES: Appropriate scales do exist	Providing the judgement by the DM in relation to the impact of different points of interest: the presence of a mall could have more of an impact compared to the presence of a museum because the use of cars is more common in the former case than in the latter one
Easy inclusion of potential mutual interactions of the features	NO: It is necessary for all the interactions in the model to be explicit	YES: If a feature has influence on another, it can be considered through appropriate weighting	Government support and installation permits are somehow linked together; they cover the question "how easy is it to do this business in this particular area of this particular country?"
Data required	Usually not negligible, either for validation of new model, or tuning of parameters	The amount of data required depends on the models developed to give the value of the attributes. In absence of data, the decision maker can make hypothesis to make a comparison among alternatives, enabling a successive sensitivity analysis	The evaluation of the impacts of some attributes (for example, the existence of point of particular interest, such as malls or museums) may require complex simulation approaches referring to social aspects and human behaviour, which are only partially implementable and would require the creation of numerous customer profiles that can be built only with a large amount of detailed information. The use of MADM would reduce the amount of data required (see the first item in this table)
Model updating	The update of the model is constrained by the number and types of state variables and on the optimization method	The framework is usually easy to modify, with some exceptions	The addition of one or more alternatives does not change the entire mathematical formulation (as instead may happen with optimization methods), even though the impact of the reversal ranking must be evaluated
Normalization	Depending on the method	Included as part of the procedures	-

2.3. Choice and Implementation of the MADM Method for EVCS Location

As shown in Table 1, the choice of MADM with respect to the MODM approach is ultimately linked to five elements, all of them favouring MADM compared to MODM. In fact, the following pointa were uncovered:

1. MADM methods allow the decision maker to use non-numerical attributes. Conversely, MODM approaches do not.

2. Mutual interactions among the features can be taken into account (even without formulating a model that links them together) through adequate weighting in MADM methods. As an example, government support and installation permits are somehow linked to each other (they are the features covering "how easy is it to do this business in this particular area of this particular country?"). The decision maker can provide weights whose sum represents how important the policy aspect is for him/her, without any model linking these two aspects. In MODM approaches, it would be quite complex to account for these interactions.
3. Without accurate and trustable data, MODM approaches are not suggested (because parameter tuning and the validation of new introduced models require a huge amount of "good enough" data).
4. The introduction of new features and the consequent updating of the model is usually simple with MADM approaches, while it is more difficult for MODM methods. In fact, introducing new features may involve the introduction of new state variables that must be included in the overall formulation. This limits the flexibility of use.
5. Data normalization is naturally included (and tested) in MADM methods, while it is truly "method-dependent" in the case of MODM optimization methods (i.e., it is an additional aspect to include).

In conclusion, (i) when all the features may be represented with a mathematical formulation, (ii) when it is not of interest to catch mutual interaction among features, and (iii) when the data (quantity and consistency) are enough for validating the model and tuning parameters, a MODM approach may be a viable option (even though the normalization and model update aspects must be carefully considered). Otherwise, MADM methods are the suggested choice. For EVCS location, there is a variety of features with possible mutual interactions, some of which are expressed in a categorical or qualitative way. Moreover, availability of enough data from the field cannot be guaranteed, and some choices need to be made by the data analyst. On these bases, adopting the MADM approach is suggested.

3. Proposed MADM Scheme

The MADM problem can be formalized in terms of the useful attributes found during the review of the scientific literature. To identify relevant case studies on the EVCS location problem, a systematic literature search was conducted using the main indexed databases. It was necessary to identify all studies that had as one of their objectives the EVCS location based on each attribute and characteristic. These studies were then combined with the results of the MCDM approach searches. Articles were considered based on their relevance and impact, excluding any publication that could not provide sufficient data on the EVCS location methodology. Publications that were outdated and those that were not peer-reviewed were also excluded. It was considered that studies more than 10 years old may not accurately represent the current problem. This filtering process resulted in a set of 43 scientific articles that helped to define categories, attributes and features. In this way, the selected studies were analysed to identify the most recurring attributes and features used to locate the EVCS. The attributes were coded and classified according to their frequency of occurrence and assigned weights. This analysis made it possible to determine the relative importance of each attribute and feature in the context of EVCS location. Since each scientific paper customizes the attribute classification (based on the purposes of their own analysis of the problem), it is worth reorganizing the attributes according to a novel scheme that better suits the purposes of the analysis. The new classification scheme is built according to a three-level arrangement, represented in a synoptic form in Table 2. The columns show the following data:

1. *Attribute category*: This identifies the macro-sector fields and includes all attribute subcategories. The most recurring and interesting attribute categories are the following:
    (a) Economic;
    (b) Territorial;

   (c) Social;
   (d) Technical.
2. *Attribute subcategory*: This highlights a particular aspect of the category to which it belongs. Each subcategory includes one or more attributes that complement and satisfy the meaning of the targeted aspect (for a total of 11 attribute subcategories).
3. *Output attributes* (forming the proposed classification): Starting from several basic attributes considered relevant with respect to the purposes of the EVCS location problem, along with other interesting attributes to be considered, the basic attributes have been grouped into 24 output attributes. Each category is described below by relating it to the basic attributes.

Table 2. Proposal of the new attribute framework.

Attribute Category	Attribute Subcategory	Basic Attributes	Output Attribute
Economic	Cost	Construction cost; Total Construction cost; Land occupation; Power grid connection costs; Equipment purchasing costs	Installation costs
		O&M costs	O&M costs
		Update/Removal costs	Update and removal costs
	Benefit	Annual profits; Solar energy potential/Renewable resources; Alternative revenue sources	Revenues
	Policy	Installation permits	Installation permits
		Incentives; Local government support; Maturity of the legal framework to implement tenders	Government support
Territorial	Traffic	Traffic convenience; Traffic condition	Traffic flow
		Road patency/topography; Slope; Number of roads; Main number of roads; Roads; Accessibility of the site	Road network characteristics
		Presence (and type) of EVCS (public/private); Public facilities; Coordination with the transportation network; Parking lots; Public transport; Hubs; More interaction with other infrastructures	Interactions with other infrastructures
	Geography	Service radius ("green" field)	Service radius
		Spatial coordination with urban development planning; Urban development	Urban development
		Terrain advantage; Heatwave zone; Flooding zone; Landslide zone; Earthquake zone; Forest; Soil type; Availability; Utilization	Land
	Environmental	Dismantling waste; Easiness of re-establishment in the future; Recycling	End of life management
		Sustainable development of charging station areas; Ecological influence; Destruction of soil, vegetation and landscape; Destruction of water resources	Territory sustainability
		Global emissions; Local pollutants/noise reduction; Air quality	Emissions
Social	Collective	Acceptability of new solutions; Adverse impact on people's lives; Improvement of employment; Benefits for people life	Impact on people's lives
		Population density; Population intensity; (Local) Number of vehicles; (Local) Number of EVs; (Local) EV sales; Residents' average income	Demographic information
		Social areas; Fuel station proximity	Points of interest
	Personal	Driver comfort; Home/private charging vs. public charging; ICE vs. BEV	User preferences

Table 2. *Cont.*

Attribute Category	Attribute Subcategory	Basic Attributes	Output Attribute
Technical	Grid side	Power and energy management; Power quality; Harmonic pollution on power grid; Impact on load levels of power grid; Impact on voltage; Power grid security implications; Consumption level; Electromagnetic interference; Level of penetration of RES	Grid operation
		Power supply capacity of transmission and distribution systems; Distance to the substation; Substation; Substation capacity permits; Substation capacity; Power grid capacity	Grid planning
	User side	Further services to drivers; Charging services; Fast-charge ratio	Charging station services
	EVCS side	Possibility of EVCS capacity expansion in the future	EVCS planning
		Safety/Security and ability to tackle with the emergency; Reliability; Charging station capacity; Service capability/service capacity	EVCS operation and reliability

3.1. Category 1: Economic Attributes

The first category considers the economic aspects, directly or indirectly related to investments, construction and policy framework. It is divided into three subcategories: (i) costs, (ii) benefits, and (iii) policy.

3.1.1. Cost Subcategory

This subcategory takes into account some output attributes such as the installation costs, the operation and maintenance (O&M) costs, and the update and removal costs. The installation costs include the following basic attributes found in the literature:

- Construction cost: This includes land cost, demolition cost, equipment acquisition cost, and project investment cost [13–15]. In [16], the following items are listed: land lease or acquisition costs, survey and design costs, infrastructure construction costs, equipment and tool purchase costs, construction management and production costs, and project capital costs. Moreover, ref. [17] lists the following items: land acquisition costs, demolition costs, transportation costs, and auxiliary facilities costs.
- Equipment purchasing cost: In [18], this cost is reported with reference to a Battery Swapping Station (BSS) and is explained as the initial equipment acquisition cost during the construction of BSS. This concept is generalized for the equipment required for the EVCS construction.
- Land occupation cost: Considering BSS, it is described in [18] as the land that the Battery Swapping Station needs to occupy in order to store the battery, which will affect the cost and economic benefit.
- Power grid connection cost: The cost sustained for the connection of the EVCS to the power grid (Table 3). In [19], this cost depends on the distance of the charging station from the point of connection to the electric grid, as well as on the connection technology, assuming that the EVCS is directly connected to the electrical substation via a dedicated overhead line.
- Total construction cost: When no detailed description of the construction cost is available, often the total construction cost attribute is instead used, considering different aspects. These can refer to the equipment purchasing cost, land occupation cost, and power grid connection cost attributes explained above. The O&M costs include aspects such as the electricity charge, staff wages, financial expenses, taxes, battery depreciation, and so on [13–15]. The daily maintenance cost of machinery is also indicated in [15]. In [16], the operation and maintenance costs include personnel salaries, employee benefits, daily operation and maintenance, equipment depreciation, and business costs. The update and removal costs group the costs related to the

expected price of the surrounding land in the future and the fixed cost of the targeted EVCS site [17]. Higher update and removal costs mean that it would be more difficult to change the intended destination of use of the site.

Table 3. An example of investment and operating costs of EVCSs [20].

Economic Data	Unit	2 × 22 kW AC Charging Station	2 × 22 kW DC Charging Station
Equipment costs	[€]	5000	25,000
Grid connection costs	[€]	2000	5000
Authorization and planning costs	[€]	1000	1500
Installation and building costs	[€]	2000	3500
Total investment cost	[€]	10,000	35,000
Operating costs	[€/y]	1500	3000

3.1.2. Benefit Subcategory

The benefit subcategory considers all the possibilities to account for earnings and revenues related to the operation of the EVCS. It includes the revenues that can be broken down through the following basic attributes:

- *Annual profits*: Defined in [15] as the future revenues of the EVCS without an analytical expression, this basic attribute refers to the profits derived directly from charging operations.
- *Alternate revenue sources*: Proposed in [21], this is related to the capability of a location to profit from non-power sales such as advertising, participation in grid dispatching, and renewable energy generation. An additional example can be represented by the possibility to integrate different mobility solutions according to the needs to be charged, such as parking spot payment while charging the EV through a shared information technology platform. Another possible revenue source can be represented by solar energy potential related to Renewable Energy Sources (RESs). RESs can be exploited as an opportunity for implementing and feeding the power grid through a sustainable energy production network [22]. In particular, a practical example may indeed refer to the possibility of installing an RES production plant in areas suitable for selling the energy produced on the market.

3.1.3. Policy Subcategory

The policy subcategory considers all the issues that may arise facing the bureaucracy of a country to locate one or more EVCS. In particular, it reflects the actual legal conditions that may or may not allow for the installation of an EVCS in a given location. This subcategory encompasses two output attributes. The first one is the installation permit output attribute, including the necessary authorizations and approval procedures as strong factors for selecting a project. In addition to the licensing procedures for the charging station installation, construction approvals may be required depending on the space ownership and type [20]. This strongly depends on the legal framework of the country. The second output attribute is the government support, which is mostly related to the legal framework existing in the eligible location of installation for an EVCS and includes the following basic attributes:

- *Incentives* (or subsidies to increase the EV fleet): The adoption of measures, either financial incentives for EV purchase or non-financial traffic incentives for EVs, or tax exemptions and subsidies for charging infrastructure, all play a positive effect on the promotion of e-mobility, especially at the early stage of the market, when the economic viability of investments in charging infrastructure is uncertain [20].
- *Maturity of the legal framework to implement tenders*: In the case of developing public charging points through open tenders held by a municipality, the limited experience

for the implementation may adversely affect the interest in the charging infrastructure market [20].

- *Local government support*: This basic attribute includes the subsidy policy, favourable prices, and tax preferences, which are established to strongly promote the development of EVs [23]. Most of these aspects have already been reported in the attribute incentives and maturity of the legal framework. The EVCS project has a large initial investment cost and a long payback period, which is highly vulnerable to the influence of government policies [24]. Specifically speaking, the approval of construction land, the upgrading and transformation of the distribution network, the implementation of the subsidy policy, and the traffic planning in the vicinity of the EVCS all need government support. Currently, green policies are meant to be discussed and approved to push towards an electric conversion of mobility. Hence, the attitude of local government support is one of the indicators that must be considered.

3.1.4. Cost Functions

To provide some quantitative values, we refer to interesting analytical relations reported in [20] about the infrastructure costs; these are classified in investment costs, fixed operating costs, and variable operating costs. Investment costs concern equipment ownership and installation, grid connection, and licensing expenditures. In [20], the values reported in Table 8 of that paper are taken as reference, even though the authors stated that they "*are not precise cost figures but provide a clear picture of the economic parameters that serve this study to highlight the cost differences between the two technological options*".

Almost all the papers contain a description of economic objectives without any analytical expression; an exception is [25], which reports an equation for the calculation of the costs of an EVCS. They consider V types of EV charging stations, Q cells and U EV charging units. An optimization problem is set up, in which the decision variables are x_{quv} (binary variables, equal to 1 if a charging station of type v is located in cell q with u charging units). The objective function is the total cost (intended as all the necessary costs of building a refuelling station). Let c_{qv} denote the cost of locating a new charging station of type v in cell q with one charging unit; the cost of constructing a new station with h charging points is $h^{\delta}c_{qv}$, where the exponent δ (with $0 < \delta < 1$) refers to the rate of cost increase as capacity options rise. The value of δ is less than unity because of the economies of scale for constructing a station. The construction cost saved by a gas station-based location is denoted by ϵ. The 0–1 parameter b_q is used to describe the existing gas station network. The total costs is thus determined:

$$C_T = \sum_{q=1}^{Q}\sum_{v=1}^{V}\sum_{u=1}^{U}(h^{\delta}c_{qv} - \epsilon b_q)x_{quv} \tag{1}$$

Another reference that reports analytical expressions for cost determination is [26]. The total cost in [26] is the sum of the annual construction cost of the charging station, the annual O&M expense (including worker wage, maintenance expense, equipment depreciation expense, and electricity purchase expense) and operation expense of charging stations, and the wastage cost in the process of user charging (containing direct and indirect costs). Also, ref. [19] includes some analytical expressions, which are reported below. The "Station development cost" is the sum of the station equipment cost and land cost. The equipment cost is assumed to vary linearly with the station capacity, which is itself a function of the number and capacity of the connectors installed in the station [19]. For station e, the development cost DC_e is then calculated as

$$DC_e = C_{init} + 25C_{land}NC_e + P_C C_{con}(NC_e - 1) \tag{2}$$

where P_C is the single EVCS connection rate power (in kW). In the EVCS, more than one connection may exist. C_{con} is the connection development cost (in USD/kW or EUR/kW); C_{init} (in USD or EUR) is the EVCS fixed cost (i.e., the cost associated with basic equipment and facilities used to establish a charging station); C_{land} is the land rental cost (in this case, for 5 years); and NC_e is the number of connectors in the EVCS; hence, the capacity of the e-th EVCS is calculated as $P_{EVCS} = P_C NC_e$. The station electrification cost depends on the distance of the station from the point of connection to the electric grid, as well as the connection technology. It is assumed that the station is directly connected to the substation via a dedicated overhead line. The electrification cost of the e-th EVCS to the closest substation by a line with a given cross-section $A_e^{(line)}$ in [mm^2] is [19]

$$C_e^{(EL)} = \left(8000 + 65.7 A_e^{(line)}\right) l_e^{(line)} \tag{3}$$

where $l_e^{(line)}$ is the length of the line from the substation.

3.2. Category 2: Territorial Attributes

The second category of attributes considered is territorial. This category focuses on all aspects involving environmental variables, from the surrounding nature to the human activities. The identified subcategories are (i) traffic, (ii) geography, and (iii) environment.

3.2.1. Traffic Subcategory

It is strictly important to evaluate the traffic to decide where to locate an EVCS, since charging needs depend on traffic volumes. Furthermore, the physical characteristics of roads influence the traffic volumes—let us think about a large high-speed road rather than a narrow low-speed limited road. The location of the EVCS must also take into account the possibility of the potential interactions with other networks like public transport. In this way, intermodal e-mobility can be enhanced, accelerating the change in transport habits and mobility. Therefore, this subcategory considers the following output attributes: traffic flow, road network characteristics, and interactions with other infrastructures. Traffic flow consists of two very similar basic attributes:

- *Traffic convenience*: This refers to the number of main roads surrounding the targeted EVCS site, the level of traffic flow, and possibility of traffic jams. Convenient traffic implies that more consumers would be willing to use the targeted EVCS site and there would be higher potential customers [17]. In [27], this basic attribute is evaluated as the number of intersections within 5 km from site location.
- *Traffic conditions*: This is seldom defined as the actual distance between two adjacent EVCSs [15]. However, it can refer to the actual traffic criticalities being present in particular points or zones of the road network, thus giving a starting thumb-rule on identifying the critical points of traffic and hence concerning potential on-route charging demand.

Road network characteristics include all information regarding the roads. This output attribute is particularly interesting in terms of factors involved as basic attributes, since it declines different aspects, like the actual conditions of the road network, their topographic characteristics, and number. Below is the attributes in detail:

- *Road patency/topography*: The "patency" is defined as the average status of maintenance for the road surface. Sometimes, it is also meant to indicate road topography, with superimposition with the slope, the next basic attribute [28].
- *Slope*: It collects the slope of road sections considered within the area eligible to locate an EVCS. The location of an EVCS must avoid sites in which the road slope is high, and it is established that the maximum threshold slope is 7% [29]. Moreover, roads featured by high slopes offer a negative impact for construction and operations [22].
- *Number of roads*: This represents the total number of roads included within the eligible areas considered where to install an EVCS.
- *Main road number*: This defines the total number of main roads present within the considered area, thus neglecting roads of minor importance. It is closely related to the

previous basic attribute traffic conditions. The main difference is that here the number of main roads is taken into account.

- *Roads*: The meaning of this attribute seems to recall what was already seen for the previous road-related attributes. Here, the meaning is centred more on the energy demand depending on the vehicle mobility: the EVCS should be close to high-energy demand due to vehicle mobility [22]. The measure used is the Euclidean Distance.
- *Accessibility of site*: It is mentioned as an attribute in [30,31] without any definition published. It can be easily associated to guarantee an accessible EVCS location to allow for and facilitate charging operations.

Interactions with other infrastructures gather all information regarding the possible interchanges with every kind of transportation-oriented infrastructure. As previously exposed, the aim of this attribute is to create an inter-modal transportation system, thus pushing human behaviour to exploit inter-modality. This attribute is relevant in terms of the following:

- *Presence (and type) of EVCSs* (public/private): Since the location of alternative EVCSs should not be very close to existing EVCSs, the suitability of current EVCSs is examined and a comparison among current EVCSs is made [22]. No distinctions are made referring to EVCS ownership of competitors.
- *Public facilities*: This is mentioned in [28] with no definition given. According to the Collins dictionary, facilities are buildings, pieces of equipment, or services that are provided for a particular purpose. It can represent every kind of public infrastructure available in the eligible areas, i.e., mayor or other public institutions' offices, public network, etc.
- *Coordination with the transportation network*: This is an evaluation of the level of integration of EVCSs with the public transport network [32]. It is based on the availability of an already existing public transportation system near the EVCSs, which is essential when the EV user/driver intends to continue the journey by public transport [32]. Here, the drawback is represented by a transportation network that is too widespread and branched, since it would discourage the use of EVs—and the mobility of private vehicles in general—in favour of public transport.
- *Parking lots*: Since the EV charging time is long, parking lots are suitable EVCS locations [22]. The measure used is the Euclidean Distance. This attribute refers to the achievement of inter-modality in the transportation system. Parking lots are thus a very suitable area to install EVCSs since the vehicles can recharge when parked. Parking lots can also be managed by public transport operators themselves that are located and built in the neighborhood of a public transport line.
- *Public transport*: The measurement of the simplicity of accessing public transport [15]. It can be related to the ease of connection with the public transportation network. This attribute highlights that if the eligible area is close to a public transport service (line, terminal station or stop), the probability that customers will use the EVCS installed will be high. It is strictly linked with the previous attributes, parking lots, coordination with transportation network, and the following hubs basic attribute, since inter-modality is the main concept shared among them.
- *Hubs*: The EVCS should be close to a place with high-energy demand due to vehicle mobility [22]. The measure used is the Euclidean Distance. As previously recalled in the attribute roads, hubs (also called junctions) are meant as interchange spots with transportation services. This helps in increasing the potential charging demand. More interactions with other infrastructures are defined as the coordination with the main artery, inlet and outlet, residential areas, urban main functional areas, and a stable supply of electricity power [14]. This coordination is a benefit. It contributes to assign a high rate to the area considered if a high number of infrastructures of any type are present.

3.2.2. Geography Subcategory

Alongside traffic-related aspects, a relevant field to be analysed is the geography of the sites. This subcategory is more focused on examining the environmental and natural characteristics of the potential sites for locating EVCSs. The focus starts to move outside the urban area and evaluate the environmental impact of the EVCS location on the area. This subcategory considers the following attributes: (i) service radius, (ii) urban development, and (iii) land.

Service radius is expressed as the actual distance between two adjacent EVCSs [15]. This underlines the aspect already considered in the presence (and type) of EVCS (public/private) with an additional value. This attribute focuses on the aspect of the "green field", i.e., on the planning phase of new EVCSs to be added, and therefore, it focuses on areas that are not already reached by a capillary diffusion of EVCSs, thus contributing to increasing the diffusion of CS infrastructure.

Urban development gathers two basic attributes that results in a relationship between the EVCS infrastructure and the urban network. They are as follows:

- *Spatial coordination with urban development planning*: This highlights the integration of the EVCS infrastructure with the spatial development of urban pattern. Thus, the aspect highlighted by this basic attribute is the need of coordination between the charging needs and demand—that is expected to grow—with the expansion or improvement of urban areas [20].
- *Urban development* (or coordinated level of EVCS with urban development planning): This basic attribute gives the name to the corresponding output attribute and is defined as follows: It indicates if the targeted EVCS site satisfies the development planning for the urban electric grid and road network. If the targeted EVCS site is better coordinated with the urban development planning, there is less update and remove risk [17]. In this way, the meaning added by this last attribute goes to complete the global meaning of the output attribute. An EVCS plan coordinated with the urban development results in a less unpleasant impact on the urban pattern.

Land includes all information regarding the geographic characteristics of the areas considered. This output attribute aims to highlight the impact that the environment can have on the proposed location and also evaluates the possible produced drawbacks. Here, risks deriving from land characteristics are taken into account to assess if the location can be considered eligible for the installation of an EVCS. In detail, land is formed by the following basic attributes:

- *Terrain advantage*: It represents the eligibility of the area in terms of potential space to be used and traffic volumes. It is a general evaluation on the area.
- *Flooding risk*: This attribute was not found in the reviewed scientific literature. Since climate-related phenomena are becoming more and more destructive and aggressive on anthropic activities, it is reasonable to consider it. Flooding directly involves the EVCS infrastructure since its effects can heavily interfere with the electrical system. Historic and open-access data publicly available either from research institutes or released by public administration can be a good starting point to establish a rank of alternatives among the sites selected.
- *Heatwave risk*: Similar to the validity of the details for flooding risk, it is important to focus on heatwaves as well. Thermal phenomena can especially influence the underground distribution system, affecting the quality of the service.
- *Landslide risk*: Similar to the flooding risk, it is important to also consider the landslide attitude of the area within the process of selecting the appropriate location to install an EVCS. Landslide can compromise the availability of the EVCS and, in the worst case, can generate damages to the infrastructure. Therefore, the EVCS location must avoid sites in which the risk of landslide is high [29]. Also, here, open-access historic data can help in ranking the alternatives.

- *Earthquake risk*: Similar to the details for landslide risk, earthquakes can compromise the availability of an EVCS infrastructure as well. Therefore, the eligible locations for installing an EVCS must avoid sites in which earthquake events can downgrade the availability of EVCS [22] or damage it in an irreversible way.
- *Forest*: The presence of a forest surrounding the EVCS site location can represent a potential danger for the natural environment. Anthropic activities like construction works can interfere with wild fauna and vegetation and vice versa, undermining the full availability and operation of the EVCS infrastructure. Therefore, the potential location of an EVCS must be far from naturalistic areas, thus avoiding exploitation and interference with the surrounding environment of natural areas [22].
- *Soil type*: This strongly influences construction operations, since further technical aspects must be taken into account in the presence of a non-suitable soil (e.g., foundations, stability of soil type). Therefore, soil type influences the choice of the eligible location for the installation of EVCSs [23].
- *Availability*: With this basic attribute, a focus is set on the resources that are available for the construction phase of an EVCS once the location is selected. A site featured by the good availability of construction water and power should be given priority for the purpose of allowing for a fast construction schedule [23]. This is mainly determined by the nature of land use and intensity of land development [5,33]. Under the same conditions of residential land, different residential communities have different development intensities. With a larger intensity of land development, a greater charging demand is expected. An alternative name for this basic attribute could be a more generic resources distribution [31].
- *Utilization*: This attribute indicates aspects that are directly correlated to the previous attribute. In fact, it gives a measurement of the efficiency of resource utilization during the construction and operation of the EVCS, made by expert evaluation after discussions [16]. It can be classified as a preliminary evaluation of the potential eligible sites.

3.2.3. Environmental Subcategory

Once examined traffic-related and geographic-related aspects, the environmental characteristics of the sites must be considered. Here, the focus is on the environmental impact that all human activities connected to the installation of EVCSs can generate. The following output attributes are gathered: (i) end of life management, (ii) territory sustainability, and (iii) emissions.

End of life management groups all the basic attributes that focus on the future of the area selected to install the EVCS. In this way, the aim is to at most reduce the environmental impact of anthropic interventions. In particular, the basic attributes recurring here are as follows:

- *Dismantling waste*: This measures two fundamental aspects. The first is more related to the operative activities such as the construction garbage and sewage discharged during the EVCS construction, as well as battery disposal during the EVCS operation [14]. This is the most occurring definition given to waste problems. The second aspect that can be added is related to the waste that will be produced in case of dismantling the EVCS from the area. In this way, an accurate choice on the building materials can be set in advance during the preliminary design phase preferring eco-friendly or environmentally low-impacting materials, thus reducing the whole burden of environmental impact related to the dismantling phase.
- *Easiness of re-establishment in the future*: This gives a measurement of the simplicity of generalization and re-establishment of the area [15]. It completes the last aspect of the previous basic attribute since it focuses on the future destiny of the area selected. In this case, the post-business phase is considered.
- *Recycling*: With this basic attribute, the direct environmental impact of the EVCS installation is fully examined. Improving the recovery and utilization rate of resources

is crucial for achieving sustainable development [16]. This is a measure of the resources recovered during the construction and operation phases of the EVCS. It underlines the degree of recycling (or reuse) of the resources available in the area.

Territory sustainability focuses on all aspects that have a role on the destruction and ecological influence on the surrounding environment. Also, here, the aim is to at most reduce the environmental impact of anthropic interventions, joining and completing the target of the previous output attribute. Here, the following are considered:

- *Sustainable development of charging station areas*: This basic attribute focuses on the effects carried out by the presence of EVCSs on both the environment and humans. In particular, the benefits generated on e-mobility by the presence of EVCS infrastructure are reflected in exceeding the cost of financial incentives for new EV acquisition even in an adverse EV penetration scenario [20]. The EVCS infrastructure acts as a flywheel for EV penetration and plays a fundamental role in enhancing EV diffusion.
- *Ecological influence*: This prompts the measurement of "the influence on the flora and fauna surrounding the targeted EVCS site" [17], recalling the details marginally presented for the land attribute.
- *Destruction of soil, vegetation, and landscape*: This basic attribute is one of the most important, as it quantifies the measurement of "the vegetation deterioration due to the land development for building EVCSs" [14]. Sometimes, it is found to also be referred to as the water losses. For this peculiar aspect, it is better to reserve a dedicated basic attribute.
- *Destruction of water resources*: Similar to the previous one, it prompts the measurement of the damage to the surface flow and groundwater system [17].

Emissions is an output attribute that groups all the basic attributes that focus their attention on the future of the area selected for installing the EVCS. In this way, the aim is to at most reduce the environmental impact of anthropic interventions. In particular, the basic attributes recurring here are as follows:

- *Global emissions*: This attribute gives a measurement of the environmental pollutants' emission reduction by using EV rather than ICE vehicles [14]. In this case, the immediate effect carried out by the enhancement of EVs and EVCSs is evaluated as a benefit for citizens.
- *Local pollutant and noise reduction*: ICE vehicles cause significant noise pollution and have an adverse effect on community health. The enhancement of e-mobility contributes to a drastic reduction in noise pollution [20]. This basic attribute provides an additive part with respect to global emissions since it includes the noise reduction factor, which contributes to city life quality improvement.
- *Air quality*: Reducing air pollution is the biggest motivation for the use of EVs [22]. This basic attribute is defined in a very similar way to the two previous basic attributes. Moreover, here, it is seen from a social perspective, improving the effects on the use of EVs. It is evaluated as a benefit.

3.3. Category 3: Social Attributes

The third category is named "social". It regards all social factors that are involved in EVCS network expansion; these can positively (or negatively) influence or be influenced by the EVCS propagation. The subcategories identified here are (i) collective and (ii) personal.

3.3.1. Collective Subcategory

The collective social factors considered here are related to demographic, behavioural, and attitude aspects that can influence the location of EVCSs or that can be influenced by the chosen location of the EVCSs themselves. Here, the focus is on the environmental impact which can be generated by all human activities connected to the installation of EVCSs. The following output attributes are considered: (i) impact on people's lives, (ii) demographic information, and (iii) points of interest.

Impact on people's lives groups all basic attributes that are related to the influence that the operations of positioning the EVCS can have on the local people. This output attribute is better described by the following basic attributes:

- *Acceptability of new solutions*: Public awareness and support will affect the development of similar projects and the future development speed of EVs [24]. A diffused positive acceptance of EVCSs in the neighbourhood will increase the expansion of EVCS network, boosting the technical solutions offered. This can be achieved through social commitment in creating or developing new social areas capable of carrying forward the improvement of selected areas.
- *Adverse impact on people's lives*: This takes into account the adverse impacts of noise and electromagnetic field due to the construction and operation of EVCSs on the daily life of local residents [14]. An alternative approach is to account in advance for the local resident attitude and opinion on the EVCS construction and operation. This enables to find out in advance whether the local population is inclined to tolerate noise and electromagnetic field due to the construction and operation of the charging station [23].
- *Improvement on employment*: The construction and maintenance of EVCSs can provide more job opportunities, including for local people in different fields. In this way, if the employment rates of the local territory are low, it can offer work opportunities; therefore, employment rates can be boosted up [5]. This can become an important aspect regarding the social well-being of the local areas.
- *Benefits for people's lives*: The difference compared to the previous basic attribute is that, here, it is defined in a more general way and can also consider positive effects, i.e., improving the quality of life of the residents, in people's opinion, which are underlined here [15]. An alternative point of view is given considering that the construction and operation of EVCSs may generate poor acceptance among the local population due to the negative effects of noise and electromagnetic radiation. This can lead to forcing the shutdown of the project even at the very beginning, particularly in residential communities. Therefore, efforts must be put into practice by investors to change the level of acceptance of residents to reduce investment losses at most [5]. For example, if the local area sees a contextual improvement of the residential zone through the construction of new social areas or the redevelopment of the same neglected areas, this can lead to changing the mentality of local residents, pushing them to accept rather than refuse the presence of EVCSs.

Demographic information includes all the basic attributes that can address the needed information related to EV diffusion. These can be summed up as follows:

- *Population density*: This attribute indicates that the need for charging stations is higher in areas where EVs are frequently used. Population density can be used as an indicator to determine which regions are best suited to see the location of one or more EVCSs, since population density may represent a potential ideal charging request. If the location is characterized by a high population density, it will be more suitable [34]. The information suggested here needs to be strengthened by considering further information given by the next basic attributes listed here; otherwise, it will have no meaning when considered alone.
- *Population intensity*: This is defined in the same way as population density, but it seldom appears to be called with a different denomination.
- *Number of vehicles (local)*: This considers the total number of vehicles (of all types) in the local area selected. It represents an additive information with respect to population density, since it prompts the indication of high vehicle potential and the transformation of conventional vehicles into EVs [22]. This information must be associated with the next basic attribute: the number of EVs (local).
- *Number of EVs (local)*: This considers the actual number of EVs being present in the local area considered as eligible to locate EVCSs. It is important to be considered because it addresses the relation between the charging demand and EV ownership.

The former is meant to increase if the latter increases. It gives the estimated potential charging demand at the beginning [22].

- *EV sales (local)*: This basic attribute addresses the projected number of EVs that the EVCS site is called to serve. When the number of EV sales in the area surrounding the targeted EVCS site is higher, a higher number of the EVCS is needed [17].
- *Residents' average income*: The consumption characteristics and income levels of residents in different residential communities are diverse, which depend on the employment level, the consumption structure, the growth of consumer expenditure, and the cost of living [5]. High-income-rate districts are meant to be suitable to locate EVCSs [34].

Points of interest includes all the basic attributes that focus on locating EVCS in correspondence of nodes important for what concerns the public utility, seen by the user perspective. These can be summed up by the following:

- *Social areas*: EVCS locations should be close to popular centres like shopping malls, stadiums, universities, public buildings, hospitals, due to merging the needs of mobility, sociality, and public services [22]. Also, working areas can represent a potential location in terms of charging demand.
- *Fuel station proximity*: This basic attribute takes into account two aspects, given by the variety of EV typologies. PHEVs need both fuel products and electricity, while BEVs require longer charging times. Therefore, the proximity of fuel stations can represent a constraint for EVCS location [22].

3.3.2. Personal Subcategory

Personal social factors considered here are related to behaviours and attitude aspects seen by the user perspectives. Hence, the only output attribute is user preferences. This is described by the following basic attributes:

- *Driver's comfort*: This refers to whether the driver can immediately start charging operations and avoid waiting times due to queuing. If the EVCS is located in a place featured by heavy traffic and large charging volumes, it may generate longer waiting times, thus reducing the drivers' comfort [18]. This last concept is defined for the location of Battery Swapping Stations, but it can be easily applied to the location of EVCS cases.
- *Home/private charging vs. public charging*: Since charging needs for EV owners is becoming more and more urgent, the balance between public and private infrastructure must be accounted for, since home charging can show "high rates of preference by EV users" [20].
- *ICE vs. EV*: This aspect was not found in the literature review, but it constitutes a threshold attitude for users. Even though the available EVs ensure a relatively long duration of a fully charged battery, the users can still prefer to travel by using an ICE for covering long hauls rather than using an EV. In addition, waste management for existing vehicles replaced by EVs could impact the possibility to purchase an EV by benefiting from dedicated incentives for vehicle replacement or fiscal discounts applied to the use of EVs.

3.3.3. Social Category: Analytical Expressions

Analytical expressions are provided in [32] for evaluating the level of integration of EVCSs with the public transport network, and it is divided into two terms, i.e., the intensity of integration of primary and secondary transport networks with a considered EVCS. The values considered are the number of stops of the public transport system located at a distance not exceeding a given threshold:

$$\max \sum_{l=1}^{L} \sum_{p=1}^{P} x_l (B_l(\bar{R}) \cap S_S) \tag{4}$$

where L indicates the number of potential EVCS locations; $x_l \in [0;1]$ is a binary variable, i.e., 1 if EVCS is located in the l-th alternative location and 0 otherwise; B_l is a zone around l potential location of the ECVS with radius $\bar{R}$; and S_S is a set of s stops that belong to the public transport system. The reference [32] also provides similar analytical expressions for evaluating the integration of EVCSs with the main roads of the city system in terms of the number of EVCSs located no more than a threshold distance from the main roads of the city. Adequate indicators to represent the integration of EVCSs with points of interest are also reported.

3.4. Category 4: Technical Attributes

The last category is named "technical". It regards all technical factors and engineering aspects that are involved in both EVCS and grid planning and operation. The interaction between an EVCS and an electrical grid can represent an obstacle to the physical integration of the EVCS infrastructure. The identified subcategories are (i) grid side, (ii) user side, and (iii) EVCS side.

3.4.1. Grid Side Subcategory

Grid planning gathers several technical aspects that can impact the electrical grid transmission and distribution once the suitable location of EVCS is chosen. This is described by the following output attributes: (i) grid operation and (ii) grid planning.

Grid operation focuses on all aspects concerning the operability of the EVCS infrastructure. Here, several technical issues are considered and explained:

- *Power and energy management*: This aspect involves the effects of the EVCS operation on the actual balance of electric loads influencing the power stability of the grid. EVCS constitutes a non-negligible component of medium- and low-voltage distribution systems. As an immediate consequence, the EVCS should be located in an area that is sufficiently far from the heavy loaded electric lines to ensure a stable operation of the distribution network [23,35,36]. Moreover, to improve the stability of the grid, energy storage systems can be installed to increase the reliability of the grid and its response to extended overloads.
- *Power quality*: This is defined with the same meaning for power and energy management, but with the focus that is put on an EVCS, from an opposite perspective. As already mentioned in the previous attribute, the quality for EVCS-delivered electric power can be improved with the installation of energy storage systems, thus contributing also to stabilize the network against unforeseen overloads or voltage drops.
- *Harmonic pollution in the power grid*: This basic attribute focuses on the harmonic distortion of the EVCS. This is due to a large amount of charging demand that generates harmonics injection in the power grid. If it cannot be effectively compensated and filtered, it will seriously affect the power supply quality, damage the already existent capacitors, and threaten the safety of the whole power grid [18].
- *Impact on the load levels of power grid*: This basic attribute is associated with an aspect that is becoming more relevant in the last period, that is, vehicle-to-grid (V2G). It is assumed that the battery can also serve as an energy storage system for the grid while satisfying the charging needs of EVs. In order to ensure the stability of the power grid and to avoid the rising of huge impacts on the power grid, the real-time load levels of the power grid itself should be taken into account, and the charging and discharging threshold of the battery should be reasonably selected, ending in a good compromise [18].
- *Impact on voltage*: This is defined as the quality of the electricity supplied to the targeted EVCS site that determines the service quality of targeted EVCSs. Since the EVCS is usually planned within an electric power distribution network, when charging operations start, a higher power load will be generated, which will cause the voltage to drop by seriously endangering the safe and stable operation of the power grid [17,18].

- *Power grid security implications*: This basic attribute refers immediately to the previous one, since it quantifies through a significant indicator the measurement of the influence of the targeted EVCS site on power grid the [17]. A higher score of this index indicates a greater threat to the local power grid security.
- *Consumption level*: This refers to an energy efficiency measure that can be seen either under an energy point of view, i.e., if the EVCS shows high efficiency with minimized energy and thermal losses, or from an economic perspective in terms of missing cash flows [28,37]. Although it is not occurring with the following meaning within the scientific literature examined, it can also refer to the difference between the potential demand initially estimated and the actual charging demand.
- *Electromagnetic interference*: This can be wrongly misunderstood and confused with the effects of electromagnetic fields on the natural environment. Conversely, it identifies the interference produced by electromagnetic fields generated by large radio transmitters and industrial electromagnetic fields on the site location of EVCSs. Therefore, it measures the influence of an electromagnetic interference on the power supply stability of the EVCS. It is assumed that at a longer distance, a weaker electromagnetic interference on the targeted EVCS will be observed, ensuring a stable feeding of charging power [17].
- *Level of penetration of RES*: This aspect is not adequately pointed out from the literature review. Despite this, it can represent an important aspect due to the following reasons. First, a high-RES penetration can enable us to dedicate an RES production that is able to reinforce the actual electric/power grid distribution network feeding the EVCS, and thus increase the responsiveness of the EVCS infrastructure against the overloads and unforeseen peak demands. Secondly, it can represent a huge potential for what concerns an increment of the capacity of EVCS sites.

Grid planning accounts for all the technical issues that can influence the supply capacity and thus the technical problems that can potentially rise in the presence of EVCSs. In particular, it is described by the following basic attributes:

- *Power supply capacity of transmission and distribution systems*: This is defined as the amount of electric power that must be delivered by the grid when the EVCS operates and electricity loads are supplied. It strongly depends on the charging services that the EVCS will provide that must show compatibility with the actual state of the grid. Therefore, it should be adapted to the power supply capacity of the local transmission and distribution systems [17,18,35].
- *Distance to the substation*: This is defined as the distance between the EVCS infrastructure and the first useful substation, which should be close enough to areas characterized by high energy demand [22]. In a few cases, this aspect is included in a cost item [19]. In fact, the farther away the substation is, the longer the wiring will be; therefore, the higher the power losses will be. This can be related with O&M costs output attribute.
- *Substation*: This refers to the concept of substation proximity, with a very close meaning already reported by the previous basic attribute [22].
- *Substation capacity permits*: This is defined as a measure of the integration degree between the electricity demand of the targeted EVCS site and the substation capacity of the located area [17]. It can also indicate the level of overloading of the substation and its attitude to sustain these conditions. A higher score to this index indicates that the site is more suitable and can obtain permits for its installation.
- *Substation capacity*: This is used with the same reference of the previous definition [28]. Here, it indicates the power capacity of the substation.
- *Power grid capacity*: This basic attribute focuses on an important aspect that must not be overlooked when defining the planning phase. The power grid capacity is an important factor for the integration of the charging infrastructure. Major technical work may occur due to a strengthening of the existing network or the need for transformer installations to enable a full operability of EVCSs in the area [20].

3.4.2. User Side Subcategory

The focus is now progressively set on all aspects concerning the services and options offered by the EVCS infrastructure. Here, only the charging station services output attribute exists, whose basic attributes are described as follows:

- *Charging services*: This basic attribute refers to the service level offered by the EVCS. This is defined as the EV number and service radius that the EVCS can serve [16]. This basic attribute can consider the different possibilities of charging the EV offered by EVCS, like, for instance, DC/AC sockets, and the related maximum capacity.
- *Further services to the drivers*: Although in the scientific literature the services are limited to the charging services offered to the drivers—indicated at the previous point—the services can be extended by also referring to different additional services that can be offered to the drivers while charging. This basic attribute is the opportunity to offer appropriate services to the drivers in correspondence to the EVCS, meant as a benefit indicator. Often, the notion of Electricity Accessibility (EA) is introduced, aimed at measuring the service quality of a charging station network. EA is measured by the average time spent by a random driver to complete charging [15,25]. The analytical formulation of the EA used in [25] is represented with t_{qz}, i.e., the travel time from cell q to cell z, and with t_v the service time of charging stations of type v. The objective function to be minimized is the average EA, where F is the total number of charging demand in the network; D_q is the demand in cell q; and y_{qzv} is the fraction of vehicles in cell q that is served by charging station of type v in cell z, as reported in (5). The perspective here is seen as the opposite of the point of interest attribute, where the EVCS is located depending on an already existent service of public interest. The difference here is that an additional point of interest can be created, with paybacks that could also directly involve the local population.

$$EA = \sum_{q=1}^{Q} \sum_{z=1}^{Z} \sum_{v=1}^{V} D_q \left(t_{qz} + t_v\right) \frac{y_{qzv}}{F} \quad (5)$$

- *Fast-charge ratio*: This is defined in the literature as the ratio of the number of fast-charging stations to the total number of EVCSs. EV users can prefer using fast-charging facilities to save time rather than conventional charging. Therefore, the location served by EVCS infrastructure with a higher fast-charge ratio is thus more likely to provide efficient charging services and to attract more customers to charge, thereby exploiting fast-charging solutions [21].

3.4.3. EVCS Side Subcategory

The EVCS infrastructure is now focused on the planning phase. This subcategory is described by the two last output attributes, concerning several aspects: (i) EVCS planning and (ii) EVCS operation and reliability.

EVCS planning accounts for the possibility of capacity expansion in the future, since the expansion of the capacity of EVCSs needs to consider the number of charging users in the future, the projected new EV sales in the area, land resources nearby, government policies, and the upgrade of the distribution network [24].

EVCS operation and reliability focuses on the aspects of safety and reliability of the EVCS. In particular, here, several basic attributes are grouped, each described with a technical or safety issue that must be considered:

- *Safety/security and ability to tackle the emergency*: This refers to the capability to sustain emergency conditions and also evaluate the protection of the EVCS. It can consider the security of the EVCS in an emergency situation, including grid safety, fire protection facilities, and the resilience properties of the EVCS site, i.e., the ability to resist natural disasters [15,16].
- *Reliability*: This evaluates the reliability as the resistance and durability of the EVCS with respect to many external conditions. It is measured as the stability of alternative

EVCS sites to future changes in external conditions. It sometimes accounts for the reliability of the power supply located near the site locations, meant as time to failure. It is often defined as derived from the concepts of Mean Time To Failure or Mean Time Between Failures [15,16,27]. A high score means high reliability.

- *Charging station capacity*: The power capacity of the EVCS determines the maximum number of daily charging sessions. These are essentially the "sales units" of the investment. A high-power 50 kW charging station can serve up to 60 charging sessions per 24 h, while the maximum capacity of a normal-power 22 kW station is limited to 26 charging sessions [20]. During the operation phase, an increased number of EVCS units available on the same charging site could emerge as needed to satisfy the demand.
- *Service capability/service capacity*: This is defined as the number of EVs that can obtain access to the charging service provided by the EVCS, the daily charging volume, and the maximum charging volume. It can also be defined as the daily service volume and the maximum number of EVs that could obtain access to the charging service provided by the charging station [14,23].

4. Importance of the Attributes

This section provides a review of the attribute appearances and weights as they are used in the literature, organized in the form of matrices. In this context, absolute and relative weight values can be distinguished throughout the literature examined. In particular, the following can be noted:

- An absolute weight provides the importance of a single attribute compared to the total attributes considered in all categories. To be as clear as possible, the absolute weight value defines the global influence of one specific attribute on the rest of the attributes considered.
- A relative weight defines the importance of one attribute in comparison to the others within the same attribute category. It defines the local influence of the single attribute among the others that belong to the same category of attributes.

The evaluation of absolute and relative weights requires a broad and in-depth literature review, so that it is possible to extrapolate the weights of each attribute from every single study contribution and then evaluate the impact of the weight of each attribute by considering the whole set of attributes. According to this rationale, the sum of the weights for the single literature contribution will be unitary. A practical example, with values referring to the contents of one of the papers considered [17], is shown in Table 4. The output attributes mentioned in this paper are marked with one, while at least one of the basic attributes included in the output attribute appears. Conversely, the output attributes that are not included are marked with null value. Furthermore, the corresponding weights assigned by the authors are reported in the "Weights" column. The total number of the appearances reported at the bottom of Table 4 indicates the number of attributes appearing in [17], while the sum of all weights assigned reaches unity (i.e., 100%). This operation has been repeated for covering all the works selected and reviewed from the scientific literature.

It is important to highlight that the weight values found in the literature are strictly connected to the total number of attributes considered in the single literature contribution. Moreover, the same attribute may be calculated differently in different papers, because of the different attributes considered within the same paper. In fact, as indicated in Section 3, the literature contributions examined were retrieved to deal with different attributes among them, but that showed similar semantics. And seven significant papers are taken as examples here. With a focus on the overall multiplicity of the criteria, only 10 attributes are considered in [34], rising up to 13 in [20] and 15 in [15,29]. Higher numbers are found in [22,30], with 19 and 21 total attributes, respectively, while [36] considers up to 45 attributes jointly. Moreover, despite the variability encountered, a further difference is identified in the way of proceeding the aggregation for the attributes considered. For example, three categories are exploited in [29], four categories in [15,30], five in [20,22], and nine are used to group attributes in [36]. Conversely, [34] does not use any category to enclose attributes. Treating the attributes recalled in those contributions semantically, it is possible to observe that the same meaning is not always reflected uniformly across the examples with the same undertone. If only the *economic* category is isolated, no attributes are considered by the authors of [34], which represents an outlier in this sense, while [29] focuses on land cost, thus discarding construction costs and O&M costs as [15,20,22,30,36] have reportedly performed.

The approach chosen by the authors of [20] is noticeable since it considers O&M costs and equipment cost rather than construction costs. This comparison can also be extensively repeated for other categories (environmental, social, and technical), where basically each paper proposes its own framework of attributes, thus increasing the multiplicity of criteria classification and hence the sparsity of approaches, given that the topic covered is common. Therefore, a re-ordered categorization of attributes aimed at constituting a common practice needs to be provided to be adopted in future research, allowing for direct comparisons between different strategies and consequently increasing uniformity.

Table 4. Example of appearances and weights calculated from the contents of [17].

Attribute Category	Attribute Subcategory	Output Attribute	Index (row,col)	From Xu et al. (2018) [17]	
				Appearance	Weight
Economic	*Cost*	Installation costs	1	1	4.50%
		O&M costs	2	1	4.30%
		Update and removal costs	3	1	3.40%
	Benefit	Revenues	4	1	5.50%
	Policy	Installation permits	5	0	0
		Government support	6	0	0
Territorial	*Traffic*	Traffic flow	7	1	6.40%
		Road network characteristics	8	0	0
		Interactions with other infrastructures	9	0	0
	Geography	Service radius	10	0	0
		Urban development	11	1	3.70%
		Land	12	0	0
	Environmental	End of life management	13	0	0
		Territory sustainability	14	1	24.80%
		Emissions	15	0	0
Social	*Collective*	Impact on people life	16	0	0
		Demographic information	17	1	12.10%
		Points of interest	18	0	0
	Personal	User preferences	19	0	0
Technical	*Grid side*	Grid operation	20	1	29.70%
		Grid planning	21	1	5.40%
	User side	Charging station services	22	0	0
	EVCS side	EVCS planning	23	0	0
		EVCS operation and reliability	24	0	0
		Total		***10***	***100.00%***

Starting from the information relating to each paper, the basic attributes of the entire sets were jointly considered, with the aim of providing the outcome regarding the relative importance of the output attributes to which they refer. The relative importance of each attribute is provided by considering different aspects: (i) the occurrence of the output attribute in the literature and (ii) its weight. The generalized scheme of attributes described in Section 3 is validated using numerical analysis to motivate generalized considerations, in order to orient the decision maker about the importance that each attribute has in the literature. Therefore, to provide a synthetic analysis of the two aspects mentioned above, two matrices have been built and calculated as illustrated below, considering the general case with N_T output attributes and N_P papers analysed:

$$\mathbf{A}_O \in \mathbb{N}^{N_T,N_T},\ a_o(g,j) = \begin{cases} \sum_{p=1}^{N_P} x_p^{(j)} & g = j \\ \sum_{p=1}^{N_P} x_p^{(g)} & g \neq j \end{cases} \tag{6}$$

where $x_p^{(j)} = 1$ if the output attribute j exists in the literature contribution p, and $x_p^{(g)} = 1$ if both output attributes j and g are mentioned in the literature contribution p, and

$$\mathbf{A}_W \in \mathbb{R}^{N_T,N_T},\ a_w(g,j) = \begin{cases} \sum_{p=1}^{N_P} w_p^{(j)} & g = j \\ \sum_{p=1}^{N_P} w_p^{(g)} & g \neq j \end{cases} \tag{7}$$

where $w_p^{(j)}$ is the weight of attribute j in the literature contribution p, and $w_p^{(g)}$ is the weight of attribute g in the literature contribution p when attribute j is also included in the literature contribution p. These two matrices have been computed and graphically rearranged in heatmap form, as shown in Figures 2 and 3, considering the correspondence shown in the column named "Index (row, column)" of Table 4. The rearrangement in the heatmap of the matrix $\mathbf{A}_O$ shows that the higher the number of papers citing the output attribute j, the darker the colour of the element $a_o(j,j)$. Moreover, it is worth to note that matrix $\mathbf{A}_O$ is symmetric due to its construction. In fact, let us take as an example the values contained in $a_o(1,3)$ and $a_o(3,1)$. In $a_o(1,3)$, the output attribute of row 3 (update/removal costs) appears 13 times together with the output attribute of column 1 (installation costs). The dual condition is represented by the element $a_o(3,1)$, which contains the number of appearances of the output attribute in row 1 (installation costs) when the output attribute of column 3 (update/removal costs) appears, and it is already known that it appears 13 times.

Normalization of the matrix $\mathbf{A}_O$ could lead to the notion that a relative importance with respect to appearances of attributes can emerge. This is misleading, since the symmetry of the matrix does not prompt reciprocity relationships between the elements below and above the main diagonal. With reference to the matrix $\mathbf{A}_W$, shown in Figure 3, the higher the value of $a_w(g,j)$, the higher the relevance of the g-th output attribute with respect to the j-th output attribute. Conversely, the lower the value of $a_w(g,j)$, the lower the relevance of the g-th output attribute with respect to j-th output attribute. This provides an immediate comparison among the different output attributes. In addition, if $a_w(g,j) > a_w(j,j)$, the g-th output attribute takes more importance than the j-th output attribute. When $a_w(g,j) = 0$, no weights were assigned in the literature for the given association of the g-th and the j-th output attribute, i.e., the two attributes were never considered together. Also in this case, the normalization of the matrix $\mathbf{A}_W$ would lead to misleading results. An immediate example is given considering column 5—the one featured by the lowest value on the main diagonal. Normalizing the values of column 5 with respect to cell $a_w(5,5)$ will result in having values higher than 1, which are difficult to interpret, as the matrix $\mathbf{A}_W$ is non-symmetric and no reciprocity relation exists with the corresponding elements on row 5.

The matrix of occurrence for the output attributes shown in Figure 2 provides a detailed view of the frequency with which each attribute is mentioned in the literature. This specific visual representation provides an immediate understanding of the absolute importance of the attributes. On the other hand, the matrix of weights for the output attributes, proposed in Figure 3, provides an immediate comparison between the different attributes, showing the relative importance of each one. This systematic, visual approach makes it possible to identify meaningful associations between attributes, providing new insights that may influence future EVCS siting decisions.

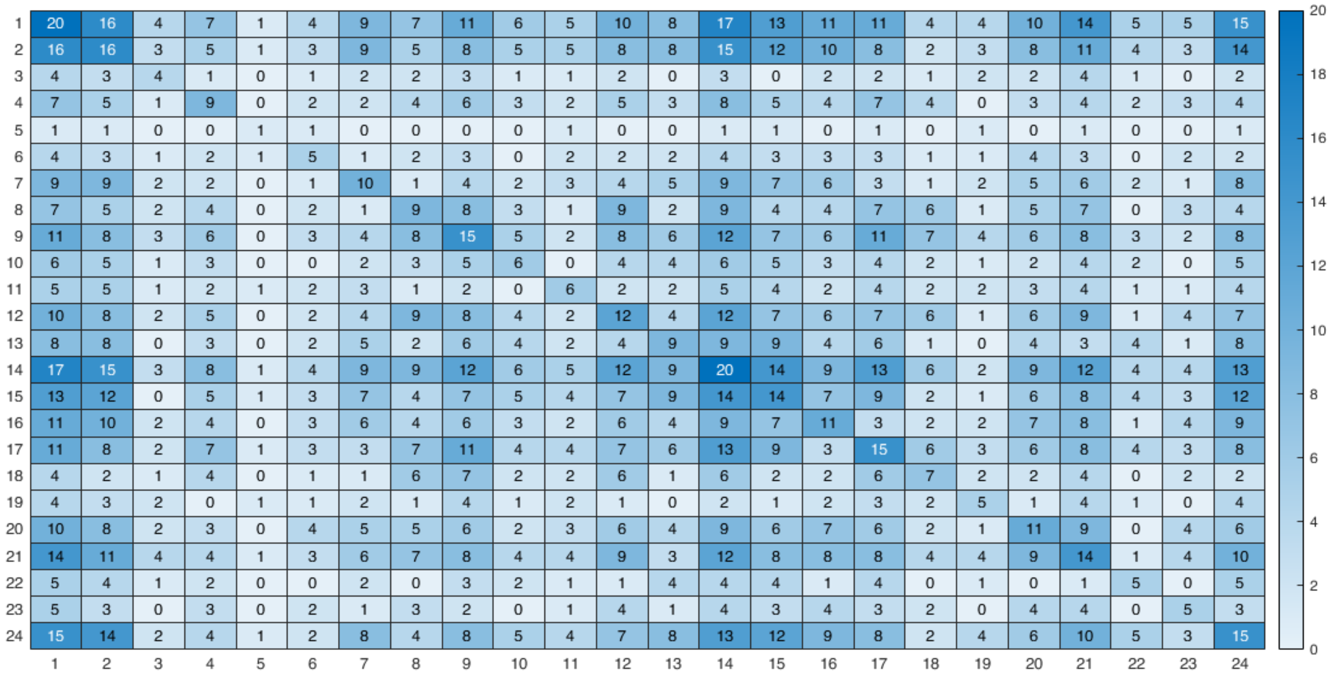


Figure 2. Matrix of occurrence for the output attributes.

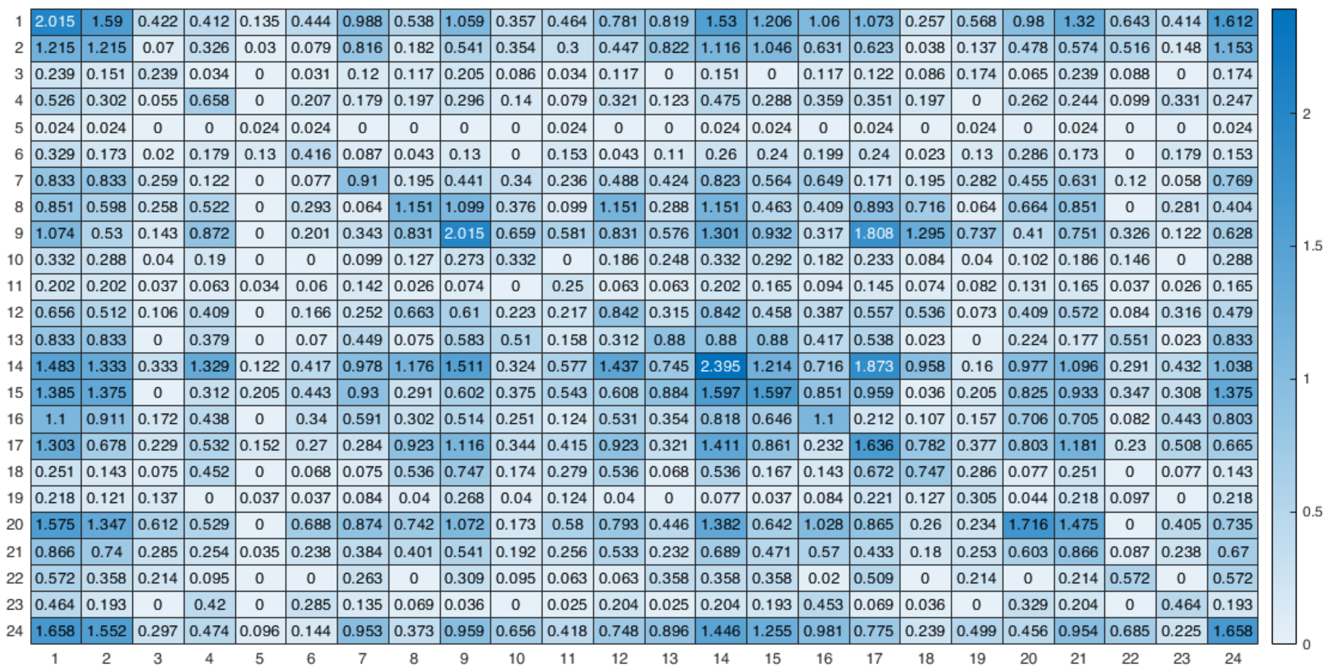


Figure 3. Matrix of weights for the output attributes.

By combining the information from both matrices, it is possible to list the ten most relevant output attributes:

- 14—Territory sustainability;
- 1—Installation cost;
- 9—Interactions with other infrastructures;
- 20—Grid operation;
- 24—EVCS operation and reliability;
- 17—Demographic information;

- 15—Emissions;
- 2—O&M costs;
- 8—Road network characteristics;
- 16—Impact on people's lives.

The same procedure has been repeated considering the subcategories of attributes, thus aggregating the original starting data according to the scheme reported in Table 5. Thus, the results are constituted by a pair of $[11 \times 11]$ matrices for subcategories of attributes, i.e., $\mathbf{A}_O^{(SC)}$ and $\mathbf{A}_W^{(SC)}$, with the first for appearances and the second for weights assigned (shown in Figure 4). If only subcategories of attributes are considered, the reduction in the matrix dimensions is observed with the corresponding increase in the values contained in the cells. In the presence of one or more recurring attributes belonging to the same subcategory in the literature, the appearance will be set as equal to 1 within the same paper considered. For instance, the attributes belonging to the *economic costs* subcategory in Table 5 all appear in [17], but the appearance of the *cost* subcategory for that particular paper remains to be equal to unity.

Here, the aggregation of attributes belonging to the same subcategory is performed. The matrix $\mathbf{A}_O^{(SC)}$ has been computed and reported in Figure 4a. As was previously reported for the matrix $\mathbf{A}_O$, here, the rearrangement of the matrix into a heatmap also points out which subcategories are considered more relevant. It appears that rows and columns 3, 8, and 10 are less considered in the literature, corresponding to the *economic–policy*, *social–personal* and *technical–user side* attribute subcategories. The matrix $\mathbf{A}_W^{(SC)}$ instead considers in each matrix element the corresponding sum of weights assigned in the literature. The matrix $\mathbf{A}_W^{(SC)}$ remarks the distinction pointed out by the matrix $\mathbf{A}_O^{(SC)}$, considering the aggregation of weights. Hence, weights of attributes included within the same subcategory are summed up for each paper, thus resulting in the matrix reported in Figure 4b. It is possible to note that weights are now taking a very high value with respect to the values that appear in the matrix $\mathbf{A}_W$, because of the aggregating procedure of weights coming from the first step. It is possible to perform a subsequent step towards aggregating all subcategories of attributes in their corresponding categories; thus, a pair of $[4 \times 4]$ matrices for categories of attributes, i.e., $\mathbf{A}_O^{(C)}$ and $\mathbf{A}_W^{(C)}$ shown in Figure 5, can be computed. These will deliver the idea of which category is predominant among the others. The indices of matrices are reported in Table 6 for the sake of simplicity. As already presented for the subcategories, all the attributes belonging to the *economic* category in Table 6 appear in [17], but the appearance of the *economic* category for that paper is always equal to unity.

Table 5. Indices of attribute subcategories.

Attribute Category	Attribute Subcategory	Index (row,col)
Economic	*Cost*	1
	Benefit	2
	Policy	3
Environmental	*Traffic*	4
	Geography	5
	Environmental	6
Social	*Collective*	7
	Personal	8
Technical	*Grid side*	9
	User side	10
	EVCS side	11

The attribute subcategory matrices shown in Figure 4 aggregate the data to clearly show which subcategories are most highly regarded in the literature. As for the matrices for the output attributes, the occurrence matrix representation defines the relevance of the subcategory in the research, while the weight matrices define its relative importance among them. This representation offers a level of detail and clarity that helps us to better understand current trends in EVCS research. From Figure 5a, it is possible to appreciate the appearance distribution of the four categories of attributes in matrix $\mathbf{A}_O^{(C)}$. The total number of occurrences of each category compared to the other categories is very close, thus pointing out that all attribute categories are considered with equal importance. Only the associations of the *technical* category with the *social* and *territorial* categories show a slightly lower number of appearances. This means that the scientific literature reviewed focuses mainly on *economic* with *social* and *territorial* aspects, giving relatively less importance to *technical* aspects. The matrix $\mathbf{A}_W^{(C)}$ in Figure 5b instead points out the aggregation of weights assigned by the different authors to these four categories. From this distribution, it is possible to note that the aspects related to the *territorial* category and linked with the *economic* and *social* categories are featured by a higher aggregated weight assigned, thus considered relevant within the literature examined. *Social* seems to be less important than the other attribute categories. This can be explained with the fact that, in general, lower weight is assigned to this specific category. Finally, as far as the *technical* category is concerned, the results shown in the matrix $\mathbf{A}_W^{(C)}$ allow us to classify this category as having a relevance similar to the *economic* one.

Table 6. Indices of attribute categories.

Attribute Category	Index (row,col)
Economic	1
Environmental	2
Social	3
Technical	4

The analysis carried out herein allows us to formulate further considerations, contributing to set a path for future research related to the EVCS location problem. Keeping in mind the aforementioned information that is valid as general considerations and mediated by numerical analysis—i.e., the inter-relationships discovered between categories and subcategories of attributes—it is worth noting that the analysed literature contributions have mainly focused on solving the EVCS location problem under technical and environmental aspects, since those attribute categories are retrieved to have high aggregated weight compared to the rest. This is what Figure 4b points out, where the aggregated weight provides a hierarchical order of attribute categories: *territorial*, *technical*, *economic*, and *social*. Motivations can be extrapolated from this, extending the attention from attribute categories to output attributes as follows. The urgency of pushing towards the widespread use of EVs with a charging infrastructure aware of the surrounding environment and harmonized with existing electrical grids and loads should be realized.

The *territorial* aspect is strongly considered, even much more than *technical*, in order to propose environmentally sustainable solutions oriented towards providing less impact on the natural environment and a satisfactory level of integration with the surrounding environment. The *economic* category is therefore only considered afterwards, but the higher aggregated weights set a priority in considering this category with respect to *social*. These statements are reflected in the analysis of how the aggregated weighing is distributed across the subcategories and, furthermore, across the output attributes. In fact, within the *territorial* category, all subcategories are considered (4—*traffic*; 5—*geography*; 6—*environmental*), with 4 and 6 predominantly weighted, while *technical* presents high weights for 9 and 11 (*grid side* and *EVCS side*, respectively). Then, both *economic* and *social* are represented with only one subcategory, having high weight among the others belonging to the same attribute category (i.e., 1—*cost* and 7—*collective*, respectively).

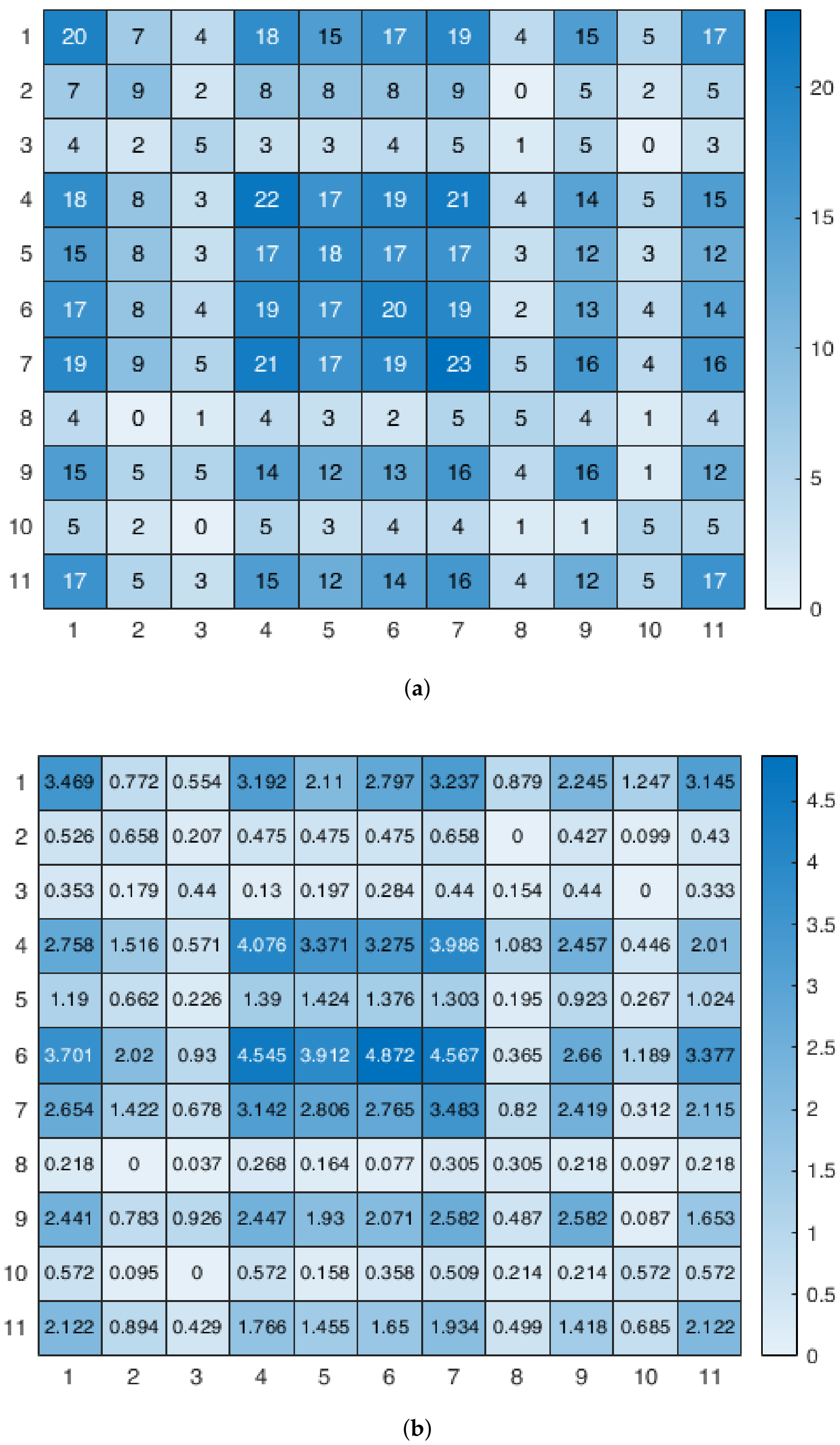
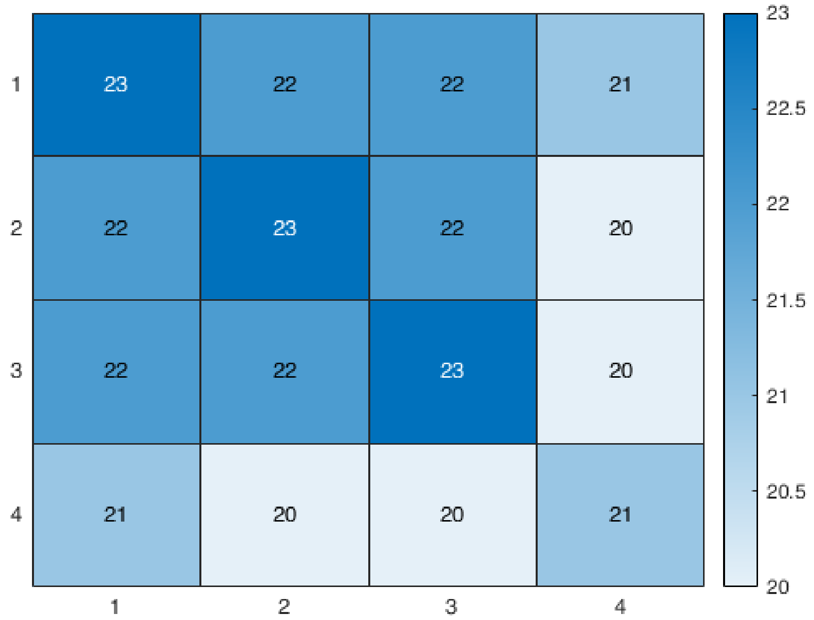
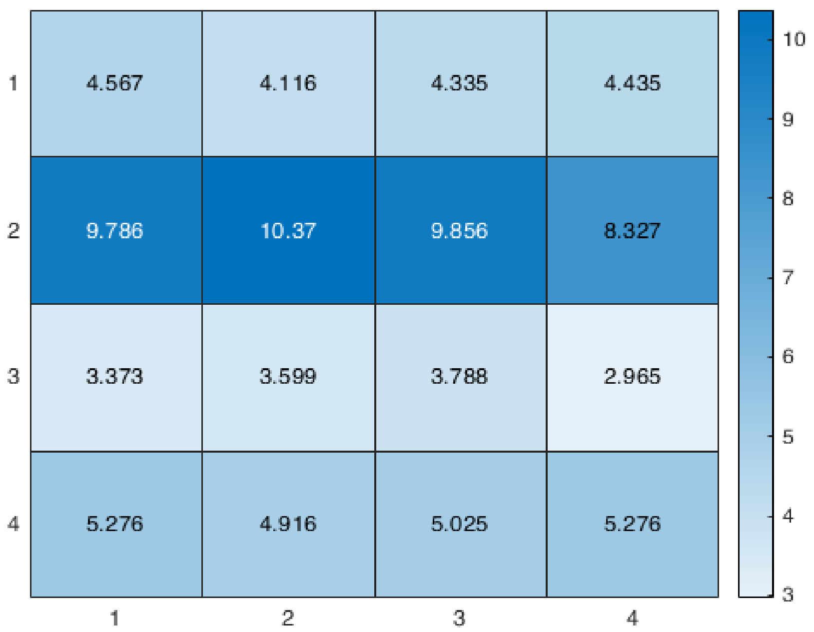


Figure 4. Matrices for attribute subcategories: (**a**) occurrence, (**b**) weights.

Other subcategories that are less considered are, for instance, 2 (*benefits*) and 3 (*policy*) in *economic*, 5 (*geography*) in *territorial*, and 8 (*personal*) in *social*. These last considerations can be analysed item by item considering the weighing of output attributes. As recalled before, aspects related to the *territorial* category are targeted by the existing research, with some valuable differences among them. Output attributes no. 8 (*road network characteristics*), 15 (*emissions*), 9 (*interactions with other infrastructures*), and 14 (*territory sustainability*) are the most predominantly weighted; this implies a selection of EVCS locations able to increase the level of integration into the citizens' pattern and facilities in order to potentially increase the future use of EVCSs from EV users.



(**a**)



(**b**)

Figure 5. Matrices for attribute categories: (**a**) occurrence, (**b**) weights.

As far as *technical* aspects are concerned, a strong attention is set on 20 (*grid operation*) and 24 (*EVCS operations and reliability*) to ensure that the locations of EVCSs are fully integrated in the existing infrastructure for electric distribution, minimizing the disturbances induced on the grid operation and risk of outages. In the *economic* category, the majority of the literature contributions addressed 1 (*installation costs*) and 2 (*O&M costs*), while lower weights are assigned to other attributes. An outlier here is represented by 6 (*government support*), which is considered in only a few papers (5). For *social*, the two most relevant attributes are 17 (*demographic information*) and 16 (*impact on people's lives*), while less relevance is assigned in general to 18 and 19 (*points of interest* and *user preferences*).

The discussion proposed here strongly depends on the point of view considered, i.e., of the different stakeholders involved, in the process and on the targeted focus preliminarily set by researchers. In fact, the recently developed research is strongly dedicated to reducing invasive impacts or interferences arising from the installation of a new infrastructure in an already-existing context, i.e., grids and roads. Furthermore, the location of EVCSs must address social aspects in an important way, aiming to maximize the future exploitation of the charging infrastructure from the user side, and thus also increasing economic incomes. Here, the capillary presence of EVCSs on a given area must be intended as strategic to allow for the increase in EV penetration within the private vehicle fleet, in terms of being diffused based not only on traffic volumes, but also on social activities, and thus reaching the highest number of EV users and capturing their need to charge. Moreover, the policies being progressively approved in Europe to increase the number of EVs in the private sector is enhancing the local administrations to concede more areas to be included in public tenders to be assigned for the installation of EVCS infrastructure. Therefore, this last point is expected to be considered with increasing weight with respect to the past, as stakeholders will orient their business strategies where public governments are supporting this change. This analysis offers a valuable overview of the broad set of key factors influencing the EVCS infrastructure's location selection process and a practical approach to systematically categorize and weigh the main attributes to support the deployment strategy of a CPO. The framework aids in making informed decisions that balance technical, economic, and environmental factors, facilitating a more streamlined and effective roll-out of charging stations. The emphasis on attributes such as territory sustainability, grid operation, and installation cost is in line with practical considerations in infrastructure planning. Furthermore, the inclusion of both numerical and non-numerical attributes in the MADM approach allows us to consider a very broad spectrum of factors, thereby enhancing the robustness of the decision-making process. Overall, this study provides a comprehensive basis that can support a CPO's approach to strategic EVCS location planning, fostering the development of a more efficient and user-oriented charging network.

5. Conclusions

This paper has presented a structured categorization of the attributes considered within a multi-attribute analysis that addresses the EVCS location. The analysis of the literature highlighted the existence of different nomenclatures for similar aspects, introducing difficulties in defining the multi-criteria problem, as well as confusion in choosing the most convenient attributes. Therefore, the proposed categorization started from the information found in the literature and introduced a novel structure with basic attributes, categories, and subcategories. In this way, similar aspects have been methodically merged, allowing the decision makers to easily find high-level aspects to be included in the analysis. In particular, the new framework is composed of input attributes obtained from the literature review, combined with additional items relevant for the actual application, shaping the features contained as categories and subcategories. The new framework is defined according to four main categories (economic, territorial, social, and technical), and the features are defined by tailoring the solution on real cases, which represents the novelty of this work.

The new feature framework also focuses on the relative importance among groups of features, evaluating both the occurrences and the assigned weights based on the literature outcomes. A numerical assessment was carried out through the computation of aggregated appearances and weights organized into two matrices for all the literature contributions considered. Through this analysis, it was possible to examine both the distribution of the criteria and their relative importance, finally establishing a hierarchical order based on the actual literature background retrieved. The proposed categorization is also convenient for better understanding the most common attributes used in the literature and their relative importance. This provides suggestions to the decision maker on the choice of weights.

As a future development, the analysis can be extended by setting up a comparison among the different MCDM methods mainly exploited for EVCS location, evaluating their performance, limitations, and strengths. Moreover, an interesting insight is to examine the relevant points of view of the different actors involved in the EVCS location problem. Based on this last point, it can be observed how the categorization of the attributes will change, highlighting which output attributes will be considered or excluded in the analysis.

The application of the new criteria presented here offers a conventional basis for future research works in the field. The adoption of this framework can allow for a direct comparison among different works and proposed solutions. This makes it possible to partially attempt to resolve the inhomogeneity of the retrieved attributes, which constitutes the main challenging aspect in the application of the proposed framework.

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Nomenclature

BSS	Battery Swapping Station
CPO	Charging Point Operator
EA	Electricity Accessibility
EMO	Evolutionary Multi-objective Optimization
EV	Electric Vehicle
EVCS	Electric Vehicle Charging Station
ICE	Internal Combustion Engine
MADM	Multi-Attribute Decision-Making
MCDM	Multi-Criteria Decision-Making
MOCO	Multi-Objective Combinatorial Optimization
MODM	Multi-Objective Decision-Making
MOLP	Multi-Objective Linear Programming
O&M	Operation and Maintenance
RESs	Renewable Energy Sources

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