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Sustainability Assessment in Infrastructure Projects

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Abstract: We present an easy-to-apply method for assessing the sustainability of infrastructure projects. The proposed methodology consists of determining the evaluation criteria to be applied to the projected infrastructure, considering the three fundamental pillars of sustainability (economic, environmental, and social), quantified according to impact values, in a range from zero to five. Once these were determined and assessed according to the range of impact, we established the sustainability limits or admissible impact limits for each type of infrastructure. The interaction between the sustainability limits assessed for each of the sustainability pillars and the evaluation criteria gives rise to the total influence factor (TIF), which is a value that represents the level of sustainability of the project analysed, according to which it can be classified into one of the five categories included, ranging from minor impact to unfeasible. It also allows for the local identification of criteria to which corrective actions can be applied, with corresponding scores calculated based on a rubric system. The result of the assessment of these corrective measures is the average of the scores of these three aspects. The corrective measures applied to the affected criteria will reduce the TIF and, therefore, increase the sustainability of the evaluated infrastructure.

Keywords: sustainability; civil infrastructures; total influence factor; corrective measures

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1. Introduction

Nowadays, when considering the development of an infrastructure, the sustainability point of view must be carefully taken into account since it will have a significant impact on the environment, the economy, and the society [1]. In particular, intercity transport infrastructures lead to urban aggregation and diffusion, greatly boosting regional economic development [2]. In addition, the largest linear infrastructure contributes to landscape fragmentation and impacts natural habitats and biodiversity in several ways [3]. On the other hand, the construction of infrastructures also entails a strong impact on the ecosystem as a result of the actions caused by the project [4].

In 2015, different countries that are part of the United Nations met at the Sustainable Development Summit and developed the 2030 Agenda containing the 17 Sustainable Development Goals (SDGs) [5]. These goals have led most industrialized countries to readjust their strategies to align them with the achievement of the SDGs [6]. Infrastructure projects form an important part of industry and contribute directly to SDG 9 and 11 [7]; so, sustainable infrastructure development and planning become a necessity.

Therefore, it is necessary to evaluate the sustainability of these projects from the three pillars on which sustainability is based: environmental, economic, and social [8], as well as to understand that a sustainable infrastructure can take different forms, depending on the location and the choices of strategy in the transformation process.

The environmental factor regards the conservation of environmental heritage and natural resources. It is based on the principle of taking advantage of these resources in the short and long term but without compromising the existence of these resources for future generations [9]. Ecosystem-sensitive project design and nature-based solutions provide flexible, cost-effective, and widely applicable alternatives to mitigate the impacts of climate change [10]. On the other hand, the economic factor is linked to the implementation of an integrated approach with a view to promote responsible long-term growth. The available means of production must be used as efficiently as possible and without compromising future use [11]. Finally, the social factor must take into account that development in countries must be usable by their citizens, covering their basic needs [12]. This has to be accomplished by taking into account cultural diversity and the integration of all citizens into the society, as well as protecting workers' rights [13]. However, the social factor of sustainability in infrastructure is perhaps the most difficult to consider, since the definition of the criteria that make up sustainability from the social point of view in civil engineering projects is not clearly defined [14]. Social criteria are more or less important depending on the context, the perspectives of the stakeholders, and the stages of the life cycle [15,16]. Taking into account the three pillars of sustainability, the concept of sustainability in infrastructure is likely to take different forms depending on its location, the needs of the population to be served, and the economic availability [17].

In the last decades, some institutions have developed different tools for the evaluation of civil engineering projects, many of them oriented to road infrastructures, in order to introduce the concept of evaluation of Green Infrastructures (GI) and sustainability [18].

The GI assessment systems are the result of a scoring of different criteria that, when weighted, summed, and compared with admissible limits, will establish the degree of sustainability of the infrastructure. This scale ranges from nonsustainable to sustainable [19]. Thus, there are several tools for assessing the sustainability of infrastructure projects. One of these tools is STARS [20], developed in 2019 by three transportation agencies in the Pacific Northwest in the USA, and which can be used to plan the type of transportation project to be built and how it is operated. The Canadian Guide for Greener Roads [21], developed in 2015 by the Transportation Association of Canada, can be applied during the planning, design, construction, and development of the project, also including operations and maintenance.

Other evaluation tools are INVEST [22] and I-LAST [23], both developed in 2012 in the USA by the Federal Highway Administration (FHWA) of the US Department of Transportation and the Illinois State Department of Transportation, respectively. INVEST (FHWA 2012) consists of a set of best practices aimed at identifying, recognizing, and promoting efforts beyond sustainability in transportation programs and projects. Its objective was to provide guidance to practitioners in assessing the sustainability of their transportation projects and programs and to promote the progress of sustainability in the transportation field. On the other hand, I-LAST [23] is a tool that can be applied during project scoping, at the end of the design phase, and during construction. It consists of a checklist of sustainable practices with points assigned to each practice in nine categories and 25 subcategories. It is an easy-to-use tool that requires minimal time and effort, although it does not provide a level of certification.

In 2011, the Institution of Civil Engineers of the UK developed CEEQUAL [24], which is a system for assessing the sustainability of civil projects in the design and construction phases by measuring the performance of different criteria. CEEQUAL-trained evaluators assess project/contract strategy and performance following a scoring system that includes a series of environmental and social issues organized into nine sections and 48 subsections from the perspective of the three key stakeholders (clients, designers, and contractors) involved in the project.

Envision, created in 2012 by the Harvard Graduate School of Design's Harvard Zofnass Program for Sustainable Infrastructure and the Institute for Sustainable Infrastructure (ISI), aims to assess the overall contribution of infrastructure projects regarding sustainability [25]. This comprehensive approach to infrastructure development seeks to evaluate projects based on their value to communities, efficient use of funds, and contribution to long-term sustainability. It likewise considers all aspects of the life cycle, allowing for better-informed decisions at all stages, from planning to deconstruction or decommissioning [26]. The ISI rating tool differs from other rating systems because it uses a much more detailed level of communication between the main parties involved in the projects during the rating process. In addition, unlike other rating systems, it allows for greater flexibility in meeting the criteria required for its application [27]. Other remarkable tools are GI-Val [28] and Greenroads [29], both from 2010 and GreenLITES [30] from 2008.

The evaluation systems analysed are based on the assessment of different indicators that reduce the complexity of the data, simplify interpretations and evaluations, and facilitate communication between experts and nonexperts. In addition, these evaluation methodologies help in the decision-making process to improve the execution of the infrastructure project towards sustainable development, and their main mission is to minimize the environmental, economic, and social impacts throughout the project life cycle.

Within this group of tools for assessing the sustainability of civil engineering projects, the following stand out for the comprehensive approach proposed in their implementation: Envision in the United States [31,32], CEEQUAL in the United Kingdom [24], and the Infrastructure Sustainability Rating Scheme in Australia [27]. These projects reflect various aspects of the sustainable development of a wide range of infrastructure projects [26]. Therefore, these are the models for the design of this methodology.

Regarding the normative point of view, ISO/TC 59/SC 17 [33] and ISO/TS 21929-2:2015 [34] are the available standards for the development of engineering projects. The ISO/TS 21929-2:2015 standard deals with adapting general sustainability principles to civil engineering projects and includes a framework that develops sustainability indicators to be used in the evaluation of projects according to economic, environmental, and social impacts. According to the above-mentioned standards, the indicators may include quantitative and/or qualitative descriptive metrics that provide information about a complex experience, such as the dynamic built environment, in an easy-to-use and understandable way [35].

Based on the regulations and the evaluation tools analysed, the objective of this work consisted of developing a methodology for the evaluation of sustainability in the short, medium, and long term in infrastructure projects, trying to integrate different views of the criteria and factors that are included in the project and the applied environment. The matrix created for this purpose covers the three pillars of sustainability (environmental, economic, and social). This matrix has different criteria evaluated by means of a scale of values from one to five, which, added together and weighted, result in the so-called total influence factor (TIF) and represent the sustainability of the project. In short, it is an easy-to-apply method for assessing the viability of infrastructures and provides objective data for the decision-making process in the choice of alternatives in infrastructure projects.

2. Materials and Methods

The tool for assessing the sustainability of infrastructure projects by estimating the influence factor (TIF) is the result of a thorough review of the existing methodologies, as well as the ISO standards previously mentioned. Figure 1 shows a simplified scheme of the structure of the proposed model, where it can be observed that different evaluation criteria have a certain influence on the three sustainability factors and, all this in turn, on TIF.

The proposed model is flexible because sustainability factors can be included or extracted depending on the planning of the evaluated infrastructure. It is only necessary to change the weighting or importance that each factor will have in the TIF. In brief, the methodological steps are the selection of objectives, sustainability factor evaluation criteria, calculation of sustainability limits (TIF), and application of corrective actions when necessary.

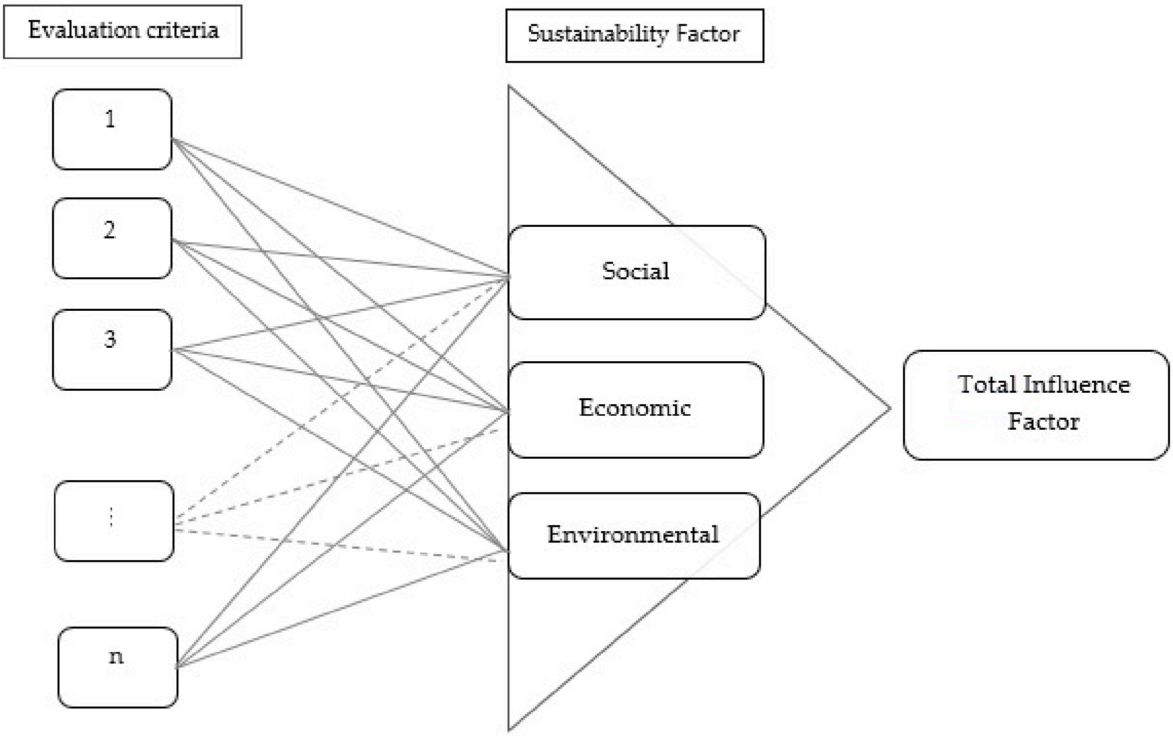

Figure 1. Structure of the proposed model for sustainability assessment in infrastructure projects.

2.1. *Selection of Objectives*

The defined objectives, considering the pillars of sustainability, are as follows:

- Minimum residual impacts on the environment;
- Profitability from the economic point of view;
- Maximum functionality for users;
- Maximum benefit for the affected territory.

2.2. *Assessment Criteria*

The definition of the evaluation criteria as the set of variables that relate to alternatives and objectives will allow us to assess the degree of approximation of each of the alternatives to the objectives. Table 1 shows the 20 general evaluation criteria, defined as having an impact on the sustainability factors. Of these, 12 correspond to the environmental factor, 2 to the economic factor, and 6 to the social factor.

Table 1. General evaluation criteria with impact on sustainability factors.

Evaluation Criteria	Description
	Environmental factor
Land Use/Site Selection	It measures the changes in the distribution of land uses over time. This criterion provides information on changes in the productive or protective uses of the land resource to facilitate sustainability, use planning, and policy development.
Water Quality	This criterion is associated with the control of the impacts generated by a project and the protection of the aquatic environment, legal requirements, and the improvement of the environment, if the project allows it.
Air Quality	This criterion aims to reduce the environmental impact generated by the project throughout its life cycle, considering the construction, operation, and decommissioning phases

Table 1. *Cont.*

Evaluation Criteria	Description
Noise Quality	The evaluation of noise impact is required as part of the environmental assessment process; however, there are elements of noise management that can provide opportunities for sustainable practices. Noise levels can be reduced by altering the source of the noise (engine and exhaust noise and tire–pavement interaction) or by protecting the receptors.
Ecology and Biodiversity	Associated with the impacts on sites of high ecological value, protected species, species susceptible to conservation, and habitat recovery measures gained by human development. The effectiveness of protected area management is an important indicator of how well-protected areas are conserving biodiversity.
Land Improvements	This criterion includes the study of the terrain (visual, physical, chemical, and biological parameters) and the improvement measures required for the support of structures, which are part of the infrastructure project.
Solid and liquid waste management	It consists of optimizing the use of construction materials to the maximum, minimizing the waste generated during the construction process. A percentage of this waste is recycled or taken to landfills in controlled sites.
Energy and pollutant emission	Energy-efficient solutions in project design include passive systems that utilize natural light, air movement, and thermal mass, as well as solutions involving energy produced from renewable sources. Opting for clean energy is one way to mitigate the effects of heavy machinery powered by polluting energies.
Pollution control	Dust is a problem on most construction sites. Even low concentrations of dust can affect plant and fruit growth, especially if the dust is very alkaline, such as limestone or cement. Odors can become an unpleasant problem when they occur. The combustion of heavy machinery, essential in the infrastructure construction process, is another source of pollution.
Erosion and sediment control	Erosion and sedimentation can result from the removal of vegetation; installation of drainage structures; removal, storage, and reuse of topsoil; during earthworks; and while revegetation is taking place. Erosion and sediment control are the measures considered.
Flora and Fauna	This criterion seeks to consider methods in the construction phase to avoid damage to existing plant communities, promote the planting of native plant material, revegetate areas of abandoned alignment, and eliminate invasive species.
Reuse and recycling materials	Appropriate reuse of structures and parts of structures can significantly reduce the demand for new construction materials and other environmental burdens resulting from their development. The objectives of this criterion are to consider designs that allow for and provide flexibility for contractors to reduce waste generation and beneficially reuse and recycle materials.
	Social factor
Cultural Heritage	The extent, nature, and significance of the cultural heritage affected by the project are determined through predesign studies. The results of these studies should be included with the Planning Application or form part of the Environmental Impact Assessment (EIA) to inform any planning decisions.

Table 1. *Cont.*

Evaluation Criteria	Description
Public access	These types of projects generate a great deal of public interest. Participation through public access via site tours, information panels, live video broadcasts, and other mechanisms helps to maintain relationships with the local community.
Health and safety	Every infrastructure project presents risks to the safety and health of workers during construction. Safety is fundamental in the development of the activities that take place during the execution of the project to protect people's lives. Health is associated with effects on the future of workers or neighbours, mainly related to pulmonary problems due to the inhalation of contaminating particles.
Stakeholder relations	Direct and fluid communication with affected communities involves a two-way dialogue and relationship that goes far beyond the immediate impact of the construction project on its direct neighbours, which is vital for a smooth implementation of the project. This will reduce delays during planning implementation, reduce the risk of protests during construction, improve community relations, and provide greater acceptance of the whole scheme.
Intermodal Transportation	There is a difference between building a road and building a public-transport network. The interconnectivity of different public systems such as road, rail, cycle, and pedestrian paths becomes essential. Accessibility, connectivity, and user attractiveness are key elements and challenges for the design team.
Visual and Aesthetic Impact	Almost any built structure has a public perception of neighbours, visitors, passers-by, etc.; so, it is necessary to ensure that the visual impact experienced by anyone who sees the designed infrastructure is as pleasant as possible. To achieve this, citizen participation is required. This consists of optimizing the use of construction materials to the maximum, minimizing the waste generated during the construction process. A percentage of this waste is recycled or taken to landfills in controlled sites.
	Economic factor
Life-cycle cost and investment	The criterion seeks to value the costs involved in the infrastructure project in question, from the execution, construction, and maintenance phases to the decommissioning phase at the end of its useful life.
Project Risk	This criterion assesses the project risk, depending on the location of the project and the different risks that may affect the infrastructure. Project risk is highest during the construction phase. However, once the projects are in the operation phase, the project risk decreases and becomes more acceptable to investors.

Figure 2 shows the diagram of the relationship between the total influence factor (TIF) and the sustainability factors so that the influence of three of them on TIF can be observed.

All assessment criteria can be quantified according to the impact values, which are in a range from 0 to 5, where 0 indicates that the criterion does not affect the evaluated sustainability factor and 5 indicates that it has a very high negative impact on the factor. Table 2 shows the breakdown of the intermediate values.

The use of the numerical values in the first column of Table 2 simplifies the evaluation process, as the significant figures may underestimate or overestimate some of the sustainability factors.

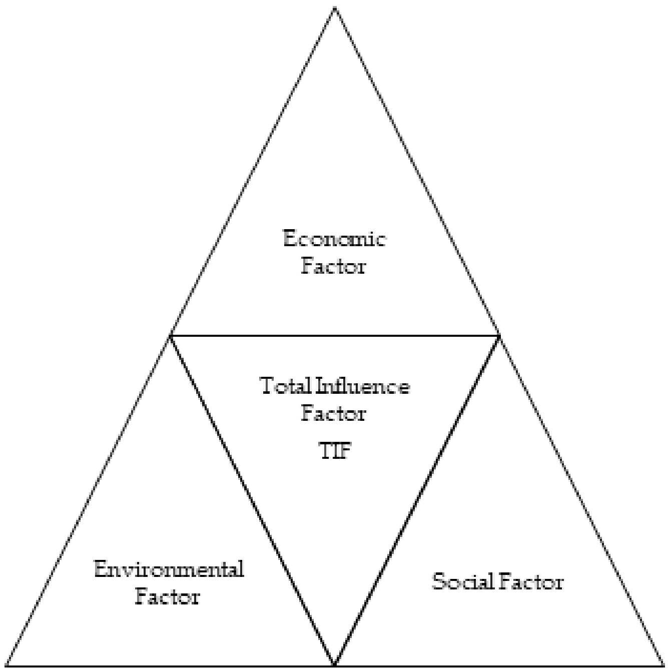

Figure 2. Diagram of direct organization of sustainability factors.

Table 2. Impact value, definition, and description of the assessment criteria, indicating in every case whether corrective actions are needed or not, and extension if needed.

Impact Value of the Assessment Criteria	Definition	Description	Corrective Actions
0	Does not affect	There is no direct or indirect relationship between the assessment criteria and the infrastructure evaluated.	No
1	Negligible or very light	The infrastructure generates a very low or nonperceived negative impact.	No
2	Light	The infrastructure visibly affects its surroundings, but no corrective actions are required.	Simple (Recommended)
3	Medium	The infrastructure affects its surroundings to a degree that it is advisable for the project to consider corrective actions.	Simple
4	High	There is a significant negative impact on the surroundings in which the infrastructure is located, which could be permanent or temporary, requiring corrective actions up to at least level 3.	Complex
5	Very high	There is permanent damage to the surroundings in which the infrastructure is located, requiring corrective actions to reduce the impact value to at least level 3.	Redesign and incorporate corrective actions

2.3. Sustainability Limits and Total Influence Factor (TIF)

Prior to the evaluation of the infrastructure, it is necessary to define the admissible impact limits or sustainability limits, as well as the weighted relationship between the factors evaluated, in order to obtain the representative TIF of the project.

This sustainability limit will depend on, or be influenced by, the administration (country, autonomous community, region, international agreements, etc.) and by the sustainability trend that the infrastructures are expected to meet, according to the three defined factors, which will adopt a higher or lower assessment depending on the type of infrastructure. These limits are variable and obtained from a statistical analysis of the sustainability factors of similar projects in an informative (initial) study phase.

The proposed method is a tool that allows the assessment of the sustainability of any infrastructure; it will only be necessary to vary the sustainability limits, which will change depending on the specific infrastructure in each case. To do this, it is necessary to collect available data from infrastructures with similar characteristics to those under evaluation.

The structure of the model created starts from the use of the weights of the objectives obtained by multicriteria analysis methods for the selection of the best alternative and comparing them with the three pillars or factors of sustainability: social, economic, and environmental calculating a redistribution of the weights of sustainability factors. A simple statistical analysis establishes the sustainability limits (SL). The last step is the estimation of the influence factor (TIF). Figure 3 shows a flow chart of the process followed to develop the proposed model.

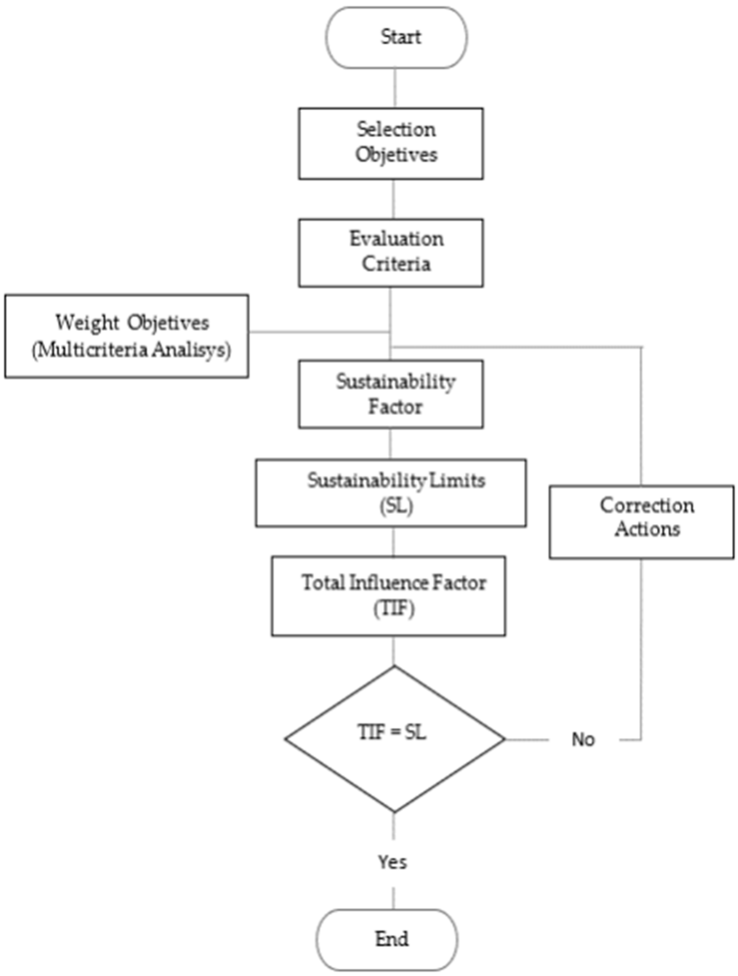

Figure 3. Flow chart of the proposed model.

3. Results and Discussion

3.1. Application of the Proposed Method for Sustainability Assessment of a Road Project

The data used for the application of the proposed methodology are from road sections in the construction phase available from the Ministry of Transport, Mobility and Urban Agenda of the Government of Spain. The road sections are:

- Road 1: El Villar de Arnedo bypass, Province of La Rioja;
- Road 2: Connection alternatives between the Trujillo–Cáceres Highway (A-58) and the La Plata Highway (A-66) in the area of Cáceres, Province of Cáceres;
- Highway 3: Bypass of the A-1 Highway, Section: Airport Axis Highway junction (M-12) and R-2 Highway, El Molar Bypass, Province of Madrid;
- Road 4: Study of alternatives and development of the solution adopted for the new road connecting the municipalities of Onda and Betxi from "Carrer Tosalet hata Camí D'Onda, 33", Province of Castellón;
- Road 5: Inca Bypass, Modification of the section between the Ma-2130 (Lluc) and the MA-12 (Palma-Sa Pobla Highway), Province of Palma de Mallorca;
- Road 6: Highway between Ávila (A-50) and the Northwest Highway (A-6).

In these informative studies, the Pattern methodology [36] is used to choose the best alternative that a project can have. It is a multicriteria analysis method of total aggregation, where the weights assigned to each of the objectives involved in the calculation are fixed. Table 3 and Figure 4 show the allocation of weights for each of the best alternatives of the roads used in the study.

Table 3. Summary of weight assignment according to the Pattern method to the best alternative in each one of the roads used.

Weight Allocation—Pattern Method for the Best Alternative						
Objective	**Weight**					
	Road 1	Road 2	Road 3	Road 4	Road 5	Road 6
Environmental	0.30	0.25	0.25	0.15	0.30	0.20
Economic	0.30	0.25	0.25	0.35	0.10	0.20
Functional and Safety Vial	0.30	0.40	0.25	0.40	0.30	0.40
Territorial	0.10	0.10	0.25	0.10	0.30	0.20

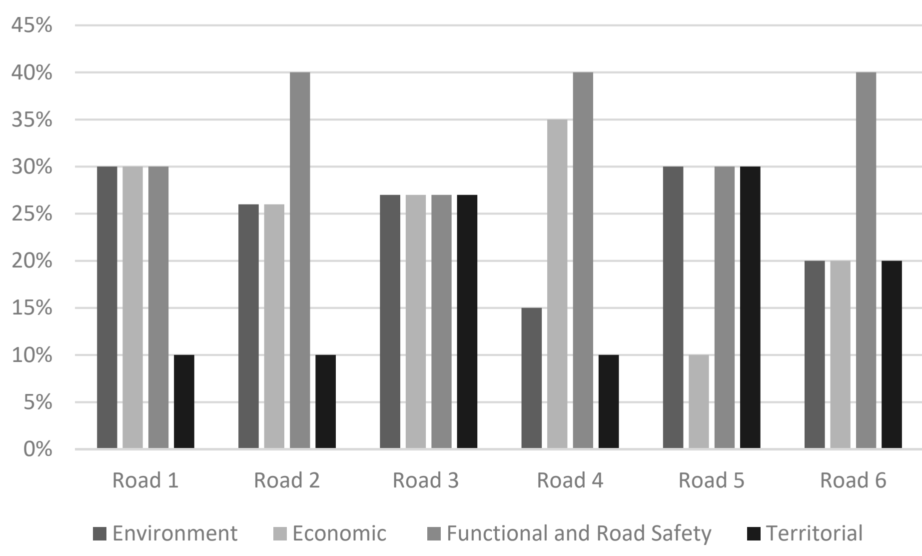

Figure 4. Weighting of project objectives for the studied roads.

The comparison of the four objectives with the three factors of the sustainability pillars results in a direct relationship between the environmental and economic objectives and the environmental and economic sustainability factors. Regarding the social sustainability factor resulting from the comparison, it could be associated with the functional objective and road safety. The fourth objective, territorial, has been distributed homogeneously among the three sustainability factors.

$$Swf = SO + \frac{1}{3}\,TO \tag{1}$$

$$Ewf = EO + \frac{1}{3}\,TO \tag{2}$$

$$Ecwf = EcO + \frac{1}{3}\,TO \tag{3}$$

$$\sum wf = 1 \tag{4}$$

where:

Swf = Social weighting factor according to the type of infrastructure;
SO = Functional and road safety objective;
TO = Territorial objective;
Ewf = Environmental weighting factor according to the type of infrastructure;
EO = Environmental objective;
Ecwf = Economic weighting factor according to the type of infrastructure;
EcO = Economic objective;
wf = Weighting factor.

Table 4 and Figure 5 show the redistribution of the weights of the four objectives to the three sustainability factors.

Table 4. Redistribution of the weighting of objectives and association with sustainability factors.

Redistribution of Evaluation Weighting Factors						
Factor	**Weight**					
	Road 1	Road 2	Road 3	Road 4	Road 5	Road 6
Environmental	0.33	0.28	0.33	0.18	0.40	0.27
Economic	0.33	0.28	0.33	0.38	0.20	0.27
Social	0.33	0.44	0.33	0.44	0.40	0.46

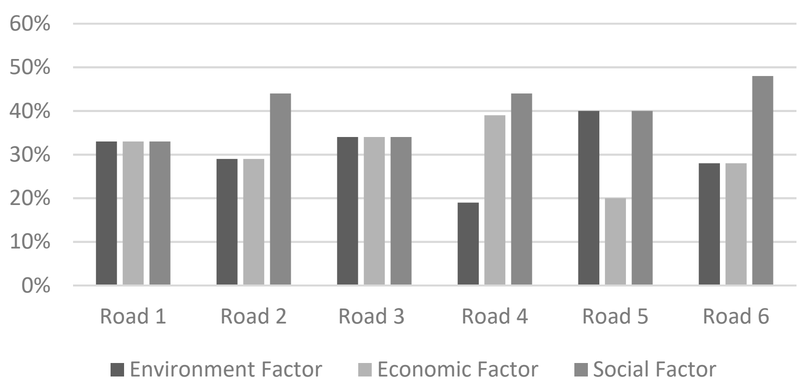

Figure 5. Weighting of objectives redistribution and association to the sustainability factors for the studied roads.

The distribution of the objective weights with the three sustainability factors results in a simple statistical analysis of the data, as shown in Table 5. According to this table, the standard deviation of the data is lower than 0.1, a value used in most of the informative studies analysed.

Table 5. Statistical analysis of objective weights.

	Factor		
Main Measurements	**Environmental**	**Economic**	**Social**
Minimum	0.18	0.20	0.33
Maximum	0.40	0.38	0.47
Mean	0.30	0.30	0.40
Standard Deviation	0.07	0.06	0.06

Table 6 shows the sustainability limits (SL) for road projects based on the statistical analysis, including the sustainability factor, the limit values, and the descriptions.

Table 6. Sustainability Limits (SL) for Roads.

Factor	Limits	Description
Social	40	This type of infrastructure fulfils the function of connecting different territories along the route that directly influences the development of communities (job opportunities, trips with mentor time invested, increased tourism, etc.).
Economic	30	It is related to the social factor since connectivity generates ways to supply communities that are close to infrastructure and increases business opportunities, the dynamism of the region's economy, and the internal rate of return (IRR), among other reasons.
Environmental	30	Valuation that has its greatest impact on territorial division, especially in areas with high biodiversity.

The definition of SL for roads allows, in turn, the definition of the TIF, obtained by multiplying the sustainability limits of each evaluation criterion by each sustainability factor; the total sum being the number that represents the level of sustainability of the project analysed. Table 7 shows the classification according to the established ranges.

Table 7. Data measurement for sustainability factors.

Range	Infrastructure Classification	Description
0–20	Minor Impact	The project has a low impact on all three sustainability factors.
20–40	Viable	The project complies with the minimum requirements for its execution.
40–60	Adjust	The project requires some adjustments to reduce the impact on some of the sustainability factors.
60–80	Redesign	The project requires a complete redesign.
80–100	Unfeasible	The project is not executable at all.

3.2. Assessment of the Infrastructure

As previously mentioned, it is possible to assess the infrastructure in a local and a global way; the local way refers to each of the sustainability factors, whereas the global way refers to TIF. This assessment allows for the cataloguing of the infrastructure project in terms of its sustainability.

3.2.1. Assessment Triangle of the Project

The impact triangle graphically shows the interaction between the sustainability factors and the assessment criteria, providing visual information on the project evaluation and the admissible impact limits or sustainability limits.

Thus, Figure 6 shows the assessment triangle of the project. This triangle consists of a theoretical maximum of 100 points, which is represented in the triangle vertices for the three sustainability factors; a recommended maximum or a sustainability limit, represented by the triangle with the dashed line and according to the values shown in Table 7; and the results of the sustainability assessment, represented by the solid triangle.

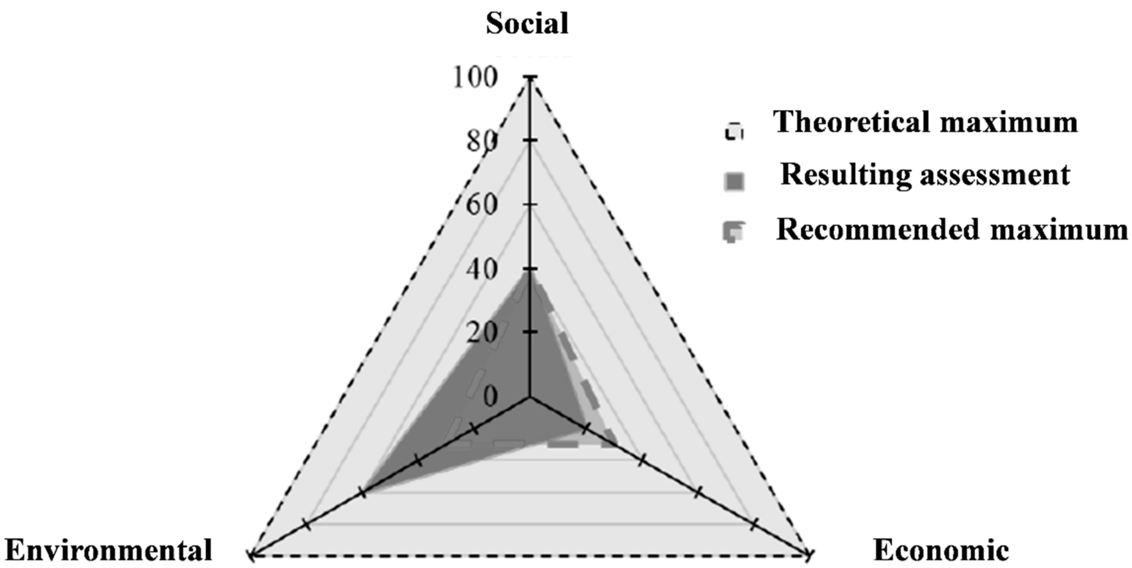

Figure 6. Assessment triangle of the project.

3.2.2. Classification of the Infrastructure

The TIF calculation estimates the degree of sustainability of the evaluated project. Previously, there was a local evaluation of the infrastructure for each sustainability factor. The TIF calculation expression is:

$$TIF = Ewf * Se + Swf * Sc + Ecwf * Sec \tag{5}$$

where:

Se: Sum of criteria scores according to the environmental point of view;

Sc: Sum of criteria scores according to the social point of view;

Sec: Sum of criteria scores according to the economic point of view.

A comparison between the TIF value and the infrastructure rating ranges in Table 7 provides a value. The lower limit for a project to be sustainable without applying corrective measures is 40 points. When the TIF value is higher than 40 points, corrective actions are required. These corrective actions will cause the TIF value to decrease, in order to keep the infrastructure within the admissible range.

3.2.3. Corrective Actions

There are corrective actions that, depending on the evaluation criteria, reduce the negative impacts caused by any of the sustainability factors. They may be differently difficult to implement due to the cost, the space required for their execution, the necessary equipment, the existence or not of qualified personnel for their implementation, etc.

The application of corrective actions is generally needed to reduce the negative impact of an assessment criterion whenever such impact has a value of two or higher, as previously indicated in Table 2.

We propose some corrective actions, with their corresponding evaluations, based on a rubric structure. The development of the rubrics considers aspects, such as human resources, execution times, and implementation costs. Tables S1–S3 show, as examples, four of the rubrics created for this purpose that refer to different evaluation criteria, such as reuse and recycling of materials, cultural heritage, public access, and project risk. The values used for the evaluation have been one and two so that one refers to a simple corrective action and two to a complex corrective action. The result of the evaluation is the average score of the three aspects. Table 8 shows the overall assessment of the corrective actions.

Table 8. Aspects evaluated for the corrective actions.

Aspects	Correction Action Simple → Value = 1	Correction Action Complex → Value = 2
Human Resources	Team of 2 to 4 unskilled workers for the development of simple tasks.	Team of more than 4 workers, with some type of qualification or specialization in the task performed.
Execution time	A short period is required for the execution of the corrective action, without a detailed planning of the procedure.	A considerable time for the execution of the corrective action is required, either for particular or repetitive activities. The development of a detailed plan of the sequence of tasks is required.
Implementation cost (maintenance, materials, machinery, and expenses)	Relatively low cost of materials, light machinery, and payment to workers and associated with a short execution time. The corrective action does not require major maintenance.	Medium-to-high cost, involving higher technology materials, heavy machinery, and payment of skilled workers and associated with a medium-to-long execution period. The corrective action may or may not require maintenance depending on its complexity.

The implementation of corrective actions generates an increase in the economic sustainability factor, which implies an increase in the cost of the project. The quantification of this factor is important to determine the possibility of increasing the project in the operation phase. Table 9 shows a summary of alternatives referring to the corrective actions for one of the evaluation criteria for environmental, social, and economic sustainability factors.

Table 9. Summary of alternatives referring to the corrective actions for one of the assessment criteria for the environmental, social, and economic sustainability factors.

Criteria	Corrective Action	Description of the Evaluation	Value
	Environmental factor		
Land Use /Site Selection	To take into account the greatest length of tunnels in linear works projects, such as highways, if this generates an optimization in the total length of the road.	Due to the increased cost involved in the construction of tunnels (excavation, support, interior installations, etc.).	2.0
	Change in the layout of a linear work, in order to minimize some of the sustainability factors.	Due to the impact of interdisciplinary changes during the design phase.	2.0
	Reduce the surface area occupied by the infrastructure during its operation stage, considering in its design a verticalization of its main structures.	Due to the increased cost involved in the verticalization of major structures.	2.0

Table 9. *Cont.*

Criteria	Corrective Action	Description of the Evaluation	Value
	Selection of sites with sufficient existing infrastructure for the use of the new site will minimize the need to build new roads, railroads, etc.	Due to the increase in the time required for site selection, but which can be assumed by the project without a relevant increase in the cost.	1.0
Social factor			
Land improvements and incorporation of technology	Geosynthetics implementation (geotextiles and geogrids).	Given for implementing an alternative technology with a slightly higher cost than other, more conventional, technologies.	1.0
	Implement a compensatory policy for the municipality in which the infrastructure is located, by performing bioengineering soil treatment.	This value is calculated by the cost and time required to perform the soil studies and then apply the most appropriate solution to improve the properties of the selected land.	1.7
	Combination of plant material (such as hydroseeding) and structural elements for slope protection, reconstruction, stabilization, and erosion control.	Associated with the implementation of a solution that visually improves the environment, which also contributes to the increase of green areas.	2.0
Economic factor			
Life-cycle cost and investment (initiation phase, planning phase, implementation phase, control and monitoring phase, and closure phase)	In the implementation phase, enhancement area at the infrastructure site, sites for commercial sale	Involves an insignificant increase in the cost of the project since the corrective action must meet the minimum safety requirements for users without requiring a unique design	1.7
	In all types of infrastructure (roads, railroads, ports, airports, etc.), negotiate with the administration to extend the concession period, if the link with the administration is of this type	Physical work on site is not involved, but contractual work, which financially can significantly improve cash flows for the period of operation of the infrastructure	2.0

The proposed tool is an efficient method for assessing the sustainability of any type of infrastructure and lifecycle phases (initiation, planning, implementation, control and monitoring, and closure), as shown in Figure 7. For this purpose, it is necessary to choose the sustainability limits that best respond to the characteristics and phase of the life cycle of the project under evaluation.

Compared to the other existing methods, INVEST [22], I-LAST [23], and STARS [20] are only applicable to linear infrastructures, whereas Envision [25] and CEEQUAL [24] are methods that evaluate the sustainability of civil infrastructures in general but based on a certification system that requires a bureaucracy. That certifies whether or not the projects meet the requirements demanded by these methodologies. However, the method developed is not a certification method; it is a measure of project sustainability as an aid in decision-making.

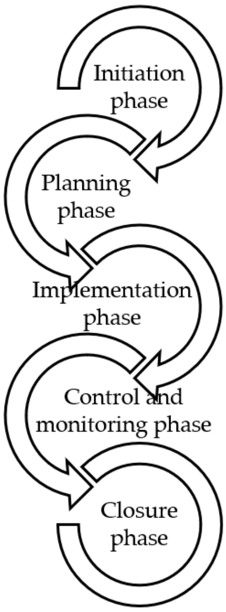

Figure 7. Phases of the life cycle of a project.

4. Conclusions

The assessment triangle of the project, associated with the TIF (Total Influence Factor), defines the proposed methodology. This factor is calculated after defining the sustainability limits, incorporating a set of estimated corrective actions based on a rubric structure that considers human resources, execution times, and implementation costs with the values of one when it is due to a simple correction action, and two if it is a complex one.

The methodology is applicable to any type of infrastructure. To do this, the following steps must be followed: select the objectives, define the evaluation criteria according to the type of infrastructure, evaluate the variables considered, define the decision rule for the project alternatives, compare with the sustainability factors and redistribute the weights, use statistical calculations to obtain the sustainability limits, calculate the TIF, and incorporate corrective measures in the evaluation in order to make the project sustainable.

For the calculation of the sustainability limits, it is necessary to use real data from similar infrastructures already built, so that the indices calculated are more like the real project and the accuracy is greater. The indices calculated in this paper were on the basis of several road sections, in which the best alternatives have been chosen using a multicriteria selection method called the Pattern method, widely used for this purpose in Spanish infrastructures.

The three pillars of sustainability used as basic criteria are applied depending on the particular characteristics or complexity of the evaluated project, which generates a change in the TIF and the admissible limits. The assessment triangle of the project is useful to understand what the impact index of the project is, as well as if the project itself is feasible or unfeasible.

In addition, if the TIF is above the sustainability limits allowed, a series of corrective actions can be applied (which are included in the methodology and have been assessed through a system of rubrics), which will reduce the value of the TIF and turn the evaluated work into a sustainable project.

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