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Revision of Sustainable Road Rating Systems: Selection of the Best Suited System for Hungarian Road Construction Using TOPSIS Method

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Abstract: There are a number of sustainable and environmentally friendly techniques and methods currently available in the construction industry. To promote sustainable development, different rating and certificating systems that evaluate the level of sustainability during the development of infrastructure construction projects have been developed. The aim of the research presented in this paper was to examine the applicability of sustainability rating systems in Hungary and find the most suitable option. After a review of commonly used rating systems, i.e., Greenroads, GreenLITES, I-LAST, Envision, and INVEST, the most suitable existing rating system is selected with the help of the Technique for Order Preference by Similarity to the Ideal Solution (TOPSIS) mathematical decision analysis method. This was achieved by utilizing 12 categories of input data (weights) analyzed through TOPSIS. The input data (weights) of the TOPSIS method were determined by a small research group of industry experts and academic professionals based on Hungarian practices and methodology. As a result of the calculation, the study found that the Envision rating system satisfies the criteria best, closely followed by Greenroads.

Keywords: sustainability; Hungarian construction practice; road rating systems; TOPSIS

1. Introduction

It is widely agreed that the construction industry has one of the most significant impacts on our environment, contributing significantly to air pollution, resource depletion, waste generation, global warming, and climate change. Energy-intensive processes are required to produce and build the raw materials for structures, and the finished structure influences the aesthetics of the environment and, in the case of transportation, can affect the ecosystem of natural habitats, water quality, and noise pollution [1–3]. To optimize these factors, the application of sustainable development has also become important in the construction sector. Recently, sustainable development has become an economic issue for business, as long-range economic models have to include rising energy costs and will soon have to include CO_2 emissions permits as well. These items represent new risks but also an opportunity to change technological and operational trade-offs, especially in the built environment or transport-related sectors [1].

The construction industry is taking huge steps toward supporting a wide range of environmentally friendly strategies and technologies and promoting green building practices. Structural engineering plays a leading role in the development of green assessment systems, such as Leadership in Energy and Environmental Design (LEED) and the Green Globes and Building Research Establishment Environmental Assessment Method (BREEAM), which helps stakeholders to identify green practices and assess progress towards sustainability. Despite the popularity of green rating systems in civil construction over the last 20 years, they have become less widespread internationally in road construction [4]. Nevertheless, many systems have been developed, largely in the United States. These rating and evaluation systems have generally been established by trusted governmental and private organizations working with academia. They analyze, evaluate, and sort out the existing facilities. In general, when a project is evaluated using a certification system, it should meet certain minimum, mandatory prerequisites or a minimum score in the evaluation. In any of the rating systems, self-assessment takes place without the involvement of a third party—a certifier—where the goal is to measure and monitor sustainability in order to define future development goals and analyze and communicate sustainability for the benefit of the society. Ratings of segments (categories) and subclasses are collected and compared. Certification and rating systems typically include general components that are part of the certification tools: systematic and strategic environmental performance, water, energy, materials, safety, education, and innovation. Each rating system includes a specific weighting methodology, which differs depending on the system.

Achieving sustainable planning and design is becoming essential in Hungary (due to EU directives). This requires changes on the capital investor and political side. While most of the techniques and practices are available, there is a need for customers to be committed to sustainable practices. A low demand can be a result of fear of lower levels of performance (warm mix asphalt (WMA), recycled asphalt pavement (RAP)) or the extra cost and extra work hours caused by sustainable design. Therefore, well-structured regulation or incentive tools are needed to spread the requisite techniques and mindsets. Different "green" objective rating systems can help increase the level of sustainability in both design and implementation. Therefore, the application of a rating system is very significant in Hungary with regard to the promotion of sustainable development and keeping up with the leading European countries.

This study focuses on the Greenroads, I_LAST, Envision, GreenLITES, and INVEST systems and shows how different national systems were developed. The aim of the paper is to select the system that is most suitable for the promotion of sustainability in Hungarian road construction.

2. Literature Review

In recent decades, in Hungary, as in many other countries, a lot of research, regulation, and innovation has been conducted to make the construction industry more sustainable. As a member of the European Union, Hungary's construction regulation complies with European regulations. Based on this, project developments often start with green public procurement (GPP) and are examined by cost-benefit analysis (CBA) and environmental impact assessment (EIA). Within the evaluation of EIA, an examination of the land use, interference with ecosystems, changes in natural capitals, and changes in ecosystem services is extremely important for maintaining the rich biodiversity of the country. Therefore, some of the available sustainable evaluation methods are used in Hungary; however, many of the available other tools are typically not or are rarely involved in the project development phase. For instance, the energy consumption throughout the life cycle of a project, the costs for the whole life cycle in the project development phase and the amount of recycled-material usage are often not considered in practice [5]. The use of local materials is important in the Hungarian practice; however, this is more likely caused by cost implications, which is still the most important aspect of the decision-making process in the country.

Based on the abovementioned issues, in order to make Hungarian construction practices more sustainable and promote sustainable long-term strategies, the use of a green rating system or national sustainable indicators is required. For this reason, the Hungarian Road Administration conducted a study in 2015 [5] with the title "Sustainable pavements and highways: An analysis of green roads rating systems". This internal study reviewed international practices, analyzed the methods and tools, and narrowed down the suitable rating systems. This paper further analyzes these systems; a comparison of these system with the TOPSIS method is also provided which has not been conducted before.

This section presents the Greenroads, GreenLITES, I-LAST, Envision, and INVEST rating systems, mentions some other important, frequently used systems, and presents the commonly used ways to develop national rating systems or a sustainable set of indicators. A more detailed literature review can be found in Appendix A, where the previously selected rating and certificating systems are presented based on their manuals.

2.1. Greenroads

The Greenroads rating system was developed by the University of Washington in 2007, with the participation of more than 100 professionals. It is primarily applicable to the US environment but can be applied worldwide. The system is project-based and can be used to certify projects to support sustainable practices [6]. The evaluation has two parts, project requirements and voluntary credits. The project essentially requires compliance with technical and legal requirements and consists of some basic, forward-looking but not necessarily legally binding parts. There are currently four certification levels: Bronze (40-point minimum); Silver (50-point minimum); Gold (60-point minimum); Evergreen (80-point minimum) [7]. With over 1100 organizations and members from 62 countries around the world and 50 states in the US, the system has been used in more than 130 different types of projects with investment beneficiaries and 50 qualified projects. It can therefore be stated that the system is highly successful.

Greenroads places great emphasis on management tools. The system is detailed enough to perform the assessment work in practice but general enough to provide a comprehensive picture of sustainability on a larger scale. The system considers the three pillars of sustainability; however, the emphasis is clearly on the environmental impacts.

2.2. I-LAST

The Illinois-Livable and Sustainable Transportation Rating System and Guide (I-LAST) rating system was developed in collaboration with the Illinois Department of Transportation and the engineering and construction community. The system aims to assess and encourage the sustainability of investments using simple tools. The system consists of a Microsoft (MS) Excel spreadsheet with a detailed description and instructions attached to it. The use of the system is voluntary and free. It is intended to be simple and quick; therefore, it has quantitative criteria. The handbook consists of a detailed system of scoring criteria which can be used to increase the sustainability of an investment. Projects are evaluated based on nine main categories, which are divided into subcategories. There is a total of 153 criteria in the system, and the number of points that can be obtained is 233 [8]. The evaluation takes into account practical aspects, which assess sustainability on the basis of the presence or absence of specific technologies and methods. Because of this, without development and continuous expansion, it may become obsolete in the medium to even short term with the development of new technologies.

2.3. ENVISION

Envision was developed through a collaboration between Harvard University Graduate School of Design and the Institute for Sustainable Infrastructure, together with a Zofnass Program for Sustainable Infrastructure. The methodology, released in 2012, was developed primarily for use in the design and project development process, but the most recent and expanded version also evaluates the processes of construction, operation, maintenance, and demolition. Envision is therefore a family of tools that covers all stages of the project life cycle. The aim of the assessment is, in addition to certification, to promote sustainability in technical, social, environmental, and economic terms using the detailed descriptions provided in the guide. The Envision manual contains goals and performance levels that the user can employ in evaluating the project. The rating system can be paired with other Envision tools, such as the Envision checklist, which is a series of yes or no questions for self-evaluation. The checklist can be useful at the beginning of project planning, when the specific performance data for the detailed assessment are still unknown [9].

Currently, both the second and third versions of the system can be used to evaluate projects [10]. Any version of Envision examines projects according to five main categories, which can be further subdivided into a total of 60 credits with a total of 1000 points. The collected data are reviewed by an independent third party, the so-called ENVISION Verifier. The system is both detailed and general enough to provide a comprehensive picture of sustainability on a larger scale; therefore, the use of the Envision system is widespread.

2.4. GreenLITES

The Green Leadership in Transportation and Environmental Sustainability (GreenLITES) rating system was developed by the New York State Department of Transportation (NYSDOT, Albany, USA) based on the LEED and Greenroads systems. The first version was released in 2008 for evaluation at the design level (GreenLITES Project Design). In 2009, a version for the evaluation of operation and maintenance strategies (GreenLITES Operations) was released. A project can be examined using 175 subcategories, which are divided into five main categories, with a total of 271 points. Depending on the amount of points earned, the project may earn one of four certification levels [11]. For the evaluation, a downloadable MS Excel spreadsheet is available. The listed aspects include several questions, for which 0–4 points can be awarded based on the guide. The purpose of the rating system is not only to evaluate projects but also to measure the NYSDOT performance itself, identify areas for improvement, and use it as a tool to show the public how they are making progress in sustainable practices [12].

2.5. INVEST

Infrastructure Voluntary Evaluation Sustainability Tool (INVEST) was established by the US Federal Highway Administration (FHWA, Washington, USA) in 2010. The system is free, user-friendly, and available online. As there is no third-party verification, it does not provide an officially accepted certificate. The purpose is to apply more sustainable solutions during self-auditing and design, as well as to guide users toward focusing on more sustainable solutions. INVEST can be used in three phases of a project, which is evaluated according to separate categories. The phases are the System Planning (SP), Project Development (PD), and Operation and Maintenance (OM) phases; however, the PD phase is the most detailed, consisting of several scorecards designed to identify the varying scope, size, and context of projects across the country [13]. The aim of the SP modules is to assess the sustainability of a greater network, such as state or region. The SP modules contain 17 criteria each, which are combined into a single scorecard. The Project Development modules evaluate the investments from the beginning of the planning, through the selection of alternatives, environmental analyses, and preparation of the final plans, to the implementation. In terms of scoring, INVEST has seven evaluation sheets for project evaluation. This approach provides flexibility, as not all conditions apply to all projects. Six of the scorecards are based on the type of project, such as paving, urban basic, urban extended, rural basic, rural extended, or scenic and recreational. A total of 33 complete criteria are defined. From these, different elements (subsets) should be fulfilled, depending on the type of project. The seventh is a unique evaluation sheet, which contains 11 basic criteria and user-selected criteria, thus allowing for an individual self-assessment of projects that do not fit well with the defined evaluation sheets [14]. The aim of the OM module is to evaluate system-level operation and maintenance activities based on their contribution to the sustainability of the transport system. There are 14 criteria in the module, with the 210 points that can be obtained divided equally between the criteria.

INVEST is, therefore, a free self-assessment tool that covers the entire life cycle of a transport facility using different worksheets, without the need for third party certification. The Scoring Guide section specifies the condition for earning points. Depending on the criterion, the condition can be qualitative or quantitative. The biggest advantage of the system is that it is also suitable for the strategic and operation-maintenance phases. It should be noted, however, that at the strategic and operational maintenance levels, the system is very general, as the effects in these phases are much more difficult to measure and delimit compared to those at the project level.

2.6. Other Rating Systems

CEEQUAL: A British rating and reward system for improving sustainability in the civil engineering and public realm. The system was developed in 2003 and has been recognized in the UK and Ireland. CEEQUAL Version 6, which provides a global benchmark for infrastructure sustainability to compare projects across markets and regions, was launched in 2019. The system conducts its evaluation according to eight main categories: Management, Resilience, Communities and Stakeholders, Land Use and Ecology, Landscape and Historic Environment, Pollution, Resources, and Transport [15]. The system also has some prerequisites that must be fulfilled at the beginning, including some issues that must be solved for certification.

Sustainable Transportation Analysis Rating System (STARS): This system was developed by the North American Sustainable Transportation Council (STC). Project credits are divided into eight categories: Integrated Process, Community, Access and Mobility, Climate and Energy, Ecological Benefit, Cost-Effectiveness, Safety and Health, and Ecological Function [16].

GreenPave: This project was developed by the Ontario Ministry of Transportation. It is a computerized checklist with four main categories: Pavement Technologies, Materials and Resources, Energy and Atmosphere, and Innovations and Design Processes [17].

Sustainability National Road Administrations (SUNRA): This project was set up by the national road administration (NRA) to measure sustainability performance in Europe in collaboration with seven countries, including Germany, Denmark, Ireland, the Netherlands, Norway, Sweden, and the United Kingdom [18].

Building for Environmental and Economic Sustainability (BE^2ST): This system was developed by the Recycled Materials Resources Center (RMRC) at the University of Wisconsin College of Engineering. It provides the opportunity to assign weight based on importance and the analysis is conducted through the Analytical Hierarchy Process (AHP) [19]. For modelling, the recommended software is available for free; however, it has not been further developed. Moreover, the national databases required for the input data are missing for Hungary; introducing this system would require extensive data collection, which significantly complicates and delays the practical application.

2.7. Development of National Rating Systems—A Global Overview

Recognizing the benefits of sustainability rating systems, many countries have followed the example of the systems listed above, including South Korea, Malaysia, India, Indonesia, Iraq [20–25] and, in Europe, Italy [26]. Moreover, within the framework of the SUNRA project, Germany, Denmark, Ireland, the Netherlands, Norway, Sweden, and the United Kingdom [18] have examined the introduction of sustainability assessment systems. Literature research shows that some of these countries (South Korea, Malaysia, and India) have established their own assessment systems due to national specifics, such as climatic and environmental conditions, social needs, and national construction practices. The method of setting up the rating systems was similar in the three countries. For South Korea, Malaysia, and India, the systems were also initiated by their governments and have been requested from academia and/or transportation authorities. The methodology for creating a national evaluation system is illustrated in Figure 1 below.

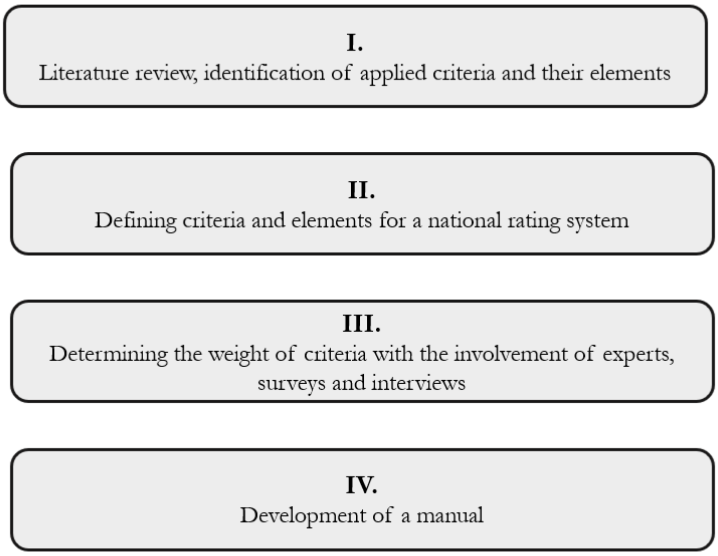

Figure 1. The framework of establishing a national sustainability assessment system for South Korea, Malaysia, and India.

While the main steps of the methods are the same, the establishment of country-specific systems after the identification of the criteria and their elements slightly differed for the three countries. According to Park and Ahn [14], in the case of South Korea, once the objectives of the green road grading system had been set, 10 industry experts (five architects and civil engineers firms and five construction firms), who had been working in the profession for at least 20 years, were asked to identify and develop the categories, indicators, and credits for the green rating. Once this was determined, expert groups of 10 construction and architecture/engineering (A/E) professionals, 9 researchers and professors, 3 government officials, and 4 business owners were interviewed for individual and group interviews to form the scoring. The participants were asked to rank measures based on their importance for establishing a South Korean green road rating system. The application of the technique allowed the developers to identify the main aspects, categories, and parameters of the evaluation system (indicators and credits) and to assign appropriate weightings to each. This study used a mathematical decision-making technique called the analytic hierarchy process (AHP). The developed system includes six categories, which are Green Road Design/Pavement Technology, Green Environment, Green Resources and Energy, Green Traffic System Highway, Green Traffic System National Highway, and Costume Credits.

The development of Malaysia's Green Highway Index was studied by Zaim et al. [25]. In this study, after defining the main criteria, a group of 30 experts identified the 27 main and 58 sub-elements of the national rating system through workshops. The importance of the elements was then determined according to the responses of 239 participants in a questionnaire survey by evaluating the responses by factor analysis using the statistical software package (SPSS) developed for the social sciences. The final system in Malaysia includes five categories. These are: Design and Construction Activities, Energy Efficiency, Environmental and Water Management, Materials and Technology, and Social and Safety Activities.

The establishment of India's sustainability rating system is described in the study of Singh and Jain [27]. After defining the objectives of the scheme, India identified 20 industry experts (10 from the government and 10 from the construction industry), who determined the categories, subcategories, and credits suitable for the promotion of sustainability. This was achieved by reviewing the existing systems (BE2ST, GreenPave, Envision, STARS, CEEQUAL, Green-guide, GreenLITES, GreenRoads, I-LAST, and INVEST). The system was developed with the support of the LEED India and the Green Rating for Integrated Habitat Assessment (GRIHA) building evaluation systems. To weigh the categories and their elements, the scoring system was determined by a questionnaire survey, where the interviewed parties rated the importance of the elements in the Indian practice on a scale of five. The developed system evaluates projects based on six main categories. These are: Selection and Planning, Energy Conservation, Water Conservation, Material and Resources, Environment Quality, and Innovation in Design. Within the categories, a total of 56 indicators and 170 credits support the evaluation.

Another method was used to establish a rating system for the US state of Georgia. A report from the Georgia Transportation Institute [28] shows that after studying the rating systems, the project team decided to select an existing one as a template and base for developing the system. The selection was made in conjunction with the project team based on the research team's experience in road construction and information from a team of state engineers, designers, and environmental experts. The working group chose the GreenLITES system from New York, which was modified to make it applicable to the unique natural and regional characteristics of the state of Georgia.

In Latin America, the World Bank Latin American and Caribbean Region established a rating system, which is described by Montgomery et al. [29]. The guide aims to help decision-makers and technicians in the road construction industry to achieve more environmentally sustainable road projects in developing countries. It is designed to be applicable at any stage of a project. The elements of these Environmentally Sustainable Criteria are based on the following five rating systems: Envision, CEEQUAL, INVEST, Green Roads, and GreenLITES. The final tool consists of over 330 sustainability-based criteria, which are separated into four main road transport project phases: 41 for Systems Planning, 108 for Project Planning and Design, 94 for Construction, and 91 for Road Operation and Maintenance. These are available on a separate evaluation sheet. It is, obviously, not expected that a project will meet all the criteria; instead, they should be used as a list of "potentially sustainable ideas and opportunities". The assessment should be carried out in cooperation with the involved persons, such as decision-makers, road construction engineers, environmental and social professionals, construction contractors, and operation and maintenance professionals. Furthermore, the selected sustainable activities must be cost-effective and add value to the project. Measuring performance through on-site monitoring, observation, and documentation is an important step in presenting actual results and should be designed and implemented well. The guide can be used as an input or reference for project design, construction, operation, and maintenance contracts, as well as third-party oversight contracts. The article also presents an experience of using the guide in one Argentinian and two Brazilian projects.

2.8. Conclusion of the Literature Review

The literature review points out that there are two options in setting up a national evaluation system. One way is for a country to develop its own criteria and credit system, which are defined by a larger group of experts and professionals. This approach usually uses the Analytic Hierarchy Process (AHP), Analytic Network Process (ANP), or Delphi technique through a set of questionnaires to calculate the importance (or weight) of the indicators [30]. The active participation of different professional parties in the processes, both in the working group and during the determination of the weighting, is important. Thus, this method is usually used when the evaluation system is developed on behalf of the government.

The other solution is to select a sustainability assessment system that has already been proven as effective in practice and use that as a basis. In this case, the next step is to adapt its elements to fit national specifics.

3. Materials and Methods

Firstly, this paper collected the relevant and commonly used systems, as well as some of the established national rating or certificating systems. The literature review intended to show the wide scope of application and wide variability of the existing systems and the method of formation and installation of different national practices relating to rating systems. It should be noted that the examined systems differ in terms of the range of applicable projects that can be evaluated, the stages of evaluation (planning, design, construction, and maintenance), and the system of criteria.

The aim of the research presented in this paper is to examine the applicability of sustainability rating systems in Hungary and select the most suitable system. The compared systems were previously analyzed in a study conducted by the Hungarian Road Administration earlier. The scope of that study was to review the international practices related to green rating systems and to analyze the existing and proved tools and methods for the clarification and establishment of the preconditions of a domestic model. In this paper, the selection of the most suitable system using Multi-Criteria Decision Making (MCDM) analysis has been made. Based on the literature review, the Analytical Hierarchy Process (AHP) method was found to be the most commonly used method for numerous construction-related decisions, as well as in the case of the determination of the weights of different indicators or criteria for sustainability ratings [4,19,30–37]. Next to AHP, studies also commonly used the Delphi model, Simple Additive Weighting (SAW), the TOPSIS method or other MCDM techniques, and combinations of them for decision-making or ranking [38–43]. This paper uses the TOPSIS method, since the focus of this paper is to rank the already existing rating systems instead of weighing the indicators of a new national evaluation tool.

TOPSIS is a well-known technique for dealing with the ranking problem of alternatives so that the preferred option should be closest to the positive ideal solution and, at the same time, furthest from the perfect negative solution. A more detailed description of the method can be found in section 4.2. The first step of the calculation is to define the criteria and their weights. The criteria were mainly taken from the result of an already mentioned Hungarian study [5]. The expansion of the criteria and the input data (weights) of the TOPSIS method were determined by a small research group of industry experts and academic professionals based on Hungarian practices and methodology. The research group consisted of experts from the National Infrastructure Development Corporation representing the asset owner side and experts from one of the largest infrastructure design and consulting company (Unitef '83 Zrt.), representing the designer side. The eleven members of the group collected a wide range of experience (5–32 years) throughout their career with conducting and approving environmental studies, innovation, and assessing sustainable technologies. Some of the members also have academic background. After the selection, the aim of the research was to examine the application of the most suitable system through a Hungarian transportation system project. With this, the authors intend to examine the elements of the selected system in order to determine the strengths and weaknesses of the Hungarian practice and filter out the elements that cannot be applied in the local practice.

4. Analysis and Interpretation

4.1. Comparison of Green Rating Systems and the Selection of the Most Suitable System Using the TOPSIS Method

Several rating and evaluation systems are currently available and used around the globe. The systems examined in this study were selected by the previously (in Section 3) mentioned study, which was conducted by the Hungarian Road Administration in 2015 by a small research team of experts with an academic or industry background. The summary of the Greenroads, GreenLITES, I-LAST, Envision, and INVEST systems are presented in Table 1 [44].

Table 1. Summary on the examined rating systems.

Name	**Greenroads**	**GreenLITES**
Full Name	**Green Roads**	**Green Leadership In Transportation Environmental Sustainability**
Origin	University of Washington Washington	Department of Transportation New York
Year of establishment	2007	2008
Website	www.greenroads.org	www.dot.ny.gov/programs/greenlites
Certification	Bronze/Silver/Gold/Evergreen	Certified/Silver/Gold/Evergreen
Last Version	42970	2010 April (2012 February)
Project level	Project development	Project design, Operation
Duration of validation	90 day	120 day
Number of criteria	61	175
Maximum points	130	278
Minimum point	30%	5%
Name	**I-LAST**	**Envision**
Full Name	**Illinois- Livable and Sustainable Transportation**	**Envision**
Origin	Department of Transportation Illinois	Institute for Sustainable Infrastructure Washington
Year of establishment	2010	2012
Website	www.idot.illinois.gov	datahttp://sustainableinfrastructure.org/envision/
Certification	-	Verified/Silver/Gold/Platinum
Last Version	41179	43207
Project level	Project development	Planning, Project development, Operation and maintenance
Duration of validation	-	90 day
Number of criteria	153	64
Maximum points	233	1000
Minimum point	-	20%
Name	**INVEST**	
Full Name	**Infrastructure Voluntary Evaluation Sustainability Tool**	
Origin	Federal Highway Administration Washington	
Year of establishment	2010	
Website	http://www.sustainablehighways.org/	
Certification	-	
Last Version	2018	
Project level	System planning, Project development, Operation and maintenance	
Duration of validation	90 day	
Number of criteria	11/27/34/29/27/11+(/op)	
Maximum points	63/136/171/119/153/136(/210)	
Minimum point	-	

In general, each system examined the rates of projects at different levels of projects, i.e., planning, project development, operation, and maintenance (Figure 2). To achieve this, checklists with different categories, different weights, and maximum points are used.

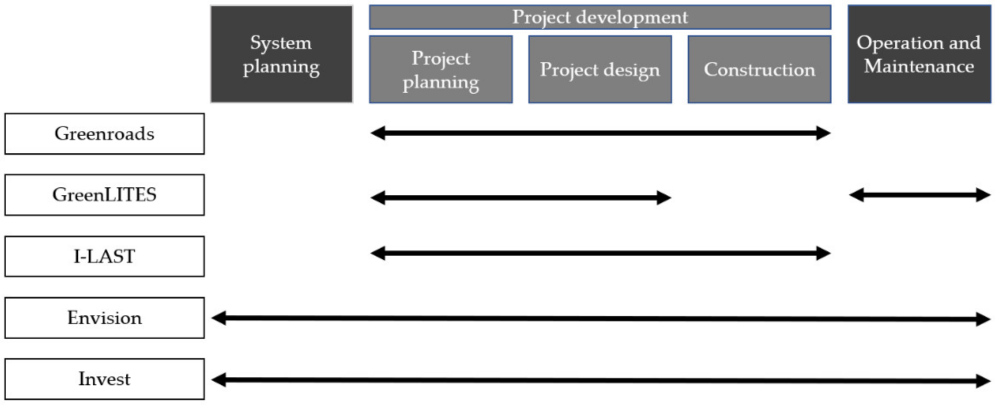

Figure 2. The stages of the project, in relation to which the different rating systems are applicable.

Most of the system credits fall into the following categories:

- Material and pavement technology.
- Environment and water.
- Design and construction.
- Accessibility and equality.
- Energy efficiency.

However, different systems consider different areas as the "most important" (Figure 3), i.e., they emphasize (weight) the importance of environmental solutions in the main categories in different ways.

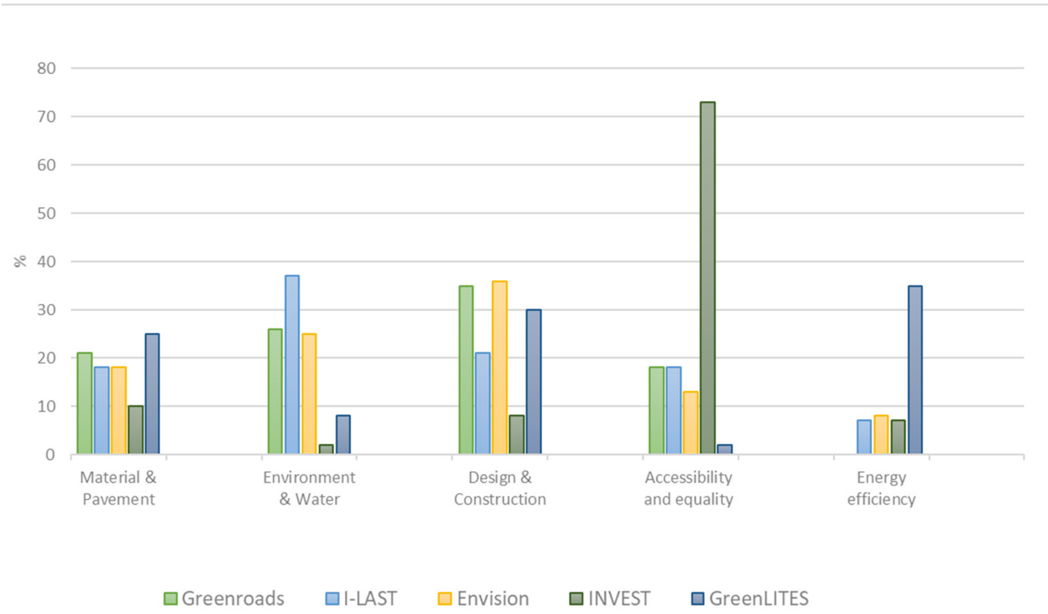

Figure 3. The distribution of the weight of the categories by rating system.

The number of credits listed and the maximum points available also vary significantly, but all certification systems have a minimum score that is required for certification (5–30%). The results of the project can be used for educational, labelling, and various marketing purposes and can aid in decision-making [45] (Greenroads, 2017) (GreenLITES, 2017) (I-LAST, 2012) (Envision, 2018) (INVEST, 2018).

Some of the abovementioned categories have greater importance in relation to the current Hungarian situation than the others. For instance, the protection of water quality and the ecosystem as well as having a proper pavement design system are very important and should be considered as significant features. Innovative design ideas and construction methods are, on the other hand, used only occasionally, usually in pilot projects. Energy efficiency during the lifecycle of the projects is not examined during most of the projects [5]. The study considers these aspects of sustainability criteria to be extremely important; therefore, they will form part of the evaluation in the comparison of the rating systems.

4.2. Description of the TOPSIS Method

The "Technique for Order Preference by Similarity to the Ideal Solution" (TOPSIS) method, developed by Hwang and Yoon [48], is suitable for solving multi-objective decision-making (MODM) problems. Hwang explained that the multi-criteria decision analysis problem can be considered as a geometric system. The m alternative evaluated by the n attribute is like the m point of the n-dimensional space, so the most advantageous alternative should be the point that is located closest to the ideal solution and furthest from the worst solution. The idea of the method is, therefore, to have the most advantageous alternative, which is as close as possible to the "high-level solution" and as far as possible from the "low-level solution" from a geometric point of view (Euclidean). The advantage of this is that this method results in a simple and indisputable order of preference.

In the publication of Lai, Liu, and Hwang [47], the application of TOPSIS by multi-criteria decision-making problems was presented. According to this, for many of these problems, the decision-maker wants to achieve more than one goal when choosing a course of action, while meeting the constraints required by the environment, processes, and resources. From a mathematical point of view, these problems can be represented as:

$$\max\,[f\_1\,(x),f\_2\,(x),\ldots,f\_k\,(x)] \tag{1}$$

$$\text{s.t. } x \in X = \{x \mid g\_i\,(x) \leq 0,\ I = 1,2,\ldots,m\} \tag{2}$$

where x is the n-dimensional decision variable vector. The problem consists of n decision variables, m constants, and k objectives. Any of the functions can be nonlinear. In the literature, this problem is often a vector maximization problem. In general, MODM techniques can be divided into four classes: (a) preferential information, which is not articulated; (b) a prior articulation of preference information; (c) a progressive articulation of preference information or interactive methods; (d) a subsequent articulation of preferred information or non-dominant solution generation methods. In the case of TOPSIS, preferential information is not articulated.

The principle of the method is, therefore, that the chosen alternative should be as close as possible to the positive ideal solution (PIS) and the furthest from the negative ideal solution (NIS). A single criterion that has the shortest distance from a given goal or PIS is not enough to satisfy decision-makers. In practice, an ideal decision is preferred that not only provides as much benefit as possible but also avoids as much risk as possible.

Based on the summary of D. L. Olson [48], TOPSIS determines the ideal attribute through a series of steps:

(1) Determination of performance data for n alternatives over k criteria. (Raw measurements (xij) are usually converted to standardized measurements (sij)).
(2) Development of the set of importance weights for each criterion.
(3) Determining an ideal alternative, s+.
(4) Defining a negative maximum (low point) alternative, s-.
(5) Determining the distance measurement over each criterion to both the ideal (D+) and negative maximum (D-).
(6) For each alternative, determining the ratio R by:

$$R = D^{-}/(D^{-} + D^{+}) \quad (3)$$

where R equals the distance to the negative ideal solution, divided by the sum of the distances to the ideal and nadir solution.

(7) Ranking alternatives by maximizing the ratio in Equation (3).

With this series of steps, TOPSIS minimizes the distance to the ideal solution while maximizing the distance from the negative ideal solution. For steps (2) to (5), several different methods can be used.

4.3. Determination of the Most Suitable Rating System Using the TOPSIS Method

As a result of the evaluation, we want to determine which of the evaluation systems of Greenroads, GreenLITES, I-LAST, Envision, and INVEST is the one that satisfies the criteria to the greatest extent and should be chosen; therefore, it can potentially be used in Hungarian road construction practice. The first step to achieve this is to define the set of criteria which is used to examine and distinguish between the systems. This study identifies 12 different criteria for the evaluation. Seven of the criteria (K1–K6 and K12) were taken over from the previously mentioned Hungarian research [5]. This paper, after interviews with experts, expanded the criteria with K7–K11 based on their importance in Hungarian practice. Further revision of these categories was beyond the scope of this paper.

The examined criteria are:

K1—Accessibility.
K2—Clarity and comprehensibility.
K3—Scope of applicability at different stages of projects.
K4—Availability of required data.
K5—Availability of required documentation.
K6—Internationally applicable experiences.
K7—Training and development.
K8—Importance of energy efficiency.
K9—Importance of environmental awareness in relation to the material and track structure.
K10—Importance of environmental awareness in relation to water and the ecosystem.
K11—Importance of accessibility and equality in the project development.
K12—Promotion of innovation.

The results of the obtained performance data are summarized in Table 2. This is a normalized classification of the rating systems, where the classification is conducted according to a 1 to 5 scale. A result of 1 is the least favorable, and a result of 5 is the most favorable result for the criteria. The determination of the weights in the research is based on the results of personal interviews of industry and academic experts, in addition to the personal experience and technical estimation of the authors. It also draws from the comprehensive publications of Andrew S. Chang and Calista Y. Ts. [49,50]. Details on the scoring can be found in Appendix B.

Table 2. Classification of the rating systems for the Technique for Order Preference by Similarity to the Ideal Solution (TOPSIS) analysis.

Rating System	Criterion											
	K1	K2	K3	K4	K5	K6	K7	K8	K9	K10	K11	K12
Greenroads	5	5	3	4	4	5	5	5	4	4	4	3
GreenLITES	3	4	2	3	3	2	2	5	5	3	2	3
I-Last	4	5	3	3	3	1	2	3	3	5	4	2
Envision	5	5	4	4	4	5	5	4	3	4	3	5
Invest	4	4	5	3	3	3	3	3	2	2	5	3

The next task was to calculate the weighted normalized classification based on the following Equation (4):

$$d_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{5} x_{ij}^{2}}} \tag{4}$$

Table 3 shows the results.

Table 3. Weighted normalized classification results.

Rating System	Criterion											
	K1	K2	K3	K4	K5	K6	K7	K8	K9	K10	K11	K12
Greenroads	0.524	0.483	0.378	0.521	0.521	0.625	0.611	0.546	0.504	0.478	0.478	0.401
GreenLITES	0.314	0.387	0.252	0.391	0.391	0.250	0.244	0.546	0.630	0.359	0.239	0.401
I-Last	0.419	0.483	0.378	0.391	0.391	0.125	0.244	0.327	0.378	0.598	0.478	0.267
Envision	0.524	0.483	0.504	0.521	0.521	0.625	0.611	0.436	0.378	0.478	0.359	0.668
Invest	0.419	0.387	0.630	0.391	0.391	0.375	0.367	0.327	0.252	0.239	0.598	0.401
SUM												

Based on the above, the positive and negative ideal solutions can be identified using Equations (5) and (6). The results and are shown in Table 4.

$$A^{*} = \{max_j d_{ij} | j \in J_1, min_j, d_{ij} | j \in J_2 | i = 1, \dots, 5\} \tag{5}$$

$$A^{-} = \{min_j d_{ij} | j \in J_1, max_j, d_{ij} | j \in J_2 | i = 1, \dots, 5\} \tag{6}$$

Table 4. Weighted normalized classification results.

Ideal Solutions	Criterion											
	K1	K2	K3	K4	K5	K6	K7	K8	K9	K10	K11	K12
Positiv ideal solution A+	0.524	0.483	0.630	0.521	0.521	0.625	0.611	0.546	0.630	0.598	0.598	0.668
Negativ ideal solution A-	0.314	0.387	0.252	0.391	0.391	0.125	0.244	0.327	0.252	0.239	0.239	0.267

The next step was to identify the distances. The distance is calculated using the n-dimensional Euclidean distance for both positive (*Di**) and negative (*Di⁻*) distances (7–8). The results are presented in Table 5.

$$D_i^{*} = \sqrt{\sum_{j=1}^{12} \left(d_{ij} - d_j^{*}\right)^2} \tag{7}$$

$$D_i^{-} = \sqrt{\sum_{j=1}^{12} \left(d_{ij} - d_j^{-}\right)^2} \tag{8}$$

Table 5. Distances from the positive and negative ideal solutions.

D^*	Criterion												SUM
	K1	K2	K3	K4	K5	K6	K7	K8	K9	K10	K11	K12	
Greenroads	0.000	0.000	0.063	0.000	0.000	0.000	0.000	0.000	0.016	0.014	0.014	0.071	**0.179**
GreenLITES	0.044	0.009	0.143	0.017	0.017	0.141	0.134	0.000	0.000	0.057	0.129	0.071	**0.762**
I-Last	0.011	0.000	0.063	0.017	0.017	0.250	0.134	0.048	0.063	0.000	0.014	0.161	**0.779**
Envision	0.000	0.000	0.016	0.000	0.000	0.000	0.000	0.012	0.063	0.014	0.057	0.000	**0.163**
Invest	0.011	0.009	0.000	0.017	0.017	0.063	0.060	0.048	0.143	0.129	0.000	0.071	**0.567**
D^-	Criterion												SUM
	K1	K2	K3	K4	K5	K6	K7	K8	K9	K10	K11	K12	
Greenroads	0.044	0.009	0.016	0.017	0.017	0.250	0.134	0.048	0.063	0.057	0.057	0.018	**0.731**
GreenLITES	0.000	0.000	0.000	0.000	0.000	0.016	0.000	0.048	0.143	0.014	0.000	0.018	**0.238**
I-Last	0.011	0.009	0.016	0.000	0.000	0.000	0.000	0.000	0.016	0.129	0.057	0.000	**0.238**
Envision	0.044	0.009	0.063	0.017	0.017	0.250	0.134	0.012	0.016	0.057	0.014	0.161	**0.795**
Invest	0.011	0.000	0.143	0.000	0.000	0.063	0.015	0.000	0.000	0.000	0.129	0.018	**0.378**

Following calculating the distances, the next step was to determine the R relative proximity ratio. This is calculated using Equation (9).

$$R_i = \frac{D_i^*}{D_i^* - D_i^-} \tag{9}$$

The results should have a value between 0–1. The solution whose value is closest to 0 has the highest priority. The result of the calculation is shown in Table 6 below.

Table 6. Determination of relative proximity.

Rating System	D^+	D^-	R_i
Greenroads	0.179	0.731	0.197
GreenLITES	0.762	0.238	0.762
I-Last	0.779	0.238	0.766
Envision	0.163	0.795	0.170
Invest	0.567	0.378	0.600

Table 6 shows that, based on the 12 criteria listed above and examined in the present study, the Envision rating system satisfies the most criteria. It is closely followed by Greenroads. The next in ranking were INVEST, GreenLITES, and I-LAST. In the future, the research should focus on the application of the Envision rating system of Hungarian road infrastructure projects.

5. Conclusions

To enhance sustainability in the construction industry, different rating and certificating systems have been developed. These usually list a set of sustainability practices in different categories, such as material, pavement, environment, water, energy, and accessibility, and can evaluate the sustainability level of projects during their stages, i.e., planning, design, construction, and maintenance. The systems aim to motivate decision-makers, construction companies, and other stakeholders to make the use of these practices and methods common at a higher level. While most of the techniques and practices are available in Hungary, the use of them varies. The concerns of a lower level of performance when using alternative technologies, such as warm mix asphalt (WMA) or recycled asphalt pavement (RAP), and the extra costs and time required for sustainable designs resulted in a low demand for such techniques and practices. Therefore, well-structured regulation is needed to promote these techniques and develop appropriate mindsets. Different "green" objective rating systems can help increase the level of sustainability in terms of both design and implementation.

The present paper reviewed some of the commonly used rating systems and the method of some of the nationally established sustainable indicator tools and systems. The literature highlights that there are two options for setting up a national evaluation system. One way is for a country to develop its own criteria and credit system using experts' input. The scoring (weighting) in this approach is usually obtained through a questionnaire survey of a larger group of professionals, and the Analytic Hierarchy Process (AHP), Analytic Network Process (ANP), or Delphi technique are typically used to calculate the importance (or weight) of the indicators. The other way is to select a sustainability assessment system that has already been proven in practice and use that as a basis. In this case, the next step would be to adopt these elements to fit national specifics.

Following the literature review, this paper compared five previously determined and widely used rating systems, with the aim of choosing the one which best fits the Hungarian specifics and therefore providing a base for a Hungarian national rating system. The compared systems were the Greenroads, GreenLITES, I-LAST, Envision, and INVEST rating systems. The comparison was conducted using the TOPSIS multi-objective decision-making method. With this approach, the multi-criteria decision analysis problem can be considered as a geometric system. The m alternative evaluated by the n attribute is similar to the m point of the n-dimensional space, so the most advantageous alternative should be the point located closest to the ideal solution and furthest from the worst solution. The systems were evaluated against 12 criteria determined in a previous study. The input weights were determined by a small group of experts representing the asset owner and designer side. With these input data, the calculation was conducted, and as a result, the Envision system was shown to be the most suitable rating system for Hungary. This was closely followed by the Greenroads system. The utilization of the multi-objective decision-making method by the use of TOPSIS provided a comprehensive and objective method for selecting the most suitable green rating system for the Hungarian road infrastructure projects.

In the future, research should focus on the application of the Envision rating system in Hungarian road design, applying it in road construction projects, with the aim of examining the elements of the selected system, determining the strengths and weaknesses of the Hungarian practices, and filtering out the elements that cannot be applied in local systems.

Further work needs to be completed in terms of expanding the expert group for the input weights, including representatives and experts from other organizations, such as construction companies, material manufacturers, organizations developing and running recycling technologies, and financial and ministerial organizations. Input from these organizations and individuals may change the weighting; however, the methodology presented in this paper could be readily re-applied. If new green rating systems would be available over time, this methodology could be used for an updated ranking to find the best green rating system for Hungarian conditions.

Appendix A. Description of the Selected Rating Systems Based on Their Manuals

Appendix A.a. Greenroads

The Greenroads rating system was introduced in 2007 by the University of Washington. The aim of the system is to quantify sustainable practices in road design and implementation. The system is project-based and can be used to certify projects to support sustainable practices [6]. Greenroads consists of 61 credits (compulsory and voluntary). The 12 required credits are called Project Requirements, which projects are required to meet and document.

These are as follows:

- Ecological Impact Analysis.
- Energy and Carbon Footprint.
- Low-Impact Development.
- Social Impact Analysis.
- Community Engagement.
- Lifecycle Cost Analysis.
- Quality Control.
- Pollution Prevention.
- Waste Management.

- Noise and Glare Control.
- Utility Conflict Analysis.
- Asset Management Systems.

In addition to the mandatory credits, 45 voluntary credits are available through five main categories.

These are as follows:

- Environment and Water—10 credits.
- Construction Activities—11 credits.
- Materials and Design—6 credits.
- Utilities and Controls—8 credits.
- Access and Livability—10 credits.

An additional four extra credits are available in the "Creativity & Effort" category, with up to 15 points. Each credit is worth 1–5 points. The level of qualification depends on the score of the project. There are currently four certification levels: Bronze (at least 40 points); Silver (minimum 50 points); Gold (60 point minimum); Evergreen (at least 80 points)[7].

With over 1100 organizations and members from 62 countries around the world and 50 states in the US, Greenroads has worked with more than 130 different types of projects with investment beneficiaries and 50 qualified projects. It can, therefore, be stated that the system is highly successful. Two examples of this are shown in the following (Figure A1). The image to the left is a North Carolina road renovation project that received a silver rating with the highest score to date (51 points). The image to the right depicts the outcome of a highway construction project in Taiwan. While it was a pilot project, so it cannot be qualified, it scored 47 points. While the location and type of projects, and thus the distribution of points earned, are different, the worksheet is equally suitable for evaluating the projects.

Figure A1. Certification of different types of projects (greenroads.org).

The work usually starts with a registration, which takes about 2 years, before the project can begin. The Greenroads team then monitors and assists the project processes and provides training for project participants. After 90 days from the completion of the project, the qualification takes place, and the joint work ends with the preparation of a final document. This can take up to 7 years for large projects.

From 2019, the organization will be actively seeking pilot projects for a branded program called Greenrails, expanding the types of projects that can be evaluated.

Appendix A.b. I-LAST

The I-LAST (Illinois-Livable and Sustainable Transportation Rating System and Guide) rating system was developed in collaboration with the Illinois Department of Transportation and the engineering and construction community. The aim of the guide is to provide a comprehensive list of practices that can produce sustainable results in road projects, to establish a simple and effective way to assess the viability, sustainability, and impact of transport projects on the natural environment, to record and recognize the use of sustainable practices in the industry, and to encourage the use of innovative and experimental sustainability concepts.

Projects are evaluated based on nine main categories, which are divided into subcategories. There are a total of 153 criteria in the system and the number of points that can be obtained is 233[8]. The main categories are:

- Planning—19 points.
    - Context-Sensitive Solutions—8 points.
    - Land Use/Community Planning—11 points.
- Design—19–24 points.
    - Alignment Selection—9–13 points.
    - Context-Sensitive Design—10–11 points.
- Environmental—50–51 points.
    - Protects, Enhances, or Restores Wildlife and Habitats—20 points.
    - Trees and Plant Communities—21 points.
    - Noise Abatement—10–11 points.
- Water Quality—29–30 points.
    - Reduces Impervious Area—10 points.
    - Storm Water Treatment—15 points.
    - Design Practices that Protect Water Quality—9–10 points.
- Transportation.
    - Transit—9 points.
    - Improves Bicycle and Pedestrian Facilities—17–19 points.
- Lighting—16 points.
    - Reduces Electrical Consumption—12 points.
    - Stray Light Reduction—4 points.
- Materials—19–31 points.
- Innovation—1–3 points.
- Construction 50–68 points.
    - Protects, Enhances, or Restores Wildlife and Habitats—3 points.
    - Trees and Plant Communities—5–10 points.
    - Maximizes Trucking Efficiency—4 points.
    - Certified Suppliers—6 points.
    - Reduces Impervious Area—2 points.
    - Stormwater Treatment—5 points.
    - Construction Practices that Protect Water Quality—11–13 points.
    - Construction Practices—14–25 points.

The purpose of the system is self-assessment, so it does not provide certification when the project is completed. The reasons for this are that it is very difficult to compare projects of different sizes and purposes, as a highly sustainable small project can earn fewer points than a much larger project where not much has been done for the sake of sustainability. Based on this, it was decided that the projects would be scored on the basis of the percentage of the applicable criteria.

Appendix A.c. Envision

Envision was developed through the collaboration between Harvard University Graduate School of Design and the Institute for Sustainable Infrastructure, together with the Zofnass Program for Sustainable Infrastructure. The idea provides a holistic framework for assessing and classifying the community, environmental, and economic benefits of different types and sizes of infrastructure projects, such as roads, bridges, pipelines, railways, airports, dams, landfills, water treatment systems, and other built infrastructure. The scheme assesses and recognizes infrastructure at four stages of development: project planning and design, construction, operation and maintenance, and demolition. Envision is, thus, a family of tools that covers all stages of the project life cycle. The Envision manual contains goals and performance levels that lead the user in evaluating the project. The rating system can be paired with other Envision tools, such as the Envision checklist, which is a series of yes or no questions. The checklist can be useful at the beginning of project planning, when the specific performance data for the detailed assessment are still unknown [9]. Currently, both the second and third versions of the system can be used to evaluate projects [10]. While the two versions are largely the same, certain elements have been added to the list (for example, minimizes construction impacts; improves construction safety; conducts a life-cycle economic assessment; reduces construction waste; reduces construction energy consumption; reduces construction water consumption; reclaims brownfields, etc.), and some elements have been rewritten.

Any version of Envision examines projects in five main categories, which can be further subdivided into a total of 60 credits. This means that there is a total of 1000 possible points. The categories to be examined are as follows:

- Quality of life—13 (V2) or 14 (V3) credits.
    - Purpose (V2)/Mobility (V3).
    - Wellbeing.
    - Community.
    - + Innovates or Exceeds Credit Requirements.
- Leadership—10 (V2) or 12 (V3) credits.
    - Collaboration.
    - Management (V2)/Economy (V3).
    - Planning.
    - + Innovates or Exceeds Credit Requirements.
- Resource allocation—14 credits.
    - Materials.
    - Energy.
    - Water.
    - + Innovates or Exceeds Credit Requirements.
- Natural World—15 (V2) or 14 (V3) credits.
    - Siting.
    - Land and Water (V2)/Conservation (V3).
    - Biodiversity (V2)/Ecology (V3).
    - + Innovates or Exceeds Credit Requirements.
- Climate and Resilience—8 (V2) or 10 (V3) credits.
    - Emission.
    - Resilience.
    - + Innovates or Exceeds Credit Requirements.

During the evaluation, five different levels of performance can be measured. These are as follows[9]:

- Improved—Performance that is above average and slightly exceeds the regulatory requirements.
- Enhanced—Sustainable performance that is on the right track. There are indications that superior performance is within reach.
- Superior—Sustainable performance at a very high level.
- Conserving—Performance that has achieved an essentially zero negative impact.
- Restorative—Performance that restores natural or social systems. This is the highest possible award.

The use of the Envision system is also widespread. In addition to the United States, it has been used to certify various projects in Canada, Italy, Israel, and Saudi Arabia. There are different rates for certification, depending on the total estimated cost of the project. The registration fee is USD 2000 in each case, and post-construction certification ranges from USD 12,000 to 56,000.

Appendix A.d. GreenLITES

GreenLITES is another sustainable infrastructure rating system. It was developed in 2008 by the New York State Department of Transportation (NYSDOT) for public use. The guide was created to demonstrate sustainable transportation techniques and develop sustainable practices. The concept is largely derived from the Greenroads Guide (NYSDOT, 2008). The GreenLITES program includes a growing set of tools (rating systems, tables, and other indicators) for planning and certificating projects, operational activities, maintenance programs, and regional investments. GreenLITES is a transparent, metric-based self-assessment program that institutionalizes sustainability, thinking at the regional level while continuously measuring performance and promoting the application of "best practices".

Projects can be evaluated in 175 subcategories, which can be divided into five main categories. These are as follows:

- Sustainable Sites—81 points.
- Water Quality—20 points.
- Materials and Resources—66 points.
- Energy and Atmosphere—104 points.
- Innovations and Unlisted.

Therefore, a total of 271 points can be scored. Depending on the amount of points earned, the project may earn one of four certification levels: Qualified (15–29 points), Silver (30–44 points), Gold (45–59 points), and 60-point Evergreen ratings. NYSDOT used 26 completed projects to determine point levels and measure the system correctly [11].

The purpose of the rating system is not only to evaluate projects but also to measure the NYSDOT performance itself, identify areas for improvement, and use it as a tool to show the public how they are making progress in sustainable practices [12].

Appendix A.e. Invest

INVEST (Infrastructure Voluntary Evaluation Sustainability Tool) was established by the US Federal Highway Administration (FHWA) to assist public transportation departments (DOTs), metropolitan planning organizations, local transportation agencies, project teams, and others to improve the sustainability of transportation projects and programs. It turns comprehensive sustainability principles into concrete actions and provides a way for transport professionals to measure sustainability.

It is, thus, a web-based self-assessment tool consisting of voluntary sustainability practices (called criteria) that cover the entire life cycle of transport services, including decision-making processes, project planning, implementation, and maintenance. To cover the entire lifecycle, INVEST divides the criteria into four modules: System Planning for States (SPS), System Planning for Regions (SPR), Project Development (PD), and Operations and Maintenance (OM). These four sets of criteria form a comprehensive self-assessment tool. The SPS, SPR, and OM modules are designed to evaluate an agency's programs, and the PD module is used to evaluate projects, from early project planning to construction. Each module is independent and must be assessed separately. The PD module consists of several scorecards which are designed to identify the scope, size, and context of different projects across the country [13].

The System Planning modules (SPS and SPR) focus on performing system-wide analyses that contribute to the overall sustainability of networks and individual projects at certain stages of the life cycle of a project. The SPS and SPR modules each contain 17 criteria, which are combined into a single scorecard. These are as follows:

- Integrated Planning: Economic Development and Land Use.
- Integrated Planning: Natural Environment.
- Integrated Planning: Social.
- Integrated Planning: Bonus.
- Access and Affordability.
- Safety Planning.
- Multimodal Transportation and Public Health.
- Freight and Goods Movement.
- Travel Demand Management.
- Air Quality.
- Energy and Fuels.
- Financial Sustainability.
- Analysis Methods.
- Transportation Systems Management and Operations.
- Linking Asset Management and Planning.
- Infrastructure Resiliency.
- Linking Planning and NEPA (National Environmental Policy Act).

The Project Development module includes early project planning, analysis of alternatives, environmental documentation, preliminary and final design, and construction activities. While the criteria cover all stages of project design, including construction activities, the project owner usually controls the decisions and actions, which need to meet all the criteria. In terms of scoring, INVEST has seven evaluation sheets for project evaluation. This approach provides flexibility, as not all conditions apply to all projects. Six of the scorecards are based on the type of project, such as paving, urban basic, urban extended, rural basic, rural extended or scenic, and recreational. A total of 33 complete criteria are defined. From these, different elements (subsets) must be fulfilled, depending on the type of project. The seventh is a unique evaluation sheet, which contains 11 basic criteria and user-selected criteria, thus allowing for individual self-assessment of projects that do not fit well with the defined evaluation sheets [14]. The criteria and subtypes by project type are shown in Figure A2.

The Operation and Maintenance (OM) module evaluates system-level operations and maintenance activities to determine how they contribute to the overall sustainability of transport infrastructure. The module contains 14 criteria.

Project Development by Criteria Scorecard

	Paving	Urban Basic	Urban Extended	Rural Basic	Rural Extended	Scenic and Recreational	Custom Core Criteria [1]
PD-1 Economic Analyses			●		●		
PD-2 Life-Cycle Cost Analyses	●	●	●	●	●		●
PD-3 Context Sensitive Project Development		●	●	●	●	●	
PD-4 Highway and Traffic Safety	●	●	●	●	●	●	●
PD-5 Educational Outreach		●	●	●	●	●	
PD-6 Tracking Environmental Commitments	●	●	●	●	●	●	●
PD-7 Habitat Restoration		●	●	●	●	●	
PD-8 Stormwater Quality and Flow Control		●	●	●	●	●	
PD-9 Ecological Connectivity			●	●	●	●	
PD-10 Pedestrian Facilities		●	●			●	
PD-11 Bicycle Facilities		●	●			●	
PD-12 Transit & HOV Facilities		●	●			●	
PD-13 Freight Mobility			●		●		
PD-14 ITS for System Operations		●	●		●		
PD-15 Historical, Archaeological, and Cultural Preservation		●	●	●	●	●	
PD-16 Scenic, Natural, or Recreational Qualities			●	●	●	●	
PD-17 Energy Efficiency		●	●	●	●		
PD-18 Site Vegetation, Maintenance, and Irrigation		●	●	●	●	●	
PD-19 Reduce, Reuse, and Repurpose Materials	●	●	●	●	●	●	●
PD-20 Recycle Materials	●	●	●	●	●	●	●
PD-21 Earthwork Balance			●		●	●	
PD-22 Long-Life Pavement	●	●	●	●	●	●	●
PD-23 Reduced Energy and Emissions in Pavement Materials	●	●	●	●	●	●	●
PD-24 Permeable Pavement	●	●	●	●	●	●	●
PD-25 Construction Environmental Training		●	●	●	●	●	
PD-26 Construction Equipment Emission Reduction	●	●	●	●	●	●	●
PD-27 Construction Noise Mitigation		●	●			●	
PD-28 Construction Quality Control Plan	●	●	●	●	●	●	●
PD-29 Construction Waste Management	●	●	●	●	●	●	●
PD-30 Low Impact Development		●	●	●	●	●	
PD-31 Infrastructure Resiliency Planning and Design			●		●	●	
PD-32 Light Pollution		●	●	●	●		
PD-33 Noise Abatement		●	●				
Total Number of Criteria in Scorecard	11	27	34	23	29	27	11

([1]) Indicates the core criteria that must be included in the custom scorecard. The user may choose as many additional criteria as desired.

Figure A2. Scorecard of the Infrastructure Voluntary Evaluation Sustainability Tool (INVEST) Project Development module by project type (INVEST User Guide, [14]).

The 14 criteria of the Operation and Maintenance module are:

- Internal Sustainability Plan.
- Electrical Energy Efficiency and Use.
- Vehicle Fuel Efficiency and Use.
- Reduce, Reuse, and Recycle.
- Safety Management.
- Environmental Commitments Tracking System.
- Pavement Management System.
- Bridge Management System.
- Maintenance Management System.
- Highway Infrastructure Preservation and Maintenance.
- Traffic Control Infrastructure Maintenance.
- Road Weather Management Program.

- Transportation Management and Operations.
- Work Zone Traffic Controls.

INVEST is, therefore, a free self-assessment tool that covers the entire life cycle of a transport facility using different worksheets, without the need for third party certification.

Appendix B. Description of the Rating Systems for the Examined Criteria of the TOPSIS Calculation

For the determination of the weights of the different rating systems by category, the study collected the relevant information for each criterion. The final determination of the weights, however, was based on the results of personal interviews of industry and academic experts, in addition to the personal experience and technical estimation of the authors. It was also based on the comprehensive publications of Andrew S. Chang and Calista Y. Ts [49,50]

K1—Accessibility

Greenroads: The evaluation sheet and the descriptions of the scoring are available on the website of the system (greenroads.org). An online evaluation form is also available free of charge. However, an exact description of the criteria and the scoring are available to non-members by paying 40 US dollars or becoming a member. Membership fees range from USD 25,000–10,000 per year, depending on the type of membership. Free trainings, webinars, and case studies are also available through the website for further understanding of the system. Points achieved: 5.

Green LITES: The latest (2nd) version of the evaluation sheet and guide can be downloaded free of charge from the GreenLITES website (www.dot.ny.gov/programs/greenlites/project-design-cert) for both the planning and maintenance project levels. However, since 2016, no new projects or developments have been posted on the website. Points achieved: 3.

I-LAST: The guide can easily be downloaded for free from the Illinois Department of Transportation website (idot.illinois.gov). The file presents the evaluation system well and provides a checklist with a detailed explanation of their elements. Points achieved: 4.

ENVISION: A lot of information about the system is available on the ENVISION website (sustainableinfrastructure.org). The guides can be downloaded from the website after a little searching, and their criteria, credits, and scoring are understandable and clear. However, the rating is membership-based and costs between USD 20,000–35,000/year, depending on the type of the membership (individual member/company of various sizes). Qualification is available for a USD 2000 registration fee + USD 12,000–56,000, depending on the size of the project. Points achieved: 5.

INVEST: The website (sustainablehighways.org) provides a lot of information about the system, its structure, elements, and results. The elements, description, and scoring of the guide are available on the website, although accessing and downloading the full rating system is not easy. The interface of the website answers a number of questions. Points achieved: 4.

K2—Clarity and comprehensibility

Greenroads: The evaluation system is understandable, the scoring is clear, and the checklist can be easily filled for the evaluation using the online interface. Qualification requires the involvement of a third party. Points achieved: 5.

GreenLITES: The evaluation form is available in Excel format, and the guide briefly describes the conditions for the points available for each criterion. Points achieved: 4.

I-LAST: The guide adequately explains which cases can be awarded 1, 2, or 3 points for the different criteria. The process of self-assessment is clear. Points achieved: 5.

ENVISION: The evaluation can be clearly carried out on the basis of the guide and the online evaluation form. Qualification requires the involvement of a third party, who reviews and approves project evaluations at certain stages. Points achieved: 5.

INVEST: While the website shares a lot of information with the interested party, it may seem chaotic at first. However, essentially all the important information is available for free through the website. Registration is required to score a project. Points achieved: 4.

K3—Scope, applicability at different stages of projects

Greenroads: The applicability of the system covers the project development phase (i.e., planning, design, and construction); however, certification is given only after the project is built. Points achieved: 3.

GreenLITES: The system is suitable for the sustainability evaluation of projects during planning, design, and maintenance. Points achieved: 2.

I-LAST: The system can be used during project development. Points achieved: 3.

ENVISION: The rating system can be applied to projects from system planning to operation and maintenance. Points achieved: 4.

INVEST: From the system planning processes to the operation and maintenance activities, the system can be purposefully applied to projects for evaluation. Separate checklists are available for the different stages. Points achieved: 5.

K4—Availability of required data

This criterion measures if a special database or regular survey is needed in order to perform the evaluation, and if so, if it is currently available in Hungary.

Greenroads: Points achieved: 4.

GreenLITES: Points achieved: 3.

I-LAST: Points achieved: 3.

ENVISION: Points achieved: 4.

INVEST: Points achieved: 3.

K5—Availability of required documentation

This criterion measures if additional documentation is needed for the planning and design phase, which is not part of the current Hungarian practice, and if so, whether it is currently available in Hungary.

Greenroads: Points achieved: 4.

GreenLITES: Points achieved: 3.

I-LAST: Points achieved: 3.

ENVISION: Points achieved: 4.

INVEST: Points achieved: 3.

K6—Internationally applicable experiences

Greenroads: Numerous projects outside of the US have proven the international applicability of the system. Points achieved: 5.

GreenLITES: While the elements of the system are generally applicable, the results of the application of GreenLITES shown on the website are only until 2016. The evaluated projects are located in the United States. Points achieved: 2.

I_LAST: There is no information about the application of the system on the organization's website. Points achieved: 1.

ENVISION: In addition to the United States, the rating system has been successfully applied in Canada, Italy, Israel, and Saudi Arabia on various types of projects, demonstrating its widespread applicability. Points achieved: 5.

INVEST: While the elements of the evaluation are applicable internationally and the system has been successfully applied in several US states, it has only been used in one project outside of the US (in Paraguay), according to the website. Points achieved: 3.

K7—Training and development

Greenroads: The organization provides webinars, training, and other opportunities to learn about the evaluation system and to spread the importance of sustainability. Currently, the second version of the guide is applicable, but the test version of Version 3 was introduced on 27th of August 2020. The system is constantly being reviewed and improved as needed. Points achieved: 5.

GreenLITES: Since 2016, no new projects or developments have been added to the website. Points achieved: 2.

I-LAST: The self-assessment system has not been further developed since the 2012 version. Relatively little information about the results and efficiency of the application is available. Points achieved: 2.

ENVISION: The latest version of Envision was released in 2018, which also shows that the system is under constant development and testing. The organization holds a number of trainings, conferences, and webinars for members. Points achieved: 5.

INVEST: The latest version of the system was released in 2018. Based on the information available on the website, the last workshop was held in 2016. Points achieved: 3.

K8—Importance of energy efficiency

Greenroads: Energy and carbon footprint are among the project requirements. This means that all projects should improve the accountability of energy and emissions for project materials and construction activities. Moreover, reducing energy and CO_2 emissions comes up in the case of other credits as well (e.g., material and design, and utility and control). Points achieved: 3.

GreenLITES: Evaluation based on the results of the previously presented Figure 3. Points achieved: 5.

I-LAST: Evaluation based on the results of the previously presented Figure 3. Points achieved: 3.

ENVISION: Evaluation based on the results of the previously presented Figure 3. Points achieved: 4.

INVEST: Evaluation based on the results of the previously presented Figure 3. Points achieved: 3.

K9—Importance of environmental awareness of material and track structure

Greenroads: Evaluation based on the results of the previously presented Figure 3. Points achieved: 4.

GreenLITES: Evaluation based on the results of the previously presented Figure 3. Points achieved: 5.

I-LAST: Evaluation based on the results of the previously presented Figure 3. Points achieved: 3.

ENVISION: Evaluation based on the results of the previously presented Figure 3. Points achieved: 3.

INVEST: Evaluation based on the results of the previously presented Figure 3. Points achieved: 2.

K10—Importance of environmental awareness of water and the ecosystem

Greenroads: Evaluation based on the results of the previously presented Figure 3. Points achieved: 4.

GreenLITES: Evaluation based on the results of the previously presented Figure 3. Points achieved: 3.

I-LAST: Evaluation based on the results of the previously presented Figure 3. Points achieved: 5.

ENVISION: Evaluation based on the results of the previously presented Figure 3. Points achieved: 4.

INVEST: Evaluation based on the results of the previously presented Figure 3. Points achieved: 2.

K11—Importance of accessibility and equality in the project development

Greenroads: Evaluation based on the results of the previously presented Figure 3. Points achieved: 4.

GreenLITES: Evaluation based on the results of the previously presented Figure 3. Points achieved: 2.

I-LAST: Evaluation based on the results of the previously presented Figure 3. Points achieved: 4.

ENVISION: Evaluation based on the results of the previously presented Figure 3. Points achieved: 3.

INVEST: Evaluation based on the results of the previously presented Figure 3. Points achieved: 5.

K12—Encouraging innovation

Greenroads: In the criterion of Creativity and Effort, 1–5 points are available for applying innovation ideas. This constitutes a maximum of 4% of the total score. Points achieved: 3.

GreenLITES: Certain elements of the system reward the application of innovation methods with points but it is not a priority in the evaluation. Points achieved: 3.

I-LAST: During the evaluation, an innovation category was created, where points can be obtained in a range from 1 to 3. This represents less than 1% of all points earned. Points achieved: 2.

ENVISION: For each major category, the scheme rewards the application of innovations with 1–10 points if the project uses innovative technologies or processes that are novel in their use, in their application, or in their local regulatory or cultural environment. Points are also awarded if the project implements measures that exceed the highest requirements within one or more quality of life credits or if it highlights additional aspects of sustainability that are not currently recognized by Envision. Points achieved: 5.

INVEST: Up to three innovative criteria are available for each evaluation sheet for each of the four modules. Bonus points can be earned if innovative criteria are used. The maximum number of innovation bonus points that can be earned is 10 points, which is about 6 to 15% of the evaluation. Points achieved: 3.

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