Engineering Educators Bringing the World Together
2025 ASEE Annual Conference & Exposition
Palais des congrès de Montréal, Montréal, QC • June 22–25, 2025
Paper ID #46885

Incorporating the Envision Rating System as a Teaching Tool for Sustainability in Civil Engineering Infrastructure

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Abstract

The Institute for Sustainable Infrastructure's Envision Rating System [1] is becoming a widely used framework for guiding design work and assessing resiliency, social equity, and environmental justice of civil infrastructure projects. To prepare our students and equip them with the knowledge base to proactively utilize this framework as a design tool, we have incorporated the Envision Rating System as a teaching tool with several touchpoints in the required civil engineering curriculum. Envision is introduced in a required sustainable civil engineering course, examined in an engineering mechanics course, and applied in senior capstone design projects. Through our approach, we are utilizing the credits and metrics of the framework to instill a mindset of design thinking that encourages students to consider all relevant Envision credit considerations in their designs, as opposed to training our students to rate projects or earn the Envision Sustainability Professional credential. At the initial introduction of the rating system, students developed an awareness of design considerations related to the environmental, social, and economic aspects of sustainable development. Then, students delve into one credit category as it relates to a large-scale water infrastructure project in a fluid mechanics course. Finally, students review the entire framework to identify and justify credits that apply to their senior capstone design projects. Through this scaffolded approach, students are challenged to evaluate how their design meets criteria within relevant credits. Examples of student work show that Envision can be used as a tool to gain knowledge of how designs can be informed by the rating system beyond using it as a tool to retroactively evaluate a project. This approach could be used by other programs as they desire to use a vetted framework to enable students to create sustainable, forward-thinking designs.

Background

The Institute for Sustainable Infrastructure's Envision Rating System (Envision) provides a framework for civil infrastructure that is sustainable, equitable, and resilient through all stages of planning, design, and implementation [1]. This holistic framework can be applied to all civil infrastructure projects, including transportation, waste management, landscape architecture, water management, information transmission, and energy production and transfer [2]. Envision Registered projects can earn recognition at various levels of achievement through a verification process. Collections of sustainability performance indicators are grouped as credits to earn under five categories – Quality of Life, Leadership, Resource Allocation, Natural World, and Climate and Resilience (Figure 1) [2]. By educating civil and environmental engineering students how they could apply Envision when designing civil infrastructure and assessing the sustainability of infrastructure, we are encouraging students to make design decisions that move beyond traditional considerations. The framework provides opportunities to achieve levels of project

Figure 1: Categories and credits in the Envision Rating System [2]

performance from improved to restorative status at all project phases from planning to end-of-life by collaborating with various stakeholders impacted by the project [2]. Figure 2 illustrates the need to strive for increased levels of performance through all project phases and stakeholder collaboration to achieve sustainability in infrastructure projects.

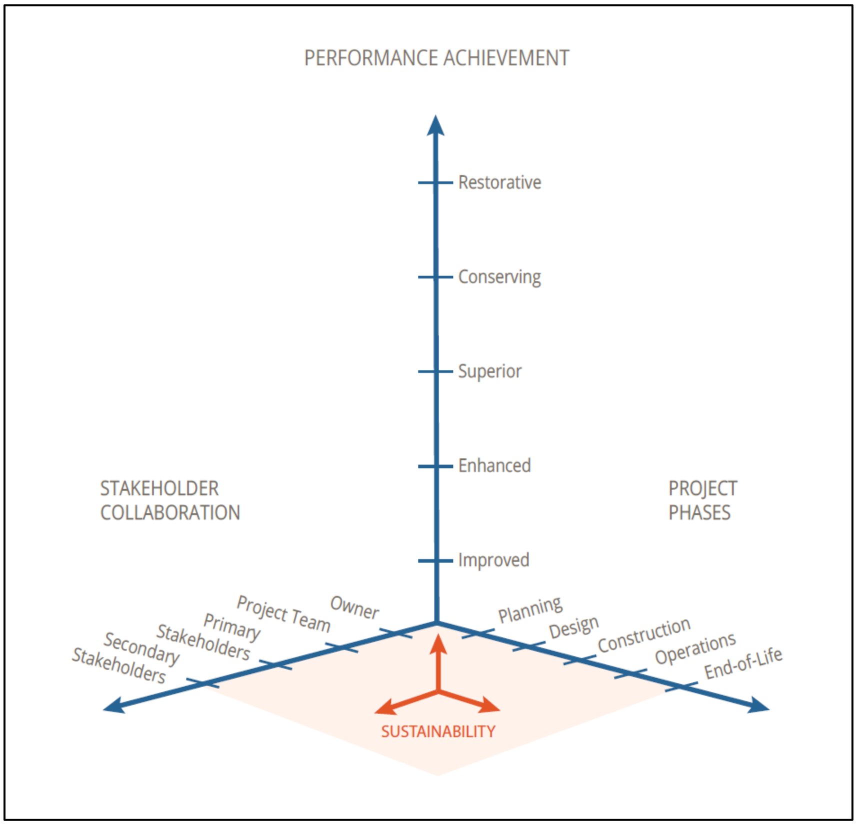

Figure 2: Representation showing the need for increased levels of performance achievement through all project phases and stakeholder collaboration to achieve sustainability in infrastructure projects [2]

Envision has been incorporated in civil engineering education for addressing issues of social inequity in infrastructure [3] and broadening the scope of the design in capstone design projects to include overall construction planning for the project, as well as project maintenance and life cycle [4]. Case studies on Envision-certified projects have been used to teach decision-making for considerations in sustainable design in civil engineering projects [5, 6]. Delatte and Hatley [7] and Burian and Reynolds [8] discuss approaches for applying Envision to capstone design projects. Expanding on this work, we are presenting an approach to introduce Envision at several touchpoints throughout the curriculum, so students are familiarized with the rating system before applying it to their senior capstone design project.

Motivation

We have previously observed students struggling to formulate metrics by which to measure sustainability of their capstone design projects. Prior to our current practice reported herein, students were asked to develop their own performance indicators to measure sustainability of their capstone design project by generating their own metrics aligned with the design objectives they established for their projects. Students often struggled to formulate measurable indicators aligned with their design objectives that addressed sustainability, even when asked to create metrics specifically related to social, economic, and environmental considerations during the decision-making process of project planning and technical design work. To address this concern, we created a scaffolded, multi-touchpoint approach to enable students to build knowledge, experience, and confidence in considering, justifying, and measuring sustainability of projects.

Implementation Approach

Through a three-staged approach, we created touchpoints throughout the required civil engineering curriculum at Rose-Hulman Institute of Technology (RHIT). First, we introduce students to Envision in a sophomore class, then students apply one category of Envision to an infrastructure project in a junior class, and finally they use the framework to assess sustainability and resiliency in the design of their senior capstone projects. In the end, the approach of using Envision to understand and evaluate sustainability of projects provides students with concrete examples of performance indicators, organized in relevant categories, that they can use in the planning and design of their capstone projects to measure sustainability.

First, students are introduced to Envision in a required Sustainable Civil Engineering course (CE250) during Year 2. Through an in-class activity, students explore the categories and performance indicators, or credits, of Envision. They learn the purpose of the rating system and that each listed credit was formulated based on a specific intent. In this way, students recognize the meaning behind the framework to shift the focus away from tallying points. After becoming familiar with the content of the framework, students applied relevant performance indicators to an actual civil infrastructure project. Students are provided with project background information on an existing problem of erosion below a culvert that blocks access for salmon to travel to upstream breeding habitat in the Pacific Northwest in the United States. They are given three alternative infrastructure solutions for replacement of the culvert. One potential solution reroutes the stream alignment through a public park to allow for a smaller length of culvert to pass under the roadway. This stream re-alignment causes a relocation of a baseball field in the park and removal of tennis courts. Another potential solution repositions the culvert at an angle to the roadway, extending the length of the culvert but not infringing on the park layout. The third potential solution slightly repositions the placement of the culvert (at the shortest length of the three options) but the drainage stream is routed through three private properties, as opposed to draining through public land as in the other two options. Students proposed which alternative they would recommend and justified their recommendation based on considerations applied from Envision performance indicators.

In a subsequent fluid mechanics course (EM301), also in Year 2, students delved deeper into one credit/category as applied to a large water infrastructure project. For a project of their choosing (e.g. Hoover Dam, Klamath River Dam Removal, Panama Canal, CA Groundwater Replenishment System, Mid-Barataria Sediment Diversion Project, Everglades Stormwater Treatment Area, etc.), students identify stakeholders using a concept map approach and researched each stakeholder's needs, concerns, and expectations to create a plan for how an engineer might engage with them. After examining the stakeholders, students leverage their research to analyze their infrastructure project in terms of its sustainability and impact on individual stakeholders. Specifically, this project asks students to use their knowledge of Envision from their previous course to analyze the sustainability of their project using the Quality of Life indicator category from the Envision Rating System. This means that students consider the overarching questions included in the Quality of Life indicator category [2]:

- Does the project improve health and safety for the broader community?
- Does the project preserve and enhance cultural resources?
- Does the project meet the needs and goals of the community?
- Does the project make a minimal negative impact on the surrounding community?
- Was the development process fair, equitable, and inclusive?

With their stakeholder research in mind, students analyzed their project at the *intent* and *metric* levels for at least one Quality of Life indicator to assess the social impacts of the project and determine its sustainability. Students were asked to justify the degree to which the project addressed and fell short of one of the following indicators:

- QL1.1: Improve Community Quality of Life,
- QL1.2: Enhance Public Health and Safety,
- QL3.1 Advance Equity and Social Justice, or
- QL3.2 Preserve Historic and Cultural Resources.

Based on their analysis, students were asked to justify a recommendation to improve the project's sustainability.

Finally, students apply Envision to their senior capstone design projects (CE488). Students are reminded of the motivation and purpose of Envision. As countries around the globe utilize more resources and generate more waste as they become more developed nations, the need for environmental protection, social equity and public health, and economic recovery amid a changing global climate is imperative in engineering design and creating resilient infrastructure. Using Envision as a teaching tool, we explain how Envision can be used as a collection of guiding principles for infrastructure design projects, as well as a set of performance indicators that motivate engineers and project managers to reach beyond minimum required codes and standards. Taking a closer look into individual credits, we review the intents of particular credits and their associated metrics to measure how well the project achieves a credit, as well as the various levels of achievement that can be met for each credit. In this approach, students focus on the *how* and *why* of meeting anticipated levels of achievement instead of only assigning point values.

Students then apply the Envision Pre-Assessment Checklist [1] to their capstone design project. This assignment (Figure 3) is given to students when they have completed planning and conceptual designs and are simultaneously working on the technical design aspects of their projects. In this way, students are making technical design decisions that are informed by the Envision checklist. The checklist (Figure 4) [1] includes a series of questions for each credit to help the students determine if the credit is relevant to their project and how they could utilize that credit as a performance indicator to achieve the intent of the credit.

> Using the Envision Pre-Assessment Checklist, describe how you addressed relevant Envision credits among the five categories in the rating system.
>
> a. Provide introduction of what Envision is, why it's used, and cite the source.
> b. Organize by overall categories.
> c. Discuss how your project has addressed relevant credits at the various levels of achievement. Do not simply identify credits and do not attach point values because you are not scoring this project for verification.
> d. Utilize the checklist for the purpose of documenting these anticipated levels of achievement for relevant credits. Focus on applicable credits and anticipated levels of achievement, not points.
> e. Be careful of wording - you have not achieved any credits - you are addressing relevant credits at varying levels of achievement; scoring and achievement occurs when project is submitted for verification.

Figure 3: Assignment for students in senior capstone design to apply the Envision Pre-Assessment Checklist to their projects

At the end of each of the three noted courses in academic year (AY) 2024-25, students were asked to participate in a brief, retrospective gains survey. Students responded that they agreed or disagreed, to varying levels on a 5-point Likert scale, to the following statements. We used the responses to assess students' perspectives, retrospectively, on their familiarity with and ability to utilize Envision. These processes adhered to an exempt human subject research protocol.

1. I am familiar with the Envision rating system for sustainable infrastructure.
2. I can explain the purpose of Envision as a rating system for sustainable infrastructure.
3. I can utilize Envision to measure sustainability in civil engineering design.
4. Work in this course has increased my awareness of the Envision rating system.
5. Work in this course has increased my ability to apply the Envision rating system to the design of civil engineering infrastructure.

Quality of Life

1. WELLBEING

QL 1.1 Improve Community Quality of Life		0 of 26 Points

Intent: Improve the net quality of life of all communities affected by the project and mitigate negative impacts to communities.

Metric: Measures taken to assess community needs and improve quality of life while minimizing negative impacts.

Applicability: It is likely that all projects have the ability to align project objectives with community needs and goals, identified through a engagement, in order to achieve broad community satisfaction. It would therefore be difficult to demonstrate that the credit is not rele applicable to a project seeking an Envision award.

		Yes/No
	Is this credit applicable?	Yes
Assessment Questions:		**Criteria Met?**
A	Has the project team identified and taken into account community needs, goals, and issues?	-
B	Does the project meet or support the needs and goals of the host and/or affected communities?	-
C	Has the project team assessed the social impacts the project will have on the host and affected communities' quality of life?	-
D	Have the affected communities been meaningfully engaged in identifying how the project meets community needs and/or goals?	-
E	Has the project team addressed negative social impacts?	-
F	Are the affected communities satisfied that the project addresses their needs and goals as well a mitigates negative impacts?	-
G	Does the project proactively address long-term social, economic, or environmental changes that quality of life?	-

Figure 4: Example of credit within Envision Pre-Assessment Checklist [1]

Assessment Results and Discussion

Survey responses from students in the Year 2 Sustainable Civil Engineering course and the senior capstone design course are shown in Tables 1 and 2. Ratings were based on a 5-point Likert scale (1 = strongly agree, 2 = agree, 3 = neutral, 4 = disagree, 5 = strongly disagree).

Table 1: Mean values and standard deviations (SDs) of student responses at the end of CE250 Sustainable Civil Engineering (n=31)

Statement	Mean response	SD of responses
I am familiar with the Envision rating system for sustainable infrastructure.	2.29	1.22
I can explain the purpose of Envision as a rating system for sustainable infrastructure.	2.32	1.25
I can utilize Envision to measure sustainability in civil engineering design.	2.48	1.23
Work in this course has increased my awareness of the Envision rating system.	2.23	1.54
Work in this course has increased my ability to apply the Envision rating system to the design of civil engineering infrastructure.	2.45	1.36

Table 2: Mean values and SDs of student responses at the end of CE488 Senior Capstone Design (n=31)

Statement	Mean response	SD of responses
I am familiar with the Envision rating system for sustainable infrastructure.	1.97	0.87
I can explain the purpose of Envision as a rating system for sustainable infrastructure.	1.97	0.80
I can utilize Envision to measure sustainability in civil engineering design.	2.16	1.00
Work in this course has increased my awareness of the Envision rating system.	2.00	1.06
Work in this course has increased my ability to apply the Envision rating system to the design of civil engineering infrastructure.	2.13	1.02

Mean responses showed that students in both CE250 Sustainable Civil Engineering and CE488 Senior Capstone Design tended to “agree” with each statement. Although response ratings were within a SD, mean values from the senior capstone design course leaned more solidly towards “agree” than mean values from the sustainable civil engineering course. This slight trend shows positive support for our approach of including touchpoints of Envision coverage that build knowledge into applying the system more fully in senior capstone design.

Additionally, the assignment in senior capstone design (Figure 3) was utilized for departmental continuous improvement and assessment of student outcomes. For the student outcome to "analyze the sustainable performance of civil engineering projects from a systems perspective," this assignment scored 83% passing rate in AY 2022-23 and 100% passing rate in AY 2023-24.

Conclusion

To support students in designing with sustainability in mind from the early stages, and to increase awareness of the importance of resiliency, social equity, and environmental justice of civil infrastructure projects, we have created a scaffolded intervention using the Envision framework. Since students tend to be motivated by sustainability measures, we teach the Envision framework to equip them with a tool through which to assess designs and challenge themselves to improve quality of life and other aspects of society through civil engineering.

References

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