Bringing Choice Architecture to Architecture and Engineering Decisions: How the Redesign of Rating Systems Can Improve Sustainability

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Abstract: To increase the long-term sustainability of architecture and engineering decisions, this research combined theory from behavioral science and civil infrastructure design to examine whether redesigning sustainability decision-making tools can alleviate potential status quo bias in planning and design decisions. Using case studies to simulate real-world decision environments, we empirically tested the combined effect of two modifications to the Envision Rating System for Sustainable Infrastructure. One modification provided engineers with sustainability points corresponding to the highest level of achievement, with any change to a lower level leading to a loss of points. The second modification showed engineers an exemplary project to serve as a feasibility example. The combined modifications produced significant gains in sustainability using predefined metrics. One concern is that these modifications work because decision makers are unaware of their effects. To assess this, we disclosed the modifications to another group of engineers. The disclosure had no significant effect on the gains in sustainability performance. We then repeated the experiment with groups. Similar gains in sustainability were achieved by groups who received the combined modifications. Our results suggest ways of using insights from behavioral decision theory to improve the growing array of tools used to plan for sustainability not only in large-scale infrastructure projects but also in a range of other upstream applications that determine downstream consumer choices. **DOI: 10.1061/(ASCE)ME.1943-5479.0000692.**

Introduction

Since its advent in the 1950s, behavioral decision theory has documented that human decision makers resort to cognitive shortcuts as a way of dealing with finite processing capacity (Weber and Johnson 2009). Although efficient and effective in most instances, a broad range of documented decision processes has also been shown to lead to biases, that is, to systematic differences from judgments and decisions made by using formal methods of rational choice and logic (Tversky and Kahneman 1974). For example, limited attentional capacity compels people to focus predominantly on the here and now, but such myopia contributes to people unintentionally failing to save enough to support their lifestyle after retirement (Benartzi and Thaler 2007) or to leaving an increasingly uninhabitable planet to future generations (Weber 2015).

These same cognitive shortcuts can lead to irrational engineering management decisions. For instance, during design, coastal engineers frequently hold to current building codes as a rationale for not investing in resilient materials (Lassiter and Shealy 2017). During procurement, construction professionals overly rely on status quo bias when making purchasing decisions about energy-efficient facility upgrades (Delgado et al. 2018). During construction, overconfidence in one's own ability and judgment can lead to risk-compensating behaviors (Feng et al. 2017). Related to sustainability, social and professional norms are strong predictors of a project manager's waste reduction intentions (Yuan et al. 2018). In response to a survey from green building experts, the most resistance to green buildings comes from stakeholders' unwillingness to change old practices (Chan et al. 2017). During operation, a third of the barriers to installing and using energy management information systems in commercial buildings are behavioral (Harris 2017), not technological or financial (Harris et al. 2018).

Better understanding how engineers apply judgment can help develop models of decision making that more accurately reflect nonrational deviations from normative models (e.g., Babaeian Jelodar et al. 2017; Delgado and Shealy 2018; Parkin 1994; Shealy and Klotz 2016; Sprauer et al. 2016). For instance, the psychological distance from past project failure plays a key role in repeat behavior among project managers (Liu et al. 2017). Recognizing how time influences behavior and accounting for this salience on choice in future decision-making offers a more practical approach and a more accurate mathematical representation of judgment and intuition compared to purely analytic methods (Benhabib et al. 2010; de-Monsabert et al. 2003). Similarly, incorporating behavioral aspects into asset management can help substantiate decisions and account for the many preferences of stakeholders (Saad and Hegazy 2015).

One approach to correct nonrational deviations from normative models is through choice architecture. The term *choice architecture* likens the effect of choice environments on decisions to the effect of physical environments on behavior (Johnson et al. 2012). For ex-

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ample, an attractive staircase in the atrium of an office building will increase the chances that workers will walk one or two levels up rather than taking the elevator. Similarly, a well-designed choice environment will increase the chances that decision makers will not fall prey to cognitive biases like myopia or status quo bias (Weber and Johnson 2009). By understanding how decisions are influenced by features of choice environments that should, from a normative perspective, have no effect, choice architects can design choice environments that help people make decisions that are in their own or their clients' best interests (Johnson et al. 2012). In the case of retirement savings, asking people to commit in advance to allocating future salary increases toward retirement has been shown to increase rates of saving (Thaler and Benartzi 2004). Another example is the use of green electricity, making renewable sources the default option (Pichert and Katsikopoulos 2008).

Such demonstrated improvements to consumer-level decision making show promise that similar behavioral modifications might be of service to "upstream" decisions about sustainability, that is, decisions that influence the behavior and thus the environmental impact of many downstream users of buildings, transportation systems, or other engineering projects by virtue of determining the options that these downstream consumers have (Shealy and Klotz 2016). Taking a train instead of driving is a downstream decision; building a railway instead of a highway is an upstream one. A single upstream decision made by agents acting on behalf of consumers can be as influential as countless individual downstream decisions.

Some examples of choice architecture applied to upstream engineering management decisions include the modification of rating systems (Ismael and Shealy 2018), embedding life-cycle costs into decision options (Saad and Hegazy 2015), and reframing risk (Shealy et al. 2017) and uncertainty (Buiten et al. 2016) to appear more favorable. For instance, status quo bias led to underestimating construction expenditures and overestimating financial profits for a capital project between a Dutch contractor and the Dutch Waterways Agency. Shifting the cognitive focus through choice architecture improved performance by removing the status quo barrier, leading to more realistic expectations and more opportunities for return on investment (van Buiten and Hartmann 2013).

In the sections that follow, we report the results of modifications to the infrastructure planning and design process that account for behavioral influences on decision making. The work presented builds on prior research in engineering management that suggests engineers make numerous complex decisions in design (An et al. 2018), construction (Bakht and El-Diraby 2015), and coordination (Antillon et al. 2018) and typically rely on intuition and quick judgment (deMonsabert et al. 2003) without a formal or analytical method (Arroyo et al. 2016). The modifications to the infrastructure planning and design process we made were based on prospect theory (Camerer 2000), query theory (Weber et al. 2007), and imitation heuristics (Nikolaeva 2014), which are different bodies of behavioral science theory. We tested the effects of combining choice modifications, disclosing their existence and purpose to decision makers, and testing their effectiveness in a group decision context. We also tested the effects with groups. Groups were necessary to include because infrastructure development involves teams of stakeholders. Multiple planners and engineers and regulatory agencies are all prominently involved in infrastructure development.

The findings reported in this paper advance our understanding of how choice architecture influences engineering decisions by demonstrating the impact of choice architecture not just on relatively simple consumer decisions but also on more complex upstream planning and design decisions made by experts that require tradeoffs between multiple objectives, involve uncertainty, and require multiple stakeholders to implement. Much prior research in engineering management has investigated similar issues (Bakht and El-Diraby 2015). However, the uniqueness of this work is in applying a descriptive rather than a normative perspective. This is a necessary advancement toward understanding decision making on a large physical scale and over long-term horizons (Brewer and Stern 2004). These findings also have broad implications for developing policy responses to global challenges, like sustainability and climate change in the future (Kunreuther et al. 2014).

Background

Too frequently, engineers act as if decision makers are fully informed, and they assume that preferences exist a priori (Gonzalez et al. 2005). Yet seldom is a formal decision-making method used when a design or construction engineering team chooses an alternative (Arroyo et al. 2016). Thus, nonrational choice processes must be considered (Fischer and Adams 2011). Specific to civil engineering, decisions require active tradeoffs and typically involve uncertain consequences (Zimmerman 2001). These decisions must also account for multiple stakeholders, each bringing unique expertise, perspectives, and motivations. The long-term horizon of infrastructure further makes these decisions challenging. For example, even innovative technologies such as the high-speed Amtrak train are constrained by decisions made in the nineteenth century. The Union Tunnel, just south of Baltimore, was completed in 1873, and the tunnels used by Amtrak connecting New York and New Jersey were built in 1910. If these decisions were less than optimal, the consequences endure more than a century later.

Tversky and Kahneman's (1974, 1992) prospect theory of risky choice describes how people evaluate the outcomes of decisions not in absolute terms (i.e., their effect on total wealth) but in relative terms as gains or losses relative to a reference point, which is often the status quo or an initially considered choice option. Such reference-dependent evaluations would not differ from an absolute evaluation if possible outcomes and their probabilities were integrated by computing their expected value. However, people generally have different nonlinear value functions for gains than for losses, namely, they are risk-averse for gains and risk-seeking for losses. In addition, people are generally loss averse, meaning they are more disturbed by a loss than they are pleased by a gain of the same magnitude, typically by a factor of two.

Choice architecture, defined as intentionally crafting the way decisions are posed to decision makers, uses prospect theory and the flexibility it describes in the way choice outcomes are perceived to help decision makers achieve desired objectives (Thaler et al. 2013). This approach works because decision makers, when faced with a choice, do not always immediately know what they want (Slovic 1995); instead, they perform an informal reasoning process known as preference construction (Weber and Johnson 2009). In this reasoning process, which operates outside of conscious awareness, people assemble different arguments for or against various courses of action. When a difference between two courses of action is seen as a loss (i.e., of income or of sustainability points) rather than a gain, because the higher of the two outcomes serves as the point of reference, then loss aversion will make the difference seem larger.

Decision makers often take shortcuts during this preference construction process (Tversky and Kahneman 1974). For example, infrastructure designers may rely solely on recent experience rather than on a complete analysis of all existing options to justify a new design decision (Nikou and Klotz 2014). This can be a problem in cases where a previous satisfactory experience leads to a reluctance

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to depart from the current industry practice and therefore to the undervaluing of an innovative new solution (Beamish and Biggart 2010). Indeed, decision makers tend to overvalue past decisions with spent costs still considered, even when they have become irrelevant to future options (Arkes and Blumer 1985). This sunk cost fallacy is likely a contributing factor to why failing infrastructure is repaired in cases when a better solution would be wholesale replacement (The Economist 2007).

Choice architects, meaning those who design choice environments, can help decision makers avoid overreliance on recent experience, sunk costs, and other cognitive biases. Relevant to the study of engineering management, choice architects can modify default decisions (Delgado et al. 2018), which serve as reference points, to make differences between choice options appear larger or smaller, capitalizing on loss aversion (Weber et al. 2007), and choice architects can provide feasibility examples, which include detailed and vivid descriptions of the options they want users to consider (Thaler et al. 2013). This extra description balances past experience by changing how information is attended to and then processed by the decision maker.

Decision-Making Guides during Engineering Planning and Design for Sustainability

To test choice architecture modifications for civil engineering planning, design, and management decisions, we used a decision-making guide for sustainability called the Envision Rating System for Sustainable Infrastructure. We used Envision because more than 7000 engineers are trained Envision professionals, the rating system is supported by ASCE, and it provides a framework to apply choice modifications and measure the effects on early-stage planning and design decisions about infrastructure. The purpose of Envision, like other decision-making guides for sustainability, such as Leadership in Energy and Environmental Design (LEED), Building Research Establishment Environmental Assessment (BREEAM), and Living Building Challenge, is to provide a performance-based framework and common language for collaboration across teams (Envision 2019). These decision-making guides help break down theories and principles of sustainability into models and methodologies that are applicable across industries (e.g., drinking water, transportation systems, housing, and commercial buildings). Envision, like other systems, is used throughout the engineering design (Clevenger et al. 2013) and construction process (Poveda and Lipsett 2011).

The Envision rating system broadly applies to all types of civil infrastructure (i.e., roads, bridges, pipelines, railways, airports, dams, levees, landfills, and water treatment systems) (Clevenger et al. 2013). Envision is used voluntarily by design and construction firms and is also mandated by some local governments and municipalities. Envision works by awarding points for 60 credits clustered into five general categories (quality of life, leadership, resource allocation, natural world, and climate and risk). These points accumulate toward various levels of certification. The scale of points varies for each credit, but all point values increase with increasing levels of sustainability, from current industry practice to improved, enhanced, superior, conserving, and restorative levels.

Prior-Choice Architecture Modifications to the Envision Rating System

Prior research has demonstrated how modifications to the Envision rating system motivates engineers to consider higher levels of sustainability, specifically in two ways: (1) changing the default option for each decision from a score of zero (current industry practice) to a higher level (conserving) by prechecking this option in the Envision software, thereby endowing users with those points toward certification (Shealy et al. 2016); and (2) providing users with a high-achieving (restorative) feasibility example to consider when making decisions about their own infrastructure design project (Harris et al. 2016).

The first modification, endowing users with the conserving level, puts to use loss aversion, the widespread finding that people generally hate losing something roughly twice as much as they enjoy winning the exact same thing. Loss aversion helps explain why home sellers overprice a house in a down market (Genesove and Mayer 2001) and why investors hold a losing stock too long (Odean 1998). Choice architects can frame the exact same decision outcome as either a loss or gain simply by changing the reference point used by the decision maker (Dinner et al. 2011). Prior work has shown that reference points that exceed the status quo, such as goals, induce loss aversion and therefore lead decision makers to expend more effort to meet or exceed the goal (Heath et al. 1999). Marathon runners, for example, will work harder when they try to achieve a specific time goal (Markle et al. 2018).

The effectiveness of this modification is supported by query theory, which states that choices are constructed by querying past experience for evidence in support of different choice options (Johnson et al. 2007). More evidence is generated for the first-choice option considered, as this first query temporarily inhibits response competitors, such as evidence for competing choice options. The default or endowed option therefore has an advantage as the choice alternative that is first suggested and is therefore more likely to be the first option considered (Weber et al. 2007).

The modification to the default level of achievement in Envision elicits both query theory and loss aversion. The changes in default to conserving shift the decision makers point of reference, and thus the requirements to meet the conserving level of achievement become the first considered rather than the last. When tested among professionals, the endowment modification to Envision led to a 15% increase in what engineers believed was possible.

The second previous modification to Envision's choice architecture was based on the imitation heuristic, by which people imitate the behavior of a successful person or, in this previous case, project (Boyd and Richerson 2005). This social heuristic works in part through motivation: do what others do because that behavior gets approval and seems realistic. The heuristic also has cognitive elements. It draws decision makers' attention to a preferred option via an example from successful others whom they might trust.

To generate social influence on decisions made for infrastructure planning, a feasibility example to the Envision credits for one group of participants was added. The feasibility example explained how Psomas Engineering achieved the highest Envision score, restorative, on the South Los Angeles Wetlands Project. For instance, the feasibility example for credit quality of life (QL) 2.3: minimize light pollution reads, "Psomas Engineering achieved Restorative. The project team assessed lighting needs and found only security lighting along the pedestrian walkways was needed. The project uses solar lights with cut-off lenses to reduce both lighting energy requirements and light spillage." Prior tests with just the feasibility example showed that the group had given the feasibility examples achieved significantly more points, about 34%, than the control group (Harris et al. 2016).

Libertarian Paternalism and Disclosure of Choice Architecture

The aforementioned types of modifications, by endowing points and providing a feasibility example, may appear paternalistic. The fear is that choice architects will promote choices that further their own interests (Bovens 2009), as opposed to helping decision makers make decisions that are in their best interest (Sunstein 2015). One response to this fear is that there is no such thing as a neutral choice architecture and that it is therefore better that the most appropriate and effective choice architecture be determined rather than the issue being ignored (Bang et al. 2018). Libertarian paternalism goes further to suggest the design of choices can respect freedom to choose as well as influence choices in a way that will make decision makers better off (Sunstein and Thaler 2003). Disclosing the choice architecture and its intent further eases concerns about people being unwittingly manipulated. Preliminary results from consumer-level decisions show no appreciable negative impact from disclosing modifications, that is, the interventions maintain their effectiveness and there is no reactance against them (Loewenstein et al. 2015). However, similar disclosure on upstream decisions with engineers has not yet been tested.

Effects of Choice Architecture on Group Decision Making

The number of people involved in the decision-making process may have an effect on the decision outcome. Changing the unit of analysis from an individual to a group multiplies the research effort required to observe a single outcome. Yet such effort is needed because, in practice, infrastructure project planning and other upstream decision processes are social activities that involve constant negotiation among multiple stakeholders, including attempts to infer the preferences of others (Olsen et al. 2016). Group dynamics may mediate different cognitive processes (Hastie and Kameda 2005) and the effects of choice architecture may not be as pronounced as among individual decision makers (Weber and Johnson 2011).

Much previous research on groups provides multiple methods to maximize the positive effects of groups during decision making. Some examples are the Delphi Technique (Rowe and Wright 1999), devil's advocate (MacDougall and Baum 1997), Condorcet jury theorem (Bottom et al. 2002), and red teams (Mulvaney 2012). However, empirical studies measuring the effects of choice architecture modifications are still limited. The known effect of choice architecture on group decisions is limited, in part because it is more difficult to organize (Sunstein and Hastie 2015).

Hypotheses

We conducted a study of choice architecture modifications within the Envision rating system by combing the endowment modification and feasibility example described above and disclosing this information to participating engineers. We hypothesized the choice architecture modifications to the default number of points and providing a feasibility example would lead to higher goals for sustainability compared to the control version. To assess whether these interventions worked because engineers were unaware of their effects, we tested the effects when the interventions were disclosed. Our second hypothesis was that disclosing the existence and intent of the choice architecture modification to decision makers before they used Envision would not diminish the effects of the modification because whether the decision maker was aware or not, preferences about options are still developed by the automatic processes and series of questions described by prospect theory and query theory and these questions depend on the starting point, which remained unchanged, regardless of disclosure. Because engineering decisions are often made in groups, we then tested the choice architecture modifications with groups of participating student engineers. We hypothesized that the modification to choice architecture would still help increase sustainability goals in the group setting, but that the group dynamics would also affect decision making, as there is evidence that choice architecture effects in individual versus group contexts can be mediated by different processes (Weber and Johnson 2011).

Methods

We used engineering decision scenarios modeled from real-world projects in which decision makers were asked to make engineering and planning decisions. These realistic decision scenarios approximated the actual decision setting and sample from the relevant population. However, because they used hypothetical outcomes, this experimental method had additional advantages: numerous and novel conditions could be examined, results were obtained quickly, and detailed process data were more easily collected. The subsections that follow describe the empirical experiment setup and sample population in more detail, beginning with participant recruitment and procedures, an overview of the case-study decision scenario, and data analysis techniques.

Participant Recruitment and Experimental Procedure

Civil engineers ($n = 80$) were recruited to participate in a training seminar that included an introduction to the Envision rating system and a case study. Informed written consent was obtained from each participant after an explanation of the study and this process was approved by Virginia Tech's Institutional Review Board.

The purpose of the training seminar was to show participants how to navigate the Envision guidance manual and online rating tool. They were given background information about the case study's intended goals, local governance, community, and site programing. Individual participants were then asked to imagine themselves as a consultant for an infrastructure redevelopment firm. In this role, participants reviewed credits of the Envision rating system, and for each credit, they were asked to select the level of achievement they believed was possible. For each credit, they were also asked to provide a detailed explanation of how the project team could realistically meet this level of achievement and receive these points.

Participants were randomly chosen to receive the current control version of Envision, the modified version of Envision endowing points and the feasibility example, or the modified version with an additional disclosure statement that explains why the modifications were made. Participants were randomly assigned to the control or modification groups because randomization is a reliable method of creating homogeneous treatment groups without involving any potential biases or judgments. When participants logged into the modified version of Envision, they saw their initial score and the total possible number of points, and they could scroll down the page to view each credit. Just as in the unmodified version of Envision, a link directed users to detailed explanations of how to meet achievement levels. The dependent measure was the level of achievement participants selected (i.e., improved, enhanced, superior, conserving, or restorative). These levels and the associated points are predefined by the Envision rating system.

In total, there are 60 possible credits within the Envision rating system. To shorten the training seminar, 10 credits were chosen that appeared applicable to the case study project. For example, the case study included a stream. So, including the Envision credit about protecting surface water was included. In the actual Envision rating system, an increase in level of achievement requires more documentation. For example, meeting improved (one point) for the credit Quality of Life 2.5: Encourage Alternative Modes of Transportation requires demonstrating how the constructed work is located within walking distance of amenities and is pedestrian accessible while restricting parking of motorized vehicles. Meeting enhanced (three points) requires additional documentation about how the constructed project is designed for multimodal transportation. Superior (six points) requires documenting everything required for improved and enhanced, plus how the constructed work encourages users to use nonmotorized transportation. Each level builds on the previous one, requiring more documentation for higher levels of achievement for sustainability.

To reduce the likelihood that participants would maximize points by thoughtlessly selecting the highest levels of achievement for every credit, participants were required to provide a written explanation of how their stated achievement level would be met. Although we did not fully evaluate the content of these explanations, we did review the content for face validity. Participant responses that did not follow instructions were discarded. The length of the written response increased with each level of achievement: a written explanation of at least 100 characters was required for the improved level, 300 characters were required for restorative, and intermediate levels were spaced at 50-character intervals. In essence, the cost of deciding to achieve more points was time and cognitive energy, which aligns with the Envision rating system; each level of achievement worth more points requires additional answers to questions. The number of characters required for each level was based on prior studies (Shealy and Klotz 2015).

Monetary costs were not included in the experiment because they are not included in Envision. In fact, a high sustainability score does not linearly correlate with an increase in cost. Actually, the opposite may be true. For example, identifying a construction method to reduce excavated materials can be cost beneficial and earn a project team six points. Either way, the decision scenario created in this experiment is early in planning stages, more closely associated with site programing. This phase of planning is before estimates of project materials or means and methods of construction that significantly influence cost. Therefore, the Envision system was kept exactly the same except for the modification to the choice architecture and required length of explanation.

In addition to measuring decisions about sustainability, we measured the amount of time participants took to make and justify their decisions. The purpose of measuring time to decision was to learn more about the effect of choice architecture on the judgment and decision-making process itself. Time was collected based on the total time to complete all 10 credits. The time began when participants initially logged into the replica system and time stopped when participants submitted their responses.

A limitation to our approach using a replica version of Envision and decision scenarios is that it required us to isolate a single decision point, and we therefore do not know how these decisions will hold up over time. Still, starting with a higher goal in the planning phase of infrastructure can only help the long-term sustainability outcomes of a project. Although there is still an ongoing discussion (Scofield 2009), higher points for sustainability using other but similar ratings systems did translate to higher efficiency (Newsham et al. 2009). Another limitation is that our data collection occurred under the guise of an Envision training session. Participants may have been susceptible to social desirability bias (Nederhof 1985), meaning setting higher sustainability goals than they otherwise would have to provide answers that align with the training content. However, any such bias would be constant across the control and experimental groups, and therefore it did not change our primary conclusions, which were based on differences between the groups.

Specific-Choice Architecture Modifications

The modified version of Envision endowed points to users at the highest level of sustainability, defined by Envision as restorative, and were also given a feasibility example explaining how another project team was able to achieve the restorative level. This is referred to as the combined modified intervention group ($n = 32$) because of the two choice architecture interventions compared to the control version of Envision. The feasibility example was exactly the same as in the prior study (Harris et al. 2016). The endowment modification changed slightly. Prior studies used the conserving level of achievement (Shealy and Klotz 2015; Shealy et al. 2016). Here, the highest level, restorative, was used as the default reference point. For example, in the standard version of Envision, the implicit reference point is current industry practice. Users begin with 0 points and gain points for achieving sustainability goals. By contrast, in the fully endowed version of Envision, users were endowed with the restorative level, which was prechecked for each credit. As a result, participants began with 169 out of a possible 169 points, and achievement below the new default option therefore resulted in a loss of points.

For the modified version with disclosure, participants were given a written description of the combined modifications before making decisions. The disclosure statement read, "In order to encourage higher Envision scores, we modified your interface with the Envision rating system in two ways: (1) We added the high-scoring example project (typically there is no example project on the standard interface) and (2) we pre-set your point scores to the Conserving level of achievement (typically there is no pre-set)." This group of participants are referred to as the disclosure group (disclosure = 24). The control group (control = 24) received neither the default nor feasibility example, nor were they told about these changes. The control replica version looked exactly the same as the actual Envision rating system software.

Decision Scenario

Participants were asked to act as if they were a sustainability coordinator for a project team designing an outdoor community center and stream restoration on a half-acre brownfield site in rural Alabama. The Envision system would help them make site design decisions about cleanup, restoration, and programing. Participants were given the site's environmental assessment reports and the community revitalization mission statement. Details like how to clean site contamination, whether to include bike paths, and where to place the outdoor community center were not provided. Participants were required to determine which, if any, of 10 Envision credits were relevant and what level of achievement was most appropriate to meet project goals. The 10 credits were predetermined because of their applicability to the case study project and because all 10 included each of the five possible levels of achievement (improved, enhanced, superior, conserving, and restorative). Some credits do not provide restorative. The 10 credits are

QL Credits

1. QL 1.2: stimulate sustainable growth and development,
2. QL 2.3: minimize light pollution,
3. QL 2.5: encourage alternative modes of transportation,
4. QL 3.2: preserve views and local character,
5. QL 3.3: enhance public space,

Natural World (NW) Credits

6. NW 1.2: protect wetlands and surface water,
7. NW 2.3: prevent surface and groundwater contamination,
8. NW 3.4: maintain wetland and surface water functions,

Climate and Risk (CR) Credits

9. CR 1.1: reduce greenhouse gas emissions, and
10. CR 2.2: avoid traps and vulnerabilities.

Post-Task Survey

As part of our study, we also asked a series of follow-up questions to better understand the ways in which our modifications influence patterns of cognitive processing, either through reference dependence, implicit endorsement, or cognitive effort. Participants were asked a series of questions, followed by a series of fill-in-the-blank response options representing the levels of Envision achievement (improved, enhanced, superior, conserving, and restorative):

- I (we) used the ____ level of achievement as a baseline and then adjusted from there;
- I (we) perceived the ____ level of achievement as the recommended option; and
- For me (us), the ____ level of achievement required the least amount of thought (discussion) to target.

We also asked follow-up questions to learn more about why and how the default and feasibility example modifications led to higher scores. Participants responded on a five-point Likert scale from strongly agree (4) to strongly disagree (0) to the statements

- When considering the possible levels of achievement for each credit, I began with the level of achievement from the example project and then moved up or down;
- I believe my decisions reflected my preferences and goals;
- I am confident a project team could really achieve the Envision score I came up with;
- I am willing to use Envision in the future if the opportunity arises; and
- I would recommend Envision to a friend.

Data Analysis

By comparing responses between the control and modification groups, we were able to measure the collective effect on the sustainability of decisions in terms of the difference in total points achieved. In each study, we tested whether responses were normally distributed before performing a one-way between subject ANOVA (Scheffé 1959). A Tukey post hoc analysis (Tukey 1949) was used to determine significant difference between treatment groups: the control, modified choice architecture, or modified choice architecture with disclosure of the modification. A confidence level of 95% was used in our analysis. We defined possible outliers in the results as a cumulative score outside two standard deviations from the mean. To remain conservative, we excluded outliers from our results except in cases when removing them made the results even more significant.

For all survey questions, significance was determined using a Kruskal–Wallis test, comparing participants who received the control version of Envision to participants who received the modified version and disclosure version (Kruskal and Wallis 1952). A Mann–Whitney U test was used when comparing only two treatment conditions (Mann and Whitney 1947).

Robustness Check with Student Groups

As a robustness check, the same experiment was repeated with groups of senior civil engineering students. Students were recruited to participate through a course called Professional and Legal Issues, offered in Civil Engineering at Virginia Tech. Similar to the individual engineers, the experiment was set up under the guise of a Envision training session. Groups of four civil engineering students received exactly the same scenario as the individual engineers. The groups discussed each credit together to select and justify an agreed-upon level of achievement. Civil engineering students were used for the experiment with groups as a form of convenience sampling (Teddlie and Yu 2007) because of the number of participants needed in the group study ($n = 116$). However, based on results from our prior studies with both students (Shealy and Klotz 2015) and professionals (Shealy et al. 2016), in which greater differences were observed among professionals than students, we expected that the results would translate to professionals.

For the group study, 29 groups of four participants ($n = 116$) were asked to work as a team to decide on levels of achievement for the same Envision credits as the individual participants. Teams randomly received either the control version or the modified version (nondisclosure). The disclosure intervention was not tested because the results from the individual test found no significant difference from the nondisclosure group (see "Results and Discussion"). In other words, the robustness check was used to test whether differences observed among individuals held among groups. Groups were instructed just as individuals and no guidance was provided about decision-making rules to develop their response. An independent t test was used to identify whether the difference in results between the groups given the modified version and the control version met our confidence level of 95%.

Results and Discussion

Participants in the modification (nondisclosure) group who were endowed with the restorative-level points and given the feasibility example ($n = 32$) achieved 79% of the total possible points. Those given the disclosure ($n = 24$) about the modification achieved 76% of the total possible points. The participants that received the control version ($n = 24$) of Envision achieved just 56% of the points. There was a significant effect of the amount of points achieved based on the modifications at the $p < 0.05$ level for the three conditions ($F_{(2,\ 77)} = 8.1$, $p = 0.0006$). For each Envision credit, the participants given the modified version of Envision and the participants given the modified version with the disclosure about the modification chose a higher level of sustainable achievement than the control group (Fig. 1). Using a Tukey post hoc analysis, we found that the average number of Envision points achieved from the participants given the modified version of Envision compared to the participants given the control version was significantly different ($p = 0.001$). The average number of Envision points achieved from the participants given the disclosure compared to the control version was also significantly different ($p = 0.008$). Disclosure of these modifications did not diminish their effect. In other words, whether participants were aware of the modifications to the choice architecture or not (modified version compared to disclosure) had no significant influence on their final number of points achievement ($p = 0.8$). Note that because the purpose of Envision is to encourage consideration for sustainability, the choice architecture modifications were likely to be consistent with decision-makers' objectives. Disclosing choice architecture that conflicts with decision-makers' objectives may be more likely to diminish the effect of modifications (Jachimowicz et al. 2019).

The modification also shaped group decisions, as teams of four given the combined modification ($n = 12$) achieved an average of 75% of points, whereas teams of four given the control version ($n = 17$) achieved 61% of the points. There was a significant difference in Envision points for modification (M = 126.7, SD = 31) and control (M = 102.5, SD = 29) conditions; $t_{(23)} = -2.14$, $p = 0.04$. As shown in Fig. 2, the average results from the group

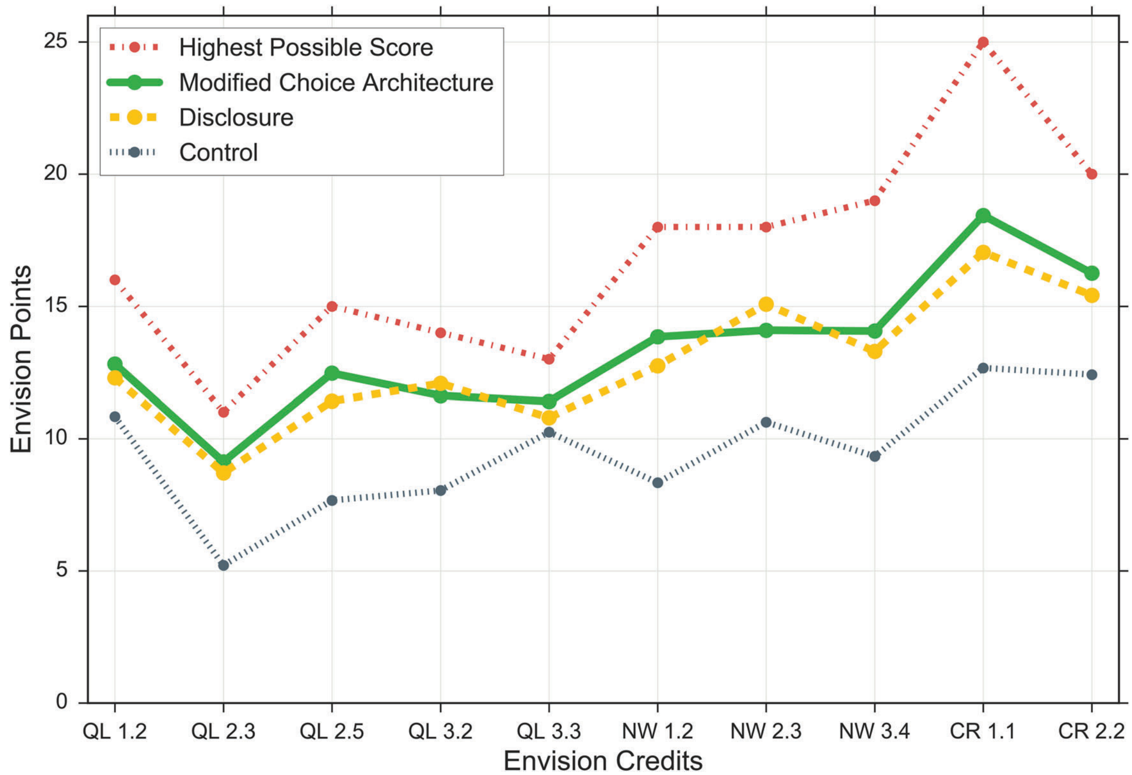

Fig. 1. Disclosure does not diminish the effect of choice architecture on setting high goals for sustainability when using the Envision rating system.

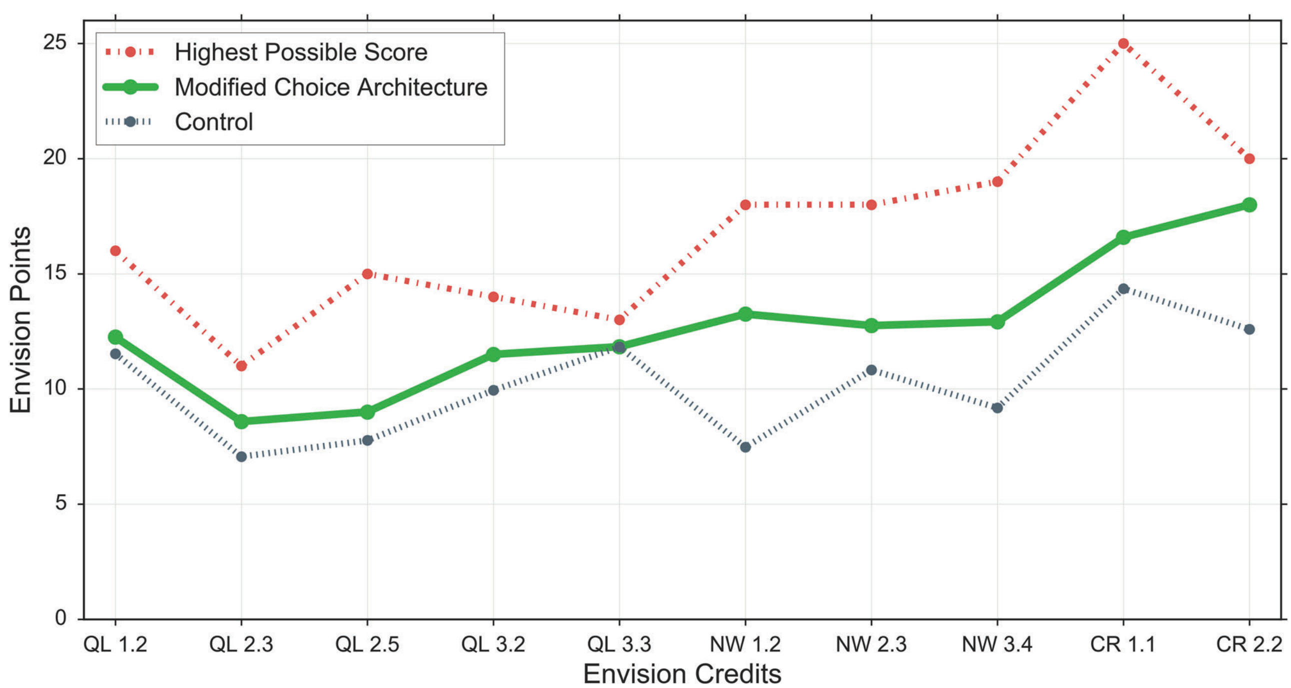

Fig. 2. Choice architecture modifications to the Envision rating system significantly influenced group decision-making goals for sustainability.

decisions were closer in score related to QL credits compared to the average results from the individual decision makers. The average total score for the control group (M = 102.5, SD = 29) was higher compared to the average control score of individual (M = 95, SD = 37) decisions, although the difference was not significant $t_{(38.5)} = 0.66$, $p = 0.5$. However, it would be worth exploring whether group decisions alone are leading to more ambitious sustainability goals.

As summarized in Table 1, our findings show that modified versions of Envision with endowed points to the restorative level of achievement and given a feasibility example, whether disclosed or not, led decision makers to set more ambitious planning goals for infrastructure sustainability. Making decisions in groups did not diminish the choice architecture effects.

Based on the treatment groups, plus the previous tests on endowed default that resulted in setting goals to reach 66% percent of

Table 1. Choice architecture modifications led to higher goals for sustainability

Treatment groups	Treatment 1 (SD)	Treatment 2 (SD)	Difference	p
Control versus modified	56% (24%)	79% (24%)	23%	<0.001
Control versus disclosure	56% (24%)	76% (24%)	20%	<0.01
Modified versus disclosure	79% (24%)	76% (24%)	3%	>0.05
Group (control versus modified)	61% (17%)	75% (19%)	14%	<0.05

the possible points (Shealy et al. 2016) and a feasibility example that resulted in setting goals to reach 74% percent of the possible points (Harris et al. 2016) individually, it appears that there is a maximum of what is actually achievable through the modifications. The average among those receiving the modifications in this study was 77%. One plausible explanation for this ceiling, or maximum, is that a score higher than 77% of the Envision points is not appropriate for this infrastructure project. Another possible explanation is that Envision users satisfice to meet a high but not the highest level of achievement. If this is the case, complementary choice architecture modifications designed to promote optimization could be introduced in an attempt to raise achievement levels even higher. Nevertheless, it is worth pointing out again that the average achievement without our modifications of Envision was only 56%.

To learn more about the effect of choice architecture on the decision-making process itself, we measured the amount of time participants took to make and justify their decisions. The difference in time to complete the decision tasks provides further evidence that the modified choice architecture influenced participants' decision processes. The difference was significant between the three conditions ($F_{(2,\ 77)} = 6.1$, $p = 0.003$). A Tukey post hoc analysis identified significance between the following conditions:

- Participants who received the modified version of Envision (M = 52 min, SD = 38 min) needed on average 1 h less time than participants who received the control version (M = 113 min, SD = 134 min). The difference was significant ($p < 0.05$).
- Participants to whom the combined modifications were disclosed also took less time (M = 42 min, SD = 10 min) than the control group (M = 113 min, SD = 134 min). They spent even less time than the group with the modified version, although a Tukey post hoc analysis showed that this difference was not significant ($p > 0.05$).
- Similar to individual decision-making results, groups of four given the modified version of Envision came to decisions more quickly (M = 39 min, SD = 18 min) compared to the control groups (M = 41 min, SD = 10 min) but the difference in time was considerably less than that of individual participants and did not meet the 95% confidence interval, $t_{(27)} = 0.4$, $p > 0.5$.

Participants who received either the combined, modified version with default endowment of points and feasibility example or the version given the disclosure of Envision modifications both took less time compared to participants who received the control. These results are somewhat surprising because participants given the modified versions achieved on average more points than the control and therefore were required to provide a longer written explanation for how to meet these high levels of achievement (see the "Methods" section). So, despite having to provide more explanation, these participants took less time to develop and write a solution. The number of participants reporting time was the same number of participants who completed the decision task.

Some discrepancy in the literature exists between loss aversion and loss attention (Yechiam and Hochman 2013). Loss attention can mean that a context involving losses may increase the attention level and cognitive effort of the participants in the task (Yechiam and Hochman 2014). Participants given the default and feasibility example spent less time making a decision than the control group, not more. Seemingly spending less attention on each of the credits and using the default and example project helped guide their decision more quickly. Interpreted another way, shorter task completion times may be an indicator of a more focused and efficient work process. Either way, the results suggest the modification to the choice architecture, whether disclosed or not, led to improved decisions for sustainability and required less time to make decisions. Ultimately, the purpose of Envision is to help guide the user to make better decisions, and the results suggest that these modifications helped achieve this outcome.

As part of our study, we also asked a series of follow-up questions to explore the previously described ways in which our endowment choice architecture modifications have been shown to work (Dinner et al. 2011): reference dependence, implicit endorsement, and cognitive effort. Attempting to assess their opinions on the effects of each of these channels, we gave participants the prompt "How did you select Envision levels of achievement?" followed by a series of fill-in-the-blank questions with response options representing the levels of Envision achievement: "improved, enhanced, superior, conserving, and restorative."

We tested for reference dependence by asking respondents to fill in "I (we) used the ____ level of achievement as a baseline and then adjusted from there." Participants for whom restorative had been the endowed default option and given the feasibility example were significantly ($p < 0.005$) more likely to indicate they started with restorative than participants in the control case, for whom no level of achievement was the prechecked default option. This difference held whether or not respondents knew about the modification. For all survey questions, significance was determined using a Kruskal–Wallis test to compare participants who received the control version of Envision with participants who received the modified version and disclosure version. A Mann–Whitney U test was used when comparing only two treatment conditions.

We looked for evidence of implicit endorsement with the question "I (we) perceived the ____ level of achievement as the recommended option." Again, participants given the modified and disclosure versions were significantly more likely [$H(2) = 9.7$, $p = 0.008$] (using a Kruskal–Wallis test) to indicate they started with restorative. The purpose of the Envision decision-making tool is to help those designing and constructing infrastructure achieve the highest possible score, which is the restorative level. The modified version, whether the modifications were disclosed or not, seemed to make this goal more implicit during the decision-making process.

We sought to measure the role of cognitive effort by asking respondents to complete the statement "For me (us), the ____ level of achievement required the least amount of thought (discussion) to target." There was no significant difference in responses between participants given the control version and those that received the choice architecture modifications [$H(2) = 3.8$, $p = 0.15$]. However, participants that received the disclosure were significantly more likely ($z = 2.04$, $p = 0.04$) to perceive that achieving a higher level would require less effort. This is expected based on the theory that the endowed modification works in part because it makes the decision easier to make.

For all three channels, there were no significant differences between participants making group decisions who received the control or modified version, perhaps due to the lower number of participants (a power analysis suggests roughly double the number of participants are needed for statistically significant results, the trend of effect is in the same direction as for individual decisions) and/or a smoothing effect from group dynamics. In other words, individual differences may have been resolved during group deliberations and therefore did not appear in the final choices made.

We also asked follow-up questions to learn more about why and how the default and feasibility example modifications led to higher scores. Responding to the statement "When considering the possible levels of achievement for each credit, I began with the level of achievement from the example project and then moved up or down," the majority of participants given the modified version and the disclosure version agreed or strongly agreed that the example project helped them establish a reference point. In response to a different question, all cases (controls, disclosure, nondisclosure, and groups) believed their decisions reflected their own (or their groups') preferences and goals (with mean scores greater than 2.5 on a scale from 0—strongly disagree to 4—strongly agree).

The presence and awareness of modifications made to the Envision system did not significantly affect respondents' perceptions of Envision or of their own decisions. Nor did it affect respondents' confidence in these decisions. We measured these factors by asking participants to what extent they agreed or disagreed with the following statements: "I believe my decisions reflected my preferences and goals"; "I am confident a project team could really achieve the Envision score I came up with"; "I am willing to use Envision in the future if the opportunity arises"; and "I would recommend Envision to a friend."

Conclusions

Explicit consideration and testing of the best way in which infrastructure planning decisions can be explained and framed can help optimize the impact of tools like Envision and other similarly-structured sustainability rating systems, from LEED to EnergyStar, with wider implications for developing more robust policy approaches to improve energy efficiency. Our work builds on previous research in behavioral science but extends it in several important ways. While modifications based on behavioral decision theory are applied almost exclusively at the individual consumer level, we empirically examined how modifications to choice architecture impact upstream design and planning decisions for sustainability. We found that behavioral modifications can shape upstream decisions, that combining modifications can lead to improved effects, and that these results are robust even when modifications are disclosed and when decisions are made in groups.

Possible impacts of these results are substantial. Suppose that an endowment with more ambitious goals led to just 10% better performance (our studies indicate upward of 20%) on the Envision credit "Reduce Greenhouse Gas Emissions." Applied to all US infrastructure, this represents a reduction of over 1.5 billion tons of CO_2 using an estimate based on a per capita carbon footprint of infrastructure of 53 tons (Müller et al. 2013) and a US population of 316 million. Of course, infrastructure is not updated all at once. But considering the successful cash-for-clunkers program invested roughly $3 billion and saved an upward estimate of no more than 30 million tons of CO_2 (Li et al. 2013), tweaking defaults and providing a feasibility example in an infrastructure decision-making tool appears cost-effective and promising.

Compared to the costs of infrastructure itself, simply restructuring choices is an inexpensive approach to support more informed decisions. These types of modifications are also less intrusive and speedier than formal legislation, although they could be so incorporated as learning develops. For instance, the feasibility example modification has already been adopted by the governing body of the Envision rating system. Assuming findings translate, the next generation of Envision projects may be better by roughly 20% across a variety of measures (e.g., reduced climate emissions, better quality of life).

Those seeking to encourage more sustainable decision making through policy in general and rating systems in particular can draw on research findings like ours to design their own choice architecture. Through additional empirical studies and field experiments, the research community can begin to predict decision outcomes based on these and other cognitive biases and therefore improve decision making with the result of more sustainable infrastructure and related benefits to all the people this infrastructure serves.

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