5-2015

DECISION ENVIRONMENTS TO ENCOURAGE MORE SUSTAINABLE INFRASTRUCTURE OUTCOMES

Earl Shealy
Clemson University, eshealy@g.clemson.edu

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A Dissertation
Presented to
the Graduate School of
Clemson University

In Partial Fulfillment
of the Requirements for the Degree
Doctor of Philosophy
Civil Engineering

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by
Earl Wade Shealy III
May 2015

Accepted by:
Dr. Leidy Klotz, Committee Chair
Dr. Kalyan Piratla
Professor Dan Harding
Dr. Cliff Ellis

ABSTRACT

Physical infrastructure (i.e. roads, pipelines, airports, dams, landfills, and water treatment systems) contributes directly to sustainability outcomes such as energy and water use and climate changing emissions. The infrastructure built today will likely impact future generations for many years. Planning, design and development decisions about infrastructure are critical to the future performance of these systems. Such decisions about infrastructure are complex with multiple variables, alternative options, and design stages. To manage decisions that exceed cognitive capacity to consider all options, decision makers often create mental shortcuts (heuristics), and accompanied errors (biases). The potential cognitive biases when dealing with complex decisions about infrastructure are examined and an approach to reframe the decision process during infrastructure planning is explored. A more critical analysis is then provided for decision aids, like energy codes and rating metrics (e.g. LEED and Envision), which are intended to reduce complexity and improve decision making using set goals and scaled points for achieving predefined objectives in sustainability. However, unintentionally, these tools may create additional biases that limit the higher achievements in sustainability that are possible. For instance, framing a decision as a loss, rather than a gain, in value can reduce the decision makers' acceptance of risk and, in turn, influence the outcome. The Envision rating system for sustainable infrastructure is presented to measure the influence of framing effects on engineering decision environments. Envision's current framework, starts users with zero points and points are achieved when design considerations move beyond conventional construction standards. In a modified version of Envision, a higher benchmark is set. Users are endowed points and can lose points for not maintaining high consideration for sustainability. Students (n=41) and professional engineers (n=65) were randomly assigned the replica Envision software or the modified version endowing points. Participants were asked to make design considerations for a redevelopment project using Envision. The results indicate, the endowed version significantly improved students' and professional engineers' consideration for sustainability design achievement. The student participants that were endowed points (n=16) scored 63 percent of possible points compared to the standard group's (n=25) 44 percent (p=0.002). The professional engineers that were endowed points (n=32) achieved 66 percent of possible points compared to the standard group's (n=33) 51 percent (p=0.002). Both students and professional engineers that were endowed points acted loss averse trying to maintain the initial points in sustainability given. These findings suggest engineers' process design decisions by comparing alternative options. And options framed as a loss or gain in value affects the decision outcome. This research underscores the advances possible at the intersection of behavioral science and engineering for sustainability. Slight changes in framing decision aids can lead to greater achievement in sustainability, and at a relatively low cost to implement. Future research should continue to explore how engineers make

decisions and what behavioral and decision theories can merge with engineering to encourage more sustainable infrastructure outcomes.

ACKNOWLEDGMENTS

I would like to thank and acknowledge my advisor Dr. Leidy Klotz. His guidance through this process advanced my ideas far more than I ever expected. Our weekly conversations helped refine my research message and provided the foundation for my future research. As a mentor and friend, Leidy has shaped my views about academia. His genuine compassion for others is evident in his mentorship of students. As I begin my teaching career, I look forward to sharing with students what I have learned from him.

I would also like to thank my committee members Dr. Kalyan Piratla, Dr. Cliff Ellis, and Professor Dan Harding. Their feedback from the proposal notably improved this dissertation. In addition, I am grateful for the ongoing research partnership with Elke Weber, Eric Johnson, and Ruth Greenspan Bell. Their insight and collaboration shaped the research methods for this study. Furthermore, Tim Smail supported many of my projects at Clemson. The opportunities he provided largely contributed towards my Ph.D.

I must also acknowledge my grandfather Ellis Smith, whose tireless effort to improve industry practices in construction has inspired me to better the industry through research. I hope to provide similar models for change in the industry as he has done. Finally, thank you to Carlisle. Her frequent feedback and daily support, enduring my many migraines, broken collarbone, and crashed hard drive, along the way, enabled me to complete my Ph.D.

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CHAPTER ONE

INTRODUCTION: IMPACTS OF INFRASTRUCTURE DECISIONS ON SUSTAINABILITY

Decisions about infrastructure contribute directly to sustainability outcomes and determine future infrastructure performance for many decades. The critical decision point for infrastructure is often during early planning phases. Once built, infrastructure increasingly becomes more complex to change, or alter. The case study of Onondaga Lake is a testament for how decisions about infrastructure contribute to sustainability and the complexity of decision making. Engineers in Syracuse, New York, built a central wastewater treatment facility in 1960 to receive combined wastewater and rainwater. The next three decades proceeded with large urban development and construction of impervious surfaces. And unfortunately, the once modernized treatment facility began polluting local tributaries. High volumes of rainwater caused the combined overflow system to expel untreated sewage into Onondaga Lake. The excess phosphorus and ammonia stimulated algae blooms, consuming oxygen, killing fish and plants. By 1988, the once modernized wastewater treatment facility was contributing to an environmental disaster. Onondaga was one of the most polluted lakes in the country.

New regional treatment facilities to control the sewage overflow proved ineffective to reduce bacteria levels (Hughes, 2008) and forced vulnerable communities to uproot (Lane & Heath, 2007). As the city struggled to reduce pollution, public sentiment grew against the county decision makers (Perreault et al., 2012). The city's problems were largely due to infrastructure decisions made in the mid 1900s (Flynn et al., 2014). In 2008, Syracuse developed several new programs to address pollution and more closely work with the community to find appropriate engineering solutions. Projects like *Save the Rain* are now significantly reducing decades of pollution (Flynn et al., 2014). Syracuse recently won an environmental remediation award from the Environmental Protection Agency for the recent programs reducing lake pollution.

The decision to build a combined overflow system, combined with urban development, resulted in unanticipated pollution, which residents of Syracuse are still feeling the affects 50 years later. Once built, communities became increasingly dependent on the infrastructure services and rerouting, or altering, service was progressively more complex. The three-decades of anticipated remediation, from 1988 to 2008, stresses the complexity of decisions about existing infrastructure. In Syracuse, local communities, county decision makers, and engineers were dubious how to proceed in union. The initial infrastructure built in 1960 created path dependence that lasted decades and constricted future development. As the demand for new infrastructure continues to grow in the United States (OECD, 2013), current decisions about infrastructure will leave new legacies, determining sustainability outcomes for entire generations.

Fortunately, civil engineers today are equipped with more tools and resources to design and build infrastructure. Such tools range from rating systems to design software to building codes, and are used to evaluate, and reward infrastructure projects that consider alternative design and construction methods. These technologies, in conjunction with better governance and evolution in design thinking, enabled the city of Syracuse to finally reduce runoff and pollution. While no decision tool is all-inclusive, the intention of tools and metrics is to support engineering decisions. Yet, very little is actually known about *how* these tools influence decision making. Can more be done to encourage greater achievement in sustainability?

1.1 Psychological Barriers to Decision Making

Decisions are bounded by rationality and informed by preferences and beliefs (Gintis, 2006). Research in behavioral sciences has focused on the use of mental short cuts (heuristics), and the associated errors (biases), to overcome the cognitive constraints that exist when making decisions (Khaneman & Tversky, 1979). In essence, complex decisions with multiple variables, alternatives, and scenarios can exceed the mental capacity of the human brain. Decision makers must use shortcuts to reduce the amount of information for processing. Simplifying decisions, for instance in a linear order, can seem rational. Yet, when decision makers do this, inherently biases in how the information is structured can cause errors in the decision. These errors, or biases, can result in choosing suboptimal outcomes. For example, given to many choices, referred to as choice overload, can overwhelm the decision maker and result in decision paralysis. By understanding how decisions are made, the choice architect – the one designing the choice options, can help reduce choice overload by removing the least likely options or staging options over a series of decisions. Decision tools are meant to improve the mental processing and support the decision maker choosing the optimal outcome. However, without knowing the potential psychological pitfalls in the decision process, those designing decision tools can unintentionally create barriers leading to suboptimal outcomes.

The same psychological barriers may affect decision processes for infrastructure. Infrastructure development is complex, interdependent, and uncertain. Engineers use decision tools to breakdown project complexities. Assessing how engineers use these tools to inform decision making may uncover possible errors that can lead to less than rational choices about infrastructure. These decisions are critical to the future performance of many systems – social, environmental, and economic. The decision tools used by engineers should improve, not impede, mental processes for decisions about infrastructure. Better understanding how engineers are using decision tools can uncover potential biases in decision making. Small changes to the decision environments may lead to better informed decisions and ultimately improved infrastructure performance.

1.2 Objective

There are numerous methods, decision points, and theoretical perspectives to approach decisions about infrastructure. Organizational theorists developed hierarchal structures for information processing steeped with levels of authority and distributed responsibilities (Galbraith, 1974). Institutional theorists have suggested normative, regulative, and cultural pillars that frame complex decisions about infrastructure (Javernick-Will & Scott, 2010; Scott, 2008). And social psychologists have posed individual interest driven by resources and relationships and the conflict between these items (Finch et al., 2013). Additional perspectives exist within each infrastructure phase: project shaping, design, construction, operation and renovation/replacement. Each phase holds unique stakeholders and decision processes to meet defined objectives.

The contribution of this study is to present how engineers form judgments about design options and how this influences decision making during upfront planning and goal setting. The theoretical perspective most closely aligned with this research is behavioral decision theory (Slovic et al., 1977), more accurate prospect theory (Khaneman & Tversky, 1979) and judgment and decision making (Hardman, 2009). While numerous phases of infrastructure could have been studied, upfront planning holds great potential to influence project outcomes with relatively small associated cost compared to decisions later in project development. Findings from this research offer recommendations to reduce psychological barriers and encourage higher achievement towards a defined goal in sustainability when using decision tools during planning stages of infrastructure.

As the Syracuse case implies, decisions about infrastructure hold powerful influence on the future wellbeing of communities and long-term dependence of other systems. More understanding through research of how critical decisions about infrastructure are made can lead to more informed decisions, and ultimately towards more sustainable outcomes. This research identifies ways to help those involved in the infrastructure development process and presents a new approach to encourage greater consideration for sustainability during initial planning stages.

1.3 Outline of Chapters

The following chapters are organized as a series of independent papers each with their own abstract, introduction, body, and conclusion. Chapters support each other to examine how engineers make decisions and possible psychological barriers that narrow choices towards sustainability. Each chapter more closely examines psychological barriers to decision making about infrastructure. Final recommendations based on the findings present cognitive biases that exist and provide recommendations to improve decision processes for infrastructure delivery.

In chapter two, sustainable infrastructure is defined as meeting users needs with less complexity, the ability to relieve pressures on other systems, and capacity to satisfy growing demands. This chapter provides a necessary foundation, merging behavior and decision science with infrastructure systems. Cognitive biases that can inhibit infrastructure stakeholders from achieving sustainability are outlined. And parallels between choice architecture, in various fields of study, are presented as potential strategies to improve infrastructure design decisions. The chapter concludes with suggestions for further research, specific choice architecture interventions that could offer relatively simple and cost effective approaches to achieving more desirable outcomes.

Chapter three outlines the path forward for this research emphasizing decision making during upfront planning. A leading rating system for sustainable infrastructure, called Envision, is introduced as the tool to test the hypothesis that psychological barriers inadvertently limit designers from achieving the highest possible levels of sustainability. Envision is used because the metric outlines a defined rating for achievement in sustainability. Findings from a pilot study with students are presented as a prelude to chapter four.

Chapter four tests the hypothesis that Envision's current framework inadvertently limits engineers' ability to set the highest possible goals for sustainability. Professional engineers use Envision to make tradeoffs about site programming and functionality for a rural Alabama redevelopment project. Half of the participants are given the standard version of Envision, starting with zero points and achieve points when design considerations move beyond conventional construction standards. In a modified version, a higher benchmark is set. Participants in this group lose points when high sustainable achievement is not maintained. The results indicate that a choice posed as a loss, rather than a gain, significantly improved engineers' consideration for sustainability. The endowed group acted loss averse trying to maintain the initial points provided. These findings suggest behavior science can inform how engineers interface with decision processes and more thoughtfully designed decision tools are needed to better inform engineers' decisions about infrastructure.

Chapter five is intended to stress the need for more research merging behavior science and engineering. Design and decisions for sustainability occur in many stages of infrastructure development. Future research should consider these additional decision points. Further, an analysis of stakeholder degrees of motivation and ability is also needed to identity systemic approaches to overcome cognitive biases. This includes perceptions of ability (e.g. what is believed possible), external motivation (e.g. financial, economic benefits) and internal motivation (e.g. perceived risk). Finally, Appendix A includes the figures of the modified and original Envision software highlighting the changes made to the modified version. Appendix A is included to show the minimal adjustments needed to design software, which have a significant impact on decision making.

CHAPTER TWO

INVESTIGATING CHOICE ARCHITECTURE AS A METHOD TO ENCOURAGE ELEGANT INFRASTRUCTURE OUTCOMES

2.1 Abstract

Infrastructure that meets users' needs with less complexity can satisfy growing demand and relieve pressure on budgets. We define such solutions as elegant and describe social and cognitive biases that can inhibit infrastructure stakeholders from achieving them. We then explore the potential to overcome these biases by applying choice architecture, which draws from behavioral science and helps explain how the presentation of choices impacts the decisions that are ultimately made. Using a meta-synthesis research approach, we prioritize cognitive biases that can inhibit elegant infrastructure and present choice architecture interventions with potential to help overcome them. This article provides a necessary foundation, merging behavioral science and infrastructure systems. Readers can draw parallels to imagine how choice architecture may influence other desirable outcomes. With further study, specific choice architecture interventions could offer a relatively simple and cost effective approach to achieving elegant infrastructure. We provide a path for this future research emphasizing high-impact decisions with cost-effective and plausible choice architecture interventions.

2.2 Introduction

Hundreds of billions of dollars are spent every year to build and retrofit our physical infrastructure systems (OECD, 2013). Those managing and designing these systems use procedures and processes such as contract structures (Anastasopoulos et al., 2010), project management hierarchies (El-Diraby, 2013), and operation and maintenance schematics (Bolar et al., 2014). We present choice architecture as an approach to help meet growing infrastructure demands with less complexity.

Choice architecture uses insight from behavioral science to help explain how the presentation of options can impact the decisions that are made. Grouping options together, presenting options before others, pre-selecting choices, or framing attributes as positive or negative all are examples of choice architecture (Thaler et al., 2010). Fields from medicine (Johnson & Goldstein, 2003) to law (Johnson, 1993) to finance (Thaler & Benartzi, 2004) are using choice architecture to improve decision processes and we suggest more intentional consideration of how choices are presented in infrastructure planning may lead to improved project outcomes. Consider, for example, a building information modeling (BIM) program presenting designers with material choices. Materials shown first are more likely to be selected than those in the middle of the list, especially if the list of materials is long. Lists like these could be organized so that desirable materials appear first (perhaps those that will promote energy efficiency, if that is a goal). Choice architecture also influences larger-scale decisions. A request for design proposals for "any practice to reduce overflow of combined sewers" will yield many more options than a request for proposals to "install storm water piping and sewage retention structures to reduce overflow of combined sewers." Both descriptions describe the problem, common in cities with aging infrastructure, but the first description encourages more solutions to be presented.

Choice architecture can be designed to meet many infrastructure outcomes. In the BIM example, if energy efficiency is a goal, materials that insulate well could be listed first. If the goal is to sell more of a certain product, that product could be listed first, and so on. In this article, we focus on how various types of choice architecture can lead to elegant infrastructure outcomes.

2.3 Objective

Previous studies suggest cognitive biases and social heuristics distort managerial decisions in complex infrastructure governance, planning, and delivery (Klotz et al., 2010; Klotz, 2010; Beamish & Biggart, 2012; van Buiten & Hartmann, 2013). Research at the intersection of behavioral science and technical solutions may help reduce these biases (Allcott & Mullainathan, 2010). This article is meant to point researchers to potentially high impact opportunities for choice architecture to encourage elegant infrastructure decisions.

This article begins with a characterization of elegant infrastructure outcomes using a meta-synthesis research approach. As part of this approach, barriers to these elegant solutions are outlined. Then, choice architecture is presented as one method to overcome these barriers; we synthesize choice architecture concepts and explain how they can affect elegant infrastructure outcomes. Using the common theme of elegant outcomes is intended to help readers see the connections between the various choice architecture considerations. The article concludes with a path for future research enabled by our meta-synthesis. We match high-impact decisions with seemingly cost-effective and plausible choice architecture interventions.

2.4 Background: Elegance in Infrastructure (and barriers to it)

A biologist sees elegance in a neuron's electrical transmitters or the way a desert mouse's kidney efficiently recaptures moisture. A product designer sees elegance in a functional and seductive iPhone. A computer scientist sees elegance in code that requires fewer lines to accomplish a task. Elegance has a slightly different meaning in these and other contexts, but there are unifying similarities.

To distill these similarities and apply them to infrastructure, we explored domains which have previously defined and characterized elegant systems. These included (as described in the remainder of this section): manufacturing, product design, architecture, computer science, organizational systems, and biology. We synthesized our list developed from these domains to core elements and themes and checked for face validity with a team of graduate researchers. The graduate panel compared and contrasted previous definitions of elegance with ours. The panel was given infrastructure design case studies and asked to decide which examples, if any, are considered elegant.

The resulting definition for elegant infrastructure outcomes are those which: satisfy stakeholder needs; fix a root problem, not a symptom; and subtract rather than add to create value.

Most infrastructure projects meet some degree of *stakeholder needs*, but elegant solutions do so efficiently and to a higher degree of functionality. For example, a home designed with a mechanical air conditioning system likely meets user needs for space and comfort at a competitive cost. However, a passive house design, with features like superior insulation, south facing windows, and extended overhangs, may be able to satisfy these same needs more elegantly by reducing operation costs without increasing production costs.

In public infrastructure, such as a water treatment plant, there are more stakeholders (e.g., water consumers, contractors, plant employees, neighbors, public interest groups). Elegant solutions require consideration of each of these stakeholders' needs (Smith, 2010; Madni, 2012). For the water treatment example, this could mean the plant must provide clean water, be easy to maintain and cost less to construct, all while relieving pressures on outdated systems (Billow 1999). Satisfying all users' needs is not easy, which is one reason why elegant outcomes are uncommon.

Elegant outcomes do not just meet stakeholder needs, they also go beyond symptoms to *fix root causes* (Madni, 2012). Looking deep to the root cause requires persistence, as shown in Figure 1. Initial "solutions," represented on the left side of the graphic, may be simple, but they do not meet user needs. Adding complexity can lead to user needs being met, but elegant outcomes result when pushing beyond this point to the right side of the graphic, where user needs are met with less complexity (May, 2009; Madni, 2012; Siegel & Etzkorn, 2013).

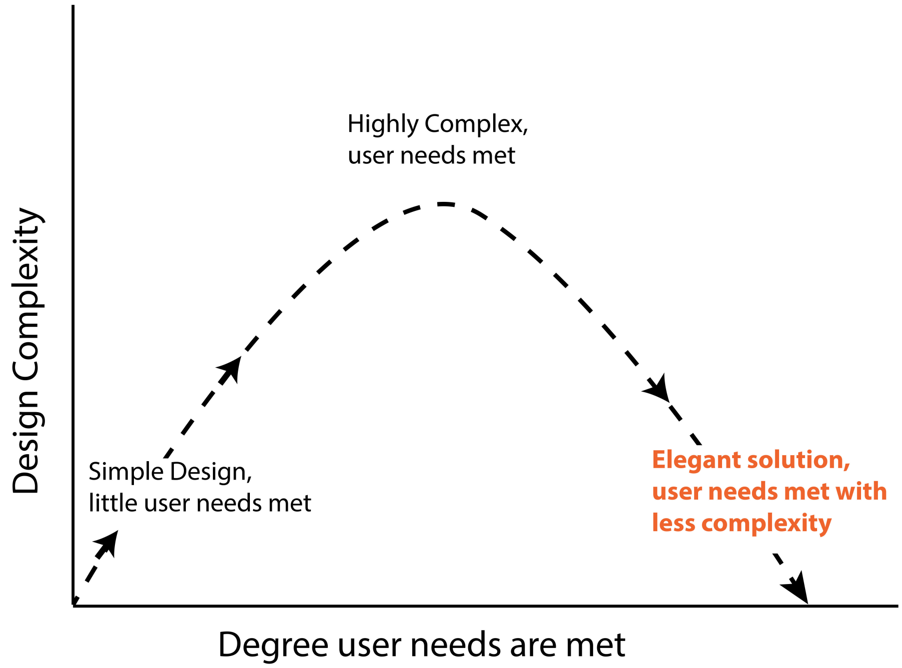


Figure 1: Solutions Overcoming Complexity Move Towards Elegance

Related to fixing the root cause, *subtraction that adds* value is present in many elegant solutions (May, 2009). Apple's simple user interfaces are one example and companies including Toyota, Google, Trader Joe's, and ING Direct all emphasize subtraction in various forms (Siegel & Etzkorn, 2013). An infrastructure example of subtraction that adds value is when reduced artificial lighting leads to improved productivity. Because office workers spend the majority of their time looking at backlit computer screens, reducing lighting decreases the glare, which in turn decreases headaches (Loftness, 2013). Subtraction that adds value is also found in the example of the "shared space" concept in city transportation design. By removing traffic lights, street signs, roadway markings and curbs, drivers feel uncertain about right-of-ways and reduce speeds to accommodate pedestrians (Vanderbilt, 2008). Cities including West Palm Beach, Drachten, Germany and London, England report fewer accidents and more efficient traffic flow after implementing this subtractive design approach (McNichol, 2004; Shore, 2010; Moody & Melia, 2013).

2.4.1 Barriers that can discourage elegance

Unintentional incentives for complexity in contract structures can prevent elegance in infrastructure projects. Some military contracts, for example, do not allow engineering design costs to exceed six percent of total construction costs (Niece, 2005). Design firms subject to this well-intentioned rule face a perverse incentive; identifying a less expensive, elegant construction solution, could lead to a reduced fee for their firm. Similarly, fixed fee contracts pay designers to review drawings and technical specifications on an hourly basis. When designs are complex, the designer can more easily justify their hours spent (Brydges, n.d.). Elegant designs, on the other hand, may appear intuitive or simple, making it more difficult for the designer to illustrate just how much time was spent to overcome complexity and arrive at elegance.

Social norms can also impede elegance, in particular the desire to see something tangible for investments, including those in infrastructure improvements ("Sunk infrastructure," 2007; Wald, 2007). Homeowners attempting to reduce energy use are more likely to buy a new refrigerator that they will see every day than add hidden attic insulation, even though the insulation is typically more cost effective and saves more energy (Gardner & Stern, 2008). Similarly, funds allocated for building code enforcement are sometimes redirected toward other activities more visible to taxpayers (Eisenberg & Persram, 2009).

Other social norms that may impede elegance are those celebrating conspicuous consumption (O'Cass & McEwen, 2004). Preference for new infrastructure could result from similar norms that lead to preference for the newest model television. Compared with infrastructure projects that have subtracted towards invisible elegance, complex and visible projects lend themselves to ribbon cutting ceremonies, magazine feature articles, and donor naming rights. Visible improvements celebrate tangible progress and completion of a complex task, which is part of our social norm (Elster, 1989).

Biological characteristics of the brain may also make subtractive elegant outcomes less likely. Compared with addition, subtraction takes longer for the brain to process and produces lower degrees of accuracy (Gonzalez, et al., 2005; Payne et al., 1993; Yi-Rong et al., 2011). Functional magnetic resonance imaging (fMRI) brain scans that measure blood flow of activated neurons may offer one explanation. These scans show that subtraction activates more neurons than addition, and therefore requires more energy (Yi-Rong et al., 2011).

2.4.2 Cognitive biases as barriers

In addition to the incentives, social norms, and biological characteristics of the brain, other possible barriers to subtractive elegance in infrastructure include cognitive biases (See Figure 2). This is when decision makers deviate from predicted outcomes and make seemingly "irrational" choices that are not in their best interest (e.g., Ariely, 2008; Hilbert, 2012). Specific cognitive biases that may be inhibiting elegant infrastructure are described more in the results and analysis section along with proposed approaches to counter these biases.

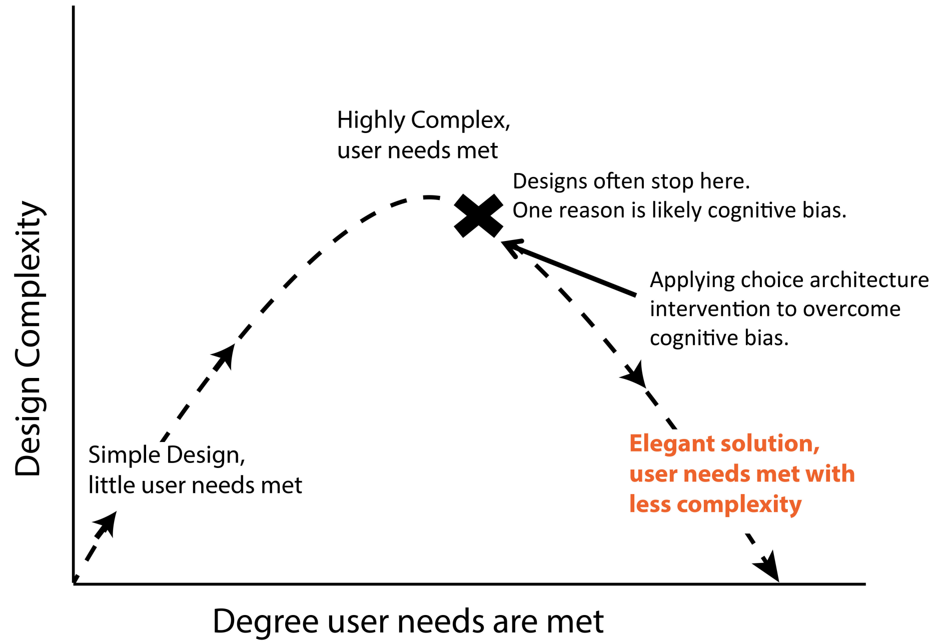


Figure 2: Cognitive Biases Act as Barriers to Elegant Infrastructure Outcomes

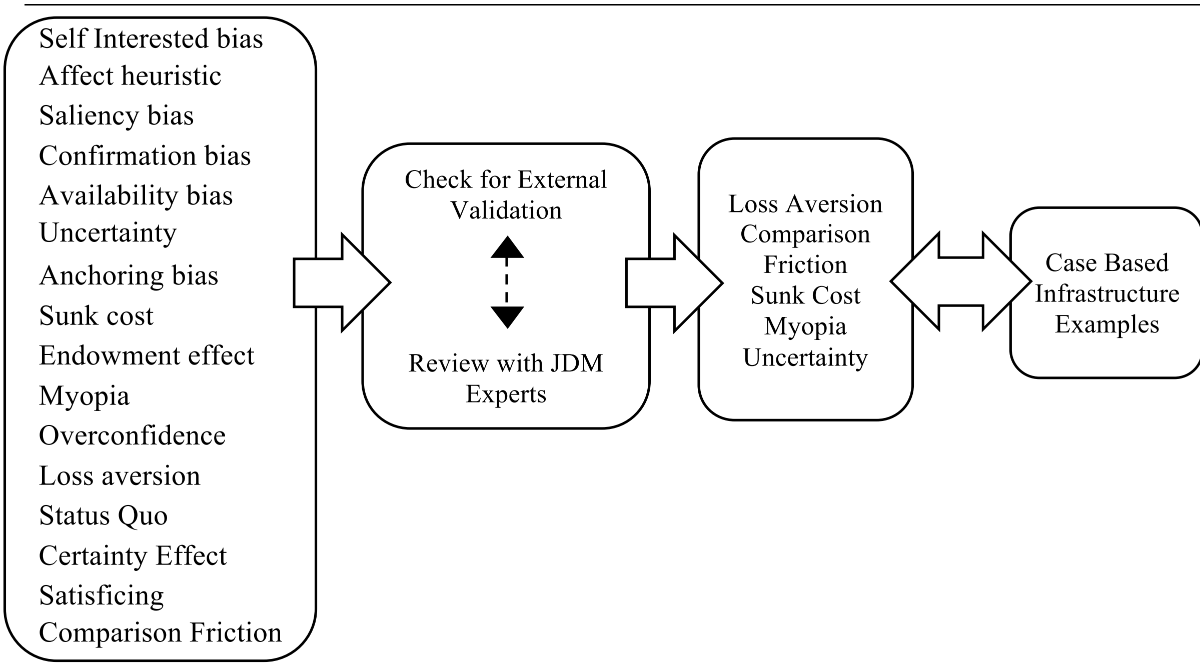
2.5 Method: The Meta-Synthesis Approach

A meta-synthesis approach is appropriate when researchers seek to integrate findings from multiple research studies, often from several fields of study (Ogawa & Malen, 1991). In literature about sustainable infrastructure, a similar conceptual approach to merging research domains has led to a new unified definition of sustainability and resilience (Bocchini et al., 2014) and insight about infrastructure as a chaotic sociotechnical system (El-Diraby, 2013). We used the meta-synthesis approach to investigate and illustrate how understanding cognitive biases and applying choice architecture could assist efforts to achieve elegant infrastructure outcomes.

Starting with seminal overviews of prospect theory (Kahneman & Tversky, 1979), bounded rationality (Kahneman, 2003), and decision making under risk and uncertainty (Hardman, 2009), we developed a framework for applying judgment and decision making literature to infrastructure decisions. This framework is similar in structure to previous hierarchical frameworks that include a review of sustainable building practices (Abdellatif & Al-Shamma'a, 2015) and relating economic lab experiments to real world examples (Camerer, 2004). Our preliminary findings were developed in consultation with a panel of experts in the field of judgment and decision making. Our review of literature produced a list of biases and case-based infrastructure examples. A compare and contrast method with the judgment decision making (JDM) experts synthesized these biases to those that hold the greatest potential barriers to elegant infrastructure outcomes. Table 1 provides the cognitive biases we examined and our synthesized list using the compare and contrast method with JDM experts.

Table 1: Meta-Synthesis to Combine Cognitive Biases and Infrastructure Cases

1. Biases and heuristics*	2. Distillation	3. Synthesized Results	4. Overlay Infrastructure



Note: Compiled from Wilson & Dowlatabadi, 2007; Todd & Houde, 2011; Johnson et al., 2012; van Buiten & Hartmann, 2013.

The example cognitive biases that follow in this article all exhibit external validity, meaning results from multiple studies in many domains suggest similar conclusions. For example, one of the biases we present is loss aversion. The original study by Kahneman and Tversky (1984) has been replicated, and modified, in studies of decisions about candy bars (Knetsch, 1989), hunting permits (Cummings, Brookshire, Bishop, & Arrow, 1986) and college basketball tickets (Carmon & Ariely, 2000). Loss aversion is now generally accepted as both a description and explanation of the phenomenon (Novemsky & Kahneman, 2005).

The cognitive biases and associated choice architecture examples in the following section are meant to illustrate the vast potential for research in this area and point researchers to some opportunities that seem to have potential for high impact. The examples are not exhaustive, there are infinite cognitive bias/elegant infrastructure combinations to study related to infrastructure design and decision making. We combined the recommendations of the judgment and decision making experts and present in this article five high-impact biases and associated choice architecture examples: loss aversion, comparison friction, sunk cost, myopia, and uncertainty.

2.6 Results and Analysis: Selected Cognitive Biases Inhibiting, and Choice Architecture Approaches to Encourage, Infrastructure Elegance

Based on the meta-synthesis approach, the examples that follow illustrate how cognitive biases can inhibit elegant infrastructure and how choice architecture can be used to overcome them. As part of our conceptual merging of these domains, we prioritized the cognitive biases that appeared to have a choice architecture approach with high potential to influence infrastructure decisions and high practicality for intervention. In other words, we present the choice architecture that is likely to have a big impact and able to overcome these biases.

2.6.1 Loss Aversion

Khaneman and Tversky's (1984) concept of *loss aversion* shows that people generally prefer not losing something to winning the exact same thing. In other words, loss provokes greater degrees of discomfort than a win provides satisfaction. At 50/50 odds, the risk to overcoming initial loss often requires the potential win to be roughly twice as great (Benartzi & Thaler, 1993). Decision makers are not always uniformly risk averse. When decision makers are already losing, for example, they are more likely to become risk seeking (Khaneman & Tversky, 1992. Loss aversion helps explain why home sellers over price a house in a down market (Genesove & Mayer, 2001) or when investors hold a losing stock too long (Odean, 1998). This effect is measureable in the brain. Financial gains generate activity in the analytic section of the brain whereas losses generate processing between the emotional and analytic sections (Martino, Kumaran, Seymour, & Dolan, 2006). Because of the different locations of this neuron activity, losses are associated with an emotional pain in a way that gains are not (Rick, 2011; Sokol-Hessner et al., 2012).

This same psychological obstacle may have been a contributing factor to delayed redevelopment of the Embarcadero Freeway in San Francisco. Loss averse city officials and groups advocating for removal of the freeway were unable to make progress until an earthquake caused structural failure making removal a necessity (Eckerson, 2006). With the freeway removed, property values jumped three-fold as redevelopment plans were enacted including newly constructed tree lined boulevards, a pedestrian promenade, bicycles paths, and a neighborhood streetcar (Norquist, 2000). In this case, it took an earthquake to free the decision making process from loss averse stakeholders, which led to a more elegant infrastructure and street design.

2.6.2 Comparison Friction

Decisions are often made by comparing differences between options. However, when information is not available, or when it is not in a format decision makers can use, decision making can suffer. An example from the auto industry shows the potential benefits from reducing this *comparison friction*. Until recently, fuel economy labels on new vehicles displayed city and highway mileage per gallon. Now, similar labels display projected annual fuel cost over five years as well as a comparison to the fuel cost of the average vehicle. These labels provide more information to the consumer in a format that makes sense, therefore improving their ability to pick the most beneficial option (Larrick & Soll, 2008).

An analogous example from infrastructure could be the use of intelligent transportation systems (ITS) to provide information to reduce comparison friction. Data collected from smartphones and GPS can allow engineers to see traffic patterns in real time, which helps inform their decision making (Walker et al., 2014). Appropriate solutions can then be identified, including other ITS applications such as adaptable speed limit signs and traffic light sequences, and smartphone applications to alert drivers of delays ahead. ITS technologies like these can provide information to reduce comparison friction for those making decisions during infrastructure planning.

2.6.3 Sunk Cost

People become emotionally invested in money already spent and continue to pay regardless of current costs, benefits, or losses (Arkes & Blumer, 1985). This *sunk cost* thinking can lead to continually trying to recoup the initial investment (Thaler, 1980). A familiar example is continuing to watch a bad movie simply because the ticket is already paid for (Arkes & Blumer, 1985).

Costs already sunk into complex infrastructure can be a barrier to choosing elegant future solutions. The preliminary design for the Columbia River Crossing (CRC) highway cost Oregon and Washington taxpayers $140 million. When citizens pleaded for a more elegant multi-modal design, government officials cited this (relatively) small sunk design cost as a reason for the $3.5 billion construction project to proceed without the multi-modal considerations (Manvel, 2011).

2.6.4 Myopia

Myopia is characterized by a desire for immediate gratification and can lead to decision making that does not give sufficient weight to future outcomes (Shiv et al., 2005). In experiments where subjects were given a choice between receiving $100 immediately or $120 in one month, the majority chose the immediate $100 (Buonomano, 2012), even though there are very few investments that would return 20 percent in one month.

Shifting short-term decisions to longer-term ones can reduce myopic influences.

For example, in experiments where subjects were given a choice between receiving $100 in 12 months or $120 in 13 months, the majority chose to wait the extra month for the $120 (Buonomano, 2012). The reason for the shift in preference ($100 to $120) is because immediate gratification ($100 now) was no longer an option. When both outcomes required a waiting period, subjects' decision making shifted to view the increase in money as more gratifying. Field studies show similar results. Employees are more likely to commit to, and follow through with, retirement savings if it is through upcoming bonuses and salary increases rather than current take-home earnings (Thaler & Benartzi, 2004).

Applied to infrastructure, myopia may be a contributing influence in decisions to reduce construction costs at the expense of future operation and maintenance costs (Chalifoux, 2006). In residential construction, for example, the upfront costs of "green" homes are cited as a purchasing barrier ("Green homeowner," n.d.). Thermal insulating windows and polyurethane wall insulation are more efficient than single pane windows and fiberglass batts, but the added efficiency brings additional upfront cost. These premium products produce substantial payback over the lifetime of the home, yet the upfront cost and delayed payback is a myopic barrier homeowners often cannot overcome (Cabeza et al., 2010). Like delaying the $120 decision a year, offsetting initial costs or delaying costs over time could help reduce myopia in these instances. Bills such as Property Assessed Clean Energy (PACE) attempt to create more immediate paybacks and delay upfront costs by providing loans that are attached to the property, rather than homeowner. Owners' benefit from the savings immediately and pay the PACE loan back over an annual term (typically 15 to 20 years).

2.6.5 Uncertainty

When decisions involve risk but lack a numerical probability, decision-makers tend to assign their own probability based on their experience. The problem is that having prior experience leads to underestimation of risk, while having no prior experience leads to overestimation (Heath & Tversky, 1991a). The amount of detail the decision-maker has about each choice can influence their perception of probability. All else being equal, the more information, the more confident the decision-maker becomes about the outcome, regardless of the relevance of the information (Fox & Tversky, 1998).

Uncertainty could be a contributing factor to reluctance in the construction industry to depart from industry standards and norms (Beamish & Biggart, 2010). Stakeholder groups, such as building code officials, are less likely to approve systems they have no previous experience inspecting (Eisenberg & Persram, 2009). This reluctance can become a problem when it inhibits adoption of unfamiliar, but elegant infrastructure approaches, such as decentralized wastewater systems, which removes needless piping by treating wastewater closer to the source.

Table 2: Choice Architecture Interventions to Overcome Cognitive Biases

Cognitive bias	Barrier to elegant solution	Possible CA intervention (See Choice Architecture Section)
Loss aversion	People do not like to lose; elegance requires subtraction.	Risk framing (Kahneman & Tversky, 1984); Attribute framing (Marteau, 1989).
Comparison Friction	Choices are limited; elegance requires looking past these limitations.	Setting goals rather than choices (Heath, Larrick, & Wu, 1999); Feedback loops (Houwelingen & Raaij, 1989).
Sunk Cost	Previous investments influence current choice; elegance may require abandoning these investments.	Risk framing (Kahneman & Tversky, 1984); Attribute framing (Marteau, 1989).
Myopia	Prefer now over future; elegance requires thinking about future costs and value.	Partitioning options (Levav, Heitmann, Herrmann, & Iyengar, 2010); Attribute framing.
Uncertainty	Reluctance to depart from industry norm; elegance requires moving past industry norm.	Defaults (Madrian & Shea, 2000); Attribute framing.

2.7 Choice Architecture – overcoming the barriers to subtraction

Choice architecture is an approach well suited to overcoming the cognitive barriers to subtraction and elegant outcomes. Choice architecture demonstrates that the way information is presented influences the decisions made (Thaler & Sunstein, 2008). Just as there is no "neutral" building design, there is no "neutral" choice design. Building materials, location, size, and color influence how people interact with a building's space. Similarly, the orders of options, preselected choices, or even added detail can all influence decisions made. How a choice is presented affects the reasoning process even when two methods of posing a decision are formally equivalent, because each may give rise to different psychological processes including the influential cognitive biases mentioned in the previous section. This rationale is supported by query theory, in which choices are made based on a linear series of questions and these questions are dependent on the starting point (Johnson et al., 2007). Initial questions produce longer richer responses than later questions and, subsequently, this impacts the outcome (Weber et al., 2007).

Those constructing decisions for infrastructure planning can use choice architecture to remove barriers to, or even promote, the subtractive qualities that can lead to more elegant outcomes. For example, Autodesk's Ecotect BIM tool provides designers with construction and material options. Rearranging the program inventory to show energy efficient products first or in a way that reduces the number of clicks to select them might lead to more designers selecting these options. Ecotect could reduce the psychological barrier of comparison friction by incorporating renewable energy sources such as photovoltaic panels, wind turbine, and geothermal wells into the energy modeling software (Cho et al., 2010). Designers could more easily compare the cost-benefit of including these features into a project.

Selected choice architecture concepts are described in the following sections including: risk framing, attribute framing, partitioning options, setting high goals, feedback, and defaults (Choice architecture tools abound and not all of them are discussed here. Interested readers can start with Beyond Nudges: Tools of a choice architecture (Johnson et al., 2012); Nudge (Thaler & Sunstein, 2008); Simpler (Sunstein, 2013)). An example for each concept illustrates its relevance to infrastructure decision making to encourage subtractive elegant outcomes. Our list of choice architecture applications was developed using a similar approach as the list of cognitive biases: leading experts in the field of choice architecture provided content and face validity by reviewing and editing our findings.

2.7.1 Risk Framing

Risk framing is a way to describe outcomes of choices that have varying levels of risk in different ways. Khaneman and Tversky (1984) demonstrated that people made decisions in a health context differently whether the risk was framed in terms of losses or gains. Two groups were asked to select a treatment option for a disease outbreak expected to kill 600 people. Group one was asked if they would rather "save 200 lives" or provide a "one-third probability to save all 600 lives and two-third probability that no lives are saved". Group two was asked if they would rather let "400 people die" or provide "one-third probability that nobody will die and two-third probability that all 600 people will die". When outcomes were framed positively, as lives *saved*, participants were more likely to choose the certain choice – saving 200 people. Conversely, the negatively framed outcome (lives *lost)* prompted the risky option – trying to save all 600 people. The change in frame from gain to loss reversed participant preferences. Subsequent research shows experts are just as susceptible as laypeople to framing effects (Duchon et al., 1989; Marteau, 1989).

Risk framing could be applied to the previously described San Francisco Embarcadero Freeway example. Perhaps city officials would have been more likely to support the project before the earthquake if their decision was framed in terms of losses; "by not demolishing the bridge and not adding a mix-use boulevard, the city could *lose*

$50 million in economic development.” If the city council and public viewed demolishing the bridge as the risky choice, presenting the loss option likely provides a better chance for this choice to be selected.

2.7.2 Attribute framing

Highlighting one attribute over another evokes different feelings and thus influences decisions. Those with different political affiliations changed preferences when a carbon dioxide surcharge was labeled a “tax” or “offset” (Hardisty et al., 2010). Patients told a surgery is 90 percent successful are more likely to opt for surgery than when told the same surgery fails 10 percent (Marteau, 1989). People pay more for a burger when described as 75 percent lean than 25 percent fat (Levin & Gaeth, 1988). Attribute framing is not the same as risk framing because only one attribute within the context is the subject of manipulation (Levin et al., 1998).

Highlighting attributes of elegant infrastructure could have similar results. The former mayor of Bogota, Colombia, Enrique Penalosa, used attribute framing to gain support for building a Bus Rapid Transit (BRT) system instead of expanding the city highways. When talking with other city officials, Penalosa frequently cited the 80 percent of citizens relying on public transportation as a reason to support BRT over highways. Penalosa credits this statistic as being a critical decision making influence (Eckerson, 2007).

2.7.3 Partitioning of options

Providing too many choices can have negative impacts, in the form of choice overload, where users become indecisive, unhappy and even refrain from making a decision. Partitioning decisions, both in groups and over time, is one way of structuring decision processes to more effectively deal with a long list of options more efficiently. Rather than asking a car buyer numerous decisions about each feature, the car manufacturer acts as the choice architect grouping decisions into "packages." This allows car buyers to make one decision rather than many. Each choice within a given partition receives the same amount of time and weight (Levav et al., 2010). Isolating a choice causes the opposite effect. Decision makers perceive non-partitioned options as equally important in decision weight to the entire group of decisions within a partition (Martin & Norton, 2009).

An example of isolating choices as applied to selection of transportation options is the "Summer Streets" program, which limits city streets to pedestrians and bicyclists for one day a month (Khawarzad, 2011). By isolating transportation options, even for a short period of time, the program can lead to an elegant shift where people choose to bike or walk after the "Summer Streets" program ends. Indeed, a similar event in Bogota, Colombia attracts 1.8 million people every week. Popularity of the event lead city officials to shift transportation funding from road infrastructure to building 300 km of pedestrian and bicycle only lanes (Press, 2011).

2.7.4 Setting high, achievable goals

Goal setting provides intrinsic motivation for achievement. Once a goal is reached, that motivation to achieve more decreases (Heath et al., 1999). Reaching a goal provides a similar satisfaction as overcoming loss aversion. Excelling past a goal is a similar feeling to winning – a great feeling but not the same as not losing. Setting higher goals can extend motivation to achieve the highest-level outcomes.

Policy makers and industry groups establish infrastructure sustainability goals through certifications and rating systems such as EnergyStar, LEED, and Envision. Setting goals in these systems too low can decrease the motivation to achieve higher scores and, more possibly, elegant outcomes (Jacowitz & Kahneman, 1995; Strack et al., 1988; Klotz et al., 2010). Raising sustainability goals to higher levels would prompt greater motivation and likely lead to a high score, even if the goal were never met.

2.7.5 Feedback

Decision makers are more accountable about performance when they receive feedback about their decisions. More knowledge allows for more frequent improvements. Equipping homes with display screens showing real-time energy consumption can lead to significant reductions in energy consumption (Dobson & Griffin, 1992). The frequency of feedback impacts savings. Those who receive continuous feedback saved more energy than those receiving monthly feedback (Houwelingen & Raaij, 1989).

Evidence-based construction management for health care facilities evaluates current research, best practices, and past performance to inform current decisions and predictions (Becker & Parsons, 2007). The evidence-based construction term draws from evidence-based medicine in which doctors track patient performance to inform future treatment options. In construction, a series of feedback loops function as indicators for future methods and design options. Relating evidence-based construction methods to other forms of infrastructure development could increase knowledge gathering and adoption of new techniques. An owner could mandate feedback in the contract asking designers and contractors to perform occupant evaluations or collect user feedback before the project is completely turned over.

2.7.6 Defaults

Setting a *default* condition imposes a decision even when an individual does not make one. European countries using opt-out defaults for organ donations report ten times the participation rates as countries with opt-in defaults. Thus, for organ donation, setting the correct default can save lives (Johnson & Goldstein, 2003).

The reason why defaults are so powerful is not as obvious as other choice architecture examples. Defaults influence three different user conditions: *effort, endorsement, and reference dependence* (Dinner et al., 2010). Employees who do not select a 401(k) plan, displaying a lack of *effort* to make a decision, still save money because of a predetermined 3 percent annual investment default (Madrian & Shea, 2000). *Endorsement* means decision makers may perceive the default as the recommended option because it reflects the most commonly chosen or fits within the social norm (Brown & Krishna, 2004; McKenzie et al., 2006). People maintaining these norms are more likely to preserve the default choice (Kahneman, 2013). *Reference dependence* means the default frames the outcome as a loss or gain and, as with risk framing, this impacts the decision (Dinner et al., 2010). The 401(k) investor who invests less than the 3 percent default, most likely, feels bad about this decision. The investor who chooses to invest more, most likely, feels better about this decision. The feeling of good or bad is dependent to the choice architect's default.

Like organ donation, defaults in construction can also save lives. Residential building codes ensure life and property safety and are reviewed, amended, and then adopted by individual counties or cities. However, in counties or cities lacking resources or knowledge, code review boards are often not in place, which means there are no safety and health design minimums. Illinois corrected this problem by setting a statewide building code default. Counties can opt-in or opt-out of the statewide codes but counties not taking action automatically opt-in (Monte, 2012). Texas is the opposite. Without a statewide default many counties, outside of the large municipalities, are not protected by codes allowing engineers and contractors to design to no minimum health and life standards ("IBHS," 2013). Changing the default could reduce the effort individual counties need to make and protect both life and property by setting a strong reference for minimum standards.

2.8 Conclusion and Future Research Opportunities

In this article, we described choice architecture strategies and their underlying theory. By making connections to infrastructure examples, we showed how choice architecture can improve infrastructure outcomes. While our outcome of interest was elegance, readers can draw parallels to imagine how choice architecture may influence other desirable outcomes. This article provides a necessary foundation, but the more exciting opportunities (in our opinion) build from here.

With further study, specific choice architecture interventions could offer a relatively simple and cost effective approach to achieving desired infrastructure outcomes. Are myopic tendencies and the sunk cost effect contributing factors to the undervaluing of long-term investments in infrastructure? Are loss aversion, uncertainty, and comparison friction inhibiting more widespread implementation of uncommon types of projects, like road diets? The behavioral science literature suggests that this is likely the case, which means choice architecture can help.

Literature on decision optimization in construction processes also suggests this is an impactful area for more study. For example, integrating loss aversion and framing effects into risk probability formulas, as part of Cumulative Prospect Theory, led to higher profit margins on a small hypothetical project (Cattell et al., 2011). In another example from the construction literature, optimism bias, or undervaluing the probability of risk, contributed to productivity estimating errors (Son & Rojas, 2011). In both of these examples, researchers call for a greater connection between understanding human behavior and construction decisions. We suggest choice architecture as one approach.

Researchers studying sustainable cities and societies likely understand the highest-impact decisions and their determinants at individual, organizational, and societal levels. These high impact decisions are a good place to start. Researchers should also consider which choice architecture interventions are most plausible for adoption by various stakeholder groups. Changing how a law is written is more difficult than changing how a Request for Proposal (RFP) is written, so all else being equal, an intervention focused on a RFP could be prioritized.

Different approaches can be used to study choice architecture interventions. As with many of the behavioral science studies, sustainability researchers can use classroom experiments with "stakeholders" represented by student populations who are future decision-makers and users of infrastructure. However, infrastructure decisions are subject to varying constraints, goals, and resources with different stakeholder schedules, agendas, mandates, and budget cycles. A complete picture requires evaluating behavioral influences on multiple stakeholder groups. So, in addition to experimental studies with students, more qualitative methods such as case studies may be more suitable for studying decision-makers who are less numerous but just as influential (e.g., elected officials, master planners).

Research to identify specific choice architecture interventions for infrastructure sustainability holds promise. If results from other fields are any indication, small changes, at relatively small cost, can have a large impact on infrastructure outcomes.

CHAPTER THREE

WELL-ENDOWED RATING SYSTEMS: HOW MODIFIED DEFAULTS CAN LEAD TO MORE SUSTAINABLE PERFORMANCE

3.1 Abstract

Rating systems are often used as design/decision tools to evaluate, grade and reward infrastructure projects that meet sustainability criteria such as reductions in greenhouse gas emissions, preservation of wildlife habitat, and accessibility to community cultural resources. Embedded within any such rating system is “choice architecture”, which refers to the way information is presented to a decision maker. In this research, we examine the impact on design choices of changes to defaults in the choice architecture of the Envision rating system for sustainable infrastructure. Currently, the default score in each category of Envision is zero points. Points are earned by improving upon industry norms. To test the impact of changing these defaults, participants (senior-level and graduate students) randomly received either the current Envision version or a modified version with a higher default score, endowing participants with points in sustainability. All participants used their randomly assigned rating system to design an outdoor community center and stream restoration brownfield site. Simply modifying the default, by endowing points, led to setting significantly higher design goals. There were no significant differences in other variables measured, including student motivation or perceptions about Envision or sustainability. These findings suggest that how choices are presented to engineers, influences their decision making

process and can lead to higher sustainability goals. The construction engineering and management community can use this understanding to encourage more desired infrastructure outcomes.

3.2 Introduction

Choice architecture refers to the many different ways information can be presented to a decision maker and how the framework of choices inevitably influences the decision (Thaler & Sunstein, 2008). Even when two methods of posing a choice are formally equivalent, each presentation may give rise to different psychological processes. Choice architecture can be socially beneficial, as seen when driver's license applicants are asked to check a box on a form if they do not want to be an organ donor. In countries where this opt-out choice architecture is in place, the percentage of organ donors is significantly higher than in opt-in formatted countries which require license applicants to check a box stating their wish to be a donor (Johnson & Goldstein, 2003).

Choice architects, those who design choices, are comparable to building architects. Just as there is no neutral building architecture: the size, shape, and materials of a building determine how users interact with the space. There is no neutral choice architecture: presenting options before others, grouping options together, pre-selecting choices, or framing attributes has positive or negative influence decisions (for more on choice architecture methods see Johnson et al., 2012; Thaler & Sunstein, 2008).

Choice architecture theory is being applied to improve decision processes in fields from medicine to law to finance (e.g., organ donation (Johnson & Goldstein, 2003), tort law (Johnson, 1993), retirement savings (Madrian & Shea, 2000)). These same choice architecture theories appear to have potential to improve decision processes in infrastructure development. Engineers, architects, contractors, and other groups who design and build infrastructure often consult with planning tools such as the Envision rating system as they develop designs. The study described in this paper examines Envision's current choice architecture and explores changes to its default settings to encourage higher sustainability goal setting.

Envision is used to evaluate, grade and reward construction projects for meeting sustainability criteria such as reductions in greenhouse gas emissions, preservation of wildlife habitat, and accessibility to community cultural resources. Founded by the American Society of Civil Engineers, the American Council of Engineering Companies, and the American Public Works Association, Envision is meant to be applicable to all infrastructure projects, i.e. roads, bridges, pipelines, railways, airports, dams, levees, landfills, and water treatment systems ("EnvisionTM Sustainable Infrastructure Rating System," 2012), a uniquely broad application among sustainability rating systems (Clevenger, Ozbek, & Simpson, 2013). For example, Leadership in Energy and Environmental Design (LEED) for New Construction is limited to improve a building's sustainable design only after the decision is made to construct a new building. Envision is meant to help decision makers choose which type of infrastructure, if any, is most sustainable for surrounding networks. Envision is a two-stage assessment. Stage one is a checklist for conceptual planning and early design. The checklist helps educate the project team about the assessment criteria and works to establish project goals and priorities ("EnvisionTM Sustainable Infrastructure Rating System," 2012). Stage two in the rating system is intended to guide design, engineering, and construction decisions using a weighted scale of points. For example, stage one asks, *if* low impact development (LID) techniques will be implemented on the project. This is a simple yes or no question. Stage two asks *which* LID techniques will be implemented and how they plan to implement them. Our research focus is the stage two rating system where it is more likely specific design details will be considered.

The stage two rating system awards points in 60 credits distributed under five categories ("Envision™ Sustainable Infrastructure Rating System," 2012): Quality of Life, Leadership, Resource Allocation, Natural World, and Climate and Risk. Like LEED, these points accumulate towards a certification: Acknowledgement of Merit, Silver, Gold, or Platinum. Envision distributes points by achievement levels. Users choose to meet one of five levels: *improved, enhanced, superior, conserving,* or *restorative*. A project that *improves* the natural world receives fewer points than a project that *restores* the natural world. Users then explain how they plan to meet the level of achievement chosen. The number of points and application varies by credit. For example, reducing green house gas emissions at the restorative level achieves 25 points while assessing climate threats can only achieve the conserving level, at 15 points ("Envision™ Sustainable Infrastructure Rating System," 2012). Credits are evaluated through life cycle assessment calculations or written narratives (e.g., explain the steps taken to receive community feedback). Once these evaluations are completed by the project team, they can be submitted for Envision's third party verification and certification.

Table 3: Example of Credit Rating and Ordering of Achievement Levels

NW2.3 PREVENT SURFACE AND GROUNDWATER CONTAMINATION				
INTENT: Preserve fresh water resources by incorporating measures to prevent pollutants from contaminating surface and groundwater and monitor impacts over operations. METRIC: Designs, plans and programs instituted to prevent and monitor surface and groundwater contamination.				
LEVELS OF ACHIEVEMENT				
IMPROVED *Possible points: 1*	*ENHANCED* *Possible Points: 4*	*SUPERIOR* *Possible Points: 9*	*CONSERVING* *Possible Points: 14*	*RESTORATIVE* *Possible Points: 18*
Design for response.	Long term monitoring.	Design for prevention.	Design for source elimination.	Remediate existing contamination.

3.3 Objective

This paper builds on previous research in construction engineering management that suggests judgment and decision making, cognitive biases and social heuristics distort managerial decisions in complex infrastructure governance, planning, and delivery (van Buiten & Hartmann, 2013; Beamish & Biggart, 2012; Klotz et al., 2010; Klotz, 2010). Understanding choice architecture in engineering decision frameworks can help reduce these biases (Shealy & Klotz, 2014) and inform the new project manager needed to lead complex project delivery teams (Taylor et al., 2014).

The use of Envision is to illustrate how small changes in the choice architecture of engineering decision tools can influence decision processes and goal setting. Envision is the leading sustainability framework for infrastructure project planning. Cities such as Berkeley, California employ Envision to help prioritize backlogged projects (*City of Berkeley Process for Prioritizing Street and Watershed Improvements*, 2013). The Port of Long Beach is measuring success of the Pier A West brownfield remediation project using the Envision rating system (Sheesley, Sereno, & Wray, 2014) and the Los Angeles – San Diego – San Luis Obispo (LOSSAN) Rail Corridor is currently being evaluated using Envision (Dial et al., 2014). The LOSSAN project will set a baseline for future rail corridor project development sustainability.

While detailed design decisions must negotiate between time, budget, and project goals; the decision point we are trying understand is earlier in project planning, where goal setting holds high influence on future decisions related to time and budget. This is inline with the recommendations made in the LOSSAN rail corridor case study, which suggests had Envision been adopted earlier in the design process, greater project sustainability points could have been achieved at no additional cost. We recreate this upfront planning scenario to empirically test if changes in the Envision framework cause a shift in project goal setting. Other variables, like time and budget, are held equal.

3.4 Background: Envision as a choice architecture tool

Choice architecture is inherently embedded within the Envision framework: credits are partitioned into categories, achievement levels are associated with points, points are supported by detailed descriptions, and a default number of points are awarded to users. Intuitively or deliberately, these features may influence the decision process.

We found numerous connections between established choice architecture theories and the Envision rating system framework. An excellent review of choice architecture is presented in Beyond Nudges: Tools of a Choice Architecture (Johnson et al., 2012). We started with this review and examined each theory’s supporting literature and underlying psychological process. For example, defaults were presented in Beyond Nudges as an application to decision inertia. So, we reviewed applications of defaults in investments (Madrian & Shea, 2000), insurance (Johnson, 1993), and organ donation (Johnson & Goldstein, 2003). We also sought to understand the underlying psychological processes in each application. For defaults, this led to judgment and decision making literature in goal framing (Heath, Larrick, & Wu, 1999; Levin, Schneider, & Gaeth, 1998), satisficing (Weber et al., 2007), and loss aversion (Khaneman & Tversky, 1979). Then, searches for these same psychological processes in other fields led us to literature in energy policy (Houde & Todd, 2010), consumer behavior related to energy consumption (Allcott, 2011; Ayres, Raseman, & Shih, 2012), and environmental psychology (Nolan, Schultz, Cialdini, Goldstein, & Griskevicius, 2008). Across fields, choice architecture concepts are viewed as a method to improve the decision process (Thaler & Sunstein, 2008).

This literature review method uncovered four parts to Envision's choice architecture which appear to aid the decision process. The first three are structured within Envision as suggested by choice architecture literature and are presented as illustrative examples that improve the decision process. The fourth choice architecture embedded within Envision is not aligned with the literature and is the focus for our empirical investigation.

3.4.1 Partitions improve the decision making process

When presented with too many options, people can become overwhelmed, indecisive, unhappy, and even refrain from making a choice—a phenomenon called choice overload. Grouping decisions by features and presenting questions in a linear framework are shown to reduce these feelings produced by choice overload and reduce the time needed to make a decision (Fox & Langer, 2005; Martin & Norton, 2009). Each choice within the given partition will likely receive the same amount of decision time and weighting (Levav et al., 2010).

Envision groups 60 credits into 5 categories. These categories are subdivided and related credits are linked together. For example, Quality of Life includes three subcategories: purpose, community and wellbeing. Envision draws connections between credits QL1.2: Stimulate Sustainable Growth and Development and QL1.3: Develop Local Skills and Capabilities because both credits deal with attracting businesses as a method to create local jobs. Partitioning credits under subcategories and showing connections to other credits provides a systemic method to navigate the system, which possibly reduces choice overload. Rather than seeing all 60 credits at once (each with approximately 5 levels of achievement for a total of 275 decisions), users have a limited vantage point, seeing only one partitioned category at a time. Partitions are also likely to balance users' time and decision-weight between categories. For instance, features like climate risks, which typically receive little consideration in project planning, may now receive equal consideration to features like resource allocation or project finance risk.

3.4.2 Overcoming status quo bias through a reward system

Status quo bias is the reluctance to change one's current position. In Pennsylvania the status quo for auto insurance is the "Full Right" to sue and challenging the status quo means asking for "Limited Right" to receive a discount. In New Jersey, "Limited Right" represents the status quo and policyholders must actively ask for "Full Right." Johnson et al (1993) showed that the reluctance to break status quo meant 75 percent of

Pennsylvania motorists obtained "Full Right" yet only 20 percent in New Jersey. This difference translates to more lawsuits filed in Pennsylvania (Fischhoff & Kadvany, 2011).

Envision is a decision tool that guides infrastructure engineers away from conventional practice. Plans that keep with convention (status quo) receive no points while plans to achieve the restorative level receive the greatest points. The decision to use Envision, or not, is like that of car owners deciding between Limited and Full right to sue. Envision helps with how, but the motivation to change the status quo must come from somewhere else. The City of Dallas, the Port of Long Beach, and Massachusetts Water Resource Authority are making that movement. Each requires project teams to use Envision to submit a proposal. Just as car owners trade benefits (limited right to sue) for cost (high risk) infrastructure teams may feel similar trade offs. Moving away from the conventional industry design may perceive higher risk. The benefit can be a new project, public recognition or possible monetary bonuses from owners. As the new requirement to use Envision is implemented, firms will decide if the benefit is worth the potential risk.

3.4.3 Detailed descriptions increase confidence

Past experiences, or subject knowledge, can inform current decisions. However, this can lead to overconfidence in judgment of risk. For example, someone knowledgeable in football will feel more confident about predictions in obscure football events than in gambles of chance (such as a coin toss), even when the probabilities of both are exactly the same (Fox & Tversky, 1998; Heath & Tversky, 1991b). To shift cognitive focus away from decisions based on experience, choice architects can provide more detailed descriptions of the options they want users to consider (Erev, Glozman, & Hertwig, 2008; Khaneman & Tversky, 1979). In essence, the extra description counter weights past experience changing how information is collected then processed through the brain.

When engineers use previous construction knowledge to justify current project performance and partnerships, their current decisions have been informed by their prior experience (Hartmann & Bresnen, 2011). If past decisions kept with the industry norm, a reluctance to depart from these norms can develop and may led to underweighting innovative design solutions (Beamish & Biggart, 2010). Envision shifts decision weighting from experience to description by prompting users with questions about how the design team plans to explore new options. For example, "Has the project team identified and assessed possible changes in key engineering design variables?" ("Envision™ Sustainable Infrastructure Rating System," 2012). To answer these questions, Envision provides documentation and links to technical details of engineering design. This added information might improve user confidence levels and motivation to create new designs that meet longer-term objectives.

3.4.4 Defaults as a choice architecture

While partitions, points, and details create an Envision framework that guides users during the decision making process, we believe more can still be done to encourage the highest levels of Envision achievement—in particular meeting *conserving* and *restorative* goals. Here, we explore whether changes to one type of choice architecture, defaults, may impact design outcomes. Each category of Envision begins at a default of zero points, and infrastructure projects can earn points by improving upon the industry norm. We study whether a more ambitious default, set to *conserving* (four levels above the current default), will lead to higher point scores. Users, who uphold the default, keep the points at the *conserving* level. While users that move to the industry norm lose the endowed points and receive a lower score. Changing the default option may shape users' preferences about sustainability choices differently and, as a result, infrastructure projects may achieve higher points. We explain how these user preferences are constructed. And while there are many choice architecture strategies, we focus here on defaults to construct user preferences about infrastructure design options. Our rationale is supported by query theory, in which choices are made based on a linear series of questions and these questions are dependent on the starting point, or default (Johnson et al., 2007). Initial questions produce longer richer responses than later questions and, subsequently, this impacts the outcome (Weber et al., 2007).

Defaults can influence the linear series of questions in three ways: *effort, endorsement,* and *reference dependence* (Dinner et al., 2010). *Effort* references the cognitive energy exerted to make a decision. Employees who do not select a 401(k) plan, displaying a lack of *effort* to make a decision, still save money because of a predetermined default of 3 percent annual investment (Madrian & Shea, 2000). *Endorsement* means decision makers perceive the default as the recommended option because it reflects the most commonly chosen or fits within the social norm (Brown & Krishna, 2004; McKenzie et al., 2006). Shoppers who believed a manufacturers default product option was selected in earnest, representing the best features and not solely the most expensive, were more likely to stay with the default option (Brown & Krishna, 2004). *Reference dependence* means the default frames the outcome as a loss or gain and this frame impacts the decision (Dinner et al., 2010). Car buyers first shown the "fully loaded" package perceive lesser models as having lost features (Park, Jun, & MacInnis, 2000). Meanwhile, car buyers first shown the base model perceive those same features as add-ons. This feeling of loss or gain is reference dependent on the starting point. This study examines the impact on upfront planning and engineering design choices when changes are applied to the Envision rating system's default settings.

3.5 Hypothesis

We suggest Envision users make infrastructure decisions in a way similar to consumers, by constructing preferences about options. These preferences are dependent on the reference point, or default. We also suggest that Envision's current default may unintentionally discourage users from achieving the even higher levels of sustainability performance that are possible. By changing the Envision default from the industry norm to the *conserving* level of achievement, users will achieve more points (i.e. subtract less) and create more sustainable designs.

Table 2 shows the modified scale we developed to test this idea. Currently arranged, Envision awards 1 point *(improved)* for creating a spill prevention plan and 14 points *(conserving)* for eliminating all potential polluting substances. The modified scale, endowing points to the user, makes the 14-point option the default. Additional points are only possible by achieving the highest level, *restorative*. Achieving below the new default results in a loss of points. Now, rather than adding 1 to the 0 endowed points, a spill prevention plan subtracts 13 from the 14 points that were endowed. The *conserving* level of achievement was chosen as the endowed default because it represents the environmental neutral defined by Envision. This means the infrastructure development plan neither harms nor improves the surrounding community or environment ("Envision™ Sustainable Infrastructure Rating System," 2012).

The final amount of points for each level of achievement remains the same in both versions. The only change is the process to achieve them. We examine whether this simple restructuring will change user preferences about options and ultimately lead to a higher level of sustainable design achievement.

Table 4: Modifications to Envision Rating Scale

NW2.3: Prevent surface and groundwater contamination		
Levels of Achievement	*Current Scale*	*Endowed Scale*
Industry Convention	*0**	(-14)
Improved	1	(-13)
Enhanced	4	(-10)
Superior	9	(-5)
Conserving	14	*14**
Restorative	18	(+4)
* Indicates default number of starting points.		

Our hypothesis about endowment follows Khaneman and Tversky's (1979) study that found a loss provokes greater degrees of discomfort than a gain provides satisfaction, by roughly a factor of two. People who own an item value its worth twice as much than if they did not own the same item (Thaler, 1980). Functional magnetic resonance imaging (fMRI) brain scans show physical differences in people asked to add (gain) or subtract (loss). Subtraction takes more cognitive energy and occurs in regions closer to the emotional region of the brain (Gonzalez et al., 2005; Yi-Rong et al., 2011). The effects of framing (loss or gain) take little time to establish (Khaneman, Knetsch, & Thaler, 1990), suggesting that changing the default in Envision may be enough to promote higher scores. Envision users currently gain points. Shifting Envision users from a point gain to a point loss frame may lead to higher motivation to keep the points in an effort to avoid the discomfort felt by a loss.

This study builds on previous judgment and decision making research but differs in several ways. This is the first study we are familiar with that empirically examines how modifications to choice architecture impacts infrastructure decisions. We set a default with points, rather than product features, which may lead to different outcomes or perceived value. Envision users are not choosing options about a product for purchase, but rather to influence a physical design, and this may cause users to construct preferences differently than previous studies suggest. We are also asking questions with multiple attributes, meaning users are choosing between five options, not just opt-in or opt-out choices. This may alter the degree of influence of the default option on the decision maker.

3.6 Method

The empirical portion of our study examined student decisions when using the Envision rating system. Student participants from an undergraduate sustainable construction course were given a case study and asked to choose design options from two of the five Envision categories: “Quality of Life” and “Natural World” (26 of the 60 available credits). These categories asked participants how to improve community mobility, preserve cultural resources and green fields, and manage storm water runoff. Other Envision categories were not included to reduce the time and the cognitive load required to complete the assignment. We wanted to encourage students to spend time thinking about the design choices, rather than rush through to complete all of the credits.

Participants were given class credit for completing the rating system. Their grades were based on turning in the assignment, not on their achievement score. This was made clear during the lecture introducing the assignment and in the case study instructions. Participants accessed the assignment via an internet link, through which they were randomly directed to one of two Envision versions: the standard version with 0-points or the endowed version with 304 starting points. Instructions on the endowed version read "Decisions made below the *conserving* level will lose you points. Decisions made above the *conserving* level will earn you points". Instructions on the standard version read, "You are starting at the industry norm benchmark with 0 points. Every decision you make above industry norm will earn you points".

As students completed the rating system through the online portal, our software captured each design decision and written explanation. The online software also allowed us to set a minimum number of words for each explanation. For example, selecting the *improved* level required 100 characters of explanation and the *restorative* level required 300 characters. We included this word minimum to reduce the likelihood participants would maximize points by thoughtlessly selecting the highest levels of achievement for every credit. The word minimum acted as a sort of cost, in terms of the time and thought required to justify the achievement choice. Based on feedback from preliminary studies, we used character minimums (rather than word minimums) and a 50-character increase for each higher achievement level. Users were able to identify credits as not applicable to the project if they could justify why the credit was not applicable. Points for credits selected as not applicable were deducted from the total achievable points in the system.

As mentioned earlier, budget and time were intentionally excluded from the online software. Our objective is to measure how users set project sustainability goals. A high sustainability score does not correlate with an increase in project cost and Envision does not include an economic decision metrics. Developing a monetary cost for each decision within Envision may introduce biases not controlled for. We kept the Envision system exactly the same except for the intervention to default number of points and required length of explanation. Isolating this decision point enables us to measure the difference between groups as a result of the choice architecture intervention.

Often, the influence of choice architecture is unnoticed by decision makers and a difference in dependent variables is minimal (Thaler & Sunstein, 2008). To see whether participants were affected by the different defaults in ways other than score, we also asked survey questions related to intrinsic motivation and confidence. We define motivation as importance and effort and measured if the endowed default created greater participant motivation to not lose points compared to the industry norm group who gained points. Eight survey questions were adapted from previous post-task motivation surveys (Fernet, 2011; Thelk, Sundre, Horst, & Finney, 2009; Watson, Clark, & Tellegen, 1988; Wolf & Smith, 1995). Additionally, we asked if participants achieving above or below the 304-point default were confident a project team could meet their scores and compared responses to the 0-point default group. If we found not meeting the 304-point default discouraged participants to use the Envision system in the future, a higher default may not be preferred.

We asked participants if they were aware of the default and to explain if this influenced their decision process. Mindful, or not, participant's responses would provide supporting evidence for or against our theoretical basis of query theory. We also asked for addition information about any previous internships or jobs related to the case study topics. Survey questions included both Likert scale (1=strongly disagree to 5=strongly agree) and open-ended response.

3.6.1 Procedure

During an in-class lecture, undergraduate student participants in a sustainable construction course learned about Envision's purpose and how to navigate the rating system and use to select project features. Participants were asked to pretend they were a sustainability coordinator for a project team designing an outdoor community center and stream restoration on a 0.4-acre brownfield site in rural Alabama. The Envision system would help them make site design decisions about cleanup, restoration, and construction. Participants were given background material about the site such as its Environmental Protection Agency's brownfield Environmental Assessment report 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. Each participant used the Envision credits to make individual decisions. For example, Credit NW2.2 asks if "Low Impact Development" (LID) guidelines were used to manage storm water runoff. For this credit, participants reviewed specific LID guidelines, provided by the online rating system, and then decided whether and how to incorporate LID features into the project. Participants designed based on 26 credits, evaluating which were most valuable, achievable, and in line with project goals.

3.7 Results

As hypothesized, a higher default led to a higher final score. The endowed group (n=16) averaged 62 percent (214/343) of applicable points and the standard group (n=25) averaged 44 percent (147/329). A one-tail t-test was used because the hypothesis states the endowed group will score significantly more than the standard group ($p<0.01$). Only two students from the endowed group achieved higher than the conserving 304-point default. Thus, most endowed group participants lost points while all standard group participants gained points.

If all credits were considered applicable, the total possible achievable points would have been 384. Over 75 percent of all participants selected at least one credit as not applicable to the project. There was no significant difference in points considered applicable between the endowed group (343 points) and standard group (329 points, $p>0.1$). The endowed group achieved significantly more of the points considered applicable to the project ($p<0.01$). The endowed group received the Platinum level of recognition (achieving over 50 percent of applicable points) while the standard group received the Gold level of recognition (achieving between 40 and 50 percent of applicable points). The average completion time was 1 hour 56 minutes to complete the rating process. For completion time, there was no significant difference ($p>0.1$) between groups.

The total scores were evenly distributed between categories. Meaning, participants equally prioritized Quality of Life and Natural World credits. The endowed group achieved 68 percent (117/172) in Quality of Life and 60 percent (97/171) in Natural World. The standard group averaged 43 percent (71/167) in Quality of Life and 46 percent (75/163) in Natural World. The difference between groups is statistically significant for Quality of Life ($p<0.01$) and Natural World ($p=0.04$). Median values for each category were within 5 points of the average scores. The results, shown in Table 3, are the percent of total points achieved by the total points selected as applicable.

Table 5: Standard and Endowed Percent Points Achieved

	Score	Possible	Achieved	p
Standard	147	329	44%	<0.01
Endowed	214	343	63%	

Survey responses indicated no difference in student motivation between groups. Those in the endowed group (losing points) and those in the standard group viewed the rating process as requiring similar effort and having similar value. Additionally, we asked if those achieving above or below the 304-point default were more or less confident a project team could meet their scores and compared responses to the 0-point default group. Both groups were equally confident in their scores. And while the number of participants who scored above the conserving default was low, at only two participants, both of these participants believed their scores were average, not above the rest of the class. Participants from the endowed group who lost points indicated they were happy with their scores and, when compared to those in the standard group, no significant difference was found in responses.

We thought that the new default may lead those in the endowed group to view *conserving* as required for true sustainability. However, both groups indicate a project could be considered sustainable with only the incremental advances rewarded by the *improved* level of achievement.

We asked participants in the endowed group if they were aware of the default and to explain whether this influenced their design decisions. Of the 15 who answered the survey, just two correctly answered 304 points as the default starting point. Seven participants provided an incorrect value, and six indicated zero points. Seven of the nine participants that indicated the default number of points were greater than zero indicated the default did influence their decisions. Open-ended responses captured participants' explanations. A participant mindful of the default explained, "I at least tried for conserving each time. I looked at the requirements for conserving and then thought how I could make the project reach that requirement." Another participant said, "I started at the default setting, and tried not to lose points." These responses suggest a higher default can shift a decision makers' perspective without negatively representing the Envision rating system. In fact, the two highest scores, the participants who achieved 92 percent and 91 percent of the total possible points, were students who indicated on the survey they started with the conserving level of achievement and tried not to lose points.

3.8 Discussion

Our findings indicate that Envision's current default preserves a low benchmark of achievement, which reduces the possible higher levels of achievement that are possible. Our higher default led designers to achieve the highest possible certification given by Envision. Envision denotes certification by a percent of points: Certified (20 percent), Silver (30 percent), Gold (40 percent), and Platinum (50 percent). Our endowed default increased recognition from Gold to Platinum - an average increase of 19 percent.

Our findings support previous research in consumer decision making that states defaults influence how decision-makers process information (Levin, Schreiber, Lauriola, & Gaeth, 2002; Park et al., 2000). Our findings also align with query theory. The higher default orients users to a higher level of achievement and, subsequently, this affects the outcome. Based on their responses to the survey questions, the endowed group appeared more likely to review requirements at the conserving level of achievement and then decide to move up or down in levels. While some participants in the endowed group were more aware of the manipulation than others, it was an effective method to increase the average sustainability score.

In some instances, defaults mean that when no choice is selected a decision is still made (Brown & Krishna, 2004).In these cases, defaults obviously help reduce the cognitive energy needed to make a decision (Johnson, Bellman, & Lohse, 2002). However, in our study, the endowed default still required cognitive energy to make a decision. Levav et al. (2010) suggests a depletion effect where, as more decisions made, fewer cognitive resources are available for future decisions. Our participants did not seem to experience this depletion effect; both groups answered credits similarly in the beginning of the activity and towards the end. This may be due to participants prioritizing credits prior to beginning the rating process. Also, participants in the endowed group may have taken cognitive energy saved from the *conserving* default, and devoted it to explaining their plans to meet the *conserving* level.

Previous research suggests defaults can endorse a choice as a social norm (McKenzie et al., 2006). However, our limited findings from the survey questions did not support this. Participants from the endowed group did not view their scores differently than the standard group. The endowed default did not change participant' perceptions about sustainability or the Envision rating system. Those who met the *improved* level of achievement felt equally confident and happy in their score as those that met the *conserving* level of achievement.

We thought the endowed group may feel greater motivation to meet the higher default. But we found no statistically significant difference in self-reported post task motivation responses between the two groups. Participants from the endowed group who could recall the correct default number of points achieved the highest percentage of points out of all 41 participants. Placing even more emphasis on the default may lead to even higher scores, which is worth exploring more through the future studies we describe in the conclusions.

Those interpreting our results should keep the following qualifications in mind. Preliminary design goals often change due to monetary budgets, project schedules, and multiple stakeholder objectives. We cannot know how these early design decisions would hold through to the physical manifestation of the project. However, research in anchoring suggests a higher initial score influences future decision making (Chapman & Johnson, 1999; Galinsky & Mussweiler, 2001). Starting with a higher preliminary Envision score could help guide a project team to achieve a higher final score. Engineering firms could benefit from the modified Envision version when working with cities like Berkeley, California, which use Envision to help prioritize backlogged infrastructure projects. Additionally, participants were aware this was a one-time assignment. While there was no external motivation to embellish their design or choices, there were also no limitations to doing so. These student participants were enrolled in a sustainable construction course and already interested in sustainability topics. But Envision is also a voluntary tool and those using Envision will most likely be interested in sustainability achievement. Because our results are based on student responses, we cannot be sure these defaults would influence professionals in the same way. However, previous studies with experts and novices would suggest similar conclusions (Englich, Mussweiler, & Strack, 2006; Northcraft & Neale, 1987). A follow-up study can replicate our research methods with an industry group to confirm whether findings are transferable to professional engineers.

3.9 Conclusions

Defaults are a specific type of choice architecture that determines how users initially encounter options. Simply pre-checking a box is a powerful first impression. Private retirement plans with defaults set to invest, increase user savings (Cronqvist & Thaler, 2004; Madrian & Shea, 2000). Online shoppers purchase more expensive items when multiple product options are available and set to the highest priced default option

(Herrmann et al., 2011). Unlike in previous studies, our decision makers are not consumers but professional decision makers (in training at least), people whose decisions will eventually influence physical infrastructure. Construction engineering and management professionals can use choice architecture to help inform upfront planning and decision making. Researchers can study how choice architecture embedded in standards, procedures, and frameworks influences the decision process for infrastructure delivery and how changes to the choice architecture might influence the decisions that are made. For example, as this study shows, awarding points for slight improvements unintentionally discourages the higher levels of achievement that are possible. Shifting the default to *conserving* reframes the internal questioning process of the decision-maker and subsequently encourages higher levels of achievement.

Smartly designing the choice architecture of decision tools like Envision is a comparatively low cost method to meet societal obligations to create more sustainable infrastructure, ensuring functionality for future generations (ASCE, 2009). Our findings are just one example of the advances possible at the intersections of behavioral science and infrastructure planning.

The Envision framework allows analysis of preference construction both quantitatively through changes in point values and qualitatively through design verification descriptions for each credit. Specific to Envision, additional choice architecture studies could explore changes in commitment framing, goal framing, and greater emphasis to the reference point. For example, changing commitment could require users to explain why they could not meet the highest level of achievement. Credit

NW 3.4 *improved* currently asks, "Does the project maintain or enhance one ecosystem function?" By reversing the commitment role, users would now "Explain why the project could not maintain or enhance all ecosystem functions" to meet the *conserving* level. This change in frame strongly implies a higher commitment, and may lead to higher achievement.

Goal framing provides rules for setting a goal. Set too high and users may perceive the goal as unattainable and score less (Heath et al., 1999). In our study, participants viewed the *conserving* level of achievement as attainable and worked to achieve it. Future research should set an even higher default to identify when participants view achievement as too extreme. Another study could redesign the format of the rating system to place greater emphasize on the score. The participants in our study that could recall the endowed default scored the highest percentage of the points. More emphasis on the score may increase awareness of the starting point and possibly lead to even higher achievement. Finally, an active intervention could teach participants why the conserving score is the least possible level for true sustainability and show examples of how this level is attainable.

Envision is just one of many decision tools for infrastructure planning and similar approaches could be applied to others. For instance, understanding how an engineer constructs preferences about material options when using Building Information Modeling (BIM) could help identify if shifting the order of options, number of clicks or default settings influences a change in choice. Engineers that use Intelligent Transportation System (ITS) software may perceive computer-based models as less risky than other forecasting methods due to the large data sets used to create the computer simulations. Through feedback loops we can identify how these forecasts impact project outcomes and analyze if these high confidence levels are confounded. ITS and BIM are two examples that hold high-impact decisions yet to be examined through choice architecture.

CHAPTER FOUR

THE EFFECTS OF FRAMING GAINS AS LOSSES TO INFORM MORE SUSTAINABLE INFRASTRUCTURE DESIGN DECISIONS

4.1 Abstract

Decision aids, ranging from rating systems to design software to regulatory standards, are often used to design and evaluate infrastructure projects. Unfortunately, there is no neutral framework to present this information. Some options must be first, attributes are or are not presented, and, just as in other domains, these factors are likely to influence decisions in infrastructure development. We seek to better understand how choice structures influence engineering decisions. Prospect Theory, a much-developed concept from behavioral sciences, asserts that people tend to think of possible outcomes relative to their starting point not the resulting end point. For instance, framing a decision as a loss, rather than a gain, in value can reduce the decision makers' acceptance of risk and, in turn, influence the outcome. To measure the influence of framing effects in engineering decisions we use the Envision rating system for sustainable infrastructure. The objective of Envision is to help engineers achieve the highest possible points in sustainability. We hypothesize that Envision's current framework inadvertently limits engineers' ability to set the highest possible goals for sustainability. Users start with zero points and achieve points when design considerations move beyond conventional construction standards. In a modified version, we set a higher benchmark. Users are endowed points and can lose them for not maintaining high consideration for

sustainability. Professional engineers (n=65) used Envision to make tradeoffs about site programing and functionality for a rural Alabama redevelopment project. Participants were randomly assigned the standard version (n=33) or the endowed version (n=32). The results indicate that a choice posed as a loss, rather than a gain, significantly improved engineers' consideration for sustainability achievement. The endowed group (n=32) achieved 66 percent of points compared to the standard group's (n=33) 51 percent (p=0.002); an average increase of 2.27 points per credit. The endowed group acted loss averse trying to maintain the initial points in sustainability given. These findings suggest behavior science can inform how engineers interface with decision processes. Findings from this research indicate more thoughtfully designed decision aids are needed. However, a complete picture will not emerge until multiple stakeholders (i.e. investors, regulatory agencies, planners, and engineers) and multiple decision points (i.e. schedules and budget cycles) are examined. This type of interdisciplinary research holds potential to yield relatively low-cost solutions that support greater sustainability in infrastructure development.

4.2 Introduction

Infrastructure development creates path dependence determining energy, water use, and climate change emissions for the life cycle of the project. In addition, engineering decisions about infrastructure broadly define how the public will use infrastructure services, affecting mobility, public health, and economic development. For instance, the Woodlands Township in Houston commissioned an engineering study to either widen Interstate-45 or expand bus and trolley services. This decision will directly influence how residents commute to work, where to build future retail businesses, and construction of new residential communities. Other considerations may include material choices for infrastructure during construction. While recycled materials may reduce energy consumption early in project life cycle, if the life span of a road is reduced, the performance contribution is arguably lower. Considerations for sustainability, like these, whether type of infrastructure or materials, early in infrastructure development can result in more environmental and cost effective outcomes. This article seeks to help those in the early phases of infrastructure development make more informed decisions that lead to more sustainable infrastructure outcomes.

Decision aids, ranging from rating systems to design software to regulatory standards, are often used to design and evaluate infrastructure projects. The rating system Leadership in Energy and Environmental Design (LEED), for example, can guide project teams in site programing, building layout, and identifying energy efficiency goals (Bayraktar & Owens, 2010). LEED provides a metrics for decision makers to compare alternative options and justify decisions. Buildings labeled with LEED command higher occupancy rates (Fuerst & McAllister, 2009) and higher lease prices in commercial buildings (Eichholtz, Kok, & Quigley, 2010). These higher prices suggest commercial clients, and the public, value such rating systems and substantiate a value for using metrics in construction decision processes (Dermisi, 2009).

Envision is a leading U.S. rating system for sustainable infrastructure and is designed for a range of infrastructure projects (i.e. roads, bridges, pipelines, railways, airports, dams, levees, landfills, and water treatment systems). Developed in partnership with the Institute for Sustainable Infrastructure and Harvard's Zofnass Program for Sustainable Infrastructure. Envision is similar to LEED; both are appropriate for project planning to inform goal setting and early design considerations. And like LEED, Envision is used voluntarily by construction and design firms but can also be mandated by local governments and municipalities. Engineering companies HDR, CDM Smith, and Skanska have quickly acknowledged the benefits of Envision by pledging to train over one hundred employees to use the rating system. The city of Berkeley, California employs Envision to prioritize backlogged projects (*City of Berkeley Process for Prioritizing Street and Watershed Improvements*, 2013) and Dallas, Texas requires an Envision Certified member of the design team before submitting a proposal.

Envision broadly applies to all types of infrastructure, excluding buildings. So, there is no direct overlap with LEED. Current projects with Envision certification include a fish hatchery, an underground pipeline, and several creek and wetland restoration sites. Additional projects integrating Envision into project evaluations include the Port of Long Beach and the Los Angeles – San Diego – San Luis Obispo (LOSSAN) Rail Corridor. The Port of Long Beach is measuring success of a brownfield remediation project with Envision (Sheesley et al., 2014) and the LOSSAN project will use Envision set a baseline for sustainability, which future rail development within the corridor will aim to meet (Dial et al., 2014).

The recent scale of adoption by municipalities and engineering firms to use Envision indicates these types of metrics provide quantifiable justifications for project decisions. Also labeling a project as sustainable can be beneficial for both indirect stakeholders in the community and direct stakeholders as project owners or city officials. Understanding how these metrics influence engineers' decision making is critical to ensure non-technical barriers do not limit consideration for sustainability. Behavioral science suggests the framework, or choice structure, of options can influence the decision maker's choice. As a result of three decades of research in behavioral science, researchers can now make accurate predictions about decision making based on framing effects (Levin et al.,1998) and loss aversion (Benartzi & Thaler, 1993) among many other cognitive biases (Edwards, 1996) and social heuristics (T. D. Beamish & Biggart, 2012).

Human rationality is bounded by time and cognitive limitations (Gigerenzer, 2006; Kahneman, 2013). Modifications to decision based processes to incorporate bounded rationality are improving fields from medicine (Johnson & Goldstein, 2003) to law (Johnson, 1993) to finance (Thaler & Benartzi, 2004). Consider, for example, the difference in tort law for consumer car insurance in Pennsylvania and New Jersey. In Pennsylvania the law sets "Full Right" to sue as the default auto insurance for customers. To change the default policyholders must ask for "Limited Right" to receive a discount. In New Jersey, "Limited Right" is the default and policyholders must actively ask for "Full Right." The reluctance to break the default means 75 percent of Pennsylvania motorists obtained "Full Right" and only 20 percent in New Jersey (Johnson, 1993). The small change in choice structure translates to economic and political impact; more lawsuits are filed in Pennsylvania compared to New Jersey (Fischhoff & Kadvany, 2011).

The EPA likely used a similar perspective when deciding to revise car energy labels. When presented with a mile-per-gallon (mpg) metric, car buyers wrongly assume that increases in mpg have a linear effect in fuel use and CO2 emissions. An increase from 10 to 20 mpg reduces consumption by 50 percent. This is not the same as going from 40 to 50 mpg, which reduces fuel consumption by 20 percent (Larrick et al., 2009; Larrick & Soll, 2008). Consumers who believe the differences are equivalent either do not understand the metric or cannot do the mental calculation. But, when presented with fuel efficiency information using a linear metric, such as gallons per mile, their ability to pick the most beneficial car option improves. The recent change by the EPA to gallons per mile supports better decisions by providing an easy to understand metric of total gasoline costs (Ungemach et al., Under review).

The tort law and EPA examples demonstrate how small changes in decision frameworks can influence the decision process for consumers. We apply a similar technique to better understand how engineers make decisions. In this study, we examine the Envision rating system for sustainable infrastructure but our findings can translate to many other areas of infrastructure decision based design and project delivery and management.

The engineering decision process we are studying is early in project planning, closely associated with goal setting. High-level decisions about site programing and functionality are being considered but likely not enough detail is available to perform a cost-benefit analysis at the early stages when using Envision. The objective is to examine how engineers interface with tools like Envision and to measure the effect on decisions about sustainability due to changes in choice structures. Previous research in decision based design suggests bounded rationality (Frey & Lewis, 2005; Gurnani & Lewis, 2008), social heuristics (T. D. Beamish & Biggart, 2012), and cognitive biases (Klotz, 2010; Klotz et al., 2010) are prevalent in infrastructure development. This research adds to this on-going body of knowledge. Any recommendations to adjust the Envision framework are to support engineers consideration for the highest possible levels of sustainability. Negative connotations, perceptions, or ability about sustainability or Envision as a result of an intervention study in this research would lead to not recommending changes to the framework.

4.3 Objective

Behavioral interventions are known to shape decisions about sustainability of end-users (Dietz et al., 2013; Kempton et al., 1992; Meier & Whittier, 1983; Yates & Aronson, 1983). Yet, even greater impact is possible by guiding upstream decisions such as those made during infrastructure development. Decision made during infrastructure development, in turn, determine the sustainability of end-users' behaviors for a long period of time (Knobel, 2007).

The goal of this article is to describe how engineers make tradeoffs between design options. We empirically measure the effects of changes in choice structures of the Envision rating system. How information is presented, or framed, within Envision may inadvertently limit engineers' consideration for the highest levels of sustainability possible. In our study, we hold all other project constraints, like time and budget, equal. Often more sustainable design does not cost more money, only additional time and consideration during design. Findings from a case study about the LOSSAN rail corridor and Envision suggest, had Envision been adopted earlier in the design process, greater project sustainability could have been achieved at no additional cost (Dial et al., 2014). We recreate a similar upfront planning scenario to empirically test if changes in the Envision framework create a shift in project goal setting to achieve higher points in Envision. By isolating this decision point we can more effectively measure the impact of the intervention.

4.4 Background

This paper builds on previous research in construction engineering management that suggests judgment and decision making, cognitive biases and social heuristics distort managerial decisions in complex infrastructure governance, planning, and delivery (van Buiten & Hartmann, 2013; Beamish & Biggart, 2012; Klotz et al., 2010; Klotz, 2010). Understanding how engineers make decisions can help reduce these biases (Shealy & Klotz, 2014). We draw on previous research in psychology and economics (Hardman, 2009). A concept called Prospect theory, developed by Daniel Kahneman and Amos Tversky (1979), is widely accepted following three decades of research. Results from these studies indicate external validity from multiple domains with similar conclusions: decision makers are influenced by the presentation of options.

Prospect theory makes logical assumptions of economic rationality to account for behavioral biases. The main assertion of Prospect theory is people tend to think of possible outcomes relative to their starting point rather than the resulting end point (Kahneman & Tversky, 1979). For instance, factory workers given a preliminary bonus met a higher productivity level than workers promised a bonus (Hossain & List, 2009). The first group had something to lose compared to the second group only had something to gain. The potential loss is more discomforting than a gain of equal value. Prospect theory is used similarly to predict how home sellers will behave in a down market (Genesove & Mayer, 2001) or fund managers sell stocks (Abdellaoui et al., 2011). A potential loss reduces the decision makers' acceptance of risk to achieve an outcome. It also applies to issues in politics (Patty, 2006) and international relations (Berejikian, 2002). Yet, there is inadequate understanding of how these factors influence the crucial early-phase decisions in infrastructure project development, which this study addresses.

To overcome the risk of losing requires the potential gain to be roughly twice as great (Benartzi & Thaler, 1993). This is modeled as the value function within Prospect theory. A loss is more sharply felt compared to a gain of equal value. The effect of a marginal change in value decreases from the distance of the reference point. Meaning a gain from $100 to $200 is subjectively greater than a gain of $1,100 and $1,200. The distance from the starting point changes the perceived value and therefore acceptance of risk. More risk is often accepted when further from the decision makers' perspective of the starting point.

Decision framed as positive or negative can have a similar effect as a loss or gain. Patients are more likely to choose a medical procedure when presented as probability of survival (positive frame) compared to probability of death (negative frame) (McNeil et al., 1982). Similarly, political affiliations changed preferences when a carbon dioxide surcharge was labeled a "tax" or "offset" (Hardisty et al., 2010).

These differences are measurable in brain scans, as well. Losses are associated with an emotional pain in a way that gains are not (Rick, 2011; Sokol-Hessner et al., 2012). Endowment effect can change the reference point, or frame, to induce a risky choice. By endowing someone with an object, or giving ownership, their willingness to accept a sale or trade decreases. In other words, people expect to earn more money when selling an item and expect to pay less when buying the same item. In some instances the endowment effect increases the perceived value of an item by as much as 14 times (Carmon & Ariely, 2000). The increase in valuated price is a reflection of the discomfort of the potential loss. Compellingly, experts appear just as susceptible as laypeople to framing effects and loss aversion (Duchon et al., 1989; Marteau, 1989).

These findings show the need for research to understand how framing effects may influence not just relatively simple consumer decisions but also upstream decisions about infrastructure that require active tradeoffs with multiple variables and uncertain consequences. To summarize, decisions are made by constructing preferences about options (Ariely & Norton, 2008; Johnson et al., 2007; Slovic, 1995) and Prospect theory provides the model for predicting which option likely fit ones preferences. Applying this theoretical perspective to engineering decision making may aid in the decision processes. Intentionally designed, or not, there is no neutral framework to present information. Some options must be first, attributes are or are not presented, and, just as in other domains, these factors are likely to influence decisions in infrastructure development. Across fields, modifications to choice structures are viewed as a method to improve the decision process (Thaler & Sunstein, 2008). The methods can be controversial (Bovens, 2009) but better understanding how choice structures influence engineering decisions can provide insight to design more thoughtful decision aids, and ultimately lead to more sustainable development.

4.4.1 Envision Framework

Envision is a leading sustainability rating system for infrastructure, developed by the Institute for Sustainable Infrastructure and Harvard's Zofnass Program for Sustainable Infrastructure. The American Society for Civil Engineers, American Public Works Association, and American Council for Engineering Companies founded the Envision program. The rating system is composed of 60 questions divided into five categories: Quality of Life, Leadership, Resource Allocation, Natural World, and Climate and Risk. Each question, or credit, is associated with a series of points. Engineers use Envision's guidance manual to decide the amount of points achievable for their project. Levels of achievement are ranked from lowest to highest: *improved, enhanced, superior, conserving,* and *restorative*. The scale of points varies for each credit but all points accumulate moving from i*mproved* through *restorative.* For example, Quality of Life question 1.3, asks how will the project team develop local skills and capabilities. The *improved* level (1 point) is achieved by hiring a local work force and *conserving* (12 points) is achieved through a training program for minorities and disadvantaged groups. The training program must leave a competitive local workforce in place for future projects. To meet *conserving* and *restorative* means the project provides sustained benefits to the community, economy, and local environment after the construction phase is complete (i.e. a trained, diverse workforce is more competitive for future projects in the community).

The goal of Envision is to move project teams from the conventional construction standards (zero points) to the highest possible levels of sustainability (defined by envision as *conserving* and *restorative*). To more effectively motivate Envision users to consider the highest achievement, we suggest starting users at the *conserving* level of achievement, and endowing them the points to that level. The modified scale in Table 1 shows the endowed scale, starting users with 12 points. Additional points are still possible by achieving the highest level, *restorative*. Achieving below the new reference point results in a loss of points. Now, rather than adding 1 to the 0, 11 is subtracted from 12. The final amount of points for each level of achievement remains the same in both versions. The only change is the process to achieve them. The shift from starting at the conventional standard to *conserving* restructures the frame of reference from a gain option to a gain/loss decision. The conserving level of achievement was chosen as the frame of reference because it represents the environmental neutral defined by the Envision rating system.

Table 6: Modifications to Envision Rating System

Levels of Achievement	*Current Scale*	*Endowed Scale*
Industry Convention	*0**	(-12)
Improved	1	(-11)
Enhanced	2	(-10)
Superior	5	(-7)
Conserving	12	*12**
Restorative	15	(+3)
* Indicates number of starting points.		

Prospect theory states decisions are made in reference to other options. The further away from the reference point the less significant the change appears. In the standard version of Envision, users may see 0 to 5 as a bigger gain than say 10 to 15 because the starting reference is zero. Endowing users with points may shift the value function of the reference to a higher level of points. In essence, starting more closely to the center of the metric may frame the decision, either loss or gain, more equal.

4.5 Hypothesis

We hypothesize engineers make decision in reference to alternative options and the beginning number of points will frame how participating engineers construct preferences about subsequent choices in Envision. Currently, engineers using Envision begin at the lowest possible level with zero points. Much cognitive effort is required to move up five levels of achievement to meet *restorative*. By changing the reference point to *conserving,* users will consider, and achieve, a higher level of sustainability. This hypothesis follows Kahneman and Tversky's Prospect theory (1979). A more ambitions starting position, endowing users with points, will motivate them not to lose points compared to gaining the same exact points.

Consumer studies report participants are often not aware of these types of framing effects (Duchon et al., 1989; Levin et al., 1998). Similarly, we hypothesis, engineers will not be aware of the framing effects. Users will construct preferences about options differently but this will not change their general perspective of sustainability or the Envision rating system.

We do not suggest a higher Envision score alone determines a more sustainable outcome. Obvious financial, economic and political decisions will play a factor. This research holds variables like those equal. This is done intentionally to empirically measure how engineers' decision making processes adapt to sustainability as a potential loss, rather than gain. Future research is needed to identify how framing effects influence complex multi-stakeholder decisions.

4.6 Methods and Procedure

The empirical study in this paper examines engineers' decision making when using the Envision rating system. A replica of the Envision software captures participant responses. The replica appears identical to the original version of Envision. Users login to see their initial score and the total possible points. Users scroll down the page to view each credit. Just as the original version, a link directs users to Envision's detailed explanations of how to meet achievement levels. Once users review a credit, they select the level of achievement they believe is possible and provide a detailed explanation of how the project team can meet these points.

One version of the replica software presents the standard rating scale, starting users with zero points, and another the endowed scale, starting with 150 out of a possible 181 points. Users with the endowed version see the drop down menu for levels of achievement preset to *conserving.* Expanding the drop down shows a negative value instead of positive for *improved* through *superior.* The negative values in points are the points lost from the endowed starting point. Lesser achievement still results in a final positive score. The negative value is subtracted from the endowed score.

Both versions require users to explain how a team could meet the level of achievement specified. Similarly, if an infrastructure project is submitted to the Institute for Sustainable Infrastructure (ISI) for verification, an independent reviewer must authenticate the documents that support the project team's claims. A project team selecting *conserving* must also explain how they plan to meet *improved* through *superior*. Achieving a greater number of points requires a longer explanation. In our replica software, written explanation of at least 100 word characters in lengthen is required for *improved* and 300 characters for *restorative*. Intermediate levels are spaced by 50 character minimums. We included this text character minimum to reduce the likelihood participants would maximize points by thoughtlessly selecting the highest levels of achievement for every credit. The character minimum performs as a sort of cost, in terms of the time and thought required to justify the achievement.

We considered introducing a monetary cost for each decision; however, points in Envision do not correlate with an increase in cost. In fact, meeting a higher level of achievement may actually cost less. For example, identifying a construction method to reduce excavated materials can be cost beneficial and earn a project team six points. Our objective is to understand how engineers make these types of tradeoffs and if losing versus gaining points in sustainability deviates project considerations. To include additional time or cost variables in this study may create biases that are not controlled. This study underpins future research measuring the effects of framing with multiple variables. We kept the Envision system exactly the same except for the preset number of points endowed and required length of explanation.

The replica software was pilot tested with two student groups. The first group was told to review a redevelopment case study using the Envision software and explain how the case study project team could achieve Envision credits. The students used the text box within each credit to fill in their responses. These responses guided our setting required length of explanation for levels of achievement. Students preferred a character minimum to a word minimum. The students also identified a potential flaw in our system. In the first version, an explanation was not required when participants selected a credit as *not applicable* to the project. Selecting *not applicable* would decrease the total possible points and increase the total percent achieved. We changed this for the second student group and industry group. Participants now must also example why the credit is *not applicable*.

We tested the software again with a larger student group of upper-level and graduate engineering students (n=41) who are close to making these types of decisions in their careers. Student participants were given class credit for completing the rating system. However, their grades were not based on their achievement score. This was made clear when introducing the assignment. Two of the five Envision categories, Quality of Life and Natural World (26 of the 60 available credits), were included in the pilot study. These categories ask participants how to improve community mobility, preserve cultural resources and green fields, and manage storm water runoff. Other Envision categories were not included to reduce the time and the cognitive load required to complete the assignment. We wanted to encourage students to spend time thinking about the design choices, rather than rush through to complete all 60 of the credits.

Students were instructed to review a case study and use the Envision rating system to identify credits and possible level of sustainability the project team could meet. They were randomly assigned the standard or endowed software. Instructions for the endowed version read, "Decisions made below the *conserving* level will lose you points. Decisions made above the *conserving* level will earn you points". Instructions on the standard version read, "You are starting at the industry norm benchmark with 0 points. Every decision you make above industry norm will earn you points".

For the pilot study, the endowed group scored significantly higher design achievement for sustainability than the standard group. The endowed group (n=16) averaged 63 percent (SD=19.2) of applicable points and the standard group (n=25) averaged 44 percent (SD=19.8). Scores were evenly distributed on a normal curve and a t-test identified that the difference was significant, p=0.002. A power analysis ($p < 0.05$, power level = 0.80), using results from our pilot study suggest a sample size of 70 professionals is roughly twice the number needed to yield significant findings. This conservative sample size of industry professionals will yield statically significant results, to accept or reject our hypothesis.

4.6.1 Procedure for Industry Group

Professional engineers volunteered to participate in a training seminar about the Envision rating system. Six training sessions were organized and group sizes ranged from eight to twenty-five people. The trainings averaged 90 minutes in length. Participants first listened to a presentation about the purpose of Envision, how to navigate the guidance manual, and access to the online rating tool. A case study was presented about a redevelopment project in a rural Alabama town. Background information about the projects intended goals, local governance, community and site programing were also included in the presentation. Participants were instructed to act as the consulting engineer and make recommendations to the owner about site use, layout, accessibility, public space, and alternative modes of transportation. Details like how to integrate alternative transportation was intentionally left open-ended to encourage engineers to develop their own ideas. Each participant was instructed to use the online Envision rating system to help guide their decision making. Their job was to identify and explain how their designs could meet Envision credits. Because of the limited time for participation, only Quality of Life credits were given to the participants (12 credits out of a possible 60). Similar to the student group, the objective was to aid the decision making process. By reducing the number of credits participants needed to consider they could spend more time consciously reviewing each credit and option.

The online software randomly assigned participants to the standard or endowed version of Envision. Once logged in, participants could see their score and total possible score. Participants could scroll down the page to credit QL1.1 through QL3.3. We used Quality of Life credits because the case study will likely impact the health and wellbeing of the local community and environment. For example, participants had to explain how their ideas align with the community goals and define the long-term community benefit. Physical safety of the construction workers and community were also addressed. Participants were asked to develop methods to reduce noise, vibration and construction odors. As mentioned earlier, we did not include financial considerations because a cost-benefit analysis was not available this early in project planning and a correlation between a higher infrastructure cost and greater achievement in sustainability could be misleading. For instance, several of the student participants, from the pilot study, suggested reducing the number of lanes, and width of roadway, which would lower re-paving costs and help achieve Quality of Life Credit 2.5. Requiring participants to include detailed financial considerations for these types of decisions, at this point, during upfront planning, would be misaligned with the objective of the study to understand framing effects of the rating system.

After participants finished the rating process, the online software directed them to an online survey. The survey asked whether the framing effects changed their motivation or confidence in their score. Eight survey questions were adapted from previous post-task motivation surveys (Fernet, 2011; Thelk et al., 2009; Watson et al., 1988; Wolf & Smith, 1995). We measured a difference in motivation and confidence by the average scores of the standard and endowed groups. Responses were given on a 5-point anchored scale ranging from "1 – Strongly Disagree" to "5 – Strongly Agree." If survey results indicate the loss frame decreases participant motivation or confidence, the higher reference point may not be a preferred starting point.

Additionally, we asked, in several forms, if the framing influenced their decision. We asked if their strategy was to begin with *improved* and then move to *enhance, superior, and conserving* in that order. We also asked if they were aware how many points they started with before reviewing the credits. Furthermore, we probed for their perception of achievement by asking if they believed meeting *improved* is a big accomplishment and later asking if *conserving* is a big accomplishment.

The training session ended with a group discussion about Envision, and the need for tools like Envision, in the decision making process for infrastructure. The overwhelming sentiment was Envision is a valuable tool. The majority of design engineers who participated said the greatest benefit to Envision is the ability to provide an extra deliverable to the owner. Each credit is categorized and provides supporting justification and reasoning for the designer. Engineers that participated, who function professionally as an owner's representative, or city engineer, viewed Envision as a stakeholder engagement tool. The credits prompt discussions about project outcomes that are sometimes not discussed. Lastly, construction engineers who attended the training seminars said Envision is a service they can facilitate and seemed excited to use the software when alternative contract structures allow them to be involved during project planning.

4.7 Results

The current Envision framework adds points towards sustainability achievement while the modified framework endows users with points to the *conserving* level. The findings suggest participants with the endowed version strive for higher achievement. They achieved, on average (n=32), 66 percent of points compared to the standard group's (n=33) 51 percent. In total, the endowed group averaged 112 points compared to the standard group's 81 points. A t-test indicates that the endowed group score, compared to the standard group, is statistically significant, p=0.002.

The endowed group performed slightly higher in each credit compared to the standard group. The average increase per credit is 2.27 points and the greatest difference of any credit is 4.6 points. Table 1 shows the points possible for each credit, the average endowed score, and the average standard score. The cumulative difference over 12 credits is significant yet the difference per credit is slight. Results for one credit do not distort the averages.

Participants also had to decide which credits were applicable to the project. A *not applicable* credit would reduce the total points possible and increase the total percent achieved. Both groups, on average, chose an equal number of credits as applicable to the project. The total possible applicable points were 181. The endowed group designated 170 points as applicable and the standard group designated 167. These findings indicate both groups believed a relative number of credits, and points, are applicable to the project. The endowed group deemed they could achieve slightly more of these points than the standard group.

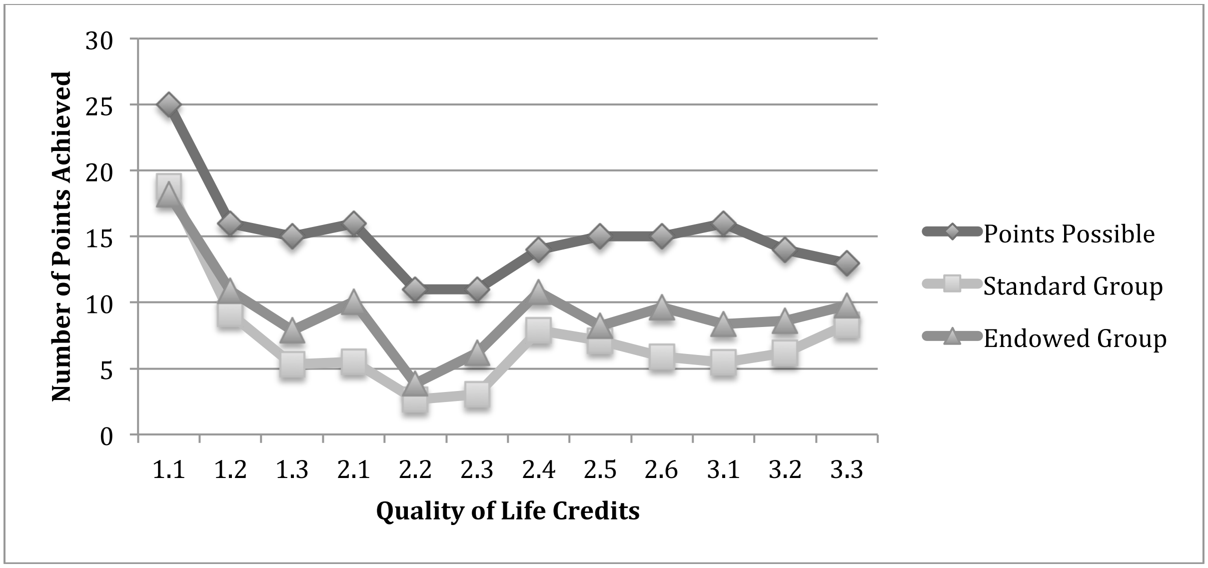


Figure 3: Average Score for Standard and Endowed Groups by Each Credit

The frequency of participants choosing levels of achievement varies with each credit and between the standard and endowed groups. The majority of participants from the endowed group fell within one achievement level. For example, in Table 2, 78 percent of respondents (26 of the 32 participants) set a goal to reach the *conserving* or *restorative* level, to enhance public space. In all twelve credits, the endowed group finds consensus within one level of achievement, shown in Table 2. The standard group, however, varies slightly more. In four of the twelve credits, they could not meet majority within one level of achievement. Their responses are more evenly distributed between levels of achievement. Moreover, the endowed group had more participants in the top two levels, *conserving* and *restorative,* than standard group in all of the credits. Meaning, for each credit, more participants from the endowed group believed they could reach the *conserving* and *restorative* levels than participants from the standard group. The frequency columns in Table 2 highlight the large variability yet higher frequency between groups. More participants with the endowed version achieve the top two levels of the rating system compared to the standard. Anchoring to a higher reference point appears to influence the decision process. Engineers associated with the endowed version achieve more points per credit and as a group they come closer to consensus about what is possible to achieve.

Table 7: Frequency of Participants Choosing Levels of Achievement

Credit QL 3.3: Enhance Public Space					
Level of Achievement	Points	**Standard**		**Endowed**	
		Frequency	% Frequency	Frequency	% Frequency
Restorative	13	13	40.63%	14	42.42%
Conserving	11	6	18.75%	12	36.36%
Superior	6	5	15.63%	1	3.03%
Enhanced	3	0	0.00%	1	3.03%
Improved	1	2	6.25%	0	0.00%
Industry Norm	0	6	18.75%	5	15.15%

In the survey, participants were asked to recall how many points they started with before using the rating system and if they believed this influenced their decision making. The majority of the participants did not believe the starting number of points influenced their decisions. Eleven participants of the thirty-three in the endowed group did believe the starting point influenced their decisions. Yet, only three of the eleven could recall the starting point as 150. The remaining eight either said they could not remember or suggested, what appears, a random value between 20 and 181.

Participant responses varied when asked how they chose to meet levels of achievement. The endowed group slightly disagreed ($\bar{x}$=2.8, 3=neutral) when asked if they began with *improved* and then moved to *enhanced, superior, and conserving* in that order. Where as, the standard group agreed ($\bar{x}$=3.8, 4=agree). Asked directly if scoring at or above the *conserving* level was their main goal, the endowed group agreed ($\bar{x}$=4, 4=agree). Where as, the standard group was more neutral. When we asked if their strategy was to avoid losing points, the endowed group agreed ($\bar{x}$=3.7) and the standard group discernibly disagreed ($\bar{x}$=2.8) because they could not lose points in their version.

Reponses varied when asked to think back to a memorable Envision credit and explain how they decided to meet a level of achievement. Some participants answered broadly, saying they used the guidance manual to identify which level was possible. Some responded with a specific credit. Stating, they started with light pollution because this was a familiar area of work. Two respondents from the standard group stated they began with *improved* and moved up in levels until they did not think the project team could meet anything higher. Four participants from the endowed group directly indicated they tried not to lose points or began with what was given and tried not to move down in levels.

Both groups responded similarly when asked about confidence in their scores and perception of sustainability. The standard ($\bar{x}$=2.4) and endowed group ($\bar{x}$=2.5) indicated not meeting the conserving level of achievement still contributes towards sustainability. Neither group indicated their strategy was to score as many points as possible. Additionally, the standard group agreed they were confident a project team could me their scores ($\bar{x}$=4) and the endowed group slightly agreed ($\bar{x}$=3.3). Table 3 is the frequency table of the participants that agree, or disagree, a project team could achieve their score. Participants appear to make realistic judgments, and tradeoffs, when selecting sustainability credits; sixty-two of the sixty-five participants are neutral or agree a project team could achieve their score.

Table 8: Participants in Agreement a Project Team Could Achieve Their Scores

Interval	Scale	Standard		Endowed	
		Frequency	% Frequency	Frequency	% Frequency
Strongly Disagree	1	0	0.00%	0	0.00%
Disagree	2	0	0.00%	3	10.71%
Neutral	3	5	18.52%	12	42.86%
Agree	4	17	62.96%	7	25.00%
Strongly Agree	5	5	18.52%	6	21.43%

To ensure background experience was not a variable to control for, we asked each participant to list the number of years in work experience directly related to civil engineering. The standard group averaged 10 years of experience and the endowed 8.6 years. Previous studies with experts and novices suggest this difference is not significant (Englich et al., 2006; Northcraft & Neale, 1987). All participants were currently working as engineers for a design firm, an industrial contractor, or employed by a city as civil engineer and participants were randomly assigned the standard or endowed software version.

4.8 Discussion

The standard version of Envision may over emphasize the conventional construction standards as the status quo. Decision makers who try to reject the status quo may perceive these options as more risky and uncertain (Dinner et al., 2010; Fox & Langer, 2005; Brown & Krishna, 2004). Envision rewards points to encourage decision makers to break convention. However, our results indicate that losing points for not meeting a higher standard enables engineers to consider greater achievement in sustainability. The modified version may set a more defined goal for users.

Previous research suggests setting a goal as a reference point can extend motivation to achieve the highest-level outcomes (Heath et al., 1999). The standard group begins with the conventional construction norm likely with less reference for what goals to set. The endowed group begins with a goal to try to keep. Our survey results indicate the reference changed the decision making process. The endowed group reached a consensus of what is achievable and the standard group did not. Furthermore, if the purpose of Envision is to guide infrastructure development to the highest levels of achievement possible, than the shift in frame from gain to possible loss, appears to help users better attain this goal. Even if the goal is never met, raising the reference point is likely to lead to a greater outcome (Jacowitz & Kahneman, 1995; Strack et al.,1988).

With each Quality of Life credit, the endowed group scored slightly above the standard group. Had participants reviewed all five categories, and the scores reflective of the findings from Quality of Life credits, the difference in score between groups may reach 125 points. Such an increase can drastically impact project goals and possible outcomes. A project team aiming for *improved* reduction of heat island effect that now aims for *enhanced* may increase high solar reflective index (SRI) pavement by up to 50 percent on a project. This slight increase in goal setting can creates a noticeable change in project performance. Likewise, the upgrades in achievement may not change project outcomes but rather project procedures and management. Leadership credit 1.1 encourages the project team to move from talking about sustainability in lower levels of achievement to making sustainability a core organizational value. An increase in points may change the process and thinking to arrive at a design decision. Whether conscious, or unconscious, the framing can affect decision making.

If the intervention caused a negative perception of sustainability, or Envision, we would not recommend shifting the reference point to *conserving*. A negative association may create resentment for the rating system and reduce the chance of using the tool in the future. Instead, the endowed group indicated they were happy with the score and both groups believe their score is attainable. The survey responses indicate participants in both groups tried to make realistic mental tradeoffs and likely used previous work experience to guide their decisions. Unrelated to the version participants used, the majority of participants believe meeting *improved* is still a significant achievement for a project.

These findings follow our hypothesis and Kahneman and Tversky's Prospect theory (1979). Engineers make decisions similar to consumers by comparing options in reference to other options. Knowing how to frame decision tools, like Envision, can help improve engineers' decision making. Anchoring engineers to a higher goal can help (Chapman & Johnson, 1999; Galinsky & Mussweiler, 2001). Engineers could benefit from the endowed version of Envision when working with cities like Berkeley, California, who use Envision to prioritize backlogged infrastructure projects. Additionally, the higher goal in the endowed version may enable decision makers to more closely reach consensus. This could benefit infrastructure teams who are each using Envision separately come to a project agreement more quickly. For example the multi-city infrastructure development project Los Angeles – San Diego – San Luis Obispo (LOSSAN) Rail Corridor by setting a higher baseline for future projects.

Those interpreting our results should keep in mind that participants were aware this was a one-time assignment. They volunteered to learn about Envision and are likely already interested in sustainability topics. But, Envision is also a voluntary tool and those using Envision will likely be interested to consider sustainability in their design. Also, our results are based on engineers' individually using the Envision system making tradeoffs between design options. We cannot postulate how the endowed version may influence a team of professionals working together. Or what the effects may be if participants were explained why the decision is framed as a loss. Lastly, our results appear promising, and future research should incorporate complex tradeoffs between design considerations on sustainability including time and budget constraints which effect decision later in project planning phases

4.9 Conclusion

Infrastructure development requires deliberate design in conjunction with key stakeholder input. Understanding how the presentation of options, in relation to others, informs the decision process can assist those developing decision aids, metrics, or project simulations to better inform decision making. Three decades of research in behavior science now enable more accurate predictions of decision outcomes based on the presentation of choices, framing effects, and loss aversion (among many other cognitive biases). In the case of Envision, the objective is to help users meet the highest possible levels of sustainability. The shift from a positive frame (only point gain options) to a positive/negative choice (gain/loss point options) empowered engineers participating in the study to set a higher sustainability goal. The endowed group was more likely to initially consider a higher level of achievement and tried not to lose points compared to the standard group, who tried to earn points. The intervention induced a loss averse response from participants and resulted in an increase in achievement by roughly 15 percent.

Numerous project considerations, and project phases, could have been study but we used Envision because of its ease to manipulate the point scale and ability to quantify a difference in score. Envision provides a defined metric for sustainability and the levels of achievement allowed us to infer how engineers are making decisions in relation to other design options. The findings suggest engineers make tradeoffs between design choices and the *conserving* reference point reframes subsequent decisions. We intentionally isolated project considerations about sustainability to measure the outcome of the framing effect on a single variable, the number of points towards a sustainability goal. This study can serve as a baseline for future research examining how the similar interventions impacts complex tradeoffs later in project phases.

Succeeding iterations could involve modifying the order of questions/points in Envision. So, rather than progressing through the decision making process based on topical ordering of points, as is currently the case in Envision, points could be rearranged within each of the five categories so that those requiring the largest tradeoffs were asked first. A similar approach has shown promise in consumer decisions for car configurations (Levav et al., 2010).

The assertion of value outcomes described by Prospect theory may hold additional advances to inform sustainable infrastructure development decisions. Value outcome states a gain in value closer to the starting point appears greater than value further from the starting point. For instance, winning $200 rather than $100 dollars is more impactful that winning, say, $1200 compared to $1100. The difference is the same however the $100 appears greater relative to the lesser winnings. Similarly, Envision rewards points from the reference point. Changing the scale of points between levels of achievement may influence motivation to achieve more, or less. A score further from the reference point should hold a greater relative difference than points closer to the reference in order to have the same cognitive effect. Future research with Envision could explore a change in the point scale that aligns with value outcome models.

Finally, observing how tools like Envision influence decisions throughout a project could offer new insight into infrastructure delivery and decision making. In cities like Berkeley, the framing effect may change which projects are granted funding. Or, a similar intervention may hold influence on a multiple cities project like the LOSSAN rail corridor. By observing how a change in a rating system, impacts goal setting, and how these goals translate to project outcomes could underscore the larger impact of a relatively small intervention to long term sustainability.

Much research in behavior science can support infrastructure researchers to better understand complex decisions, stakeholder tradeoffs, and the influence of cognitive biases on choice structures. Rating systems like Envision (and EPA's EnergyStar, and the U.S. Green Building Council's LEED) are filled with choice structures. And those framing these and other decisions in the infrastructure development process need to understand how decisions are made, and when appropriate, apply interventions to help guide users towards defined objectives. We assert that choice structures influence how engineers interpret design options, and in turn, affect the design outcome. More interdisciplinary studies are needed to describe how changes in choice structure can aid infrastructure delivery. Further, Each stakeholder includes a diverse array of needs and interests. A complete picture will not emerge until internal and external stakeholders are also examined.

CHAPTER FIVE

CONCLUSION

Strategies for choice architecture and their underlying theory were presented. Potential psychological barriers to decision making during upfront planning for infrastructure was then explored. In chapters three and four, a specific choice architecture intervention to the Envision rating system uncovered how engineers make design decisions. The empirical test with students and professional engineers found that how choices are framed, as a loss rather than a gain in points, significantly influenced decision outcomes. Participants in this study chose to meet higher levels of achievement when more sustainable options were presented first, and achievement towards sustainability was endowed.

Unlike in previous studies about decision making, participants in this study are not consumers but students and professional engineers whose actual decisions will eventually influence physical infrastructure. Changes in choice structure of decision aids for infrastructure appear to affect engineers' decision making. The structure of choices can predict the outcome. Awarding points for slight improvements unintentionally discourages the higher levels of achievement that are possible and the shift to a higher goal reframes the internal questioning process of the decision-maker and subsequently encourages greater achievement.

Additional decision factors may also be at work with Envision and future research should evaluate the cognitive effort required to make a decision and perceptions that the higher endowed score is the new status quo. Results can then be compared to studies with individual consumer decisions to further identify how behavioral science theory and phenomena generalize to upstream decision making about infrastructure and sustainability.

Further, decision making corresponds with behavior. Decisions are made based on ones beliefs and preferences (Gintis, 2006) and these beliefs and preferences can be systematically improved through changes in decision environments. Decision making about infrastructure must consider internal (e.g. perceived risk), external motivation (e.g. financial benefits) and perceived ability (e.g. what is believed as possible). Without studying decisions within the context of behavior change, the framework to improve decisions is limited. Data about covariates including psychometric scales and instruments designed to assess differences among stakeholders (e.g. risk aversion, loss aversion, time discounting) to influence decisions under uncertainty and with time delay are also needed.

In the case of Envision, endowing points reframed the motivation from a potential gain to a potential loss. However, the effect with Envision is unfortunately limited to the decision maker who already possesses the motivation to use Envision and has acquired the ability, and knowledge, to meet higher achievement. In this study, Envision acts as the trigger to consider alternative options, where the endowed version enables more consideration for higher sustainable design. Additional triggers for decision making, beyond Envision, are also needed and likely hold similar possible advances to reduce psychological barriers that limit sustainable outcomes. Triggers for sustainable decision making at each phase of infrastructure should be tested. This includes decision processes during conceptual deign, detailed design, construction, operation, and demolition.

Additionally, many stakeholders, including direct stakeholders (e.g. owners), indirect stakeholders (e.g. investors), and external stakeholders (e.g. planners) all are prominently involved in infrastructure development decisions. As such, these decisions are subject to the varying constraints, goals, and resources of all of these stakeholders, who have different schedules, agendas, mandates, budget cycles, and sources of funding. Decisions should be study empirically but need grounding to the actual context to which they will be applied. Dissemination of results should work towards advancing theories applicable to real world decisions.

To close, the research findings suggest complex decisions about infrastructure are susceptible to systemic biases during decision making. The engineers in this study appear to make decisions relevant to other options. By reframing the Envision rating system engineers were able to consider the higher levels of sustainable performance that are possible. Those framing these and other decisions about infrastructure need to understand how decisions are made, and when appropriate, apply interventions to help guide users towards meeting higher goals.

Training future engineers in such skills as decision making can produce well-rounded problem-solvers; enabling their ability to bridge the boundaries between disciplines and make the connections that will produce deeper insights and lead to more creative solutions. If those who plan, design, and build infrastructure recognize behavioral influences on decisions, they will be better able to manage their own decisions and be more likely to develop the desire and tools to consider how their designs influence users' decisions. The contributions of this research are to better understand how engineers make decisions and, more importantly, to teach engineers how to improve decision process that enable greater achievement in sustainable development.

APPENDIX A: ENVISION WIREFRAMES

Participants in this study were randomly assigned the standard or modified version of Envision. The standard version, shown in Figure 1, begins with 0 points and a total possible score of 181 points for Quality of Life. Participants see first QL1.1: Improve Community Quality of Life. The column titled "Credit Intent and Metric" provides an explanation for how to achieve points for this credit. The details/guidance link within the "Credit Intent and Metric" column directs users to the Envision guidance manual for additional information and requirements to meet levels of achievement. Users can decide if the credit is applicable to the project, or not. Non-applicable credits are subtracted from the total possible score. For example, if credit QL1.1 were not applicable the max score would change from 181 to 156.

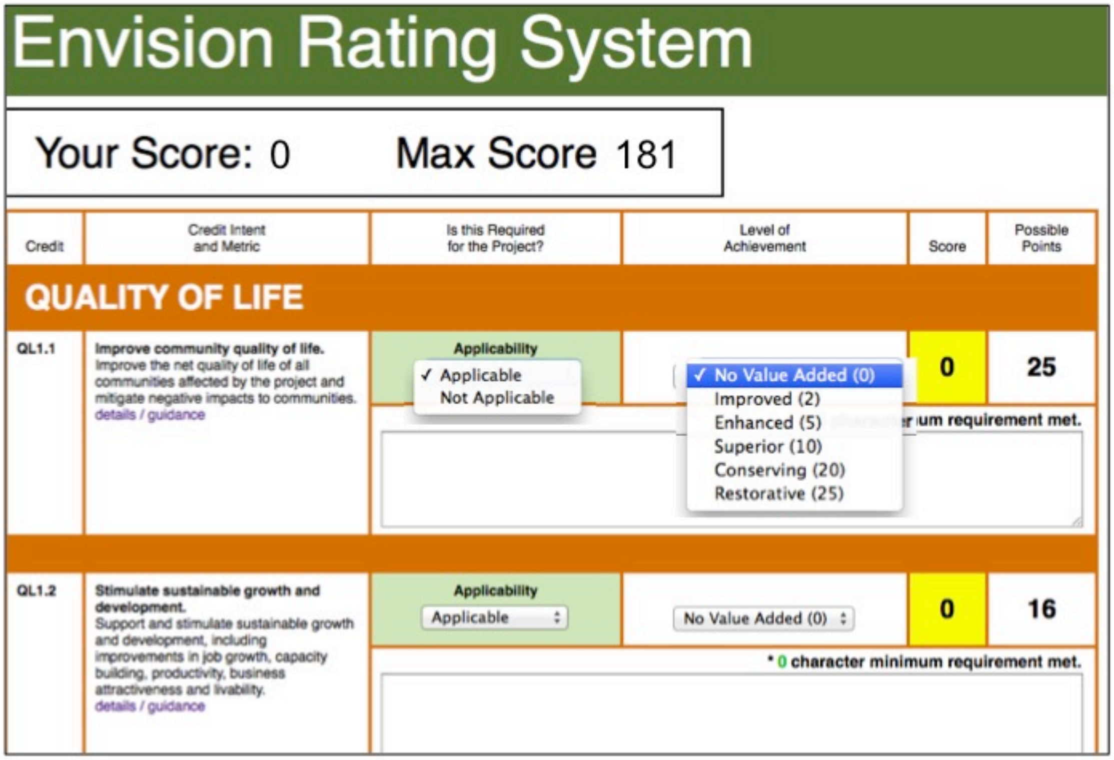


Figure 4: Standard Envision Software

All improvements above construction norms earn users points in the standard version. The drop down menu in Figure 1 shows the level of achievement and number of points for each level. When users select an achievement level, the score appears in the yellow highlighted column to the right of the drop down menu. Achievement at any level requires users to explain how a project team can achieve these points and what documentation is required. Higher level of achievement requires more explanation. If the credit is not applicable the user must explain why. The "character minimum requirement" is listed above the text box. Participants cannot submit the rating system until the character requirement is fulfilled.

The modified version of Envision, which endows users with points to the conserving level of achievement, is shown in Figure 2. Users begin with a current score of 151 points and a max score of 181. To keep these points users, similar to the standard version, must explain how a project team can achieve points to the conserving level and list what documentation is required.

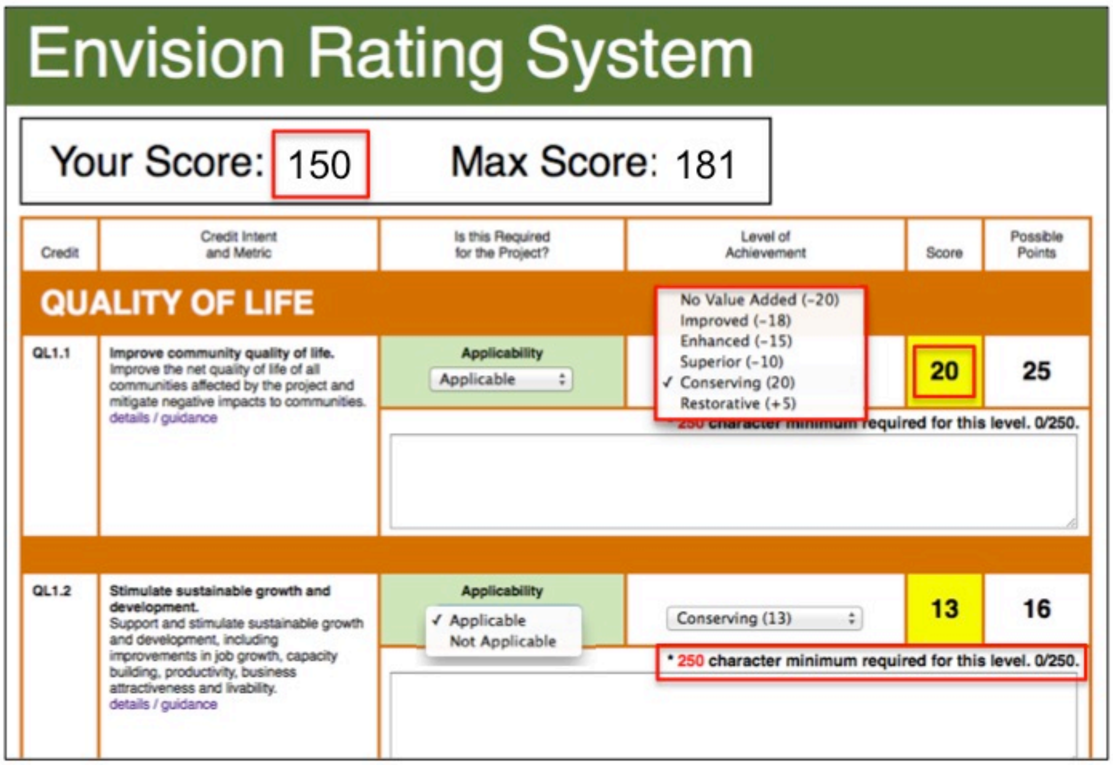


Figure 5: Modified Version of Envision Endowing Users to Conserving

The endowed version is modified in several ways compared to the standard version:

1. "Your Score:" is preset to 150 points – the *conserving* level of achievement.
2. The Level of Achievement drop down menu shows negative points. When selected, these points are subtracted from the default conserving level.

3. The “Score” column is preset to the conserving score for each credit.
4. The character minimum is preset to the conserving level. Users must still explain how they will achieve the conserving level. The default requires users to make a decision and provide an explanation.

These changes appear to significantly influence the decision making process for both civil engineering students and professional engineers. Endowing users with points, anchoring them to a higher level of achievement, reframes the decision as a possible gain to a loss/gain decision.

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