Road Diets and Greenways: Barriers and Strategies for More Innovative Infrastructure

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Abstract

Decision-makers for road and stormwater infrastructure across America are faced with numerous problems that require immediate action. These decision-makers are faced with an option when the time arises to consider alternatives for these infrastructure systems: abide to the status quo solution or attempt a different strategy. Typically, these stakeholders choose solutions that are built to be rebuilt. Roadways and stormwater infrastructure provide two examples of infrastructure that requires constant modification and addition. However, other solutions provide opportunities that go against traditional decision-making and provide an opportunity to transform the surrounding land. Road diets remove lanes instead of building more. Green infrastructure such as river daylighting relies on natural land systems to solve problems. Both solutions share the ability to solve their respective problems while also revitalizing, or transforming the land surrounding them. However, barriers are presented to these solutions, such as scope uncertainty and funding sources. Case study research of the Indianapolis Cultural Trail and the Lick Run Greenway reveals that collaborative planning, goal framing, and unique funding structures are a few examples of overcoming barriers to innovative infrastructure.

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General Audience Abstract

As roadways and stormwater infrastructure across America is placed in an increasingly precarious position, decision-makers are tasked with designing innovative solutions. Typically, the solutions that are drawn up have been used countless times over decades of research. However, in the face of an uncertain climate and population effects, old solutions are less able to solve newer, bigger problems. Innovative infrastructure can not only perform its traditional duties, but also act as an attractor to cities. Road diets, which are projects that *remove* vehicle lanes, and river daylighting, which are projects that unearth piped streams to collect stormwater, are two types of innovative infrastructure. This research utilizes case studies of both to understand their barriers and how to overcome these barriers. The barriers that were found include uncertainty in the scale of the project as well as how to procure funds for the project. To overcome these barriers, a few findings include active community planning through open forums as well as selectively framing information of the projects to highlight their benefits.

Acknowledgement

I want to express my gratitude for Dr. Tripp Shealy. I began my journey into academia with many more questions than answers. Dr. Shealy helped me explore these questions and help me make this contribution to knowledge. My sense of wonder grew through this process. Working with Dr. Shealy helped me appreciate the value of research and heighten my aspirations to become a scholar. Due to his patience, kindness, and work ethic, I was able to complete this Master's thesis. I now plan to continue this journey and pursue my Ph.D. I feel excited that this incredible journey will continue and I am excited about my future growth as a scholar.

I would like to thank my committee members, Dr. Michael Garvin and Dr. Thomas Skuzinski. I have been a student of Dr. Garvin. I admired his wisdom both in and outside of the classroom. Dr. Garvin gave me irreplaceable advice on how to conduct my research that helped shape the direction of this thesis. Dr. Skuzinski's passion for transformative urban spaces and sustainable design and planning helped spark my interest in this research topic. While the mission of my thesis shifted over time, his vision for exploring projects that dramatically and positively changed surrounding spaces encouraged me to pursue this research.

Last, I cannot thank my family enough. My mom, Vicky, has provided me with immense support throughout my life that has shaped me into the young man and aspiring scholar that I am today. My dad, Kevin, taught me to always see the brighter side in times of uncertainty. My siblings, Ben and Jake, have been the best role models that a younger brother could ask for.

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Attribution

This section outlines the contributions made by myself, my committee, research assistants, and colleagues. I was the primary researcher for this project, while Dr. Shealy served as the research expert to guide me through the various phases of conducting interviews while providing feedback along the way. Dr. Skuzinski and Dr. Garvin provided feedback on the nature of my topic and what applications may be the most relevant.

Before data was collected, Dr. Shealy, Dr. Skuzinski, and research assistant Emma Walker helped create interview questions and correspond with interviewees. Furthermore, they created an itinerary and found supporting data on the two projects where stakeholders were interviewed. Collectively, we interviewed the stakeholders as a team.

Data analysis took place throughout Fall 2019. I met with Dr. Shealy remotely to discuss the outcomes of the research. I created all of the major portions of this thesis, but Dr. Shealy's experience, advice, and edits were crucial to submitting this thesis. Furthermore, my colleagues Emma Coleman and Mo Hu gave valuable feedback about my papers. Their comments and edits helped shape the papers. I am very grateful to have them in my professional network.

Thesis Introduction

Infrastructure Problems

Current infrastructure systems are not meeting societal needs. For example, traffic congestion and stormwater issues require innovative design strategies to meet increasing demand with fewer resources and more constraints (Schrank, Eisele, Lomax, & Bak, 2015; Hobbs, Munoz, Kasina, & Ho, 2014). One reason infrastructure systems are inadequately meeting societal needs is because demand for these services are greater today than when these infrastructure systems were designed and constructed. For example, the average age of a bridge in the United States is 43 years old (ASCE, 2017). Forty three years ago, in 1976, the number of cars on roadways annually was 138 million (FHWA, 2019). Today the number of cars on roadways exceeds expected demand totaling nearly 272 million. Similarly, stormwater systems across the country are at capacity, as 19th century planning for stormwater infrastructure is inundated by the effects of a changing climate (Fletcher et al., 2011; Rosenberg et al., 2010).

Infrastructure must adapt to meet societal needs. Infrastructure quality remains stagnant (Arnold & Gibbons, 1996a; Berland et al., 2017) while the growing population and influx of users on infrastructure systems has reduced service capabilities. Infrastructure needs to more quickly adapt to meet growing expectations and changes in service demands (Pyke et al., 2011; Solomon et al., 2007). Infrastructure decision-makers are faced with these growing expectations, and need to develop new infrastructure that accounts for these dynamics – existing and outdated systems, a larger and growing population, and evolving expectations about service expectations and a larger focus on meeting multiple community stakeholders' needs (Heaney & Sansalone, 2013).

Need for Innovative Infrastructure

New roadways, stormwater systems, and other physical infrastructure projects generally rely on taxpayer funding. Cities and municipalities must decide how to invest these funds and increasingly must consider not only which projects will meet the functional objective (e.g., conveying stormwater) but which projects also offer the most benefit for the local economy and simultaneously restore environmental systems. For example, gray infrastructure (such as pipes, curbs, and gutters) maximize conveyance but, unfortunately, can be harmful to ecosystems and surrounding habitats (Berland et al., 2017). Green infrastructure (such as bioswales and rain gardens), when designed appropriately can meet the same functional objectives for reducing stormwater as gray infrastructure systems but also provide additional benefits to the community through biophilic design, reduction in urban heat island, and increased value for surrounding properties (Benedict & McMahon, 2002; Henn & Hoffman, 2013).

Similar to green infrastructure, road diets are unique in their societal benefits and ability to help restore and conserve natural systems. For example, in Seoul, South Korea a highway removal project reduced traffic and provided economic development. Road diets also mend streetscapes to encourage more pedestrian traffic around businesses and promote public health through walkability (Kang & Cervero, 2009).

Both road diets and green infrastructure are unique types of sustainable infrastructure projects because the added value comes from *removing* existing infrastructure systems. Too frequently, engineering solutions jump to physical responses that bid to build society out of challenges inherently rooted in resource constraints (Simonis, 2013). For example, adding a road lane to alleviate traffic congestion brings new drivers, and over time (typically within five years) leads to more traffic and pollution than before (Cervero, 2003; Noland, 2001). Applying the principle of *subtraction* can appear counter intuitive – remove existing infrastructure to yield more efficient systems. This thesis explores two of these types of projects. Projects that uniquely approach infrastructure to meet challenges associated with changing populations and the environment by beginning with what they can remove from the built environment to add value.

Barriers to More Innovative Infrastructure

This thesis explores the barriers and strategies for implementing road diets and green infrastructure. Socio-institutional barriers to green infrastructure have been researched, and a common theme among researchers is the existing path dependence on gray infrastructure (Dhakal & Chevalier, 2017; Matthews et al., 2015a). Path dependence could be underlain by other factors, such as perception of cost, feasibility, and loss aversion. This research explores these numerous barriers in more detail and identifies strategies to overcome them. Similarly, road diets also face socio-institutional barriers. For example, the imperative to build (Berthod, 2013; Hoffman & Henn, 2008). This research investigates barriers such as the imperative to build and others alongside strategies to overcome them.

Summary of Results

The goal of this research was to better understand the barriers to sustainable infrastructure projects and how to overcome these barriers for these types of projects to become more common. Specifically, green infrastructure and road dieting are exemplified as strategies for more sustainable infrastructure. While these are only two examples of a potential plethora of other instances, another goal of this research was to ground the findings through case study research. This research sought to answer the questions and found the outcomes seen in Figure A.

Road Dieting Questions

What factors contribute to project stakeholders' decision to repurpose an existing and functioning road for pedestrian space?

What barriers present themselves during the planning process for transitioning an existing road into pedestrian and bicycling space?

How do project stakeholders overcome these barriers during the planning process?

Road Dieting Outcomes

Local leaders, enhanced connectivity, and surrounding infrastructure upgrades are drivers

Funding, traffic increase, and unwillingness to give up existing infrastructure

Unique funding structure, associating the project with other projects, and framing

Green Infrastructure Questions

What drivers contribute to project stakeholders' decision to choose green infrastructure over gray infrastructure for stormwater planning?

What barriers prevent green infrastructure adoption?

How do project stakeholders overcome barriers to green infrastructure adoption?

Green Infrastructure Outcomes

Social benefits of green infrastructure, modeling, and local leaders' encouragement

Scope, existing infrastructure, and path dependence

Collaborative planning, preventing eminent domain, local stakeholders' buy-in, and framing

Figure A – Questions and outcomes for cases

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Journal Paper 1 - Barriers to a road diet and strategies to overcome them: A case study of the Indianapolis Cultural Trail

Barriers to a road diet and strategies to overcome them: A case study of the Indianapolis Cultural Trail

Abstract

Road diets can improve traffic safety and address throughput issues. This type of road infrastructure improvement has also seen substantial social benefits such as improved pedestrian mobility, increased property values, and boosts local businesses. However, road diets are not generally conceived in transportation decision-making. This paper adds to existing research on overcoming barriers to road diets through an exploratory case study of the Indianapolis Cultural Trail. Funding, the resultant increase of traffic due to the road diet, and loss aversion were witnessed as barriers to this road diet. However, a unique funding structure, associating the trail to other successful projects, and framing were employed to overcome these barriers.

Introduction

Infrastructure needs to adapt to meet changing expectations and service demands (Pyke et al., 2011; Solomon et al., 2007). One example of adapting infrastructure is road diets. Road diets repurpose existing infrastructure, shifting the balance between cars and pedestrians to focus more on pedestrian space than higher speed limits (Norton, 2011). Road diets are often conversions of four-lane roads into two or three lanes with a central turning area, providing more space for pedestrians and cyclists on the sides of the road (FHWA, 2014). The opportunity for road diet adaptation has expanded during the COVID-19 pandemic. Rapid reduction of vehicles on roadways has left streets underutilized and ripe for repurposing (De Vos, 2020). During the COVID-19 pandemic, cities and towns have been closing streets and repurposing outdoor space to expand restaurant seating and pedestrian accommodations. For example, Washington, DC has implemented “streateries” which have repurposed roadway for business and restaurant use (Chang & Miranda-Moreno, 2020).

Road diets can improve safety by reducing vehicle speed, crashes, and injuries (Huang et al., 2002; Pawlovich et al., 2006; Thomas, 2013) and do not negatively affect traffic volume under most circumstances (Huang et al., 2002; Kueper, 2007). Road diets also help repair communities that were disjointed decades ago when oversized roadways were cut through city cores by adding more room for pedestrian space (Kang & Cervero, 2009). Even before COVID-19, road diets were helping accommodate multiple modes of commuter transportation, like cycling and walking (Sierpiński, 2011). Now, in the face of COVID-19, road diets can serve an additional purpose by reducing overcrowding on sidewalks. Road diets are also helping sustain local businesses like restaurants by creating space for outdoor seating as seen in Washington, DC.

Road diets are generally implemented when infrastructure reaches its end of useful life or when infrastructure fails from a natural disaster. For example, after the 1989 earthquake destroyed the Embarcadero Freeway, San Francisco's city council voted to remove it (Garrison & Levinson, 2014). City officials debated its removal for more than 20 years prior to the earthquake but were unable to make a decision to tear it down until the earthquake made the freeway unrepairable (Garrison & Levinson, 2014). Property values around the Embarcadero jumped threefold once it was deconstructed and redevelopment plans were enacted (Cervero et al., 2009). Similar to the Embarcadero, businesses and new development boomed as a result of the removal of the Cheonggyecheon Highway in Seoul, South Korea. The removal of the Cheonggyecheon Highway eased traffic and improved the environment by reducing pollution and the urban heat island effect. Property values around the removed highway increased and people began visiting the daylit river that the highway once covered. The ecosystem also benefited when indigenous aquatic species returned to the river. (Kang & Cervero, 2009; Rao, 2011). The new space became a destination for residents and tourists to visit and use for recreation.

Temporary road diets as a result of the COVID-19 pandemic are becoming more frequent (De Vos, 2020). For example, in May 2020, 34 lane miles were closed or modified in San Francisco to allow for more space for pedestrians to walk and bike while practicing safe social distancing (SFMTA, 2020). However, these short-term closures are not the same as long-term repurposing of roadways and highways. Long-term closures of roads for other types of users are uncommon and can take decades (Congress for the New Urbanism, 2019). For example, during the freeway boom in the 1970's, plans were enacted to build an elevated freeway in Milwaukee. A mile of the elevated freeway had been built when extensions and connections were halted due to local opposition. The open spur of highway remained standing for decades until 2002 when the project was finally decommissioned and replaced with at-grade boulevards. It took more than 30 years to remove one mile of freeway that was never in use. Like the Embarcadero in San Francisco and the Cheonggyecheon in Seoul, the redevelopment in Milwaukee raised property values and spurred new development in the area (*Park East History*, n.d.)

The research presented in this paper explores the early phase decision making that leads planners and engineers to enable road diets. The purpose of the study is to understand the tipping point for these types of infrastructure projects and why they are still infrequent. The background section explains why decision making for roadway infrastructure is not conducive for road diets and outlines potential barriers. The research questions and methods follow the background. The methods outline the steps of the case study. Case study research was used to explore the barriers and enablers to a road diet in one U.S. Midwest city. The results and discussion describe the impetus of a road diet project and barriers that others trying to pursue similar types of infrastructure repurposing projects may have to confront and overcome.

Background

Decision making for transportation infrastructure involves many stakeholders and extensive planning. Project planning is typically spearheaded by state or local governments and is sometimes funded in part by the federal government. Metropolitan Planning Organizations are also critically involved with the planning process to guide localities in the decision-making process ("What Is a COG or MPO?," n.d.). In addition to coordination of multiple stakeholder interests, transportation decisions for building new roadways rely heavily on population growth. For example, Glover and Simon (1975) discuss the correlation between population growth, road availability, and new road construction, which has led to increased funding for road transportation projects (Daniels, 2001).

The process to approve and build new roadways can be long, coupled with many checks and balances between federal, state, and local organizations (Pedersen, 1999). These checks and balances serve to provide safe roads, but can also deter repurposing of roads in the future (Cervero et al., 2009). Once roadways are in place, there is little incentive to repeat the planning process to remove or repurpose them in the future (Hunt et al., 2002). The status quo is to leave roadways in place, often without revisiting their purpose despite shifts in transportation mode, community needs, or societal work patterns (Fraser & Chester, 2016).

Federal, state, and local transportation decision-makers may also deter road diet construction because it does not favor vehicle mobility. Decision-makers often focus on vehicle mobility rather than surrounding livability improvements that road diets can provide (Cervero et al., 2009). Vehicle lanes and accessibility to major highways encourages more high speed traffic but may contribute to poor accessibility within cities (Sultana & Weber, 2007). Transportation engineers are heavily focused on vehicular traffic, not necessarily neighborhood design or community cohesion (Schroeder et al., 2010).

Models and forecasts about the effects of road diets are not always accurate, which can contribute to transportation engineers' resistance to this infrastructure adjustment (Henn & Hoffman, 2013). For example, in Dresden, Germany, transportation engineers incorrectly predicted increases in traffic congestion if roads were not expanded and bridges were built within the city (Henn & Hoffman, 2013). Their predictions were inaccurate because they failed to account for human behavior. As traffic worsened, drivers switched from driving to other transportation methods, which lessened the overall traffic.

On the surface, projects like road diets can seem counter-intuitive since lanes are removed (Saak, 2007). Shrinking roadways can actually lead to traffic calming instead of traffic increase (Hymel et al., 2010a; Lee et al., 1999). Expanding roadways often brings new drivers, and typically leads to increased traffic and pollution within five years (Cervero, 2003; Noland, 2001). Despite the negative results, Atlanta is currently spending $10.8 billion dollars on roadway expansion for I-75, contributing to the imperative to build for cities (Simmons, 2016). Challenging the imperative to build goes against the Landscape Architecture Firm even though it can lead to negative effects on our cities and the environment (Henn & Hoffman, 2013).

Opposition to removing roadway is common. Removing existing roadway or parking spaces can provoke loss aversion (Shoup, 2011). The fear of losing an existing asset, like a roadway or a parking space, can outweigh the potential unknown gains from its removal. Often these fears of loss in service are unwarranted because travel patterns are largely unaffected for average daily traffic counts under 25,000 vehicles per day, besides becoming safer due to lowered speeds (Billings et al., 2013; FHWA, 2014).

Case studies on road diets and freeway removal projects provide insight on how cities can overcome barriers to repurpose existing infrastructure that better meets community needs (Napolitan & Zegras, 2008). Previous research suggests decision makers must recognize road diets will increase economic development in their city more than the level of mobility provided by the existing roadway. Economic development comes in the form of livability improvements by making areas more walkable and bikeable (FHWA, 2014). Seattle, multiple cities in Michigan, and Chicago have conducted feasibility studies for road diets, with each city approaching the design solution differently. However, decision-makers in these cities value other assets beyond the roadway itself, which has led these decision-makers to consider a road diet (Napolitan & Zegras, 2008). Research also suggests that an opportunity must arrive for decision makers to consider road dieting, like a structural failure of the existing roadway, or reaching the end of useful life (Napolitan & Zegras, 2008).

The previous studies about road diets do not explain how to overcome the barriers related to cost and risks. They also do not explain how decision makers navigate the decision to implement a road diet. More insight is needed to understand the tipping points for implementation of road diets as innovative infrastructure. How do you get decision makers to recognize the economic value from repurposing an existing roadway into a pedestrian zone? Which decision makers (elected officials, planners, community groups) need to value things like street quality or community connectiveness? Rather than waiting for an existing road to reach its end of useful life or for a natural disaster to occur how can stakeholders create opportunities for this type of decision? The research questions below begin to address these types of questions.

Research Questions
The objectives of the research presented in this paper are to explore: 1) how infrastructure stakeholders make the decision to repurpose an existing road, 2) the barriers that prevent these types of decisions from occurring, and 3) the strategies to overcome the barriers. Since this research is exploratory, propositions were formed after data analysis, connecting to grounded theory by developing theory from physical data (Strauss & Corbin, 1994).

The first research question is (Q1) *what factors contribute to project stakeholders' decision to repurpose an existing and functioning road to pedestrian and bicycling space?*

Research question two is (Q2) *what barriers present themselves during the planning process for transitioning an existing roadway into pedestrian and bicycling space?*

Research question three is (Q3) *how do project stakeholders overcome barriers during the planning process to transition an existing roadway into pedestrian and bicycling space?*

Methods
A single longitudinal case study was used to answer the research questions (Yin, 2013). The scope of the case being evaluated is during the planning stages from idea conception to plan adoption. Case study research is an appropriate approach to answer the research questions because of the focus on an emergent phenomenon that cannot be controlled or manipulated. Case study research is also appropriate because the research attempts to answer "what" and "how" questions (Creswell & Poth, 2018 ; Yin, 2013).

The case study was developed in three phases. The case study development was reviewed and approved by Virginia Tech's Institutional Review Board. Phase 1 identified potential case projects through archival research and developed interview questions for key decision makers. Phase 2, included a site visit and interviews with key decision makers associated with the case and collection of archival data. Phase 3 involved transcribing and coding the interviews and aligning the codes to the research questions.

Phase 1 – Case selection, unit of analysis, and interview questions

The case is the Indianapolis Cultural Trail (ICT) in Indianapolis, Indiana. This case was chosen because of the prominent road diet implemented by the city, access to city archival data, such as the Impact Assessment of the Indianapolis Cultural Trail (2015), and access to stakeholders. Furthermore, this case highlights the complexities of decision-making for road diets through its funding structure. Unlike road expansion projects funded by fuel taxes or tolls, the ICT was funded entirely by private donations and federal grant money. In other words, this high visibility public project was funded at no expense to tax-payers. The unique funding structure allowed the research team to understand its effect on stakeholder decision-making and various factors such as perceived risk and perceived economic value for the city. More details about the case are provided in the subsection titled Case Description.

Validity considerations

Four measures of validity were used for the case study (Burke, 1997; Taylor et al., 2010) including construct validity, internal validity, external validity, and theoretical validity. Construct validity was achieved by providing the interview questions to the interviewees before the interview. Internal validity was achieved by matching responses among the various stakeholders with archived data. External validity was pursued by connecting the findings from the stakeholders to existing work about the effects of framing in other engineering and management research. The theoretical framework that enabled external validity is grounded in prospect theory and framing effects (Shealy et al., 2016). Theoretical validity was further met by using data sources and findings from the stakeholders to draw conclusions, as well as pattern matching, which helped verify that the pre-study propositions resemble the findings of the study.

Unit of analysis

The unit of analysis was the planning phase of the ICT. The directional milestones of the information collected included: perceived problems with existing infrastructure, the main design propositions of the proposed design solution, perceived impacts and motivators of the design in the lens of each type of stakeholder, barriers to implementing the design.

Interview questions

Interview questions were developed for various stakeholder groups, including the local planner, engineer, design consultants, and lead community group. The interview questions are available in the appendix. Responses to interview questions 1 – 4 were used to answer research question one. Responses to interview questions 4 – 8 were used to answer research question two and responses to interview questions 8 – 12 were used to answer research question three. The following subsection describes the case in more detail.

Case Description

In 2001, six neighborhoods were proposed by the Indianapolis Cultural Development Commission as cultural districts to commemorate the uniqueness of the city. Indianapolis recognized its cultural districts as assets for the city, but these districts lacked connectivity (Hoppe, 2013). This lack of connectivity created community dead spaces attributed to the layout of roadways which kept major portions of the city dissociated from its neighbors. To address this perceived disconnect, the ICT instituted redevelopment projects from 2007 to 2012. The mission of the project was to remove extra lane space and business-side parking to allot space for a mixed-use pedestrian and bicyclist raised sidewalk. The final product was the Monon Trail, an 8-mile path connecting the cultural districts of Indianapolis, including the Wholesale District, Indiana Avenue, the Canal and White River State Park, Mass Ave, Fountain Square, and Broad Ripple Village (Majors & Burow, 2015).

The Monon Trail served as the inspiration for the project champion to propose the idea of the Indianapolis Cultural Trail (ICT). The Monon Trail is as a mixed-use path for pedestrians and bicyclists to commute into and out of downtown Indianapolis. The project champion's idea was to incorporate the best facets of the Monon Trail into downtown Indianapolis. In other words, the ICT could take the Monon's acclaim for being a multiuse trail that encourages mobility outside of the city center *inward* to the cultural districts.

Connectivity was thought to fix other problems beyond community dead spaces. For example, Indianapolis was levied a consent decree by the EPA for combined sewer overflows, which is a federal mandate placed on cities to eliminate these harmful pollutants from surface water. While a large gray infrastructure project was conceived to handle this, a series of rain gardens along the trail was thought to help with runoff volume and quality. Furthermore, obesity rates in Indianapolis at the time of the trail's conception were ranked as eighth worst in the nation (Mackenzie, 2020). The project champion hoped increasing connectivity in downtown Indianapolis would encourage locals to walk and cycle more frequently for transportation and exercise.

However, the project champion needed funding to implement his vision of a connected downtown Indianapolis. The project champion raised $27.5 million through private and philanthropic measures. Gene and Marilyn Glick were the largest individual donors and requested that the idea of peace be embedded into the purpose of the trail. While the project champion's mission was to create the trail for connection of the cultural districts, a "Peace Walk" was made along the trail according to the Glick's request. The "Peace Walk" commemorates figures that contributed to humanity on noble terms, including Susan B. Anthony, Martin Luther King, Jr., and Thomas Edison.

The construction of the ICT was interrupted due to the economic recession. However, the federal TIGER (Transportation Investment Generating Economic Recovery) grant was instituted in 2010 providing $20.5 million for the project (Indianapolis Press Release, 2010). This grant provided over half of the $35.5 million in federal dollars allocated to the project. The grant was awarded under the assumption that the project would help create $800 million dollars of value through new construction and private sector investment. Since the ribbon-cutting in 2013, over $1 billion has been invested in downtown Indianapolis. Figure 1 provides an illustration of the ICT and plan view of the cultural districts the ICT connects.

Figure 1 – Picture of the ICT and plan view with cultural district locations

Institutional Characteristics of Roadway Decision-makers in Indiana

Transportation planning and development in Indiana is led by the Indiana Department of Transportation (INDOT). Some of INDOT's many responsibilities include forecasting future transportation needs, proposing improvement strategies, coordinating capital investment with metropolitan planning organizations (MPOs) and regional planning organizations, and performing statewide bike and pedestrian transportation planning (INDOT, 2020b). A statewide requirement for INDOT is to develop and operate intermodal transportation systems, including accessible walkways and bicycle routes (INDOT, 2020a). Beyond vehicular safety and accessibility, a federal requirement for INDOT is to enhance connectivity among modes of transportation throughout the state that improves the overall quality of life.

INDOT partners with the 14 MPOs of Indianapolis. MPOs are a federal requirement from the Federal Aid Highway Act of 1962, which require MPOs to act as caretakers of federal dollars to ensure funding for transportation projects are based on a continuing, cooperative, and comprehensive planning process. MPOs also help coordinate long-term and short-term planning for transportation projects. A 20-year Metropolitan Transportation Plan serves as the basis for selection of transportation improvement projects. For the short-term, a 4-year Transportation Improvement Program prioritizes projects that fit inside of the 20-year goal (INDOT, 2014).

Funding that MPOs receive for transportation improvement projects are split between projects for all of Indiana and for local improvements. Indiana's statewide projects take a 75% share of the available funds, leaving the remaining 25% to local agencies. A sharing agreement is provided to split up these percentages among the 14 MPOs, with contingencies depending on the project's purpose. For example, surface transportation project funding is split by cities' populations. If a local planning agency receives federal funding for a project or improvement, a requirement is placed on localities to raise at least 20% of the project cost (INDOT, 2012).

Funding that Indiana's MPOs need for road improvements surpass what is available. In 2012, the projected cost for road improvements from by 2025 was estimated to be over $10 billion. By 2025, available federal funds for these projects in Indiana were estimated to be nearly $1.5 billion. For Indianapolis' MPO alone, over $2 billion funding shortfall is projected by 2025 (Indiana MPO Council, 2012). While elected officials for Indiana's MPOs suggest strategies to bridge the funding gap such as better payment programs, earmarking funding from the MPO presents difficulties since many upgrades are deemed necessary by 2025.

Each year, Indiana's MPOs revise their planning emphasis areas. These emphasis areas identify the categories of projects that will be given access to federal funding. For example, two emphasis areas placed for Indiana during 2021 include traffic incident management and local road safety plans (US DOT, 2020). INDOT, FHWA, and all MPOs in Indiana cooperate to create these emphasis areas to coordinate projects that connect to the long-term plan issued by the MPOs.

From 2000-2010, non-motorized accessibility to trails became a priority for INDOT. In 2003, INDOT's 25-year plan was amended, including the mission to have more walkable and bikeable trails (INDOT, 2003). By 2006, Indiana's Department of Natural Resources created the initiative, "Hoosiers on the Move", to set a goal that for all Indiana residents to have a public trail within 7.5 miles, or 15 minutes, of their homes by 2016 (INDOT, 2020a). As a result of this, hundreds of miles of trail were established, including the Indianapolis Cultural Trail.

Phase 2 – Interviews and Site Visits

Participants were selected for interviews based on their knowledge of the case. Visits were coordinated to obtain in-person interviews. Table 1 provides a list of interviewees. The Consultant worked for an Indianapolis-native firm, which mapped utilities, control points, changes in earthwork, and roadway redesign. The Consultant provided insight into the modelling decisions that had to be made for the project. As project manager, the Project Manager revealed the complexities of repurposing the existing roadway for the trail. The Engineer was the traffic engineering representing the Public Works department. He made projections and provided traffic studies about the effect of removing the existing lane on traffic patterns. The Outreach Lead explained how he managed to influence stakeholders to buy-into the project. The Designer helped with the design of the ICT. His interview provided insight for the motivation of the trail and explains the tipping point for the project getting approval. The Project Champion represented a local NGO. He explained in his interview about his vision for the trail, how he helped gain support for the project, and what it means now for Indianapolis.

Table 1 – ICT stakeholders that were interviewed

Position	**Organization Type**	**Role**
Consultant	Local Indianapolis Consulting Firm	Advised the project team with design considerations
Project Manager	Public Works	Oversaw the construction of the ICT
Engineer	Public Works	Developed traffic models
Outreach Lead	Consultant	Performed an awareness campaign around the ICT's area of influence
Designer	Design Firm	Led the design effort for the ICT
Project Champion	NGO	Envisioned and commissioned the ICT

Every interview started with a description of the scope of the research, the objectives of the research, and the use of the findings. It continued with an explanation of the interview process. The length of the interview depended on the role of the interviewee but averaged around 60 minutes. The semi-structured interview questions are provided in the appendix. Since the interviews were semi-structured, this added to the research by explaining the relationships and decisions made on the project (Yin 2018).

Before and after interviews with the stakeholders, site visits were conducted to observe and walk the ICT. One interviewee, the Designer, directed a site visit on the cultural trail and discussed the changing landscape as a result of the trail. Overall, the site visits provided supplementary information to gauge traffic patterns, user interaction, and wayfinding.

Field notes and archival data

Secondary data collection of archival data allowed for research triangulation to strengthen the conclusions of the study (Taylor et al., 2010). The secondary data includes design drawings and documentation provided by the interviewees and an impact assessment created by Indiana University Public Policy Institute. The impact assessment provides data on the background of the trail, user responses, local business owner responses, changes in property values, and financial assessments of the trail.

Field notes were taken alongside the coded, transcribed interviews for record-keeping and extra data collection. The field notes were compared with the transcriptions and compiled after the interviews were completed.

Phase 3 – Transcription and coding

The semi-structured interview recordings and annotations were transcribed and coded using Miles et al., (2014) coding protocol. Interviews were transcribed using nVivo software. A two-step coding method was used to analyze the transcripts for each case (Miles et al., 2014). The transcripts were themed into chunks of data first, and then these chunks of data were coded into subsets, searching for commonalities or relationships. For example, community engagement was alluded to several times throughout the interviews. First, the type of engagement would be themed more precisely, such as “brown-bag lunch”, “charrette”, and “door-to-door”. Then, these were attached to the broader code “community engagement”. Additionally, an organized registration of all the processes including the protocols and the data, as well as the field notes and self-reflections of the cases was kept to show reliability of the findings (Taylor et al., 2010).

Each interview question corresponded with one of three research questions, so the results were tabulated into three subcategories. Results are presented by research question.

Results

Factors that contribute to project stakeholders' decision to repurpose an existing roadway

Local leaders outside of government that championed the project were a major factor for road diet implementation. The Project Champion alluded that if he had training as a civil engineer, he would not have envisioned the ICT because of the mass overhaul of infrastructure required. This project was completed because the Project Champion acted as a visionary before focusing on the problems that engineers and government officials must consider. His persistence toward discussing traffic and funding options for the trail with elected and non-elected stakeholders sparked life into the project. The Outreach Lead, the Project Manager, and the Engineer all commented on the Project Champion's involvement in the project. The Project Manager stated that, "once you talk to [the Project Champion], you'll know", referring to the Project Champion's ability to sell the project. The Project Manager described that the Project Champion's passion for the project classified him as the pivotal leader the project needed.

The Project Champion addressed traffic and funding concerns by advocating for increased connectivity and revitalization of the area. A feasibility study was conducted early on before a plan for the trail was finalized that accompanied a small charette process, which eventually got the mayor to approve the project. While this study was not part of the Project Champion's original pitch, the study helped him "sell" the project as one with opportunity to reverse residents leaving downtown. He claimed the project would be, "a completely new idea for bringing opportunity". Opportunity was felt in several ways, including exercise, sightseeing, and shopping. Arguably, the most stark difference between 2008 and 2014 was the 148% increase in value of the 1,747 assessed properties, resulting in over a $1 billion increase in property value (Majors & Burow, 2015). Construction of apartment complexes and businesses around the trail rebranded downtown Indianapolis as a "livable" city. The Project Champion reflected that this was due to enhanced pedestrian connectivity.

The potential for enhanced connectivity increased stakeholders' willingness to pursue the road diet project. During the planning process, the Project Champion polled local residents of Indianapolis, on their perception of distance between desired destinations. The responses from Indianapolis residents ranged from 6-10 miles when the actual distance was 1.5 miles. The Project Champion interpreted these results as, "an ugly journey is a long journey", meaning that a route without pedestrian accommodation felt much further. To gain support for repurposing the existing roadway, he highlighted these poll results when advocating to elected officials. He also shared ideas for public art exhibits, better lighting, and designated pedestrian space as staple design elements for the trail (Majors & Burow, 2015). The Project Champion was able to "sell" the idea of pedestrian space by explaining how it would increase foot traffic downtown and translate to increased spending, local business support, and tax revenue.

A third factor that contributed to repurposing the roadway was the opportunity to improve surrounding infrastructure without local government funds. The Designer and the Project Champion explained that the project team was required to revamp surrounding sidewalks to be compliant with the Americans with Disabilities Act (ADA). As a result of these upgrades, the Project Champion explained that the local mayor would celebrate the project if done correctly, saying, "there is no risk as long as he [the mayor] is not putting money into it", especially when the city gets new and improved infrastructure. The Project Manager and the Outreach Lead both gave affirmation to this idea, stating that the real pitch of the trail to the mayor and city council was the surrounding infrastructure upgrades that the city would not have to pay for. Ultimately, upgrading surrounding infrastructure had to be factored into the budget of the ICT by private donations and federal grants.

Improvement to surrounding infrastructure as a result of the ICT came to Indianapolis' stormwater infrastructure as well. Indianapolis was faced with a federal mandate from the EPA to eliminate combined sewer overflow volume known as a consent decree. To overcome this, the design team, the design firm sketched in a series of rain gardens along the trail to act as natural filters to remove limited volume and to pre-treat contaminated runoff from the street. The rain gardens added a natural element to an urban setting and helped solve combined sewer overflow.

Barriers during the planning process to repurposing the existing roadway

Funding was the primary barrier among stakeholders for road diet and ICT. When initially estimated, the project team found that repurposing the existing roadway would cost $25 million. Over 9 years, the project went through several price jumps and ultimately cost $63 million by 2010 (Figure 2). The Project Champion noted that if the original price would have been $63M instead of $35M, the project likely would not have gained local support or private investment. The Project Champion stated, "the city was not going to take money from their budget to pay for the ICT project", referring to the city's public funds and the project's private funds. The Project Champion did note that the city had access to federal grant money that could be earmarked for the ICT. The project was completely funded through private donations and a federal grant. The Consultant noted that the project was, "stop or start based on funding". The TIGER grant that supplied federal funding for the project kept the project alive alongside private donations. Over half of the funding came from federal grant dollars, and the TIGER grant injected $20.5 million to keep the project alive. The TIGER grant was awarded to transportation projects with anticipated positive economic impact in light of the recession. The Designer reflected that the trail was the main reason Indianapolis faced a duller hit from the recession because it created construction jobs and spurred developer investment downtown.

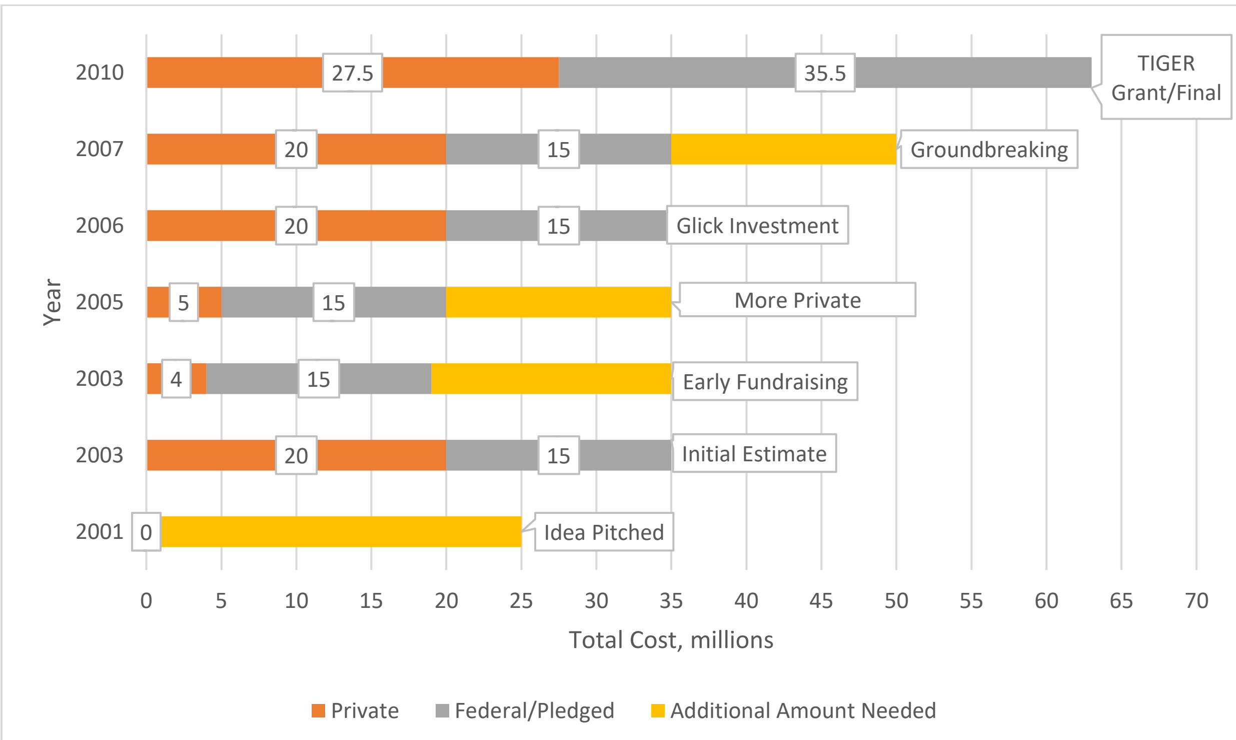

Figure 2 – Major project cost hurdles for the ICT.

The perceived increase in traffic was also a major barrier. The Outreach Lead, the Project Manager, and the Engineer voiced local business owners and motorists' concern about the increase of people downtown and at the same time removal of parking spaces and road lanes from the project. The project appeared counterintuitive to some residents and business owners. The same project that was going to attract more people downtown, would make downtown potentially more congested (with less parking and less vehicle lanes). The Project Manager said stakeholders complained to both city council and the mayor's office, saying they were skeptical about "how is this going to work with the population coming back downtown", referring to the increase in local residents as a result of the road diet and walking path but at the same time less parking and fewer road lanes for them to use. The Engineer provided input that "there was a conscious decision that there was going to be a delay for motorists … maybe somebody [adds] 20 seconds to their trip". However, the Engineer noted eventually, enough stakeholders felt that this decrease in "level of service" was worth the end product of the trail and potential economic development.

Another barrier was *local business owners that were unwilling to have adjacent parking spaces removed* for the Cultural Trail. Local business owners were hesitant to "give away" parking spaces in front of their store. The Outreach Lead described their robust door-to-door campaign. The purpose of the campaign was to provide local business owners with information about the trail and its future positive effects on business. The Outreach Lead's involvement with the outreach consulting firm and their communicative skillset enabled the team members from the outreach consulting firm to talk to stakeholders directly and hear their concerns. Some of these stakeholders, as the Outreach Lead suggested, were still reluctant about the project because of the inherent value of having parking directly outside-the-door. The Outreach Lead said business owners fixated on the imminent loss of parking. Business owners were less likely to talk about the future business opportunity that less parking and more pedestrian space would provide. Ultimately, they were not able to convince all of the business owners, but enough of them were willing to move forward with the project for the city to continue to the design phase. The Project Champion explained that it was not until foot traffic increased after project construction that the remaining reluctant business owners saw the value of the larger sidewalk and cycling path and the benefit it provided over on-street parallel parking. Business owners stated that they looked forward to what the future held after the trail was built with more foot and bicycle traffic in front of their stores (Majors & Burow, 2015).

Motorists in Indianapolis also expressed their unwillingness to give up the higher speed limit and extra road lane, which would allow for more vehicles. The Project Champion mentioned that the perception among citizens was out-of-town motorists who were visiting Indianapolis valued the ability to go 55 miles per hour downtown to get in and out of the city. The reduction in road lanes, addition of sidewalks, and a cycling lane was accompanied by a slower speed limit through downtown. The Project Champion recognized that this was for the greater good of the city because livability would increase but needed motorists to also recognize these benefits and not complain to the city about the project's proposed changes. The Outreach Lead stated that ultimately motorists would have to experience the changes to the roadway and see for themselves that the perceived problem of increased traffic and slower speeds was a net positive for the city. The 20 seconds of added travel time that the Engineer discussed was seen among decision makers as an acceptable tradeoff for the benefits that would be generated from the project.

Strategies to overcome the barriers during the planning process of the road diet

A unique funding structure overcame the difficulties that funding provided the project. Funds were not taken from local taxpayers in Indianapolis which was critical for local decision makers consideration of the road diet. The Project Champion shared that the mayor could not provide taxpayer funds for the project due to concerns of political backlash. The mayor was concerned that funding the road diet would be perceived as wasteful, especially when other issues in the city such as homelessness, food scarcity, and poverty were prevalent. The mayor believed shifting funds to transportation projects would be negatively viewed and potentially exploited by his political opponents. The initial private funding organized by the Project Champion demonstrated to the city and the mayor that local financial donors supported this project.

The unique funding structure reduced perceptions of risk among stakeholders. The Project Champion recalled the reluctance of the mayor when the trail was first pitched, stating that the project would not have been approved if the city had to contribute any of its own money. Originally, when the project was thought to be $35 million, The Project Champion approached the mayor and said that if the mayor can get federal matching to back $20 million, The Project Champion could raise $15 million. This enticed the mayor, and after two separate feasibility studies, the mayor ultimately agreed to pursue federal funding to match private dollars. The Project Champion felt that the mayor was reluctant to place any of Indianapolis' public funds into the project between 2005-2007 because fundraising for future capital improvement projects would be made more difficult. At the time, The Project Champion explained, the mayor believed raising new funds, or shifting existing funds, would be increasingly more challenging in the future if tax payers believed Indianapolis sank money into a, "silly bike trail".

Another strategy to gain approval for the road diet was *drawing associations between the project and other existing successful projects.* The Project Champion alluded to the existing Monon Trail as the precursor for the ICT. The Project Champion said, "by having a 'Monon' within the cultural districts [the ICT], businesses would be connected to customers". The Project Champion's comparison to the Monon was substantial in his pitch to get over 100 stakeholders, including potential donors, local government, and businesspeople on board with the project before pitching the idea to the mayor. Other interviewees, the Outreach Lead and the Designer, also verified this by stating that suburban Indianapolis families would be more likely to venture into the city as a result of the trail's creation. The Project Manager provided additional input on the ICT's predecessor, inferring that the ICT needed to be just as efficient as the Monon Trail for Indianapolis to host Super Bowl XLVI.

Framing the attributes of the project about the benefits of ICT rather than the loss of the roadway or on-street parking encouraged local businessowners to accept the Cultural Trail. The Project Manager stated that he would tell business owners that more customers "would frequent your business along the trail." He would tell them, "when you put anything in the right-of-way it's going to get hit". In other words, the road diet would create more space for their signs and a safer environment for pedestrians. A common saying on the project that the Project Manager and the Project Champion both affirmed was that their location would be like "beach front property". Customers would have more mobility to walk adjacent to their business. The Project Champion commented that the connectivity of the trail would join districts of the inner city of Indianapolis, potentially making businesses boom. The business owners tended to agree. One business owner expressed enthusiasm for the revamped, safe nightlife in downtown Indianapolis (Majors & Burow, 2015).

Furthermore, an "outreach team" of ICT enthusiasts (composed of outreach consultants, spearheaded by the Outreach Lead as the lead consultant) went door-to-door talking with business owners, property owners, and building managers to emphasize the benefits of the ICT. The Outreach Lead recounted that going door-to-door to businesses was the most effective strategy to explain the impacts of the road diet and the trail. The Outreach Lead described one if his roles on the project was to help refocus the conversation about future business gains rather than business owners fixating on the losses in on-street parking. The Outreach Lead recalled that when he went door-to-door, he "would look for building managers", because, "they know everything and they have most of the power" and you would meet the "unofficial mayor" of that part of town. By singling out these individuals, The Outreach Lead recalled that the benefits of the trail would be communicated most effectively because these individuals would understand the land and the surrounding environment better than a business owner renting space in the building.

Framing information in terms of benefits for motorists helped motorists focus on the gains in safety and livability as opposed to traffic delays. The Consultant stated that concerns about more narrow road lanes was framed as a negative outcome for not implementing the road diet. The Consultant said, city engineers helped change the discussion by talking about how “keeping the wide lanes would negatively impact motorists since weaving and changing lanes could reduce capacity efficiency”. In other words, the wide lanes enticed the wrong driver behavior and reduced safety. The Project Champion agreed, stating, “our streets are too wide to make it good for people”, bringing up the safety component. All of the proponents for the road diet and trail focused on the added benefits rather than the negative effects of the changes. The Engineer stated that Indianapolis was required to keep a D level of service, and that increased size of walking and cycling space would not be compromised, at the expense of the driver. However, the Engineer noted that the Department of Public Works felt that this project contributed to a greater good. While trip time for motorists would increase, the general public would receive the benefits of a multiuse trail.

Discussion

Factors that contribute to project stakeholders’ decision to repurpose an existing roadway

Local leaders outside of government were essential to repurposing the roadway. The Project Champion, the main leader of the ICT, acted as a visionary of the project by overcoming institutional barriers that encourage road building as opposed to road dieting. This aligns with

Nam and Tatum's (1997) finding that says a local leader with sufficient community power is needed to influence change. These leaders first influence change primarily by selling their vision to donors and external agencies (Gorelick et al., 2020). After the vision of the project is communicated to donors, local leaders are better equipped to leading public engagement activities that proclaim a mutual desired outcome for the project (Slotterback, 2010).

What if a locality that wants innovative infrastructure does not have a central project champion? Technical innovation in the construction sector is typically driven by a project champion (Nam & Tatum, 1997), but this does not have to be a leader outside of government such as The Project Champion. For more traditional projects, governmental checks and balances push roadway projects to completion (Pedersen, n.d.). The government can also act as the project champion for more innovative projects as well (Caerteling et al., 2009). Network governance provides an opportunity for government to coordinate private sector innovation while acting as a central decision-maker (Miozzo & Dewick, 2002; Rose & Manley, 2012). While this has been used in Europe and Australia, this is like a public-private partnership (P3) in America, which combines federal funding and ownership with private design power. Network governance and public-private partnerships can both encourage risk-sharing for innovative projects.

However, P3's are typically used for creating new roadway, not for road dieting. On a global scale, P3's have been used to fund billions of dollars in infrastructure improvements on a pay-to-use basis (Zou et al., n.d.), but traditionally have not funded the removal of roadway for surrounding livability improvements. Success for P3's must include a win-win scenario in which a locality receives infrastructure improvements while the government receives compensation through innovative payback measures (X. Zhang, 2005). In other words, for a P3 to be successful, the project must attract many users to pay for the project. Road diets shift focus from roadway to surrounding livability improvements, making property values soar as seen with the ICT. If a road diet were to be funded by a P3, the innovation in financing would have to value the economic improvements of livability more than interstate mobility.

A critical factor for this project was local stakeholders valuing economic gains over vehicle mobility (Napolitan and Zegras, 2008). Increased pedestrian connectivity for an urban area leads to socioeconomic change (K. Ball et al., 2012), which Indianapolis needed even before the economic recession. Over $1 billion in community investment from this project by focusing on connectivity downtown (Cervero et al., 2009). As interviewees mentioned some troubled areas of the city that saw little growth in decades prior to the trail flourished after the project construction. This type of economic improvement through road dieting is similar to trails in San Antonio and Atlanta (Keith et al., 2018). Furthermore, this economic development happens by making the streets more walkable, making individuals healthier and happier (Ellis et al., 2016).

Framing the trail around public health was also a factor. Individuals living in sprawled cities such as Indianapolis are more likely to live sedentary lifestyles, leading to common problems in America such as obesity and diabetes (Frumkin et al., 2004). Newly input transportation systems can affect the levels of mobility and physical exercise, causing individuals to live slightly healthier lifestyles (Frank et al., 2003; Frumkin et al., 2004). Road diets have the ability to make sidewalks larger, improving walkability scores, transportation methods, and lifestyle (Frackelton et al., 2013). For Indianapolis, this infrastructure upgrade not only made sidewalks larger, but provided protected right-of-way to bicyclists, further encouraging exercise downtown.

Required updates to existing infrastructure due to ADA policy encourages cities to fund new projects such as road diets. In past cases such as Glen Ellyn, Illinois, multiple infrastructure problems were funded through proposing one infrastructure overhaul. After road and bridge inventories to compare infrastructure's health and mobility, decision-makers in Illinois discovered that the quality of its roads was far surpassed by its bridges (Blanke & Walzer, 2019). Several funding strategies were conceived and passed, including changes to the motor fuel tax, applications for federal grants, as well as a plan for sewer repair. Under the ADA policy mandate, issuing a $12.8 million plan to solve storm sewer issues in Glen Ellyn would also require the rehabilitation of on-street parking since the sewer infrastructure was directly adjacent to non-compliant parking spaces (Smith, n.d.) This case is similar to the ICT because curbs, sidewalk widths, and entrances not part of the trail were revamped due to similar ADA requirements. In this regard, the proverbial, "two birds with one stone", was met by solving more than one problem with only one source of funding.

Furthermore, with required infrastructure upgrades, on-street ecology was revitalized to help solve the consent decree issued by the EPA. The ecological benefits of bringing a series of rain gardens to the built environment through the trail, also known as greenways, is discussed in Carlier and Moran's (2019) paper highlighting the sustainable integration of greenway corridors in downtown areas. Research on the ICT supports Carlier and Moran's (2019) findings that greenway development supports sustainable design in cities through air quality benefits, stormwater cleanliness, and habitat connectivity. While the benefits of the rain gardens in Indianapolis are still witnessed today, the rain gardens were also a critical piece of addressing a requirement for green infrastructure in the EPA's mandate as part of the solution for combined sewer overflows.

Barriers during the planning process to repurposing the existing roadway

The funding barrier for the ICT adds to existing research about the imperative to build. Cities routinely add new infrastructure, even though this has become unsustainable for the environment and the construction industry (Berthod, 2013; Changali et al., n.d.). The imperative to build is seen by cities earmarking funding for the construction of new lanes (Litman, 2003). Instead of building new lanes, road diets perform the opposite (Saak, 2007). The ICT likely would not have succeeded without private donations because city leaders refused to reserve funds for the road diet. This confirms Berthod's (2013) work finding the hold-up problem that local agencies place on private projects that challenge the imperative to build. These agencies, including political figures, want environmentally sensitive infrastructure that adds to the streetscape. Local leaders for the ICT were tasked with going beyond the traditional imperative to build, which dissuaded elected officials to use public funds.

The findings of increased traffic due to a road diet verify existing research. As new greenways are built through road dieting, traffic increase due to the change in roadway is common (Lindsey & Lindsey, 2004) and can vary considerably based on day of the week, weather, and time of year (Lindsey & Nguyen, 2004). Huang et al. (2002) provided similar findings, stating that roads with average daily traffic counts above 20,000 vehicles per day will likely experience worsened traffic as a result of a road diet. However, Huang et al. (2002) discussed that while traffic may increase on occasion, road diets are appealing for their reduction in vehicle crashes and injuries. This is due to the reduced vehicle speed that can result from removing a lane, which was a goal for Indianapolis to improve livability.

The institutional barriers on the ICT seems to provide evidence to why road diets are not used more frequently. Local leaders for the ICT had to maneuver funding possibilities at the local, state, and federal levels, similar to traditional roadway decision-making (Sundeen & Reed, 2006). Even though the ICT project was able to find funding from private donors and federal grant money, interviewees brought up the difficulty of fundraising due to limited mayoral support. While Indianapolis had several mayors throughout the time of the ICT conception to completion, mayoral support was kept at a minimum to avoid squandering tax dollars since the project did not seem feasible. Winston (2000) explains the difficulties that project-hopefuls have without political support, stating that politics can prevent constructive change. As budgets become more constrained, however, local governments may have to consider road diets to avoid expensive roadway additions (Billings et al., 2013).

Unwillingness to give up existing infrastructure was common for stakeholders along the ICT. While the complexity of removing miles of operational utilities was questioned by many decision makers, stakeholders surrounding the footprint of the ICT were fearful for business impacts. Shoup (2011) qualifies these findings, stating that stakeholders that lose parking spaces from infrastructure upgrades may exhibit loss aversion. The resultant success of the ICT at preventing business disruptions attribute to Beamish and Biggart's (2010) research that barriers such as loss aversion are unfounded when the benefits of an upgrade surpass the benefit of the existing infrastructure. The ICT may provide an example of business owners invoking a response of loss aversion because they did not realize the positive impacts of a road diet (Congress for the New Urbanism, 2019).

Strategies to overcome the barriers during the planning process of the road diet

Funding strategies that optimize federal dollars takes away risk from city or state-based funding, making these projects more likely to be commissioned. Typically, projects that are centered around pedestrian and bicycle infrastructure improvements have difficulty finding sufficient funding sources (Dill et al., 2017). Applications for federal grant money earmarked for the trail took the perceived risk away from the city. This is due to tax increment financing (TIF), which has been transformative for how cities can get funding for infrastructure from the federal government (Klemanski, 1990). TIF has been used by the federal government to place billions into many small-scale infrastructure projects throughout the country and has seen success by taking away risk from cities (Haider & Donaldson, n.d.). Property values surrounding TIF-funded projects have been seen to increase (Carroll, 2008), which attributes to the increase in tax revenue that the government expects from upgrading infrastructure. In the case of ICT, over $1 billion in extra revenue has become taxable, substantially paying for the $63 million project. Basing a start-up project off a successful predecessor supports existing theory for commissioning new infrastructure. Role model theory encourages new projects to take advice from and in some cases mimic existing, successful projects (Harris et al., 2016b). The new project can take advisement for what worked with the old project and what did not, which can lead to more sustainable infrastructure. The ICT's connectivity was modeled from the Monon, which helped the start-up project gain traction with stakeholders. This serves as anchoring, which has been seen to be effective in shaping how individuals perceive a new idea (Furnham & Boo, 2011). While the ICT anchored its application on the Monon, it added connectivity to businesses to downtown Indianapolis, leading to its success.

The use of attribute framing for the ICT adds to existing knowledge in construction management for overcoming barriers to road diets. An example of attribute framing can be taken as grocery stores advertising meat that is 75% lean as opposed to 25% fat, with the notion that people are more likely to avert from the less-appealing attribute (Levin et al., 1998). This can also be referred to as a type of choice architecture and has been seen in existing literature to affect the type of infrastructure that users desire. For the ICT, the loss of parking spaces was not accentuated because it was the unappealing attribute to businessowners, even if the project would provide walkability and connectivity. Instead, the common saying that the trail would turn business' front doors into, "beach front property", was used to infer that pedestrians would gravitate toward businesses as a result of the trail. This type of framing was useful in pushing past the status quo for complacency for roadway that does not provide much value (Fraser & Chester, 2016)

Furthermore, ICT's goal framing is rooted its ability to shift behavior. An example of goal framing in literature is the effect of positive and negative drivers to encourage physical exercise (Robberson & Rogers, 1988). In this case, physical exercise remains as a positive aspect whereas the outcomes are variable. In terms of community goal framing, individuals are more likely to not pursue a personal benefit to avoid a personal loss even if it means the individual is not entirely satisfied with the outcome (Levin et al., 1998). This finding relates to stakeholders that were frustrated with the speed reduction because of the added features of safety and livability. Majority of these stakeholders did not pursue the loss in vehicle speed in downtown Indianapolis because the added safety of reducing speeds lowered the risk of crashes while also making downtown Indianapolis more livable and appealing.

A Call for More Comparative Cases

Exploratory, comparative case studies can be eschewed for their lack of replicability. Case studies are traditionally biased against because they primarily focus on the desired outcome (Achen, 1986; Geddes, 1990). In the case of Indianapolis, this case study focused on the social implications of a road diet. Stating that a causal relationship is experienced from the case study findings is warned against, but relationships to theory can be made instead (King et al., 1994). Yin (2013) presents important factors when considering case work: think conceptually, describe the differences in the cases, and explain how the differences do not undermine the findings.

Using these factors offered by Yin, this builds the case as a connection to grounded theory (developing theory after findings are made) instead of causal relationship, which is useful for CEM research (Rahmani & Leifels, 2018).

More comparative case studies are needed in CEM research because they provide a clearer picture of certain phenomena than a single case alone. Typically, CEM research rests on quantitative data to meet the burden of proof, yet qualitative case study research offers a more robust understanding of projects that quantitative data cannot explicitly answer (Taylor et al. 2011; Yin 2013; Creswell & Poth 2018). Using case studies as exploratory research to answer questions under specific circumstances can provide insight without focusing on drawing causal relationships to the dependent variable. Having at least two case studies to compare against each other is more ideal for exploratory research since the findings draw from more than one project (Yin 2013). In the case of this research, having research data from more than one case study would further solidify the findings.

More work is needed in CEM for comparative case work to develop better relationships and replicability. With a large portion of CEM research resting on quantitative proof (Taylor et al 2011), comparative case work has not had as much opportunity in this field as in social science (Goertz & Starr, 2002). Providing work in this realm would not be trailblazing (Petroski, 1985), but would provide more comparative cases in the field for richer qualitative reasoning, and could help provide better practices in this arena.

Conclusion

To solve the infrastructure problems facing America, measures must be put in place that catalyze change. Road diets offer a way to dissuade induced demand issues brought forward by traditional roadway solutions. Where infrastructure problems exist that involve level of service demands, proven concepts that have been put in place include road dieting and highway removals. When cities are faced with the decision for infrastructure removal or maintenance, this research reveals barriers of funding, an increase in traffic, and an unwillingness to give up existing infrastructure. However, to overcome these barriers, a unique funding structure that takes away risk from public entities, modeling the project after successful projects, and framing are useful tools.

Since this research was exploratory, propositions for the research questions were formed after data for the ICT was collected. This supports grounded theory, which provides backing for exploratory research by developing theory after data is collected and analyzed (Strauss & Corbin, 1994). For the ICT, the answers to results act as the generalizations for the factors that influence road diets, barriers to road diets, and strategies to overcome the barriers.

Local leaders outside of government, enhanced connectivity for walkers and bikers, and opportune surrounding infrastructure improvements were factors that encourage road dieting for the ICT. Road diets push against the status quo of traditional roadway planning by removing roadway as opposed to creating more. As a result of less roadway, the ICT provides evidence that businesses and downtown livability for a city can thrive. Despite these benefits, some decision-makers may still be wary to implement a road diet.

Funding, perceived traffic increase, and unwillingness to give up existing infrastructure were witnessed as barriers for decision-makers to commission a road diet in Indianapolis. These barriers involve an uncertainty or unawareness of the benefits or factors that encourage road diets. Road diets seem counterintuitive (Saak, 2007), roadway can be viewed as a public amenity in the age of urban sprawl (Sultana & Weber, 2007), and road diets remove this amenity.

To overcome these barriers, *a unique funding structure, project associations, and framing the project* aided decision-makers in Indianapolis. These strategies add to literature for tools to overcome barriers to innovative roadway infrastructure through road dieting. This project was envisioned through private creativity, which meant that there was not a mandate or requirement to change the functioning infrastructure in the city. These strategies were effective for the creation of the ICT because they moderated the perception of risk for changing the city's existing layout to encourage a central public amenity through a mixed-use trail.

These findings are grounded in the data collected from the ICT case study. While these findings act as this research's generalizations for other road dieting projects (Yin, 2013), more qualitative work in construction, engineering, and management (CEM) can verify and extend these propositions. Qualitative case work is useful for answering questions involving "what" and "how" (Yin, 2013), and more cases can encourage more of these types of innovative projects. Last, this paper allows room for future research through cross-case comparisons, which are able to test theories across different settings to meet the "burden of proof" (Taylor et al., 2010).

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Journal Paper 2 - Community Green Infrastructure: A Case Study of Overcoming Barriers for the Lick Run Greenway

Community Green Infrastructure: A Case Study of Overcoming Barriers for the Lick Run Greenway

Abstract

Billions of combined sewer overflow (CSO) volume into surface waters has been a result of gray stormwater infrastructure, plaguing cities for decades. Federal mandates have been placed over the past two decades to manage this issue and demand change at the city level in the face of an uncertain climate. Cities have responded with various approaches, ranging from billions of dollars allocated to underground tunnel networks to complete surface overhauls for green infrastructure employment. While green infrastructure has become increasingly popular in environmental urban planning, it offers unique societal and environmental implications that traditional gray infrastructure does not since it is placed out of sight and out of mind for the normal citizen. Past research has uncovered several barriers to implementing green infrastructure despite its ranging benefits, which this research verifies and complements. However, past research offers scant evidence on how to overcome these barriers. Using a case study of Cincinnati, Ohio, this research presents barriers that decision-makers witnessed and overcame. Identified barriers included scope of the project, removal of existing infrastructure, path dependence. To overcome these barriers, collaborative planning approaches were used that were centered around goal framing for a revitalized neighborhood.

Introduction

Waste water systems are at capacity in many cities across the United States (Fletcher et al., 2011). Combined sewer overflow (CSO) systems contribute to this inability keep up with demand (Berland et al., 2017). Cincinnati discharges 11.5 billion gallons of raw sewage and stormwater into streams and rivers each year as a result of their CSO. Combined sewer systems like in Cincinnati were constructed decades ago when the number people and impervious surfaces were much lower (Arnold & Gibbons, 1996b). Combined sewer system performance is constrained because these systems rely on pumps and pipes underground that are not easily replaced or expanded.

Climate change is further making existing infrastructure systems, especially stormwater infrastructure systems, less efficient. Increased flooding in the Southeast United States is leading to disruption of aquatic habitats and water quality impairment (Pyke et al., 2011; Roy et al., 2005; Walsh et al., 2005; NRC 2008). Longer and more frequent droughts in Western states have lessened crop yield and reduced plant health (Farooq et al., 2009). Infrastructure was based on probabilistic models for rainfall but with climate uncertainties, American infrastructure is placed at a higher risk of large-scale disruptions (Rosenberg et al., 2010).

Infrastructure must shift, not only to meet increased demands from society (Schrank et al., 2015), but also to meet uncertainty associated with a changing climate (Pyke et al., 2011; IPCC 2007). Infrastructure development has predominately remained stagnant (Arnold & Gibbons, 1996b; Berland et al., 2017). A growing population has placed stress on networked infrastructure, causing them to degrade over time (Papageorgiou et al., 2003). Infrastructure systems and investments are needed to meet demand and improve quality to prevent failure (IPCC, 2007; Pyke et al., 2011). Green infrastructure solutions are one type of investment related to stormwater that can help reduce the need for new waste water systems. Green infrastructure uses natural landscaping and ecological systems, to capture, retain, and clean stormwater (Benedict & McMahon, 2002).

Green infrastructure provides co-benefits beyond just stormwater improvements (Bell et al., 2019). For example, the Cheonggyecheon day lighting river project in Seoul, South Korea. The city decommissioned a freeway system, exposing the Cheonggyecheon river to daylight. This helped improve water quality and increase water capacity, but it also reduced the urban heat island effect in the city and re-introduced local wildlife to the city core (Kang & Cervero, 2009; Rao, 2011). The project had traffic calming effects and it increased local property values. This type of solution transformed the city, and did so using an innovative approach – considering what to remove from the built environment rather than what to add and re-introducing natural systems (Shealy & Klotz, 2017).

Daylighting the Cheonggyecheon river and re-introducing natural plants and animal species is an example of green infrastructure. Unfortunately these types of transformative solutions through green infrastructure that improve water quality and quantity are not implemented at the same pace or scale as gray infrastructure solutions (Dhakal & Chevalier, 2017; Heaney & Sansalone, 2013; National Research Council, 2009). Stormwater engineers continue to rely predominately on conventional drainpipes, pumps, and water holding tanks disproportionately more than green infrastructure systems, like bio-swales, permeable pavements, water harvesting programs, and river daylighting (Thorne et al., 2015). Government agencies (US EPA, 2015b), academic institutions (University of New Hampshire & Stormwater Center, 2011) and private and community organizations (Dietz & Clausen, 2008; Hopton et al., 2015; Winer, 2007) consistently show that the performance of green infrastructure is equal or better than conventional infrastructure (US EPA, 2015b).

Decision-makers heavily rely on industry norms when making design decisions (Artiba et al., 2005; Beamish & Biggart, 2012; Harris et al., 2016a). Stormwater engineers perceive solutions like bio-retention systems, permeable pavements, and water harvesting programs with higher risk in performance compared to traditional, gray stormwater infrastructure (Olorunkiya et al., 2012; Thorne et al., 2015). Status quo bias (Earles et al., 2009) and attention bias can compound the effects when making decisions about stormwater management (Gray, 2015; US EPA, 2015a). For example, when decision-makers attend to the tangible construction and maintenance costs disproportionally more than the ecological and societal benefits that green infrastructure provides (Byrne & Yang, 2009).

The research presented in this paper seeks to build on this previous knowledge about the barriers to implementing green infrastructure. The research present in this paper explores how project teams arrive at green infrastructure solutions for stormwater problems, what barriers prevent green infrastructure adoption, and how project stakeholders overcome these barriers to green infrastructure adoption.

Background

Uncontrolled CSO volume undermines stormwater infrastructure systems throughout the United States. Combined sewer systems emit harmful pollutants that are threats to human and environmental health (US EPA, 2013). The lack of ability to contain CSO volume has led to federal intervention over the past two decades. The Environmental Protection Agency (EPA) started the National Compliance Initiative in 2000 to identify and reduce the negative effects from CSO systems. Through the EPA's work, at least 45 active consent decrees are in place to remove CSO volume (EPA, 2019). A consent decree is a federal mandate that demands compliance with a certain initiative. For CSO volume, a consent decree requires cities to eliminate harmful pollutants from entering waterways from CSO systems.

Innovative solutions to meet the EPA's consent decrees have led to a reduction of billions of gallons of CSO volume across the United States. Most consent decrees mandate the use of green infrastructure (such as eco-roofs, permeable pavers, and rain gardens), but the required volume that this type of infrastructure must capture remains limited (EPA, 2014; Tzoulas et al., 2007). Green infrastructure is a requirement from the Clean Water Act and the National Pollutant

Discharge Elimination System (NPDES), but gray infrastructure still dominates for its effectiveness at controlling large volumes of stormwater runoff (Bell et al., 2019; The Clean Water Act, 2011). For example, under federal mandate by the EPA to eliminate CSO, Cleveland must capture just one percent of its CSO problem with green infrastructure (EPA, 2011).

While many states have ongoing consent decrees, Ohio has seven active consent decrees issued by the EPA for necessary stormwater infrastructure improvements (EPA, 2019). Cincinnati (population ~300,000) and Cleveland (population ~380,000) offer two cities with similar CSO problems and similar consent decrees issued by the EPA. However, their responses have been drastically different (Xie et al., 2017).

Cincinnati releases about 11.5 billion gallons of CSO annually through many centralized locations, known as outfalls. One specific outfall, known as CSO 5, emits at least 500 million gallons of combined sewage and stormwater every year (Project Groundwork, 2020). Through the use of green infrastructure, the city will eliminate nearly 400 million gallons of this volume annually and ensure that 88 percent of the flows during a typical year of rain will either reach the treatment plant or be discharged as stormwater. The focus of the green infrastructure is to keep stormwater from reaching the combined sewer system through a variety of projects across the Lick Run watershed. The city is installing new bioswales, stream restoration, stormwater detention basins, bio-infiltration gardens and the creation of a mile-long constructed waterway that will mimic a stream through natural and engineered measures.

In contrast, Cleveland is constructing 21 miles of new and existing tunnels to capture all of the stormwater. Their plan is costing nearly three billion taxpayer dollars (McCarty & Dealer, 2017). Between 1972 and the 1990s, Cleveland reduced their CSO in half from 9 billion to roughly 4.5

billion gallons. Although, in 2011, they were still issued a consent decree by the EPA to further reduce their CSO (EPA, 2011). Their 25-year program using primarily gray infrastructure is expected to capture another 4 billion gallons.

Cleveland is not alone in their decision to predominately implement gray infrastructure for effective conveyance of stormwater. However, these solutions also have consequences (Casal-Campos et al., 2015). Damage to waterways, flooding, and water quality issues can be a result of more concrete holding facilities, piping, and pumps to control stormwater (Paul & Meyer, 2001; Walsh et al., 2005). These solutions are also limited in their peripheral benefits to society (Liu et al., 2015). For example, stormwater engineers in Onondaga County, NY focused consideration on the performance of a new regional treatment facility to control their CSO, without equally considering the adverse effects on the surrounding community. The construction of the new treatment facility forced the eviction of 45 families from their homes and caused massive political protests (Flynn et al., 2014). Only after the treatment facility was built and failed to address loading sources of bacteria in the watershed did the stormwater engineers cautiously adopt green infrastructure solutions. Their change in mindset had a profound positive effect on the community. Property values increased, and the city saved $20 million by delaying additional grey infrastructure upgrades (Flynn & Davidson, 2017).

Stormwater engineers' lack of attention toward community impact in Onondaga County, NY seems irrational, even from a neoclassical decision making perspective (Simon, 1955). An empirical study found that multiple stakeholder groups, including engineers, developers, and end-users consistently rank social and environmental outcomes above economic value as the most critical to project success (Zhang Lu & El-Gohary, 2016). However, cost to construct and perceived risk still dominate as reasons against implementing less conventional, green stormwater solutions (Green-Nylen & Kiparsky, 2015; Novotny & Brown, 2007).

Another possible reason that gray infrastructure is still predominately used over green infrastructure is that land laws encourage performance measures for private developments, which are more easily attained through gray systems (Rosenbloom, 2018). Decision-makers also have many infrastructure alternatives in their toolbox to solve stormwater issues (Bell, 2019; Xie et al., 2017). While gray solutions are typically encouraged, identifying barriers and drivers to green infrastructure may entice more of these projects, benefitting community and environmental wellbeing (Semadeni-Davies et al., 2008).

Identified barriers to green infrastructure

Cost, technicality, path dependence, legality, and institutional barriers prevent more green infrastructure implementation (Hunt & Rogers, 2015; Matthews et al., 2015; Beamish & Biggart, 2010; Shealy et al., 2015; Dunn, 2010; Nazir et al., 2014). For example, Dhakal & Chevalier (2017) found stakeholders hold a pro-gray mindset for addressing stormwater issues in their community. This is similar to Roy et al.'s (2008) description of stakeholders' resistance to change from gray to green. Resistance to change is also related to path dependence (Matthews et al. 2015), or stakeholders relying on gray over green infrastructure because gray infrastructure is already in place. Design solutions that expand the existing systems rather than start over with a more green, ecological approach is more likely to occur through the design process. Similarly, decision-makers tend to fixate on existing assets rather than expand their design option alternatives to visualize different outcomes (Shealy et al., 2015; Beamish & Biggart 2010).

Path dependence toward gray infrastructure solutions may also be a barrier. Path dependence can have an effect on stormwater infrastructure through what researchers call the “lock-in effect”: Stakeholders become too attached to an existing asset, preventing the consideration of new alternatives (Cantarelli et al 2010; De Bondt & Makhija 1988). For example, decision-makers were locked into the decision to construct a new holding facility in Onondaga County, NY even though it posed considerable negative consequences and political ramifications that were identified later in the design and construction process.

Field and empirical evidence suggests that stormwater engineers too frequently lock-into an initial solution, even when the solution shows signs of deficiencies (Ball et al., 1998). Minimal deviation from existing solutions may be caused by institutional factors that limit change and innovation (Byron, 1998). For example, Colorado’s Urban Water Resources Research Council reported that the leading cause for lack of implementation of green infrastructure is the reluctance among stormwater engineers to try something new (Earles et al., 2009). The Council cites that decision-makers believe conventional solutions are easier to implement.

The head engineer for stormwater project in Atlanta project mentioned balancing the optimal solution with time invested, or hours billed, to the client (i.e., challenges associated with *satisficing*) (Arkes & Blumer, 1985). The engineer said, “it is a delicate balance because a more ideal solution is always just over the horizon. Eventually the time invested to get there is too great. Justifying that to a client can be a challenge” (McWhirter & Shealy, 2018). In other words, it may be simpler for many engineers, designers, and planners to stick with gray infrastructure since it provides a sufficient solution for many applications. This reference to *satisficing* attributes to lock-in for existing solutions and may also explain why engineers implement the minimum legal requirements for green infrastructure.

To overcome lock-in, stakeholders for the project in Atlanta used "*guiding principles*". The Atlanta project involved multiple internal and external stakeholder groups with differing requirements, priorities, and interests. The stormwater project served as both a stormwater solution for the city and revitalization project for the community. This led to the decision process to require far more potential design choices than a sewer pipe and retention pond because of its unique constraints.

Many barriers exist for green infrastructure, but a limited number of studies proposed possible solutions. Brown and Farrelly (2009) put forward some corrective actions like building social capital regarding green infrastructure, more professional development in this area, and better coordination among the many fields that a green infrastructure project requires to overcome institutional barriers. Roy et al., (2008) discusses some broad strategies that can help with socio-institutional problems, such as education for watershed-based solutions and inter-governmental coordination. However, past research offers scant evidence on how the strategies overcome these barriers and the effectiveness of the solutions. Prior research posits the need to conduct more research on watershed-based designs (Roy et al., 2008),

To fill the gap, the research presented in this paper seeks to understand how decision-makers overcome these barriers. The research questions explore decision making for green infrastructure, the barriers that prevent more of these solutions, and methods to overcome these barriers. The research uses a case study approach to provide rich examples about decision making for green infrastructure and to provide recommendations based on real-world observations and insight from stakeholder groups. The results and discussion offer some generalization for theory-building about decision making and design for more sustainable infrastructure systems.

Research Questions

The research questions align with the objective to understand how stormwater stakeholders arrive at design decisions to implement green infrastructure solutions. Furthermore, this research aims to understand some of the barriers presented for green infrastructure. Strategies that past decision-makers employed to overcome the barriers are this research's main contribution to knowledge.

The first research question is (Q1) *what drivers contribute to stormwater stakeholders' decision to choose green over gray infrastructure solutions?*

Research question two is (Q2) *what barriers prevent green infrastructure adoption?*

Research question three is (Q3) *how do project stakeholders overcome these barriers to green infrastructure adoption?*

Methods

A single longitudinal case was used to answer the research questions for green infrastructure adoption (Yin, 2013). The scope of the case being evaluated is during the planning stages from idea conception to adoption. Case study research is appropriate for green infrastructure adoption because this paper attempts to capture the series of assumptions and decisions made for a particular project. Case study research is also appropriate because the research attempts to answer "what" and "how" questions (Creswell & Poth, 2018 ; Yin, 2013).

The case study was developed in three phases. The case study development was reviewed and approved by Virginia Tech's Institutional Review Board. Phase 1 identified a case project through archival research of the project's history and developed interview questions for key decision-makers. For phase 2, key decision-makers and stakeholders were interviewed as the primary source of data collection along with archival data. Phase 3 involved transcribing and coding the interviews and aligning the codes to the research questions.

Phase 1 – Case selection, unit of analysis, and interview questions

The case is the Lick Run Greenway in Cincinnati, Ohio. The case was identified and selected based on its use of green infrastructure to reduce roughly 400 million gallons of CSO. The project is currently under construction and access to archival data is available through the project's database, called Project Groundwork. The archival documents include design layouts, meeting briefs, design considerations, and outcomes of stakeholder engagement strategies primarily through design charrettes. The unit of analysis was the planning phase of infrastructure delivery.

Validity considerations

Four measures of validity were used for the case study (Burke, 1997; Taylor et al., 2010), including construct validity, internal validity, external validity, and theoretical validity. Construct validity was met by providing the interview questions to the interviewees before the interview, which provided detailed answers that were compared to archived data. Internal validity was achieved by matching responses among the various stakeholders as well to archived data provided by Project Groundwork (Project Groundwork, 2020). External validity was achieved by connecting the findings from the stakeholder interviews with existing work about in planning, design, and construction engineering and management literature. Among the sources of evidence that were used in this study are interviews with stakeholders, meeting minutes from stakeholder meetings and design alternatives, master plan documents, and notes from a site visit with project team members. Theoretical validity was achieved through pattern matching (Almutairi et al., 2014), which helped to verify that the pre-study propositions resemble the findings of the study.

Case description

Cincinnati was issued a consent decree by the EPA, a federal mandate ordering the restriction of CSO. Cincinnati's solution originally included new design and construction projects to separate sanitary sewer and stormwater infrastructure. City engineers and consultants had proposed a large expansion of their stormwater infrastructure and massive interventions to the existing system to separate the sanitary and stormwater systems. The cost of the project continued to increase until the price tag reached $244 million, which was deemed too expensive by city officials (Project Groundwork 2011).

Another idea was then put forward by the Landscape Architecture Firm. It became the only design able to remove 400 million gallons of Cincinnati's stormwater at a reduced cost compared to the entirely new gray stormwater infrastructure solution. Their design was to radically change existing land use by removing impervious surfaces and daylighting the Lick Run river to reduce the stormwater entering their combined sewer system. The project used principles of green infrastructure such as rain gardens alongside a series of small complementary conveyance boxes for bigger storms. The green approach would require the relocation of some businesses, homes, and schools in the town of South Fairmount, Ohio. The project is currently in construction and scheduled for completion in 2020 (Project Groundwork 2018).

The green infrastructure solution would require relocating some businesses, homes, and even schools to reduce development and provide new greening. Before the project began, South Fairmount was losing residents and value. Between 2000 and 2010, the population in the area dropped by 27%, with over 30% of the housing units left vacant (Project Groundwork, 2012b). This was causing total assessed property values to plummet by over 54%.

When the project was conceived, an urban audit was performed on 244 buildings and homes in the neighborhood. Of this 244, 24 buildings were found to be of historic or architectural value which meant that the buildings were required to stay in place. The audit also identified 92 buildings that were underutilized, dilapidated, and depressing surrounding property values. To improve surrounding property values and implement their green infrastructure system solution, the city decided to acquire these properties, providing fair market value, without needing eminent domain. Businesses were able to relocate with assistance from the city. Surveys were conducted after business owners were made an offer for their property, and business owners expressed they felt like a reasonable offer was provided and felt satisfied with relocating (Project Groundwork, 2012c).

To give businesses a fair assessment of their options, an economic development survey was also conducted to assess market opportunities in the area. From the market assessment, the area qualified for government assistance as a distressed community, land was $6-$8 cheaper per square foot than the average surrounding South Fairmount, and there was very little to no retail in the area prior to the green infrastructure projects (Project Groundwork, 2012a). Ultimately, however, this project involved no federal funds. The Municipal Sewer District of Greater Cincinnati (MSDGC), the owner of this project, levied slightly higher sewer taxes to pay for the watershed project, totaling over $1 billion. The Lick Run Greenway project consisted of roughly $90 million of the total project cost.

Institutional Characteristics of Stormwater Decision-making for Cincinnati

The Municipal Sewer District of Greater Cincinnati (MSDGC) service area encompasses 290 square miles and serves a population of over 850,000 individuals. MSDGC was formed as a Hamilton County entity that operated under state law even though MSDGC employees are funded by the City of Cincinnati. In 1968, an agreement was signed between the City of Cincinnati and Hamilton County for how MSDGC would operate and fund stormwater projects. The City of

Cincinnati became responsible MSDGC's management and operation, including wastewater administration, collection, treatment, and engineering (MSDGC, 2020a). The Board of County Commissioners of Hamilton County are able to change sewer service charges, pass regulations, and approve budgets.

The Board of County Commissioners of Hamilton County represents the governing body for the county. The Board takes on many responsibilities, covering over 40 departments that includes MSDGC as one department it oversees. As stated by the president of the Board of County Commissioners, the County takes on all fiduciary responsibilities for stormwater taxpayers in Hamilton County (Board of County Commissioners, 2014). Furthermore, the Board is the defendant to the Consent Decree, ensuring that improvement projects to meet the goals of the Consent Decree are funded.

The Consent Decree caused confusion among stormwater taxpayers for how projects would be funded. Since MSDGC is city-operated, but county-owned, the Board reassured taxpayers that required taxes would be issued as a county tax, not from the City of Cincinnati (Board of County Commissioners, 2014). Funding for stormwater infrastructure improvements throughout Hamilton County are paid for by taxpayers within MSDGC's service area.

To help with the execution of infrastructure improvements for the Consent Decree, an initiative known as Project Groundwork was formed to spearhead the changes needed. As the operating body, MSDGC is responsible for Project Groundwork alongside their traditional wastewater duties. MaryLynn Lodor, the COO of MSDGC, oversees the collection, treatment, and compliance services for the Consent Decree (MSDGC, 2020b). She acted on behalf of MSDGC and the Board of County Commissioners as the owner's representative for the project. She also assessed the advantages and drawbacks between the tunnel solution and the proposed Lick Run Greenway and displayed her preference for the green solution. Her input, along with the backing of MSDGC and the Board, was influential for procuring stakeholder buy-in for the project.

Phase 2 - Interviews and site visits

The interview questions were checked for content and validity with a small group of professional engineers prior to the interviews. Site visits were coordinated to obtain in-person interviews. Stakeholders who were interviewed included the local planners, engineers, and design consultants. Participants for interviews were selected based on their knowledge of the case. When contacting the interviewees, explicit authorization was requested to proceed with the interview and to record it. Interviews started with a description of the scope of the research, the objectives of the research, and the use of the findings. It continued with an explanation of the interview process. The length of the interview was dependent on the role of the interviewee but averaged around 60 minutes. The interviews were semi-structured, which benefitted the research by providing a deeper understanding of the outcomes and stakeholder relationships (Yin, 2013). Responses to interview questions 1 – 4 were used to answer research question one. Responses to interview questions 4 – 8 were used to answer research question two and responses to interview questions 8 – 12 were used to answer research question three. Table 2 provides a list of interviewees for the research.

Table 2 – Interviewees for Research

Position	Organization Type	Role
Landscape Architect A	Landscape Architecture Firm	Made executive decisions for the whole design
Landscape Architect B	Landscape Architecture Firm	Made executive decisions for the whole design
Senior Planner	County Planning Office	Provided planning services for the Lick Run Greenway
Principal Planner	County Planning Office	Oversaw all planning of the Lick Run Greenway
Engineer	Engineering Firm	Provided engineering services for the Landscape Architecture Firm's design

Landscape Architect A and Landscape Architect B are the founders of a local landscape architecture firm that has a repertoire in green infrastructure solutions. Lick Run was one of the largest designs in their portfolio and having both of them present to be interviewed gave two different perspectives from the designers' standpoint. The Principal Planner was the head planner for the County Planning Office and the Senior Planner an associate planner for the same office. Being able to interview both provided detail about the overall vision of the project and other key players and insight into day-to-day planning decisions. The Engineer was the lead engineer for the project and provided input on the relationships formed between the County Planning Office, the Landscape Architecture Firm, the Engineering Firm, and how the relationships affected the engineering decisions that were made.

Field notes and archival data

Meeting minutes from stakeholder meetings, the Lick Run Master Plan, and site visits were used as secondary data collection to compare with interview responses. For example, during site visits, the research team was able to observe businesses and homes being closed, boarded up, and demolished. Project Groundwork's website served as an archive of data for design considerations, the charrette outcomes, and up-to-date construction information. Secondary data collection allowed the researchers to fact-check the primary data as well as to strengthen the conclusions of the study (Taylor et al., 2010).

Phase 3 - Transcription and coding

Interview audio recording were transcribed using the nVivo software. A two-step coding method was used to analyze the transcripts (Miles et al., 2014). The transcripts were themed into chunks of data first, and then the data was coded into subsets, searching for commonalities or relationships.

For example, elements of strategies that stakeholders used to engage the public, such as "design charrette", "forum", and "meetings" were combined into "stakeholder engagement". The protocols, field notes, interview responses, and reflections were organized and kept to demonstrate the reliability of the findings.

The results were tabulated into three subcategories, each correlating to a research question. The results were repeated and checked multiple times to ensure replicability. The following results are presented in order of the research question that they refer.

Results

Drivers that contribute to project stakeholders' decision to choose green infrastructure over gray infrastructure for meeting the stormwater consent decree

The opportunity cost of the tunnel solution was a driver for MSDGC because it would forego any surface benefits for South Fairmount. Cincinnati's green solution led to the Landscape Architecture Firm interviewees discussing the cost of solution versus the revenue that it could bring, and an argument that was shared was the irrecoverable cost that the gray solution would entail. The original price tag of $200 million to plan to expand the existing stormwater infrastructure and separate the sanitary and stormwater systems would have required bring a large tunnel under South Fairmount community. The cost to construct this tunnel was not seen as helping improve the community. Proponents of the design team in favor of another solution began comparing the cost of the tunnel to the Cincinnati Bengal's Stadium. Landscape Architect B, said that choosing the gray infrastructure solution would be like having the Stadium entirely underground. Landscape Architect B alluded to the fact that no one would be able to see the large infrastructure investment once it was in place and for such a high price tag, it did not make sense for the city to invest in infrastructure that the community would not directly benefit from. The

Principal Planner stated the cost, and comparison to the stadium, was a tipping point for the design team. It led to exploring different alternatives. Dismissing the original design idea, the city turned to hearing from local residents and companies for solutions.

Modeling how the green infrastructure solutions would operate was also a critical factor. The Engineer explained that city officials were uncertain about the feasibility of having a primarily green infrastructure project. Landscape Architect A and Landscape Architect B both discussed the importance of value engineering review by a third-party engineering firm to evaluate the feasibility of the green infrastructure design. Landscape Architect B described this process as being, “on pins and needles”, because the engineering firm rechecked all of the existing engineering and design plans. Landscape Architect B further added, “you might not capture enough stormwater [with the green approach] to address a $10 billion consent decree”. However, through modeling of heavy rain events, the greenway was seen to outperform the gray solution, which would have difficulties if a 50-year storm hit Cincinnati. But, without expert testimony from third-party specialists, such as hydro geomorphologists, Landscape Architect B believed the modeling would have been perceived as incomplete and some of the city officials would have remained skeptical about green infrastructure’s effectiveness. Once the Landscape Architecture Firm received confirmation from the third party, their design was largely approved by the city, which put the project in motion.

Local leaders outside of the government also played a key role helping implement green infrastructure solution. The Engineer described a local pizza shop owner is South Fairmount, who in a public engagement meeting spoke up for the green infrastructure design options. Having community support for the proposed design was critical for the decisions-makers in the local government. They took notice of the business owners who supported one design over the other. The Engineer, believed business owner support was a major factor to the city “buying in to the green infrastructure" idea. The message from the pizza shop owner to the city was that he felt unsafe just leaving his shop because of the violence and poverty in the area. He saw investment from the city in green infrastructure, as chance for South Fairmount to change "its look" and increase property values for local residents through beautification that comes with the green infrastructure design plans. The Engineer said, "the pizza shop owner framed it by saying, if the local decision-makers said no to the green infrastructure design options, residents would perceive that nothing would ever happen for them". The pizza shop owner did not see the same value to the community from the gray infrastructure options.

Barriers that prevent green infrastructure adoption

The scale of the project was a barrier to implementing green infrastructure. Landscape Architect A explained that the backing of the consent decree comes from the Clean Water Act, which serves as an initial communication piece for communities to negotiate with the EPA about engineering strategies for clean water along with the timeline. Since green infrastructure would be primarily used on private land in Cincinnati, a barrier arose with pitching such a large, public green infrastructure project and needing local resident stakeholder buy-in. With traditional approaches relying on gray infrastructure, the Senior Planner highlighted the complexity of meeting the EPA agreement with green infrastructure. Saying, various stakeholders were skeptical of the green infrastructure approach and many decision-makers thought that the gray infrastructure would provide the most guarantee for tax-payer money.

Existing road infrastructure also contributed as a barrier to adopting the green infrastructure design solution. The Principal Planner and the Senior Planner explained the traffic pattern for Cincinnati as an "east to west commute" in which many citizens have to travel from west to east to get to their jobs. The Senior Planner added that Lick Run was one of the few connectors between the two sides, which feeds 50,000 vehicles per day over the Ohio River. Commuters rely on the segment around the South Fairmount neighborhood. The Senior Planner and the Principal Planner both noted their concerns with this traffic segment. The Principal Planner described Cincinnati's residents attempting to get to the east side in the mornings and west side during the after-work rush and the Senior Planner noted the importance of Lick Run as a link between both sides. Throughout the construction process, traffic was impacted by diversions and lane closures, causing delays that are still ongoing throughout 2020 (Project Groundwork, 2020). The greenway's physical construction was also constrained inside of the road layout. While removing homes and businesses was required to allow for stormwater to convey to the daylight stream, the encompassing roads were kept as a constant throughout the design. However, while this constraint made the design and construction of the greenway more complex than an underground tunnel, the design and construction teams were able to optimize the space to allow for traffic to flow.

Relocating existing businesses and homes off land designated for daylighting the Lick Run river is another barrier. The Engineer explained that one of the nation's leading McDonald's restaurants in sales was located in South Fairmount. They were unwilling to relocate due to the revenue of the existing location. The Engineer explained that the fast-food chain posed many dilemmas for the design team, stating that the location's success in the area could have been attributed to the demographics in the neighborhood. Residents had few other options for food. Eventually, as the Engineer pointed out, the property owners negotiated moving to a new location but not before the city helped sponsor a study from the University of Cincinnati to identify another site to place the restaurant (Miller et al., 2013). Once the McDonalds agreed to relocation, the design progressed quickly. The Engineer said the de-escalation to commitment for the McDonald's was peculiar, but otherwise the store would have been placed in the middle of a construction zone, making entrance and exit extremely difficult and unsafe, which would have likely detracted the restaurants customers.

Path dependence toward the gray solution was a barrier. The Engineer stated that the previous investments over time the city had made to the existing gray infrastructure was a prevented the plan to implement green infrastructure. These costs that had already been incurred, and could not be recovered, were driving the initial design alternatives for the underground tunnel and heavy focus on the gray infrastructure systems. In this context, the green alternative was made attractive to city officials for its cost savings and to locals for its promise to revitalize South Fairmount, however, the design team for the gray solution was coaxed by city officials to continue with the design.

Furthermore, the gray infrastructure design option was preferred by the city because the large underground tunnel approach kept businesses and houses that required previous investment in-place with minimal disturbance. Designers were more familiar with the industry norms of using gray infrastructure approach. Landscape Architect A said the original tunnel and stormwater infrastructure expansion approach was all about, “conveyance, conveyance, conveyance”. The Engineer agreed, adding that the gray mindset was present among the engineering team that represented the city even once the city had determined the cost was too great. The Engineer explained engineers on the project team would say “this is how we have always done it” as a rationale for including more gray infrastructure back into the design. Landscape Architect B added that the MSDGC wanted to keep the gray solution as a viable option for as long as possible, until the high cost of the gray infrastructure approach was known.

Path dependence was described as comfortability with gray infrastructure for South Fairmount. The Engineer said the city was more comfortable with the gray infrastructure approach than the green infrastructure because it was more predictable and easier to model. Community members that attended the design charrettes worried about the maintenance plan, and MSDGC could not provide an immediate answer during the charrettes since the maintenance plan was still under review (Project Groundwork, 2012b). Local business owners that attended these meetings also were not comfortable with the uncertainty of business impacts once the Greenway was built. The possible inclusion of more high-speed traffic in the area also prompted uncertainty for South Fairmount inhabitants. While the Landscape Architecture Firm and MSDGC could not provide holistic answers to these fears during the charrettes, they incorporated stakeholder concerns later in the design.

Overcoming barriers to green infrastructure adoption

Collaborative planning through design charrettes were used to demonstrate the community impact of the project to overcome uncertainty with scale and infrastructure removal. The Landscape Architecture Firm described their three-pronged approach through, "awareness, exploration, and vision" of the design. Landscape Architect A explained the importance of having a, "great civic asset that the community can rally around", emphasizing, "revitalization, reinvestment, pride, [and] education". Landscape Architect A brought up the vacancies and vacant lots in the area, stating that this project was a chance to rebuild the community. Visual preference surveys were used in the charrettes to allow individuals to voice their opinion on the design. Landscape Architect B mentioned that while not many of the local residents were on board with the project, once the visual preference surveys were provided, these stakeholders' opinions changed. The visual surveys provided mock renderings of the design in South Fairmount, allowing local residents to understand the changes that would be made, such as what the stream would look like, where trails would connect, which green features would be added, and how the project fits into the urban environment (Project Groundwork, 2012b). When these visuals were displayed, Landscape Architect B described the increased level of involvement from the residents, stating their preferences, desired nuances, and ultimately, their approval of the project. Following the design forums, four status update meetings took place from 2014-2017 to provide information to over 100 residents in each meeting on the role of the project, where the decision-makers were in the process at the time, and what would happen to South Fairmount related to the installation of green infrastructure and demolition or existing properties.

Preventing the use of eminent domain was essential to overcoming fears of relocating businesses and homes. The Principal Planner mentioned that if eminent domain was used by the project, this would have made land acquisition much simpler, however the MSDGC had to operate by Ohio's state code which did not allow them to enforce land turnover. Instead, local residents sold their property for fair value without the city using eminent domain. While many residents would lose their homes due to this project, the Landscape Architecture Firm and county planners under the MSDGC emphasized the ability of receiving fair value for their homes. The Principal Planner reinforced this, saying, "yeah they're losing their house … they were enabled to go out and find other houses too", by being able to find, "comparable houses, maybe even a lot of times better", alluding to the degraded structures around South Fairmount and the need for community revitalization. When local residents in South Fairmount would question why this project had to be done, Landscape Architect B answered that, "the government's here and we're going to fix something in your neighborhood … there's a lot of resistance to that". While it was difficult for local stakeholders to accept the imminence of this project, eventually they relented and discovered the personal and community benefits through visual design renderings and discussions of local impacts brought forth by community leaders.

Community stakeholders were also essential to overcoming the path dependence for gray infrastructure. Landscape Architect A said locals, especially older residents, were essential in providing context and the need for radical change. These older residents created a snowball effect during the design process. They shifted the conversation from improving and expanding existing infrastructure systems to stories about when the current infrastructure was installed and the negative effects it had on the community. Landscape Architect A mentioned these conversations helped move decision-makers in the room from reluctance about investment in green infrastructure to accepting this type of investment.

The Principal Planner provided more context about the senior community residents and their role as community leaders, explaining that Cincinnati is divided into neighborhoods. For this type of watershed-based project, citizens in multiple neighborhoods were required to coalesce and discuss the impacts that the project. The Principal Planner reflected that some leaders were not engaged in the process, he countered by stating that certain neighborhood leaders participated actively, which formed buy-in for the project. These individuals discussed the need for revitalization in the area and that while previous investment has been spent on South Fairmount, this was the area’s best chance at change for the future.

The use of framing effects also helped stakeholders shift their focus from the technical aspects of moving stormwater and loss of property to discussing the broader community benefits. The project was framed around the goal of community revitalization. For residents near the project, the Senior Planner said that once the decision was made to pursue green infrastructure, MSDGC publicized the project as a public asset. While the Landscape Architecture Firm interviewees stated that they did not give exact figures of how much property values were expected to rise due to the project, a comparison study of property values in South Fairmount compared to the rest of Cincinnati was provided (Project Groundwork, 2012b). Along with this study, a market assessment also illustrated the potential positive impacts of businesses relocating to nearby area. The Principal Planner said the buyouts of land in South Fairmount were framed as an "opportunity" for better housing. "Revitalization" was brought up by Landscape Architect A, further stating that this project would change the fabric of the community positively. Landscape Architect A and the Principal Planner both referred to the gray approach as a feasible design for stormwater, but not for South Fairmount itself. The inference that was made was that while a tunnel could handle the CSO dilemma, the green infrastructure added on an additional layer by being feasible and a net social benefit by greening the landscape.

Discussion

Ergonomic improvements, modeling, and community leadership drives project stakeholders' decision to choose green infrastructure over gray infrastructure

Societal and physical land changes act as a talking point for green infrastructure. A city's social and environmental characteristics act as its "ergonomics", or the physical actions that cities perform to solve human needs (Wolf, 2003). Green infrastructure, such as stream daylighting, is a method of appealing to both social and environmental ergonomics (Bell et al., 2019). As Lovell and Taylor (2013) add, social and environmental advantages act as green infrastructure's system resilience by solving problems that previous infrastructure could not. However, while green solutions are able to solve more than just environmental issues, previous literature has also brought attention to social problems that it can cause. If this infrastructure is placed in an improper area, a community can be gentrified (Anguelovski et al., 2019). While more work is needed in this arena to pinpoint how the gentrification occurs and how to overcome it, communities can be built rather than separated by using green infrastructure as an engagement tool for environmental action (Jerome et al., 2017). Structuring this type of community building requires stormwater planning solutions that go beyond issues with combined sewer overflows, which was witnessed in Cincinnati (Project Groundwork, 2012b).

Modeling green infrastructure's effects on stormwater runoff volume and quality helped overcome risk aversion of city officials for Lick Run. Such modeling has been used extensively over the past two decades (Jayasooriya & Ng, 2014; Massoudieh et al., 2017). Various modeling strategies have been used for understanding watershed-based green infrastructure and have demonstrated promise for continued application (McCutcheon et al., 2012; Pitt et al., 2011; Randolph, 2003). These models have changed expectations for green stormwater management to include various other components over time (McCutcheon et al., 2012). For example, models for landscape connectivity through green infrastructure corridors have been developed (Zhang et al., 2019), which attribute to projects such as Lick Run. Modeling has also included physical simulations, which verifies the capability for green infrastructure to perform at larger scales, such as to minimize combined sewer overflow issues (McCutcheon & Wride, 2013).

Community leaders participating in stakeholder engagement were necessary to establish the feasibility of green infrastructure. While the cost dissuaded the gray approach in the eyes of decision-makers, citizens were still not on board. Leaders such as the design team and local business owners voiced their concern for the area and encouraged a shift in judgment for a necessary change to the area. These individuals act as project champions and communicate the efficacy of their vision (Morton, 1983) through advocation. This also supports previous literature discussing a leader's role to champion technological innovation (Nam & Tatum, 1997). Since green infrastructure as a planning solution is less utilized and known as gray infrastructure, Municipal Sewer District of Greater Cincinnati (MSDGC), the Landscape Architecture Firm, and local neighborhood leaders took on the role to assuage concerns of the green solution's ineffectiveness.

Scope, land acquisition, and path dependence prevent green infrastructure adoption

The scope that stormwater solutions must conquer is large, which could explain why green solutions have not been adopted readily. Green infrastructure has been put in place for many small-scale adaptations, but stakeholders have been slow to utilize this technology for watershed and city-wide problems until the 2010s (Matthews et al., 2015; Randolph, 2003). While climate change experts have called on green infrastructure to abate rising surface-level temperatures and surface runoff (Gill et al., 2007), cities have still relied on massive gray infrastructure projects such as Cleveland's Project Clean Lake. Cleveland's consent decree only required a 1% capture of stormwater through green measures, so this raises the question: why are these large projects predominately gray? As Rosenbloom (2018) discusses, this could be due to cities' trust in human-engineered approaches to have a human-centered control on stormwater. Or, as McWhirter and Shealy (2018) found in Atlanta, this could be due to projects having constrained resources, and sometimes solutions need to be made simpler to make forward progress which was referred to as *satisficing.*

Land acquisition through infrastructure projects has been witnessed as another barrier in previous research and cases. As seen in Cincinnati's urban audit (Project Groundwork, 2012b), land acquisitions can be a time-consuming, systematic process in which stakeholders in charge of the audit process attempt to give a fair-market value for properties (Weber et al., 2006). While land acquisition is often required for large green infrastructure projects (Benedict & McMahon, 2002) and can be perceived as a barrier, prior research demonstrates that while it can be expensive, land acquisition for green infrastructure is ideal for cities with decreasing population such as Cincinnati (Schilling & Logan, 2008). Even Cincinnati is still going through minor setbacks with land acquisition in 2020, it turned out to be rather successful as Schilling & Logan (2008) theorized for the shrinking city.

Path dependence is also a critical barrier identified in the Lick Run case. Dhakal & Chevalier (2017), Matthews et al. (2015), Roy et al. (2008), and Brown and Farrelly (2009) all discuss the socio-institutional barriers present in green infrastructure adoption and connect to path dependence on gray infrastructure. Path dependence, along with a host of other socio-institutional barriers, could explain why large stormwater projects rely on gray solutions. Compared to Cincinnati, in Cleveland's Project Clean Lake consent decree, resistance to change was also seen as roughly only 1% of the conveyance for their stormwater was required to move through green infrastructure. Cleveland met this requirement by using a system of rain gardens but focused over $3 billion in funds toward a gray infrastructure approach.

Collaborative planning through design charrettes *and goal framing overcame the barriers toward green infrastructure adoption*

While previous literature sought to define barriers, this research adds to limited current knowledge by providing practices of overcoming specific barriers to implementing green infrastructure. Roy et al., (2008) discusses some broad strategies that can help with socio-institutional problems, such as education for watershed-based solutions and inter-governmental coordination, but posits the need to conduct more research on watershed-based designs, which this research helps fulfill.

Collaborative planning approaches through design charrettes have been used in prior applications for green infrastructure development. Collaborative planning has become from 2010 onward and has been applied to large-scope projects (Randolph, 2003). For example, Australia relied on a charrette process to fine-tune a continent-wide green infrastructure plan (Kilbane, 2013). This plan was put in place to provide improved mobility for various species as vegetative fragmentation has become worse due to climate change. While this was Australia's first attempt at green engineering for such a grand scope, the results of the design charrette to guide the solution process was a success in connecting theory to reality. While Lick Run does not offer the same scope as Australia's attempt, the collaborative planning that occurred connected Cincinnati residents to the problem and the solution. McCann (2001) encourages more of this ability, referring to this as public-private planning, because it connects individuals to socio-institutional problems and how to surpass them (Brown & Farrelly, 2009; Dhakal & Chevalier, 2017; Matthews et al., 2015; Roy et al., 2008).

This research adds goal framing as a solution to overcoming path dependence that may occur during planning for green infrastructure projects. Goal framing is a form of persuasive communication that highlights both the positive impact of an attribute *and* the negative impacts of not having that attribute (Levin et al., 1998). For example, to encourage exercise in adults, goal framing can be seen both by envisioning future benefits of a healthy body as well as the future detriments of poor or no exercise. In this regard, the attribute (in this example, exercise), is always desired, but the future outcomes are not. In the realm of infrastructure and decision-making, goal framing has been seen in modifying Envision ratings by endowing engineers with Envision points at the beginning of the rating process (Shealy et al., 2016). Better Envision scores, correlating to the goal of more restorative infrastructure, was the result. For Lick Run, this was witnessed from neighborhood leaders discussing the negative impacts of not having South Fairmount revamped with the project as well as MSDGC and the Landscape Architecture Firm communicating the possible benefits of the project (Project Groundwork, 2012b). Goal framing offers a solution to community buy-in and could be useful in overcoming path dependence toward gray infrastructure with more research.

Conclusion

Combined sewer systems have been heavily impacted by stormwater runoff, leaving cities faced with a formidable task to minimize overflows. Technological advancements have helped reduce combined sewer overflows in the mid-late 20th century through gray infrastructure improvements: more efficient treatment centers that handle greater capacity of wastewater and tunnel systems to hold CSO surpluses are two examples. As the 21st century came, designs for stormwater infrastructure became inclusive of the natural environment through green infrastructure: rain gardens, bioswales, and river daylighting present a few instances placed throughout the world. However, these solutions are normally used at a smaller scale, such as around parking lots or adjacent to local roads. The amount of CSO blighting cities places an urgency for stormwater decision-makers to incorporate large-scale solutions with gray-dominated projects as the default.

The results of this research serve as generalizations for future research. Since an exploratory case study was the primary method of data collection, propositions were refrained to prevent impact on shaping the results. This is based off grounded theory, which is impactful for exploratory case study research by forming generalizations after data is collected rather than hypothesizing answers (Strauss & Corbin, 1994). The findings were seen to largely agree with existing research while adding strategies to overcome barriers for green infrastructure, which future research can further explore.

The opportunity cost of the tunnel, modeling, and local leaders outside of government drove the adoption of the Lick Run Greenway. Federal mandates of CSO reduction have implored action at a local level to minimize overflows into surface waters. The drivers discovered by this research encouraged the use of green infrastructure over the initial design solution of a tunnel solution to store stormwater. However, uncertainty still lied in some decision-makers on the effects that the Lick Run Greenway would place on South Fairmount residents.

The scale of the project, the impacts on existing infrastructure, and path dependence presented obstacles for decision-makers to commission the Greenway. Traditionally, green infrastructure is not commissioned as often as gray infrastructure for stormwater solutions. Gray infrastructure projects are subsurface, meaning that the employment of these projects does not displace as many homes or businesses as green infrastructure. Surface infrastructure improvements can change landscapes drastically, placing risk on a community's outcome after the project is commissioned. These barriers qualify existing research, adding onto socio-institutional barriers as obstacles to green infrastructure across America.

To overcome these barriers, *collaborative planning, preventing eminent domain, impactful community stakeholders, and framing effects* assuaged the perception of risk for the Greenway. The project impacted the residents of South Fairmount, whereas the tunnel would have left the surface unaffected. Involving stakeholders in the decision-making process eased reservations for the Greenway's commissioning. These strategies to overcome barriers to commissioning green infrastructure are this paper's contribution to literature.

With this contribution to knowledge, this research has the potential to encourage more green infrastructure to be put in place, which could re-design city landscapes. Beyond changing landscapes, less application of gray solutions for combined sewer overflow applications could reduce urban heat island effects, infiltrate more stormwater for pollutant removal, and transform cities to become more environmentally-oriented.

However, more qualitative work is needed in the construction, engineering, and management (CEM) field. Future research can employ this paper's methodology to cross-case analyses, which are effective at drawing generalizations for more than one project (Yin, 2013). Cross-case analyses are suitable for verifying and extending this research's findings because they incorporate different groups of stakeholders for infrastructure development. Each infrastructure project is unique in its own regard since the constraints, advantages, alternatives, and outcomes that stakeholders consider vary, which cross-case analyses can synthesize. Potentially, more qualitative work in this regard can encourage green infrastructure.

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Conclusion

The conclusions of the studies on road diets and green infrastructure provide insight on how to overcome potential barriers to these types of infrastructure. While these infrastructure types serve different purposes, they share similar barriers. Stakeholders of the ICT and Lick Run both presented uncertainty for the effects of surrounding infrastructure once the projects were commissioned. Furthermore, an unwillingness to give up existing infrastructure was witnessed in both projects. While these projects both faced barriers, these projects both present the ability to impact the socioeconomic activity in the surrounding environment. For ICT, this was seen from businesses being surprised with more activity at their doors. For Lick Run, this was seen from the design goal to have a living, breathing infrastructure attraction to encourage more business and interaction in the area.

Road diets and river daylighting both face socio-institutional barriers. The research confirmed that planning for roadways faces the imperative to build more roads, despite the growing evidence of induced demand (Hymel, 2019; Hymel et al., 2010b). Furthermore, green infrastructure approaches face path dependence on gray infrastructure (Brown & Farrelly, 2009; Dhakal & Chevalier, 2017; Matthews et al., 2015b). Socio-institutional barriers are present in these types of infrastructure due to uncertainty, which could manifest as path dependence as this research has explored. For instance, stakeholders for both projects faced barriers for removing existing infrastructure.

To overcome the barriers that this research presented, both project teams relied on elements of framing to entice more stakeholders to buy-in to the project idea. Businessowners along the ICT were ensured that right-of-way along their business would be "beach-front property" as more locals would have better accessibility to their business. Lick Run was framed as a project that promised to revitalize South Fairmount, an area that is experiencing a decline in population. To build collaboration at the community level, design charrettes were also used on both projects, and were seen to be particularly effective for Lick Run. The charrettes may have been more effective for Lick Run because charrettes tend to be most useful when public funds are at stake (Lennertz et al., 2008; Roggema, 2013).

While framing and stakeholder management strategies through charrettes worked for the cases studied, more case study research is needed that targets socio-institutional barriers. This exploratory work is generally not pursued in CEM research, but it provides a robust understanding of phenomena that cannot be explained through primarily quantitative work such as understanding socio-institutional barriers (Dhakal & Chevalier, 2017; Taylor et al., 2011). This research is intended to provide a few strategies for decision-makers that may be applied broadly toward planning innovative infrastructure, and follow-up research should test and verify these findings.

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Appendix A

Interview Script

INTERVIEWEE:____

REDEVELOPMENT PROJECT:_____________________________

DATE: ____/____/____

START TIME: ___:___ AM/PM

END TIME: ___:___ AM/PM

SCRIPT:

VIDEO CONSENT?

AUDIO CONSENT?

1. What was your role in [redevelopment project]?

    1(a) Describe some of the typical tasks or responsibilities you were charged with.

2. Have you worked on similar projects in the past?

    2(a) IF YES: Can you provide a few examples?

    2(b) IF NO: Can you think of any examples of a project like this being worked on in other communities? What makes them similar in your mind?

Engineer Specific

What kind of assumptions did you have to make when modeling the proposed design?

Did your assumptions for this project look uniquely different than other projects?

How accurate were the models?

3. What do you think are the risks of a project like this? How was this one different, if at all?

4. In your mind, what do you think was the catalyst for the city to pursue this project?

5. Did you approach this project differently than other projects you have worked on in the past?

6. What would you say was the overall goal or goals of the project?

6(a) IF DOES NOT MENTION IT: Was sustainability or resilience ever mentioned as a goal of the project?

7. Do you think this project fell short of any of those goals?

8. Were there any alternative options for reaching those goals? And what made this the one that you chose?

9. This project involved taking away an existing public asset. How did you persuade the public of the benefits of doing this? What were their major concerns?

10. **FOR NON-ELECTED OFFICIALS:** What about elected officials? How did you persuade them? What were their major concerns?

11. Can you think of any other major hurdles or barriers to this project?

12. Imagine you are working on a similar project in the future. Did you learn any lessons on this project that you would carry forward into the new project?

13. Is there anything else you'd like to share about your experience on this project?

14. Is there anyone else who was involved in the project you think we should interview?