DRAINAGE IMPROVEMENTS ALONG OTTERDALE ROAD

GAUGING END USER PRIORITIES DURING THE DESIGN PHASE

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By
Logan Brock

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Technical Team Members: Amel Marzougui, Sullivan Higgins, Joshua Frye, Niko Bousquet

On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

ADVISORS

Kent Wayland, Department of Engineering and Society

Jonathan Goodall, Department of Civil and Environmental Engineering

How can civil engineering designs for flood-resilient infrastructure integrate technical requirements with the priorities of end users to create sustainable, effective solutions in flood-prone areas?

Flooding is one of the most pervasive and costly natural disasters worldwide, affecting millions of people and threatening infrastructure, particularly in flood-prone areas. As climate change increases the frequency and severity of extreme weather events, engineers are tasked with designing infrastructure that can withstand these challenges. Engineered systems can be big and bold, like a bridge, which is probably the most widely known feat of civil engineers. Some solutions are small or even undetectable to the trained eye, especially if they are hidden under shrubs or trees. One such technology is a bioretention cell, a landscaped depression designed to manage stormwater by filtering pollutants and facilitating infiltration into the ground. For a budding engineer, there exists an infinity of options to choose from when tackling a technical design challenge.

However, effective flood mitigation requires more than just technical solutions; it must also align with the needs and priorities of the communities that depend on the infrastructure. Real, living people are impacted by the work of engineers, regardless of whether that impact is intended or not. As end users ourselves, we see, experience, and often complain about engineered products every day. As a child, I remember frequently making fun of a nearby parking lot in front of a supermarket. The layout was a maze, there was barely any space to drive, and it seemed like there must have been a better way to construct it. While a little bit of annoyance from end users is inevitable, ignoring the public's opinions outright can mark an otherwise successful design as a failure.

In the realm of civil engineering, an effective design is the amalgamation of many competing factors and interests. Among these factors, incorporating the perspectives and priorities of end users is essential to creating designs that truly serve their intended purpose. Understanding what communities value most can guide engineers in making informed decisions that balance functionality with social impact. To achieve a better grasp of how an engineer can incorporate end-user feedback during the design process, I plan to research what end users deem as a priority in residential projects, and how engineers can gather this information themselves.

How do civil stormwater engineers prioritize competing design criteria such as cost, environmental impact, and flood risk mitigation?

To explore this balance in a real-world context, I will use my Capstone project on Otterdale Road in Chesterfield, Virginia, as a case study. This project provides a concrete example of how flood resilience must be engineered within the constraints of technical requirements and community preferences. My Capstone group has been tasked with proposing a theoretical solution to the frequent flooding issues that have occurred at the intersection of Otterdale Road and a river, Otterdale Branch. The section of Otterdale road that is of interest to us is unable to convey the stream discharge (flow rate) associated with even a 2-year storm event

– a relatively low-intensity storm with an expected recurrence rate of two years – causing flooding on the upstream side of the existing double box culvert. Our design must improve the conditions at Otterdale Road such that the road and surrounding area do not flood during a 100-year storm.

From a technical standpoint, this means that our criteria for success are as follows:

- The expected upstream water surface elevation for a 100-year storm must be less than or equal to what it was prior to our redesign – that is, we must not raise the floodplain in the construction site's vicinity, which will necessitate a massive increase in the hydraulic opening of the stream crossing to prevent water from backing up
- The roadway must not overtop during a 100-year storm event
- Environmental impacts of the project, such as wetland contamination via excessive sediment runoff, are mitigated
- The cost of the project is minimized
- We are able to provide an effective design solution within our limited time frame of two semesters

In order to provide a solution that is not only effective but cost- and time-efficient, all of these factors must be considered. This Capstone project serves as a simulation of the constant struggle between design choices that engineers face when trying to develop an optimal solution. To overcome this challenge, I will need to investigate an array of civil engineering design principles and gain practical experience with an arsenal of hydrologic and hydraulic modeling software.

To begin, my team started working in HEC-RAS, a software application developed by the U.S. Army Corps of Engineers for modeling the flow of through rivers, channels, and floodplains. We have constructed a HEC-RAS model to determine an appropriate hydraulic opening for a new bridge, a reasonable elevation for the top of the new roadway, and an idea of what type of precast bridges we plan to purchase. In doing so, we realized that the existing roadway crosses the river at an angle greater than 30 degrees in plan view, which would complicate the implementation of our bridge, or at least increase the minimum functional bridge length. To remedy this issue, we will need to adjust the curvature of the roadway to create a stream crossing that is roughly perpendicular to the river.

To check our HEC-RAS assumptions, we also need to explore HEC-HMS, a program from the U.S. Army Corps of Engineers that predicts how rainwater moves across a landscape, showing where it gathers and how much eventually flows into rivers or streams. Further down the road in our timeline, we will construct a HEC-HMS watershed model to predict the river discharge under anticipated future land use conditions. According to Contech Engineered Solutions – a company specializing in bridges, drainage systems, and retaining walls – authorities can reduce the risk of flooding by examining how future developments will alter the land conditions and implement stormwater infrastructure to offset the increased stream flow that results from those changes (*The Vital Role of Design Storms in Civil Engineering and Stormwater Management,* 2023). Chesterfield County has recently committed to growing and developing its land, which will undoubtedly lead to increased urbanization of the land surrounding our Otterdale Branch stream crossing. *Chapter 12: Specific Area Plans* of Chesterfield County's *Comprehensive Plan* details an array of developments expected to occur in the near future (*Comprehensive Plan, 2019*). By examining the land use graphics provided by Chesterfield County and incorporating them into our HEC-HMS model, we will be able to more reliably confirm that the discharge values assumed in our HEC-RAS design are appropriate for an effective bridge.

Beyond the hydrologic and hydraulic modeling, we will need to consider how our project will impact the surrounding area and people who live there. Since we plan to demolish the existing road, we will need to designate detours or create temporary roads to serve the community during the construction phase. Ultimately, my team hopes to present our work as if it were a proposal at a public hearing, where we would gain key insight into our stakeholders' wants and needs. However, since our project is artificial, we cannot directly ask relevant stakeholders for their priorities. It is at this point that we begin to consider the following question.

How do engineers sufficiently gauge the priorities of end users to make informed decisions in the design phase of residential construction projects?

Perhaps an even greater challenge for engineers is determining how the end users will respond to their design. There exists a plethora of technical solutions to an engineering problem, but the vast majority of them would be rejected by the end users due to aesthetics, inconveniences they pose, or misalignments with personal beliefs, to name just a few reasons. In the context of our Capstone project, one example of a technical solution to the flooding issue that would fail in the public eye is to simply demolish the road. The stream would no longer have issues conveying all the stormwater runoff, the floodplain would decrease, and the project would not consume much time or money, and yet this design would obviously be a failure. The end users of any design will always have additional criteria for success, and this adds complexity to the scope of a project. Digging deep to identify these criteria is essential if we wish to gain the support of all stakeholders.

In order to better gauge the public's needs, we will first examine the currently available avenues of design intervention for end users. As mentioned previously, engineering designs are often proposed through public hearings. However, disturbingly little analysis has been done to assess the effectiveness of public hearing practices (Checkoway, 1981, p. 566). While it is true that public hearings involve citizens, we cannot be certain that valuable end user participation always occurs. A study on the public participation activities of State Departments of Transportation in the United States claimed that in order to be considered authentic, public participation must be representative, interactive, and of high enough quality that the public's input can be used meaningfully (Figueredo, 2005, p. iii). Figueredo then categorized 219 districts by their degree of participation authenticity. The categories were: very high authentic participation; authentic participation; acceptable participation; token participation. Figueredo found that only 7 of the 219 districts demonstrated very high authentic participation, while 50 of them fell into the token participation zone (Figueredo, 2005, p. 97). This analysis suggests that public hearings currently fail to meaningfully address end users.

In a less formal setting than a public hearing, end users may also communicate with their elected officials and representatives of engineering teams at town hall meetings. However, upon examining the interactions of town hall meetings, Green argued that they primarily serve to advance research on the ideologies of activist groups or the failures of representative government (Green, 2016, p. 8). Far too many articles written about the proceedings of town hall meetings are focused on the representatives involved or the messages they spread, rather than the action items being discussed. Town hall meetings appear to be more conventionally used as grounds for political discourse and are perhaps less conducive to constructive conversations involving stakeholders.

The evidence points toward public hearings and town hall meetings providing insufficient outlets for end user input. While these methods may allow the public to influence policy decisions to create more stringent engineering regulations, they do not appear to serve as an adequate platform for direct communication between the engineers and end users of a project. Therefore, we will need to conduct further exploration of end user engagement and assess if there exists a method that is truly authentic.

To organize the relationships that exist in my Capstone project, I will describe the system as an actor network. The central actor is the group of engineers, who seek to develop an effective design that improves their communities for many years to come. As the central actor, the engineers will motivate all other actors within the system to achieve their goal. For the sake of argument, the road itself is an actor, which wishes to be preserved and improved upon so that no more flooding occurs. The road essentially enables the temporary demolition and reconstruction for the project to proceed. Another actor is the regulatory groups which oversee the design process to ensure that a project is both safe and unobtrusive. Without adhering to regulations, a design will never proceed past the design phase. Policies also exist to generally serve the public's interests. The final actor is the end users of the design, who may have a variety of concerns, such as for their community to have increased utility and function with as few disruptions as possible. These concerns ought to be thoroughly considered during the development of a project, as the opinions of end users ultimately determine how successful the project is, regardless of how low its cost is or how well it complies with regulations. It is under this assumption that we make end user concerns the focal point of our research.

By researching which factors of a project end users prioritize, we can better define what kind of design solutions will be both technically and socially sustainable. Since I am interested in how engineers bridge the communication gap, I will perform additional research for anecdotal evidence of engineers achieving collaborative interactions with their stakeholders. I will identify case studies exemplifying poor and ideal end user participation, beginning with the Flint, Michigan water crisis of 2014, which evoked sharp criticism of the Environmental Protection Agency after they failed to address the public's concerns about lead-contaminated water (*Congressman John Moolenaar*, 2016). Additionally, I intend to interview active engineers to reveal what steps are typically taken to ensure adequate end user interaction during the design phase. Exploring the practices of experts who have completed successful projects will also provide evidence of the necessity of end user interaction. I hope to determine whether technically effective and socially accepted projects had a more robust method of stakeholder engagement than less successful ones, and if so, learn more about the participation processes used.

Conclusion

Through integrating end-user priorities into flood-resilient infrastructure design, my research could provide insights into creating more sustainable and socially acceptable solutions. This work could influence how future engineering projects are designed, ensuring that they not only meet technical requirements but also resonate with the communities they serve. The findings could also inform policy makers, engineers, and urban planners on best practices for designing infrastructure that accounts for both environmental resilience and social acceptability. On the other hand, this research could serve as an initiative for preemptively assessing community priorities for future engineering projects. If I find that there is insufficient evidence of engineers communicating with their projects' end users, it will imply that the existing methods of end user interaction are inadequate, and more work must be done to bridge the gap. Future projects could explore innovative strategies for engaging stakeholders and understanding their needs, fostering a more collaborative and inclusive approach to infrastructure design.

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