Increasing the Impact of Impact Evaluations: A Mixed-Methods Approach to Evaluating Trailbridges in Rwanda

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Abstract

Communities living in mountainous regions face physical barriers that constrain their movement and, consequently, access to critical services. In Rwanda, where more than 70% of people live in rural areas, climate change has compounded these constraints, making it difficult for people to move from their homes to centers offering various services including markets, healthcare, labor, and education. The frequency and intensity of flood events has been increasing, causing significant losses and negative impacts to livelihoods and infrastructure. Trailbridges are revolutionizing rural transportation in the country's western region — connecting people to services and mitigating flood risks. In this paper, we present a mixed-methods approach to assess the impact of trailbridges on health, education, agricultural, and economic outcomes of households in vulnerable, rural communities. We seek to provide evidence on the effectiveness of trailbridge interventions in addressing the unique challenges faced by these communities. Due to ongoing data collection and analysis, the focus of this paper is on the innovative combination of multidisciplinary approaches and data sources to enhance understanding of the

impact of trailbridges and to identify methods that can be applied to evaluating other interventions at scale, and are less resource-intensive.

Introduction

The combination of difficult terrain and the increasing intensity and frequency of extreme weather events under climate change makes sustainable development a particular challenge in mountainous regions and hinders evaluating the impact of such development efforts, and specifically progress toward the Sustainable Development Goals. Further, traditional approaches to impact evaluation - namely, randomized controlled trials - are time and resource intensive, not only for evaluators, but also for the implementing organization and the communities being served by the intervention. In 2019, the non-profit Bridges to Prosperity launched a joint scaling program with the Government of Rwanda that aimed to construct 355 trailbridges, serving communities across all provinces in Rwanda. The scale of this program is motivated by evidence of benefits from similar rural transportation interventions and presents an unprecedented opportunity to evaluate the impact of consistent, safe connectivity on underserved communities in a rural, mountainous region (Brooks and Donovan, 2020; Thomas *et al.*, 2021). Moving beyond traditional research approaches, we are leveraging a multidisciplinary team to develop an innovative, mixed-methods study design that can: (1) generate evidence to support decision making by national policymakers and investment in first-mile rural infrastructure, and (2) identify low impact, cost-effective, easily-assessed measures correlated to economic and health benefits of trailbridges.

Photograph 1: A photograph of the Nyakabuye-Mwogo suspension bridge, completed October 6, 2020 in Rwanda.

Impact evaluations have become common approaches for measuring the success or failure of interventions in a range of sectors. These approaches have long been popular in medical sciences, but their use in measuring impacts in development sectors, such as water, sanitation and hygiene (WASH) (Kirby *et al.*, 2019; Iribagiza *et al.*, 2021; Thomas *et al.*, 2021), agriculture (Dhehibi, Werner and Qaim, 2018), and labor and market sectors (Brooks and Donovan, 2020), has grown significantly. Reasons for an expanded interest in impact evaluations are rooted in (i) concerns that development interventions, especially in low income settings, have not had the desired impact despite enormous amount of resources and time spent on implementation (Haque and Freeman, 2021) and (ii) inconsistencies between impact metrics or outputs (e.g. number of people trained) and outcomes (e.g. improved services) (Bamberger and White, 2007).

The complexity of sustaining interventions and providing reliable measures of impact has resulted in the development of methods and frameworks that provide better evidence that a particular intervention is meeting set objectives (Haque and Freeman, 2021). These methods are designed as iterative feedback systems that can improve program implementation, such as revising theories of change that may be found to no longer be applicable to a certain setting due to changes in conditions upon which a development intervention was originally conceived or re-defining priorities to raise outcomes for a smaller number of beneficiaries (Thomas *et al.*, 2021). Traditionally, impact evaluations have relied on quantitative approaches built around experimental designs such as randomized controlled trials (RCTs) (Hemming *et al.*, 2015), but new fields of research are promoting the use of other complementary approaches that can provide insights about outcomes that cannot be solely measured or explained through experimental methods. This thinking has led to the emergence of mixed methods that combine experimental and non-experimental approaches using quantitative and qualitative data collection for impact evaluations. The choice of methods and designs should generally be guided by the available resources and existing constraints, the nature of what is being evaluated, and the nature of the evaluation (Rogers *et al.*, 2015).

Next, we describe how such mixed methods approaches are being leveraged to evaluate the impact of trailbridges in Rwanda. This work builds upon methods first described in Macharia *et al.* (2022).

Methods

Study sites

The scaling of Bridges to Prosperity's trailbridge program was launched after an extensive needs assessment that involved consultations with resident communities and local officials in 22 districts directly affected by the lack of accessible and safe transportation across water crossings. From these multi-stakeholder engagements, B2P identified over 1000 sites for construction in Western, Northern, and Southern provinces. Construction of trailbridges at study sites began in 2020 and, to date, 86 bridges have been completed of the anticipated 97, with one build year remaining (Figure 1).

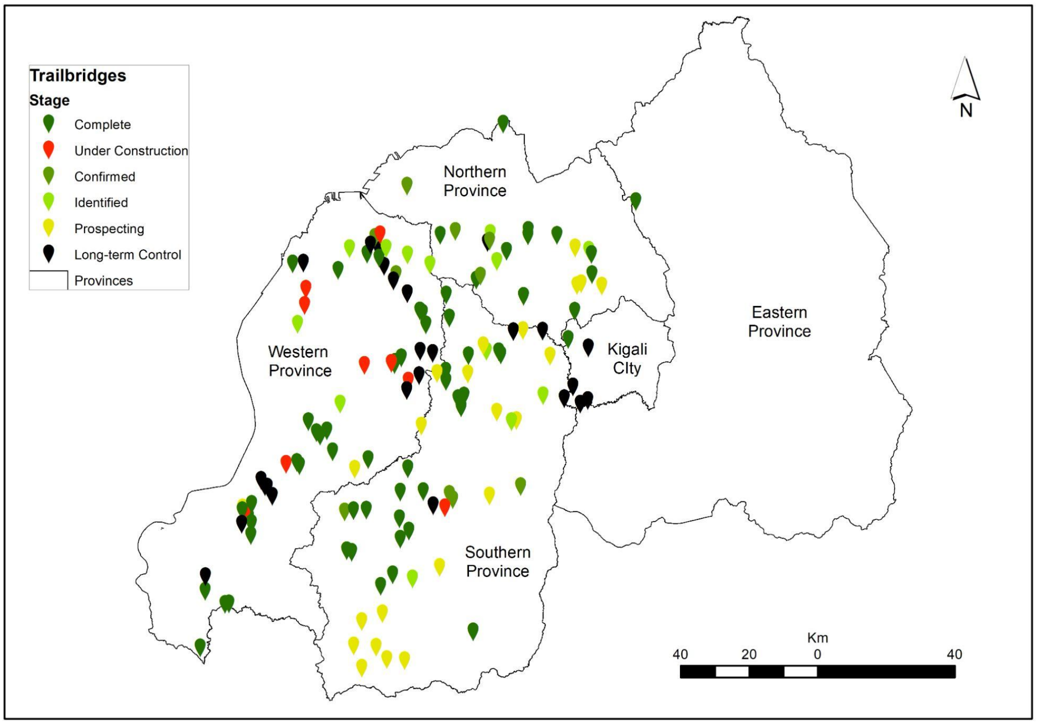

Figure 1: A map showing the location and status of the survey bridges.

The impact evaluation is anchored on a stepped-wedge, randomized controlled trial (RCT) in 147 sites. Additionally, three interlinked sub-studies additionally leverage econometrics, machine learning, and remote sensing to investigate: (1) the role of weather and flooding on bridge use patterns, (2) the impact of trailbridges on crop production and market prices of key farming inputs and commodities, and (3) the spatial extent of trailbridge impacts on more distant villages.

The Randomized Controlled Trial

The RCT is the primary study and supports complementary, non-experimental studies to scale in settings and contexts where budgets, time, and other factors do not allow for experimental designs. The RCT follows 147 district-randomized sites over four rounds of annual household-level surveys (Macharia *et al.*, 2022). In every build year, or "wave", bridges are completed at a subset of the sites. The study design is such that all sites begin as control sites and in every wave, a subset transitions to intervention sites after a bridge is constructed within the community. At the end of the evaluation, there will be 97 intervention and 50 long-term control sites to enable the continued investigation of effects beyond the initial four-year study period.

At each site, in-person, household-level surveys are conducted annually with respondents from 105 randomly selected households, 35 each from the three villages identified by local leaders as being most impacted by the potential construction of a trail bridge. This survey is also completed at households in more distant villages for a subset of sites, which is discussed further in a subsequent section. Additionally, 2,000 households are contacted by phone each month for high frequency data collection on a subset of questions from the in-person household-level survey.

Rainfall variability and flood modeling

Establishing the associations between extreme rainfall events, flooding, and outcomes of wellbeing can be challenging due to lack of in-situ measurements at scales relevant for impact evaluations. More often, such scales lack quality data that can enable a time series investigation of trends in rainfall extremes and flood risks. For example, the study sites where most trailbridges are located are in minimally observed river catchments. Because extreme rainfall events and floods can influence rural mobility, having alternative sources of time series data is paramount to a successful impact evaluation.

We are combining available river gauge data and remote sensing observations from satellites to calibrate and validate hydrologic models and estimate streamflow at bridge crossings. We are also using bias-corrected satellite rainfall estimates to investigate trends in extreme rainfall indices across the study locations. Initial findings are reported in a recent paper (Macharia *et al.*, 2023) showing remarkable potential for providing the data needed for the large-scale impact evaluation. This study developed and compared the performance of two general types of models: (1) machine learning or data-driven models and (2) a process-based hydrologic model. It was shown that the former performed relatively well when compared with observed data, enabling an extension of the timeseries to cover 20 years of streamflow simulations at the daily timescale.

The next step is to apply these models across the entire study area and simulate streamflow at each of the 147 sites. Flood event analysis will then be conducted to determine the frequency and return periods for different flow thresholds considered dangerous or impassable for people who use river baselines to cross waterways. The household-level surveys will be used to ascertain differences in outcomes between communities with and without a bridge given their experience of flood events and impacts. This investigation would mirror the analysis reported in Nicaragua that found flooding risk to have a strong effect on labor market outcomes (Brooks and Donovan, 2020).

Evaluating agricultural productivity

Agriculture is critical to the Rwandan economy and food supply: 75% of the labor force works in agriculture and 69% of total national agricultural output is from crop production (Ngango and Hong, 2021). Maize is the predominant staple crop (Ngango and Hong, 2021) due to its suitability to the climate and soil (Kathiresan, 2011). Increasing staple crop productivity and market availability has direct impacts on economic development and food security – improvements that could benefit the 20% of food insecure Rwandans (World Food Program, 2023). Prior research by our collaborators found that farmers respond positively to the presence of a bridge in their communities and changes to farming practice can lead to improved agricultural productivity and farm profit. The bridges enable more reliable access to markets for both the purchasing and selling of goods, thereby making farm inputs available and lowering the risk of investing in the farm. In response to construction of trailbridges in Nicaragua, farmers spent approximately 60% more on fertilizer and pesticide and reduced agricultural storage by 10 percentage points. Consequently, farm profit increased by 75% (Brooks and Donovan, 2020). While insightful, these conclusions were generated after three years of resource-intensive surveying and do not measure agricultural outputs directly.

Monitoring agricultural productivity is an extensive undertaking that requires crop identification and crop-specific measures of growth stages, cultivated area, and yield. This is typically accomplished with population sampling, but traditional surveying is time and resource intensive and limited in scope and resolution (Temple *et al.*, 2019). Satellite-derived agricultural monitoring, instead, provides wider coverage, greater frequency, and the ability to disaggregate to community or, even, plot level (Jin *et al.*, 2019). Thus, a method designed to take advantage of the availability of satellite imagery in Rwanda can help address some of the challenges experienced in previous studies of measuring agricultural responses to bridge construction. To undertake the same steps of crop classification and yield estimation, ground-truth samples, such as crop cuttings or human-annotated images, are needed to train and validate remote sensing-based models. Supervised machine learning, which minimizes the loss between observed and modeled data, has shown promise for remote crop monitoring. For example, various authors (Jin *et al.*, 2017; Chew *et al.*, 2020) have used random forest models and neural networks trained on imagery to classify maize in East Africa.

We are applying machine learning to measure maize productivity in the study villages and detect changes over time and differences from areas without bridges. These methods will complement and augment the RCT household surveying campaign and, more broadly, the bridge monitoring program by being efficient, reproducible, and timely means to generate estimates of bridge impact on agricultural practices, as part of overall household wealth and wellbeing.

Market price, travel time, and distant village studies

Market access can influence prices of key commodities and services due to the association between distance and transport costs. Reliable market access can boost productivity, increase incomes, and strengthen food security (Rosegrant and Cline, 2003), whereas the lack of it can increase the cost of farm inputs and commodities. Trailbridges provide accessibility that was previously unattainable and reduce transportation costs and travel time to market centers. Travel costs may be further reduced when more than one bridge is available within the market catchment area and when the bridge provides an alternative to motorized transportation modes such as roads. We are monitoring the impact of the trailbridges on agricultural input and product prices in markets serving study sites through monthly vendor surveys conducted by local enumerators to study these assumptions. This ancillary data collection started at a subset of sites (22) after the first round of household surveys, was then expanded to a larger subset (56), and is currently being expanded to cover all sites in the RCT.

We have adopted geospatial models that have shown good performance in estimating travel time to centers of interest globally (Weiss *et al.*, 2018) and in low-resource settings where data is sparse (Joseph, Macharia and Okiro, 2022). Household-level surveys being conducted as part of the RCT study will be used to validate the time travel models against self-reported travel time to various locations including farms, schools, health centers, government offices, and financial centers. The travel time models are also expected to contribute to understanding the variability of observed market prices. Once validated, such models can be applied to other settings where intensive household surveys typical of RCTs are infeasible.

The distant village study is premised on the hypothesis that, although villages proximate to the trailbridges are the primary beneficiaries and will realize most benefits from this intervention, the impact will extend beyond these immediate villages to more distant locations. To test this hypothesis, at 30 sites in the RCT - 20 intervention and 10 long-term control - we have randomly selected 10 households within a more distant village to conduct the household-level survey as part of each annual round. These distant villages are at least 2.5 km from any trailbridge site, including those constructed by B2P but not included in the study. We will apply distance-decay models to establish the spatial extent of bridge impacts. These models will also be complemented by catchment surveys intended to provide data to “catchment” area models that will enable us to determine the approximate area served by the trailbridges (Macharia *et al.*, 2021) and how origins and destinations are connected to each other via the trailbridges.

Taken together, the market price, travel time, and distant village ancillary studies augment the more detailed study and could help explain marked differences between the intervention and control groups in the RCT. Complementary mixed methods approaches form an important contribution that can be applied in other settings and contexts that require evidence of development interventions without the need for expensive experimental methods.

Recommendations for Enhancing Effectiveness of Impact Evaluations

Throughout the development and implementation of this research study, and with an eye to effective dissemination of our findings, we have kept the following objectives in mind. We share these objectives as recommendations for impact evaluations across sectors to increase the impact of their findings while reducing the resources needed to achieve this impact.

Integrate Diverse Methodologies for Thorough Impact Evaluation in Challenging Terrains: We recommend a comprehensive approach to impact evaluation, integrating traditional and innovative methodologies such as randomized controlled trials, econometrics, machine learning, and remote sensing (Macharia et al., 2022). This integration would yield more nuanced insights into intervention outcomes and would be especially beneficial in challenging terrains, like the mountainous regions of the Bridges to Prosperity's trail bridge initiative in Rwanda.

Promoting Stakeholder Participation and Utilizing Local Expertise: For ensuring sustainable and effective project outcomes, engaging stakeholders at all stages of the project cycle is paramount. Stakeholders and beneficiaries may receive greater benefit from secondary data analysis approaches since the burden of frequent participation in data collection, such as surveys, is removed. Leveraging local expertise is also critical. In our project, for instance, the Amazi Yego team and the enumeration team leadership, all of whom are Rwandan, have been instrumental. The enumerators, who already came with substantial qualifications, provided us with invaluable local insights and understanding, enriching our data collection and analysis processes. Rather than emphasizing capacity-building, our approach highlights the importance of recognizing and utilizing the existing capacities and skills in local communities.

Optimize Data Collection Through Digital Technologies and Diverse Data Sources: Digital technologies such as remote sensing, machine learning, and Geographic Information Systems (GIS) offer efficient methods for data collection. They not only reduce resource intensity but also facilitate real-time or near real-time data availability. The use of diverse data sources further strengthens our approach. Primary data collection can be significantly complemented by secondary sources, including administrative records and satellite data, reducing the need for extensive field surveys without compromising data quality or comprehensiveness.

Cultivate Multi-Sectoral Collaborations for Effective Evaluations and Resource Utilization: Promote partnerships across sectors and between researchers, practitioners, policymakers, and communities to ensure evaluations minimize burdens, maximize benefits, and yield results that inform policy and practice. Such collaboration will prevent duplication of efforts and optimize resource usage.

Establish Robust Infrastructure for Sustainable Data Management: Maximizing the benefit and longevity of data collected from impact evaluations calls for the creation of a robust, enduring data management infrastructure. Such a system would ensure data are not only accessible but also usable for future research and to inform policy decisions. Data management and storage infrastructure should be designed with an emphasis on data security and privacy, thereby fostering trust and maintaining consent with the communities who have contributed their information. This would not only safeguard the interests of participants but also enhance the overall value of data repositories, enabling researchers and policymakers to revisit and leverage this rich resource long after study completion. Furthermore, the development of standardized protocols for data collection, management, and sharing can help increase the consistency and comparability of results across different evaluations, further augmenting the impact of impact evaluations.

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