BRIDGING THE GAP: USING PEDESTRIAN BRIDGES TO CREATE RELIABLE ACCESS TO ESSENTIAL RESOURCES

THE PRESENCE AND IMPACT OF TECHNOLOGICAL LEAPFROGGING IN INFRASTRUCTURE IN UNDERSERVED COMMUNITIES

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By
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Technical Project Team Members
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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.

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Catherine D. Baritaud, Department of Engineering and Society
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On a Tuesday in May, the plink of falling rain against the steel roofs of the homes in the villages of Coilolo and Tipa Tipa slowly wake their sleepy inhabitants. For some, a rainy morning like this could mean remembering to pack an umbrella or signaling to roll over and return to sleep. In the Zudáñez municipality, in southern rural Bolivia, where these villagers wake up, the sound of rain means something else entirely. Much the rest of southern Bolivia, these villages are primarily agriculturally based (Arnade, C. W. & McFarren, P. J., 2022, p. 1966). To them, rain leads to crops and food, signals growth and preservation of their livelihoods. Without the plentiful rain in this region, these people could not live here–could not grow their crops or raise their livestock. But, for villages neighboring rivers like Coilolo and Tipa Tipa, the sounds of rain can also be a siren of warning–alerting villagers to the dangers and isolation due to river flooding. Rains and flooding make these rivers impassable–effectively removing access to essential resources like education, healthcare, and economic markets for at least 24 hours, if not longer. This is the reality for a significant portion of Bolivia, where around one-third of the population lives in rural communities, that can become isolated after rains during the six month rainy season (Arnade, C. W. & McFarren, P. J., 2022, p. 1966).

The technical portion of the project focuses on addressing this accessibility problem with the design and development of construction plans to construct a suspension footbridge across the Rio Coilolo for the villages of Coilolo and Tipa Tipa. Working with both professional engineering advisors, Leo Fernandez and Rupa Patel, and the Engineers in Action (EIA) Bridge Program advisors, the result of the technical project will provide the villages of Coilolo and Tipa Tipa with the access to the basic resources they need. Under the guidance of Professor Jose Gomez in the Civil and Environmental Engineering department, the project team will complete the bridge deliverables over two semesters, in a year-long capstone project. Over the first semester, the bridge design will be completed, submitted and reviewed by Professor Gomez, our professional advisors, and EIA. Of our team of eighth fourth-year civil engineering students, the design work will be primarily spearheaded by Design Manager Glenn Broderick and Assistent Design Manager Katherine Foley, but will also be supported by the rest of the team and led by myself as Project Manager. We will also submit an International Development Statement with our bridge design, which will address the cultural and sociological challenges commonly faced in these kinds of projects and is directly informed by our team members' STS paper topics and research. This will primarily be completed by Cultural Relations Manager Sarah Besecky. In the second semester of the project, the construction plans and schedule, along with a comprehensive bill of materials, will be developed and presented for review by our advisory team and EIA. The construction management team–John "Cooper" Hamby, Wyatt Yoder, and Timothy Maxwell–will be primarily responsible for these deliverables, supported by the rest of the team. Simultaneously, our Fundraising Manager Terence Moriarty will be gathering fundraising support for our team members to travel to our bridge site in Summer 2023.

The STS portion of the project will center around technological leapfrogging, particularly in infrastructure projects in global underserved communities, like the villages in the technical project. As such, the STS and technical topics are tightly coupled. By applying the System in Context STS framework to case studies of infrastructure projects, I plan to build an understanding of technological leapfrogging and identify the factors that foster the failure of leapfrogging and its detrimental effects. This framework is particularly relevant to this subject, since the problems with leapfrogging arise out of a lack of consideration of the sociocultural context surrounding the technology, and will be a powerful analytical tool in this research. I hope to pair this work with the technical project by identifying ways the negative impacts of technological leapfrogging develop in these projects, to avoid these practices in the technical project and provide a basis for future work into this subject.

BRIDGING THE GAP: USING PEDESTRIAN BRIDGES TO CREATE RELIABLE ACCESS TO ESSENTIAL RESOURCES

The technical problem my project hopes to address is the challenge of designing and constructing a pedestrian bridge project in rural Bolivia, providing access and aid to these communities while also giving the project team real-world project experience. Much of the work and exercises we do in structural and civil engineering classes center around theoretical situations–with all of the “hard” or “complex” aspects controlled or assumed. This project provides the opportunity to gain the meaningful and practical skills necessary for real design and construction projects.

Our project is completed under the direction of the organization, EIA. As explained on the EIA Bridge Program website (https://www.eiabridges.org/), EIA is a non-profit engineering organization that works to end poverty and assist in development in underserved areas, both domestic and foreign, through the design and construction of pedestrian bridges. They were primarily working in community-based water, sanitation, and infrastructure programs in Bolivia and Ecuador before the developing Bridges to Prosperity (B2P), a non-profit organization working to reduce global poverty by providing access of isolated communities to essential resources, helped expand EIA’s scope of work to include pedestrian bridges.

B2P began training EIA professionals on pedestrian bridge design and construction, and helped EIA host university teams for projects before transferring completely the university bridge program over to EIA, where it now exists as the EIA Bridge Program. This program is currently headed by Ethan Gingerich, who serves as Bridge Program Director, with help from

Brenton Krieger, the Bridge Program Coordinator and Educator. Both of these engineers are our team's primary contacts for EIA.

Our approach to this technical challenge is education-centered and collaborative. The Bridge Program provides educational courses to help teams learn how to complete all aspects of the project–from bridge design to fundraising–in their Bridge Binder (Gingerich & Krieger, 2022) and on their educational site, BridgeEDU. They also have adapted the Bridges to Prospersity Design Guide for more complicated design work, which our team will also refer to (Kriesa, 2022). Each team member will take and apply relevant EIA and UVA coursework to the project. Our team is organized in a traditional project management structure, with all operations directed by a project manager and then further divided into specific teams as needed.

While the technical project scope ends in Bolivia, this work in accessibility in rural communities has global implications. Westerink and Barco (2016) asserted that "...more than one billion rural residents do not have all-weather access to markets, schools, healthcare and other facilities, a condition which significantly impedes economic development," (p. 11) evident in the fact that the majority of these rural residents live in lower income nations, and make up a significant portion of the population in those nations (Zhenmin et al., 2021, p. 26-27). At the root of this economic disparity is the rural isolation of these communities–the effect of which is often a positive feedback loop. Rural isolation limits economic development and opportunities, and a lack of economic resources prevents both local and municipal invention to reduce this isolation. This isolation and reduced access to markets also hits these communities during the wet or raining seasons–which typically are the primary seasons for cropping. Without access to the markets to both buy supplies and sell their goods in these crucial seasons, the livelihoods of rural communities become increasingly vulnerable. Brooks and Donovan (2020) found that placing bridges in communities resulted in a 75% increase in farm profits as a result of this access (p. 1966).

In addition to the economic impacts, Brooks and Donovan (2020) also discuss socio-cultural impacts of this isolation that can have future economic ramifications, like barriers to education and equity (p. 1965-1967). Isolation due to weather events can disrupt education of children and sometimes keep them so far behind thay have no way to catch up; this can imply the development of current and future barriers to socio-economic mobility for those in the community with limited access to regular education. With the addition of a bridge, children enrolled in schools increased by 12% (Engineers in Action, n.d.). Accessibility in rural communities can also have impacts on reducing barriers to equity, especially for women. With regular and reliable access to education, jobs, and healthcare outside of their village, the amount of women in the workforce increase by abou 60%–addressing some issues of gender equity prevalent in these communities (Engineers in Action, n.d.). These benefits indicate broader cultural and societal shifts towards education and equity that would not be possible without the presence of the bridge.

Our primary resources for this technical project will be the educational sources from B2P and EIA, which include sample standard designs like in Figure 1 to help us begin our design. We will also be relying heavily on software like AutoCAD for both modeling and drawing generation and calculation tools like Excel. In addition to resources directly contributing to our design and construction plan deliverables, our team hopes to travel to the bridge site to aid in the construction of the bridge. We will be using a two-pronged approach to fundraising to enable this–using corporate sponsorship and academic grant or funding sources, like the Experiential Learning Fund.

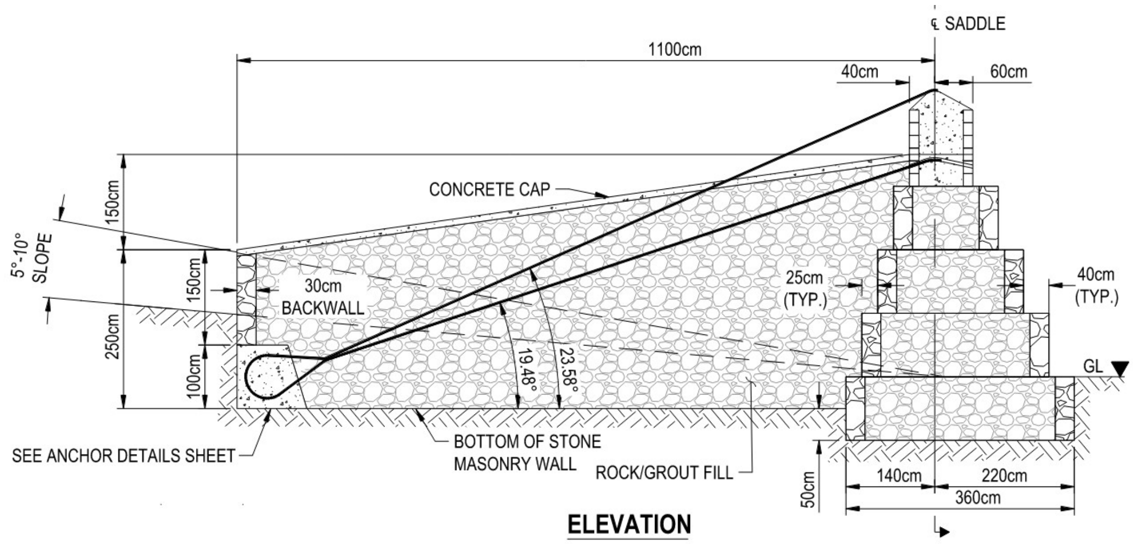

Figure 1: Three tier elevation design for suspended bridge abutment, meant to span a river of 40-60meters in width. This design is one that will be used to initially ground our bridge design, though we have already determined custom design alternations will be needed for this abutment. (Gingerich & Krieger, 2022).

The expected deliverables and ideal outcome for this project are a complete construction plan set, with design and assembly plans and accompanied by a technical proposal-style report. Looking beyond completing our degree requirements with this deliverables, the team aims to participate in an engineering project that actually has a meaningful and measurable impact on the villages of Coilolo and Tipa Tipa. For us, this manifests in the successful completion of a bridge that will provide reliable access to agricultural fields and markets, as well as educational opportunities beyond the 5th grade.

THE PRESENCE AND IMPACT OF TECHNOLOGICAL LEAPFROGGING IN INFRASTRUCTURE IN UNDERSERVED COMMUNITIES

Technological advancement is very clearly seen to play a “crucial role…in national development,” (Sharif, 1989, p. 201) but the disparity between countries’ abilities to assess the risks and benefits of a technology as well as the extreme states of global income inequality have slowed this industrialization and development, particularly in lower income nations, despite unprecedented technological development globally (Soete, 1985, p. 411). Basically, richer nations are better equipped to both develop and implement new, rapidly advancing technologies, entrenching and furthering existing national economic disparities. Observing this, a great deal of planning and mobilization has been put forward on a global scale to "jump start" development in these countries, in the form of technological leapfrogging.

Technological leapfrogging, or the "skipping" stages of technological development with the aim of more rapidly reaching a level of advancement (Sharif, 1989, p. 202), is a strategic development tool being used to boost development globally across all different industry sectors. Technological leapfrogging as a developmental tool relies on a technologically deterministic view of linear technological development, from the "low" or primitive to the "high" and complex. Assuming this process is isolated from simultaneous developments in economy and society, proponents of leapfrogging take no issue with bypassing some of the arguably necessary developmental stages to high technology (Amir, 2004, p. 110).

Globally, the investment in these vital infrastructure projects needed is about $94 trillion USD, while only about $79 trillion is predicted to actually be invested by 2040 (Oxford Economics, 2017, p. 25). This investment gap holds true for all regions of the world, including in South American countries displayed in Figure 2, on page 8, where the corresponding technical project is located. Even with trillions of dollars of investment into essential infrastructure, which is still not enough to meet the global need, there is still a disconnect between the amount of money invested in infrastructure projects and the actual development witnessed in the countries where these projects are implemented. Infrastructure projects in particular utilize leapfrogging; thus, understanding this strategy could explain this divide in these underserved areas.

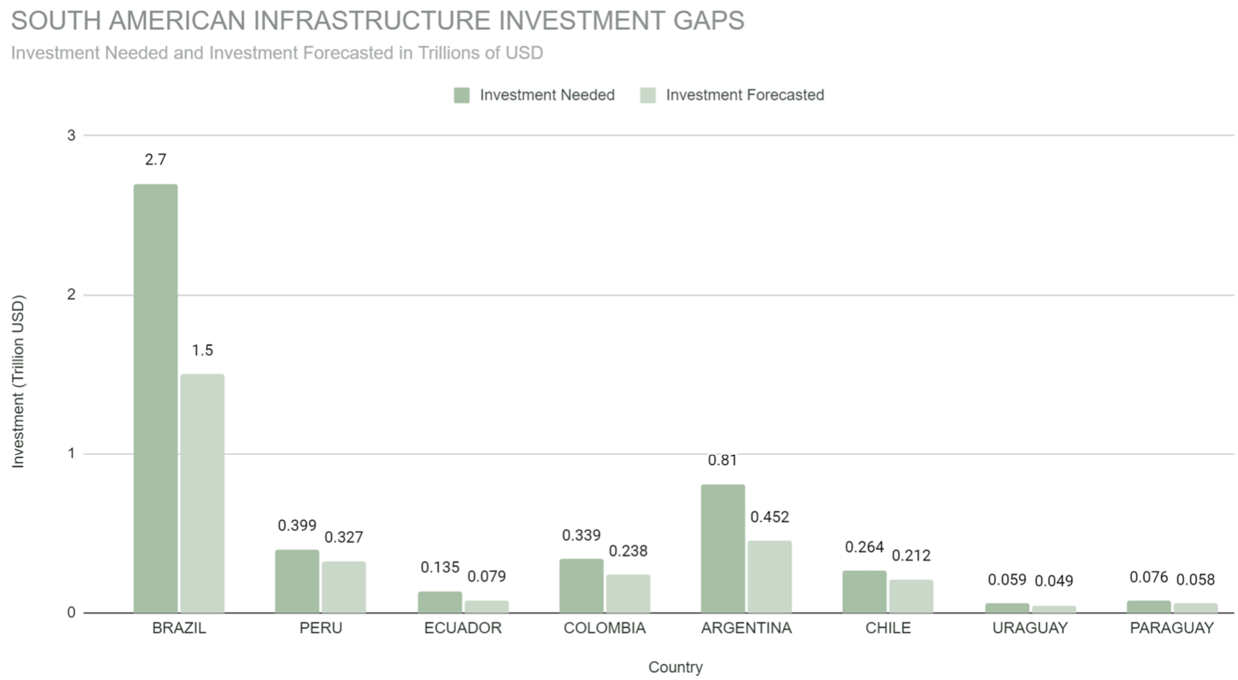

Figure 2. South American infrastructure investment gaps. Using data from the Oxford Economics Outlook report, this chart displays the gaps between the investment needed for infrastructure and the investment actually predicted to be made (Ford, 2022).

This is especially important when considering the worldwide rural accessibility and developmental gap, given that many of these underserved nations where leapfrogged infrastructure is prevalent are also rural, agriculturally based economies.

By investing this money and planning to invest more in future infrastructure projects, nations display how essential it is for these projects to serve the purpose they are intended to, so the investment is not wasted. Leapfrogging, the primary strategy that usually guides this type of development, is not a guarantee for success or advancement, which is the intention of these projects. It is successful in some instances, such as the Rwandan 4G telecommunications project in 2013. Taking advantage of the lack of existing telecommunication infrastructure, the Rwandan government utilized leapfrogging to adopt a single wholesale network for 4G and provide almost 100% coverage for the nation in just four years, as opposed to a process that otherwise would have taken significantly longer (Tashobya, 2018). In other instances, leapfrogging results in failure, as in the Indonesian aircraft industry and the N250 aircraft. Under the New Order Regime in the middle of the 20th century, Indonesian national prestige was seen as directly linked to economic and technological development (Amir, 2004, p. 110). However, in their leapfrogging quest, the chief officer for Indonesian technological development, B.J. Habibie, and the New Order regime ended up exacerbating the existing economic turmoil resulting in another violent change of regime in the region (Legge et al., 2021).

With the variation in results of the strategy of technological leapfrogging, how can one confidently implement this developmental tool to ensure the benefits of the strategy, without the detrimental effects? The STS research for this project aims to answer this question by exploring what factors, whether technical or contextual, encourage the failure of leapfrogging and its potentially harmful effects. Through research and analysis of case studies of leapfrogging failures through the System in Context framework, I hope to define a set of conditions for which a project is most susceptible to the negative impacts of technological leapfrogging and to provide recommendations for implementation in my own technical project.

SUCCESS OF INTENTION, FAILURE OF IMPLEMENTATION

Regardless of the outcome, the intention of leapfrogging as a strategy is almost always good. It is to provide the end product or technology so that one can enjoy the benefits without having to re-solve or endure again all the problems that have already been solved. Why should we “reinvent the wheel” every single time we want to share a technology? However, with leapfrogging, the issue lies in the implementation of this strategy. Sharif (1989) identifies two reasons the efforts to use leapfrogged technology to jumpstart development have continued to have issues: a missing systems-thinking understanding of and approach to the technologies, as well as insufficient consideration to the existing national technological and societal climate and infrastructure (p. 202).

To understand these unconsidered contextual factors and how they are responsible for the failure of leapfrogged technology, as Sharif posits, technological leapfrogging will be analyzed using the Systems in Context STS framework. This framework looks at what contextual factors inform and influence the technical system and vise versa, as well as how the presence of a gatekeeper entity can control exactly how this context is translated to and from the technical system. In Figure 3 below, a generic leapfrogged technology is modeled in the System in Context framework. The technical system is the leapfrogged technology, enclosed by a boundary

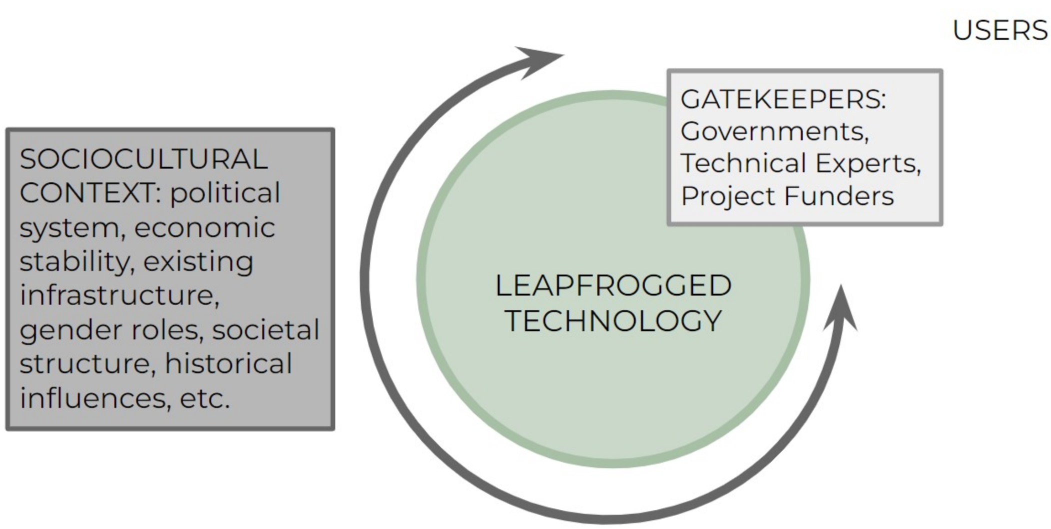

Figure 3. Leapfrogging in context. This graphic displays how the STS framework, System in Context, can be applied to the technological leapfrogging. For this analysis, modeling the technology in context is especially important, given the importance of contextual factors on the success or failure of leapfrogging implementation (Ford, 2022).

that is controlled by the gatekeeping entity. In these types of projects, the gatekeepers usually are the people of power who translate the knowledge and benefits to and from the technology as they see fit. Usually governmental agencies and officials–like in the Indonesian air craft case–serve as gatekeepers, but technical experts like engineers or project funders, like corporations or non-profit organizations, can also serve in this role. The system is surrounded by the sociocultural context of the community where the technology is being implemented. Sociocultural contextual factors can include those listed in Figure 3 on page 10, as well as things like religious beliefs, social customs and taboos, or housing practices.

CONNECTING DESIGN AND IMPLEMENTATION

When addressing this real problem of rural isolation and the resulting rural poverty, the answer is not simply in physically closing the divide between communities and the resources they need access to, but also working to close the developmental gap caused by technological leapfrogging in infrastructure projects. Developments of infrastructure become practically useless or obsolete in underserved rural regions when providing just the concrete artifact or technology without the "soft" aspects of a technology–the knowledge, experience, processes, and empowerment to use it fully and with complete ownership. Using the example of the technical project, building a pedestrian bridge in the Bolivian community will solve the immediate accessibility issue but will not provide the long term benefits intended unless the community also is given access to and empowered to use the "soft" aspects, for example, experience building the bridge and the understanding of repairs and maintenance. Marx (1987) expresses a similar sentiment regarding the need to separate the blind association of technology with social progress and recognizes the need for a direction of progress to be defined outside of the artifact (p. 41). To create meaningful and impactful solutions to problems, we must consider and incorporate the context and environment into both the design and implementation process beyond the technical solution alone.

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