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

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By

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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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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 like the rest of southern Bolivia, these villages are primarily agriculturally based (Arnade, C. W. & McFarren, P. J., 2022). 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).

The STS portion of this project centers 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. The research for this project aims to provide a method for confidently implementing leapfrogging by exploring what factors, whether technical or contextual, encourage the failure of leapfrogging and its potentially harmful effects. Exploring case studies of infrastructure projects in globally underserved communities and applying the System in Context STS framework (C. Baritaud, personal communication, 2009) to them will create an understanding of technological leapfrogging and help identify these factors that foster the failure of leapfrogging. 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.

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 1 below, where the corresponding technical

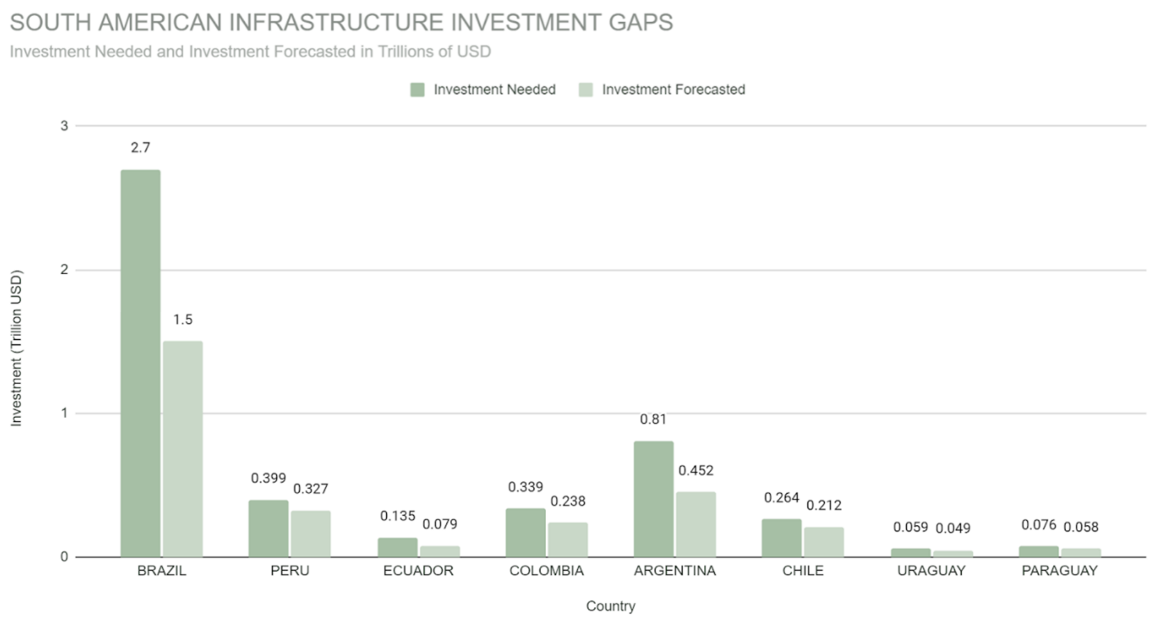

Figure 1. South American infrastructure investment gaps. Using data from the Oxford Economics Outlook report, this chart displays the gaps between the investment needed for infrastructure and the investment actually predicted to be made (Ford, 2022).

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. 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. Beyond the international divides in infrastructure equity, this gap can also be seen within Latin American nations. In their article, "Frail Modernities: Latin American Infrastructures between Repair and Ruination," Velho and Ureta (2019) describe how in many Latin American nations, infrastructure inequalities create "archipelagoes" of high quality infrastructure in affluent areas, leaving the "economically irrelevant" to endure limited access to working and safe infrastructure (p. 431). This "...patchwork infrastructure actively participat[es] in the perpetuation and production of legal and social disorders," in Latin American societies (p. 432).

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 of a project, displayed in the extreme infrastructure inequalities in these nations that exist despite the significant investment into infrastructure. 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 used 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 research and analysis of case studies of leapfrogging failures through the System in Context framework will work 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 the technical project and future projects.

EXEMPLIFYING LEAPFROGGING AND ITS NEGATIVE IMPACTS

In order to identify the factors or conditions under which leapfrogging tends to fail as a developmental strategy, this paper will examine a few case studies of leapfrogged projects. These case studies will include the Indonesian N250 project, the Coca Codo Sinclair power plant in Ecuador, and the Tachay City project.

To determine these unconsidered contextual factors and how they are responsible for the failure of leapfrogged technology, technological leapfrogging in these case studies will be analyzed using the Systems in Context STS framework (C. Baritaud, personal communication, 2009). This framework looks at what contextual factors inform and influence the technical system and vice 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 2 below, a generic leapfrogged technology is modeled in the System in Context framework. The technical system is the leapfrogged technology, enclosed by a boundary 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 aircraft 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 2 below, as well as things like religious beliefs, social customs and taboos, or housing practices.

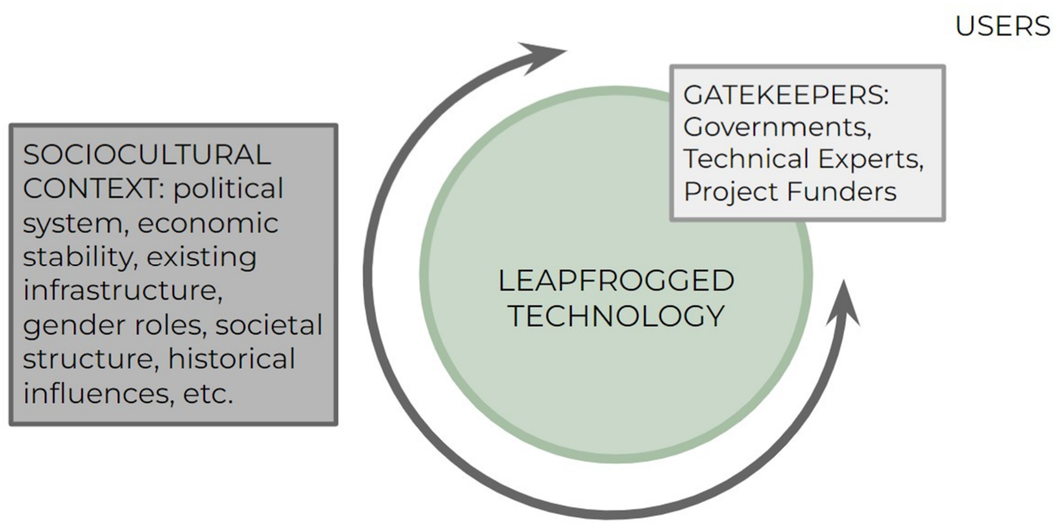

Figure 2. Leapfrogging in context. This graphic displays how the STS framework, System in Context, can be applied to technological leapfrogging. For this analysis, modeling the technology in context is especially important, given the importance of contextual factors on the success or failure of leapfrogging implementation (C. Baritaud, personal communication, 2009) (Ford, 2022).

Yachay City

Yachay, or “the City of Knowledge”, is one of the most ambitious and controversial Chinese funded infrastructure projects in Latin America now. It is an urban development initiative and project focused on bridging the gap between an agrarian society and extractive economy to one centered around innovation, research, and technological development. In the words of Gonzalez, Alvarez, and Purcell (2018), Yachay is a technocratic “...utopia of a new city that transforms a country based on an extractive economy into one based on knowledge and new technologies," (para. 1) radically changing the productive matrix of Ecuador with the aim of "...solv[ing] a large part of Ecuador's social and economic problems" (para. 5). Yachay City was a leapfrogged technological idea adapted and modeled after the South Korean technological research and development district, Innopolis Daedeok (Gomez-Urrego, 2019, p. 505). After visiting the South Korean development district, then-president of Ecuador, Rafael Correa, decided the technological metropolis would be the perfect addition to his Revolucion Ciudadana (Citizen Revolution), the political and socioeconomic overhaul lead by himself and other left-wing politicians to achieve a socialist reconstruction of Ecuador. In fact, Gonzalez, Alvarez, and Purcell (2018) assert that Yachay City was a project "emblematic of the government of the Citizen Revolution" and Correa (para. 2).

The actual site of Yachay was carefully selected as a highly productive agricultural plot of almost 5000 hectares in the Andes, sitting about 200 kilometers north of the Ecuadorian capital city, Quito (Gonzalez et al., 2018, para. 2). Based in the Ecuadorian principle of "buen vivir" or "good living" central to Correa's Citizen Revolution, Yachay "aims to combine a planned city, a technopark with a business orientation, and a research-oriented public university" to promote a shift in the Ecuadorian economy from agricultural and natural resource exports to one based on technological and research innovations (Gomez-Urrego, 2019, p. 496-7). It was originally envisioned as just the technical university, Yachay Tech–an idea that was discarded for fears that "...creating an elite university in Ecuador would have no social impact because the country lacked a national system of innovation to transform the expected high-level research, that the envisioned university was set to produce, into significant industrial and commercial applications." (p. 511). This concern reshaped the project into the technological metropolis project we know today, shown in Figure 3 below. Though the solution to these problems addressed during planning was to embed this university in a new, related city reliant upon the school's innovations, these issues of isolation were simply magnified as the project scaled up–emphasizing the ill-fitting design of this leapfrogged project for the environment it was placed in.

The problems surrounding Yachay City started before construction even began in 2012 (Gonzalez et al, 2018, para. 2) with the land acquisition process for the plot where Yachay would eventually be built. In a time where socioeconomic inequality was extremely prevalent,

Figure 3. This rendering displays the extensive plans for the Yachay City project, extending far beyond the initial plan for just the technical university. Nestled in the Andes mountains, the Yachay City project was planned over about 5000 hectares. (Gomez-Urrego, 2019, p. 497)

particularly in terms of land distribution, Correa's government rapidly and insensitively expropriated almost the entire 5000 hectares (12355 acres) of land planned for Yachay City from the poor land holders in the area (para. 16). The rapid acquisition of this land despite the gradual pace of planning and construction of Yachay has caused the erosion and decay of both the land itself and relations with the local communities, for whom this project was supposed to be beneficial (Gomez-Urrego, 2019, p. 521).

These issues over the land acquisition portended the future problems that would cause the project's "...stagnation, downscaling, legal dispute, and uncertainty regarding its future" (p. 498). Ecuador's national political, economic, and sociotechnical issues resulting from the political power struggle between Correa and his successor, Lenin Moreno, have greatly impacted the project and the fallout from this political struggle continues to affect Yachay City in the present day. Politically, this project was emblematic of Correa and his government and served to strengthen the party going into the 2017 Ecuadorian elections–so despite seeming to be publicly motivated, the main driving force behind Yachay was politically, not public welfare oriented (p. 504). When Lenin Moreno was elected in 2017 as Correa's political successor, he drastically shifted his political stances away from those of Correa and their shared party, the PAIS Alliance. This divided the party and threw Ecuador into a state of political turmoil, leaving projects born out of Correa's Citizen Revolution like Yachay City stagnant in the power struggle.

The project also faced technical and structural challenges alongside the stagnated project construction. At least five of the project's buildings have been abandoned since 2015 due to structural failures or poor site planning, like lacking "access roads or prior work on basic services, such as sewerage and drinking water," necessary for functional occupied structures (Narea, 2017, para. 2). Shown in Figure 4 on page 10, these unfinished buildings bring to life the feeling of stagnation and limbo that the Yachay City project exists in. This is a classic failure that leapfrogged technologies face, as they are often placed without regard to the technical and economic infrastructure systems needed to support the technology.

In addition, economic problems have continued to plague and halt the progress of the Yachay City project. Despite significant foreign and domestic investments into the project, including about $200 million USD from the Export-Import Bank of China, the project has not moved forward as projected and has faced serious economic challenges (Dube & Steinhauser, 2023, para. 33). More recent investigations have revealed that, in addition to suffering from the recent Ecuadorian economic downturn, many of the investments into the project from national

Figure 4. Some of the unfinished buildings in the Yachay City project, evoking the sense of limbo that the project exists in, both physically and metaphorically. Especially when compared to the rendering in Figure 3 on page 8, these buildings display the gap between the expectations and realities of the Yachay project (Gomez-Urrego, 2019, p. 498).

and international companies were falsely reported by Correa’s government, resulting in a significant gap between the actual investments and those reported (Narea, 2017, para. 3-5).

The STS framework, a System in Context, was used to analyze the Yachay City project. The diagram below in Figure 5 below on page 11 illustrates the variety of sociocultural factors that impacted the Yachay City project development and the resulting challenges and failures it faces today, as well as the role of Correa and Chinese banks as gatekeepers controlling how these sociocultural factors are translated to and from Yachay City.

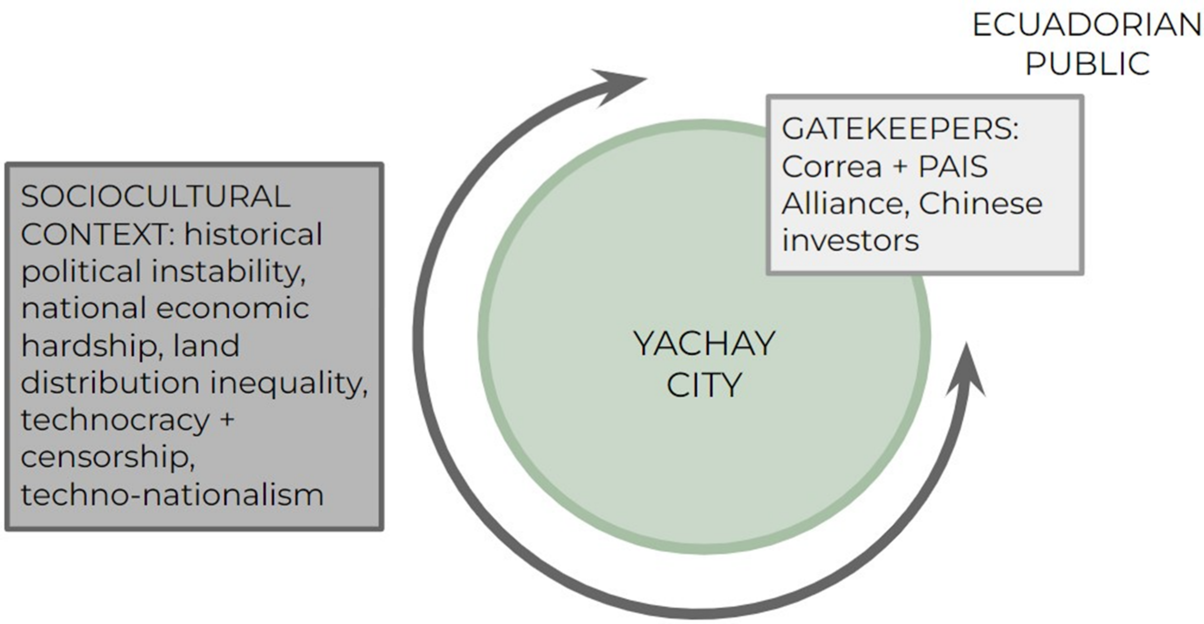

Figure 5. Yachay City in context. This graphic displays how the STS framework, System in Context, can be applied to Yachay City. In modeling this technology in context, we can understand the sociocultural factors that influenced this project and its current state of stagnation. (Ford, 2023).

Coca Codo Sinclair Dam Project

The discussion of the Coca Codo Sinclair project begins not in Ecuador, where the dam and power plant are located, but instead in China. In the last 10 years, China has loaned out a trillion dollars towards international infrastructure projects as part of their Belt and Road initiative, which was intended to develop economic trade and expand China's influence across the developing world in Asia, Africa and Latin America (Dube & Steinhauser, 2023, para. 5). Particularly in Latin America, where "...historically there has been 'an infrastructural gap' with respect to the needs of the region, and a tendency of infrastructural breakdown and disrepair," the Belt and Road program takes advantage of this "gap" as an entry point for Chinese influence in the Central and Southern American spheres (Gomez-Urrego, 2019, p. 499). This loan program has been globally criticized for contributing to debt crises, as many of the countries have limited ways to repay the loans–especially if their supposedly revenue generating infrastructure is failing. The program has also been criticized for encouraging projects that are "mismatches" for existing infrastructure–a hallmark of technological leapfrogging. Not only are these projects almost fully financed by China, they also are often awarded to Chinese construction companies and built by Chinese workers (Dube & Steinhauser, 2023, para. 6-7, 11, 33).

The former Ecuadorian president, Rafael Correa, turned to China to finance Ecuadorian public spending in an effort to accelerate development in the region, as part of his Citizen Revolution projects for the socialist reconstruction of Ecuador. In his term, Chinese banks lent Ecuador about $18 billion in loans, many of which lacked transparency in project contract awarding. This would likely be the culprit of the poorly constructed and high cost infrastructure projects, including the enormous Yachay City project described in the section above (Dube & Steinhauser, 2023, para. 30-31).

As a result of former president Correa's push for public spending, Chinese-funded hydroelectric projects across Ecuador vastly improved the Ecuadorian power grid, making electricity more reliable, less costly, and cleaner. "Today, 90% of Ecuador's electricity comes from hydro, compared with 55% in 2007 [the first year of Correa's term], according to the state utility" (Dube & Steinhauser, 2023, para. 36). The Coca Codo Sinclair hydroelectric power plant is one such project located about 100 kilometers east of Ecuadorian capital, Quito. Completed in 2016, the plant was built by Chinese company Sinohydro for $2.7 billion USD–85% of which was funded by the China Development Bank. Much like other contracts for similar projects awarded in Ecuador for the Belt and Road program, the contract awarding process was called into question during ongoing investigations into alleged bribes made by Sinohydro to officers in

Correa's government (para. 41-43). This displays the almost complete control that both Chinese banks and contractors had over these projects, in both development and construction.

The Coca Codo Sinclair hydroelectric power project was envisioned to provide reliable power and now provides almost ⅓ of the electricity in Ecuador (Dube & Steinhauser, 2023, para. 40). As such an integral piece of infrastructure, the almost 20,000 cracks in the structural concrete found by engineers in the plant's turbines is extremely worrying–especially since the plant has only been operational since 2016 (para. 45). As Velho and Ureta (2019) would say, the hydro plant "exists and functions in a state of partial disrepair and partial functionality," as do many of these Chinese funded projects in Latin America (p. 433). Currently, while the plant is still in disrepair awaiting repairs from Sinohydro, the Ecuadorian government refuses to take over operation and maintenance of the plant. As Dube and Steinhauser (2023) report, in November 2023, Ecuadorian Energy Minister Fernando Santos told local media: "Over my dead body will I accept this poorly built plant," (para. 48).

This precarious balance between failure and function of the Coca Codo Sinclair project was disrupted when in 2020, the Coca River's slopes began collapsing, causing ground tremors, mud and landslides. This had devastating effects for both the natural surroundings and the communities along the Coca River, some of which are shown in Figure 6 on page 14. Some environmentalists blame Coca Codo Sinclair for improperly disrupting the natural river flow and erosion process. Carolina Bernal, a geologist at the National Polytechic School, a public university in Quito, asserted that this scale of erosion would have naturally occurred over millions of years but the dam's disruption of the natural hydraulic flows have accelerated the erosion to this point in "...a matter of five years" (Dube & Steinhauser, 2023, para. 53).

Regardless, this infrastructure is very much at risk of destruction from this erosion if the plant's water intake is not relocated–if it doesn't fail from decay before then (para. 50-55).

Figure 6. Devastating effects of erosion. The picture above displays the destruction wrought by the 2020 disaster, where erosion caused the sliding and collapse of a highway, portion of a town, and utility lines. (Dube & Steinhauser, 2023).

This project perfectly exemplifies the problems with technological leapfrogging as a development strategy, particularly when done by a foreign power, as well as the true gravity of these problems. In rushing to build poor quality infrastructure to accelerate development, the decay intrinsic to infrastructure projects is magnified (Velho & Ureta, 2019, p. 432). Infrastructure often becomes a pillar of a community's daily life and continued operation. In the words of a local of San Luis, a town neighboring the Coca Codo Sinclair project, "'Coca Codo was initially seen as really good;'" she now anticipates that erosion as an effect of the project will destroy her town (Dube & Steinhauser, 2023, para. 57). When infrastructure eventually decays, it threatens the safety, security, and quality of life of all those who rely upon it. When this reliance and fragility are simultaneously magnified by leapfrogged infrastructure, this threat becomes even larger and more urgent.

The STS framework, a System in Context, was used to analyze the Coca Codo Sinclair project. The diagram below in Figure 7 below illustrates the variety of sociocultural factors that impacted the project development and the resulting challenges and failures it faces today, as well as the role of Correa and Chinese banks as gatekeepers controlling how these sociocultural factors are translated to and from Coca Codo Sinclair.

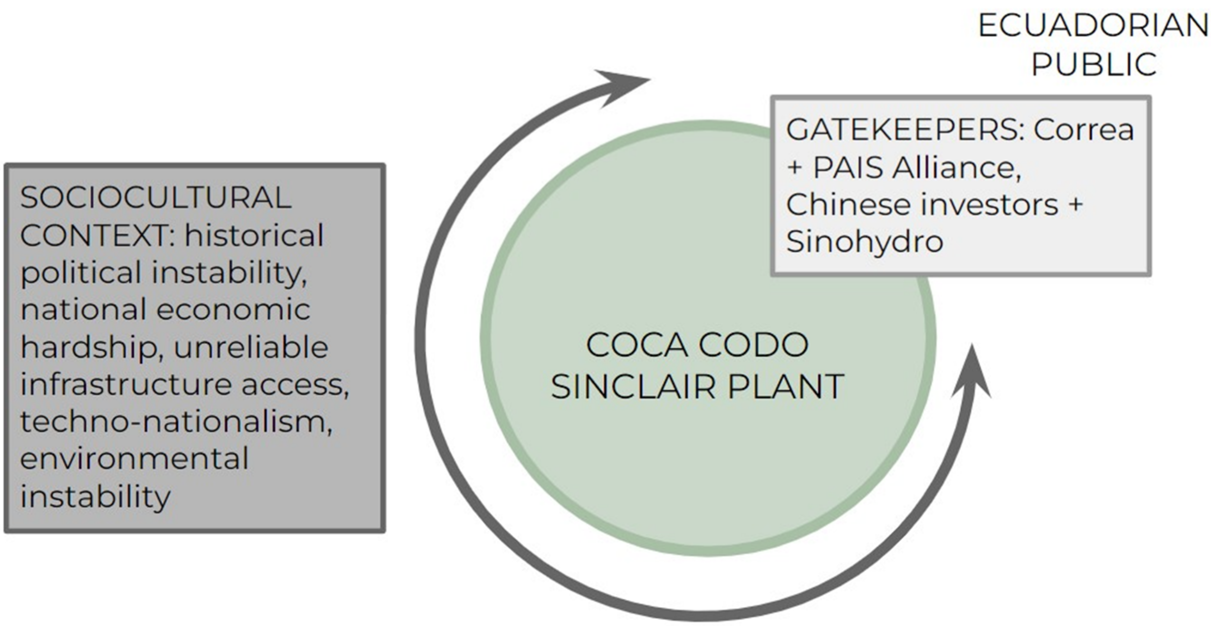

Figure 7. Coca Codo Sinclair in context. Much like the other case studies, understanding the context surrounding this technology can help reveal why the technology faces the issues it does, like the shoddy construction and structural issues of this project. (Ford, 2023)

This diagram very closely resembles that of Yachay City (Figure 5 on page 11), which makes sense given that both projects were developed under similar investment conditions for the same political initiative. This shows how the same conditions can create similar impacts in leapfrogged technologies, even when the projects are wildly different in function.

The Rise and Fall of the Indonesian Aircraft Industry

During the 1940s, the Japanese occupation of Indonesia during WWII created a completely new environment for nationalism to be fostered by Soekarno (the eventual first president of Indonesia) to lead to the eventual independence of Indonesia in 1949 under a constitutional democracy. This first government was a multiparty system with a lot of parties with diverse ideological views causing some serious instability, until President Soekarno began to take a more active role in governing, establishing the four main parties and national council with ideological as well as functional representatives. However, this was still an unstable system with many ideological and political conflicts internally and failed the people in both establishing a stable government and a strong economy. Even after an entire revolution, the general population was still very poor and still very frustrated with their government–the same conditions they began the revolution for. General, and future President, Soeharto and other members of the military organized a coup to overthrow Soekarno and establish the government (the New Order) in which the IPNT was established and this article takes place. In the late 1990s, international economic crises in the Asian Pacific region led to the instability of the New Order and a host of internal economic problems which resulted in social and political unrest and the eventual end of the New Order regime (Legge et al., 2021).

In the later half of the 20th century, before the collapse of his government, President Soeharto and his New Order regime in Indonesia wanted to solidify his regime's political power and Indonesian power on the world stage through economic, and thus technological development. He promoted the idea that economic growth was a necessary condition for prosperity, and needed to be actively pursued for development (Amir, 2004, p. 108). This desire for economic growth was the justification for many of the high technology programs Soeharto and his chief technological development leader, B.J. Habibie, implemented, like the Indonesian Aircraft Industry (IPTN), because they saw innovation of technology linearly and hierarchically, with corresponding economic values. Therefore, Indonesia needed to "leapfrog" to develop the high technology, as it would add the highest economic value or growth to the national economy

(p. 110). Despite these efforts, the IPTN and their design, the N250 aircraft, failed to gain market influence on the world stage, making the significant investments into this project practically worthless to the Indonesian people and to the New Order regime.

The concept of technological leapfrogging is explored by Amir (2004) in the study of the N250 and the Indonesia Aircraft Industry (IPNT), particularly the social, economic, and political conditions that fostered technological leapfrogging and the effect of technological nationalism on this development concept. Amir (2004) posits that the failure of the IPNT and the New Order was not solely an economic problem, but a problem of the technological leapfrog strategy, rooted in the cultural and social environment and reinforced by the strong technological nationalism in Indonesia at the time (p. 108). Myths promoted by the regime regarding the need for economic growth and political stabilization created this ideal environment for fostering detrimental technological leapfrogging. These myths created a prevailing view of national development and technology that was rooted in technological determinism and technocratic ideals–the fundamental basis of technological leapfrogging (p. 110). The chief technological development leader, B.J. Habibie, was the major driver of technological leapfrogging in Indonesian development–ideals that are best expressed in his motto, "Starting at the end, ending at the beginning" (p. 109). The first myth promoted the idea that economic growth was a necessary condition for prosperity, and needs to be actively pursued for development (p. 108).

The second myth pushed for political stabilization and stated that political stability, but not particularly democracy, is necessary for technological development (Amir, 2004, p. 109). Under the premise of political stabilization, the New Order created a strong technocratic basis in Indonesia that allowed the technical knowledge and developmental decision power to remain with the technological elites. This exacerbated the existing gap between technological progress and progress seen in society–the complete power of the technical elites over the developmental process prevented many of the wider social benefits from high technology from reaching society (p. 111).

The STS framework, System in Context, modeling this technology is displayed in Figure 8 and encapsulates the variety of sociocultural factors that influenced the N250 aircraft and its failure. Despite being in different areas globally and completely different technologies from either of the earlier cases, the framework diagrams very closely resemble each other, illustrating that there seem to be some common conditions that encourage failure in leapfrogged technology.

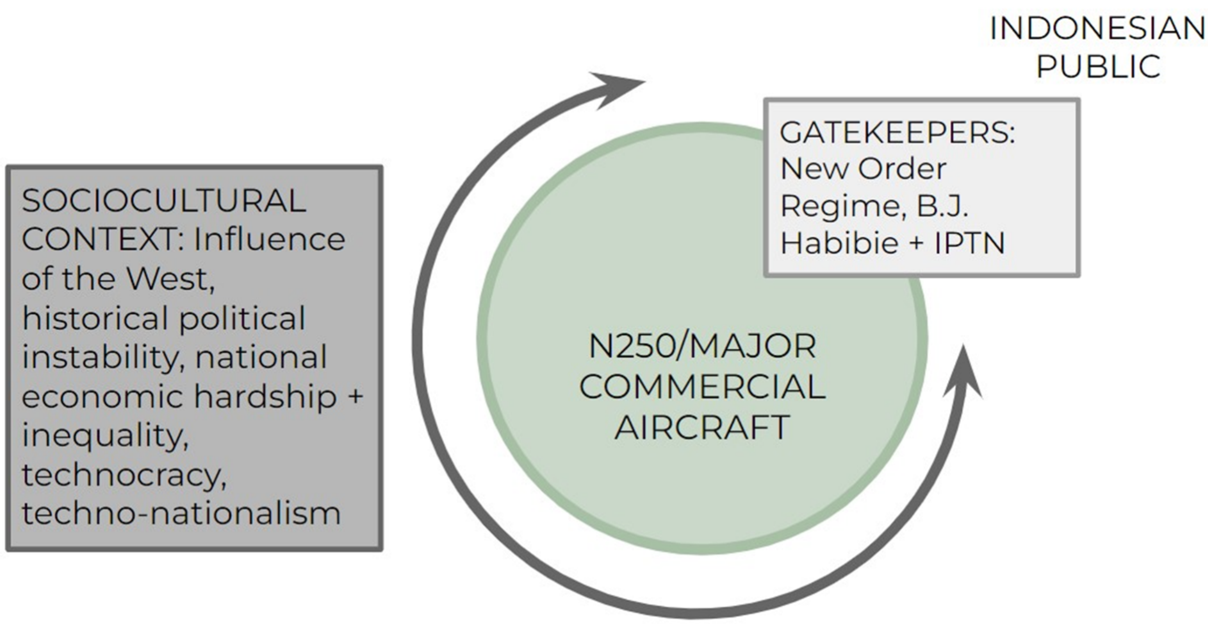

Figure 8. N250 technology in context. This graphic displays how the STS framework, System in Context, can be applied to the N250 aircraft and the Indonesian aircraft industry. Modeling this technology in context is especially important, as the understanding of this case study often neglects all of the sociocultural context that influenced the eventual failure of the artifact. (Ford, 2023).

THE ANATOMY OF A LEAPFROGGED TECHNOLOGY

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). After examining case studies of leapfrogged technologies, these two factors Sharif identifies can be refined into specific conditions discussed below. The missing systems-thinking understanding of technologies seems to manifest in failed leapfrogged projects as an understanding rooted in technological determinism without a critical look at how the technologies are actually implemented. The missing consideration to existing national technological and sociocultural climates seems to be defined by conditions of technological nationalism.

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. Here, we will discuss how technologically deterministic approaches to leapfrogged technology generally lead to failure, particularly when the other systemic developments required to support technological developments are ignored.

Technological determinism is an outlook or framework that technological innovation drives human and societal progress as a result of its own technological progress. That is to say, as technology progresses, it does so independently of societal influences, and that this progress actually drives societal development. This can be manifested in the ideas that technological innovation has simplistic, one-way relationships with the institutions it develops within. This is particularly relevant in leapfrogging as it plays a role in the technological transfer of “appropriate” technology. Martin and Schinzinger (2000) defines an appropriate technology as one that is implemented with various technical and social factors considered, and “...should contribute to and not detract from the sustainable development of the host country” (p. 231).

For example, the desire for economic growth was the justification for much of the high technology programs in Indonesia under the New Order, like the IPNT discussed earlier, because technological policy leaders saw innovation of technology linearly and hierarchically, with corresponding economic values. This necessitates the “leapfrogging” to develop the high technology in order promote the highest economic value or growth to the national economy (Amir, 2004, p. 110). The technologically deterministic factor in the IPNT example is this idea that economic development is dependent on technological development alone, instead of acknowledging the complex and interconnected nature of economics and technological innovation.

In both the Coca Codo Sinclair and Yachay City projects, technological determinism is illustrated in just how each project seems to be one that “ma[kes] little sense” for the region (Dube & Steinhauser, 2023, para. 33). Both projects were initiated as part of the same political venture in the name of Ecuadorian advancement: “...a radical change in the productive matrix of the country” (Gomez-Urrego, 2019, p. 497). Correa and his government saw the only path to shift Ecuador away from an extractive economy was through technological development, and thus pushed forward any projects that could contribute to this technological development without considering environmental and contextual conflicts that would detract from the project success. In fact, at the inauguration of Yachay Tech in the Yachay City project, Correa referred to the project as Ecuador’s “Great Leap Forward” and expressed his deterministic view in his speech, “Science, technology and innovation are essential for development...I am convinced that scientific and technological advances can generate much more well-being and being engines of social change than any class struggle or the search for individual profit…" (Gonzalez et. al., 2018, para. 17). For the Coca Codo Sinclair project, the ignorance of the environmental and geological surroundings of the project site had devastating effects. Not only was the dam placed at the foot of an active volcano, but the placement of the dam caused severe changes to the hydraulic and erosion process of the region–putting the dam itself, surrounding communities, and any areas that rely upon its power at risk (Dube & Steinhauser, 2023, para. 50-55). This dam project also was implemented without consideration for the lack of repair and maintenance infrastructure that would be needed to support its continued operation. Evident in both the shoddy construction as well as the refusal of the Ecuadorian government to take over the project before repairs are made, this project was pushed forward without regard to the serious system of repair/maintenance that would be needed to support its continued use. The Yachay City project, while similar to Coca Codo Sinclair in origination, did not consider a completely different set of contextual factors. The major contextual condition that was not considered in the planning of the project was the tumultuous political and economic environment that has historically persisted in Ecuador. For a long term project that is highly politically motivated and relies heavily on economic support from the government, it would have been prudent to at least consider how this context may impact the project as leaders change. Building in some safeguards to protect this project from stagnation or failure due to changes in economic or political conditions would have likely reduced the issues that the Yachay City project faces.

In order to combat the negative impacts that a technologically deterministic view can have on a leapfrogged technology, looking at the reactionary philosophies to determinism can be a helpful starting point. By "...emphasiz[ing] that technology itself is human-made and carries the imprint of the social and historical circumstances that formed it," instead of ignoring the mutually shaping process of technological and societal development, one can recognize how influential the more negative social and historical contexts surrounding a technology can be (Pennock, 2005, p. 511).

Nationalism and Technology

Technological nationalism is a central concept to technological leapfrogging and describes the viewpoint that a nation's technological power and prowess reflects its national power. Nationalism itself and the politics associated with it are characterized by many scholars as a highly emotive form of "identity politics." This means that in nationalist cultures, national identity is absorbed by many people as a principal form of personal identity. Often encouraged by the nation and its politicians, nationalism as identity politics is a powerful tool in mobilizing a population, particularly because it can evoke such intense emotional responses from people (Kitching, 2005, p. 1275). Nationalism has an influence over technological and scientific innovations in a nation, as is the case when discussing techno-nationalism. In the words of Kitching (2005), "[n]ationalism both energizes scientific and technological communities and has served as a justification for behavior that has been argued to violate scientific standards of conduct" (p. 1275). Leapfrogged technological failures tend to result in nations driven to development by techno-nationalism because these governments will tend to push for technological development even when it may go against scientific and engineering standards of conduct or best practices. This may be when technology implemented is poor quality, like in the Coca Codo Sinclair project, or when the projects are "mismatched" to the needs of the community, like the IPTN and Yachay City examples.

Evidence of nationalism, and particularly techno-nationalism, is not difficult to identify in the case studies presented in the earlier sections. Starting in Ecuador, where the Coca Codo Sinclair and the Yachay City projects are located, it is clear that nationalism was central to the politics that drove those projects forward. The ideas pushed by President Correa and his government centering around his Citizen Revolution and socialist reconstruction of Ecuador heavily rely upon nationalism as identity politics. Gomez-Urrego (2019) cites slogans used by Correa and his government to market their projects–"'la Patria Nueva' (the new homeland-motherland), 'Ecuador ya cambió' (Ecuador has changed), 'el futuro no se detiene' (the future cannot be stopped)"--as illustrative evidence of how Correa harnessed the national pride and identity of the people of Ecuador to support his projects (p. 506). This is particularly seen in the Yachay City project, where at the inauguration speech for Yachay Tech in 2014, Correa expressed his views that "...Ecuador's education system, and its lack of connection with the generation of science and technology policy, was one of the main barriers stopping the country from achieving greater wealth and well-being" (p. 505). This is a clear example of the technological nationalism used by Correa to connect his push for technological development with national pride and identity, as well as justify the leapfrogging used to achieve this development.

In Indonesia, with the IPNT and N250 aircraft, technological nationalism is illustrated in a very similar way. Indonesian leaders like B.J. Habibie, the chief technological development leader, and President Soeharto associated technological development with national prestige and vice versa. This version of nationalism is a major motivation for why technological leapfrogging happened in this period of Indonesian history and also why it likely failed to "modernize" Indonesia. Technological nationalism reinforces the power of the technological elites–they harness the power and support of the public while simultaneously consolidating that power to exclude that same public from the developmental process. This is exemplified in the funding process for an IPNT project. Habibie and Soeharto effectively "crowdfunded" one of their high technology projects by harnessing people's nationalism by having them pay into the project– even though most of them were agricultural workers who had never seen an airplane, would never benefit from one, and would have no say in how the project was developed (Amir, 2004, p. 113).

CONNECTING DESIGN AND IMPLEMENTATION

As a result of globalization and the ease of technological transfers, technological leapfrogging has been increasingly utilized as a tool for strategic development and poverty reduction across the world. Despite the prevalence of this strategy in projects, particularly in infrastructure, there is no clear guarantee that this strategy will result in project success. For infrastructure projects that often become central pillars to the lives of communities around them, using this strategy without a guarantee of success can be costly and wasteful, as well as dangerous. From the three case studies, two major factors were present that contributed to the negative impacts of leapfrogging: technological determinism and technological nationalism.

Technological determinism, and specifically its impact on technology transfer, was a major influence on the success of a leapfrogging project. In highly technologically deterministic societies, selecting an appropriate technology for the environment, or at least understanding the limitations of transferring the technology without adapting it, can be impossible. When driven by technological nationalism, where national pride is used to push forward development, technological determinism will most likely lead to the failure of leapfrogged projects.

Identifying these specific factors that contribute to the negative effects of leapfrogging is only a first step towards determining how to implement this development strategy and be confident of success. From these case studies, it seems that all the conditions promote a gap in understanding and communication between the users and the implementers of the technology. This analysis reveals a need to shift the developmental model for these technologies away from one with a strict gatekeeper to one where the technology can more readily interact with its sociocultural context. This project has the potential for future research and study of both the effects of leapfrogging and the factors that influence its positive and negative outcomes. In addition to implementation in my technical project, this understanding of how technological leapfrogging develops and backfires can be implemented in other projects that involve implementing non-native technology.

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