Hillink

Bridging the Geography Tax Through
Community-Driven Mechanical Infrastructure

China-Latin America Challenge to Alleviate Poverty 2026

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Abstract

Urban poverty in the Global South is not only economic, but also territorial and logistical. In informal settlements, hillside communities, flood-prone margins, and peripheral neighborhoods, geography increases the cost of survival by making essential goods harder to move through routes that formal infrastructure does not reach. This project defines that burden as the *Geography Tax*: the additional physical, economic, temporal, and health-related cost imposed on low-income communities because of where they live.

Hillink proposes a low-cost, cargo-only, non-electric, and modular mechanical transport system designed for community use. Structured through the 5W1H+ Toolkit, the project combines field diagnosis, geospatial analysis, stakeholder engagement, implementation planning, impact evaluation methods, and reference-based feasibility criteria. Grounded in Latin American hillside settlements, especially Villa María del Triunfo in Lima, Hillink offers a practical framework for identifying, testing, and reducing territorial accessibility burdens in vulnerable communities.

Keywords: geography tax, peripheral conditions, stairways, multidimensional poverty, hillside communities, transport

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Introduction

Latin America is one of the most urbanized regions in the world, yet it continues to be marked by some of the highest levels of urban inequality and spatial segregation globally. According to UN-Habitat (2022), more than 110 million people across the region live in informal settlements characterized by precarious infrastructure, territorial exclusion, and limited access to essential urban services. While poverty is often measured through income indicators, the reality of informal hillside communities reveals that poverty is also deeply geographic, where people live can directly determine their access to mobility, healthcare, education, economic opportunities, and even basic daily survival.

Across Latin American cities, such as Lima, thousands of low-income families inhabit steep vertical settlements formed through decades of unequal urban expansion and exclusion from the formal housing market. In these territories, geography itself becomes a mechanism of structural inequality. Residents must frequently transport water, cooking gas, food, medicine, and construction materials manually through extensive stair networks and unstable pathways. This daily physical burden increases living costs, intensifies bodily exhaustion, and reduces the time and opportunities available for work, education, and community development.

Despite the scale of this problem, vertical informal settlements remain significantly underrepresented in global poverty reduction and infrastructure discussions. Most urban transportation systems are designed for formal cities with stable electrical grids, high public investment capacity, and centralized maintenance structures. As a result, many existing solutions, such as electric elevators, escalators, or cable car systems, face severe limitations in low-resource environments due to high operational costs, technical dependency, and long-term maintenance challenges.

This paper argues that spatial isolation in vertical settlements should be understood as a neglected structural dimension of multidimensional poverty. Through the concept of the "Geography Tax," this project examines how topography and infrastructural exclusion reinforce cycles of urban vulnerability in Latin America.

This paper is organized through the 5W1H+ Toolbox developed by the Tsinghua University Latin America Center as an analytical framework for poverty-reduction research. The toolbox structures poverty analysis through six interrelated questions: What, When, Where, Why, Who, and How. This structure is useful because it connects problem identification, contextual diagnosis, affected populations, causal mechanisms, and implementation strategies within the same framework (Tsinghua University Latin America Center, n.d.).

For Hillink, the 5W1H+ structure helps prevent the Geography Tax from being treated as only a technical mobility problem. The What section defines the burden being addressed; the Why section explains the structural causes of territorial exclusion; the When, Where, and Who sections describe the conditions, territories, and populations affected; and the

How dimension is developed through the proposed Hillink system, its implementation strategy, stakeholder model, impact evaluation, and scalability plan. In this way, the toolbox allows the paper to move from diagnosis to intervention while keeping social context, territorial constraints, and technical feasibility connected.

In response, this paper introduces *Hillink*, a low-cost mechanical transport system designed to reduce the physical and economic burdens generated by territorial isolation in informal vertical settlements. Through a community-centered and low-maintenance infrastructure model, the project explores how simple mechanical systems can contribute to reducing spatial forms of multidimensional urban poverty.

What

Poverty is a social and cultural phenomenon that is quite complex to define. First, we find the traditional definition of poverty, which is related to the lack of income, specifically when total income does not satisfy the minimum required for subsistence. In order to determine this minimum, the World Bank calculates the international poverty threshold, which was established at USD 3 for low-income or underdeveloped countries and 4.20 USD (World Bank, 2025) for upper-middle-income or developing countries, a category that includes most Latin American countries such as Peru, Brazil, and Argentina.

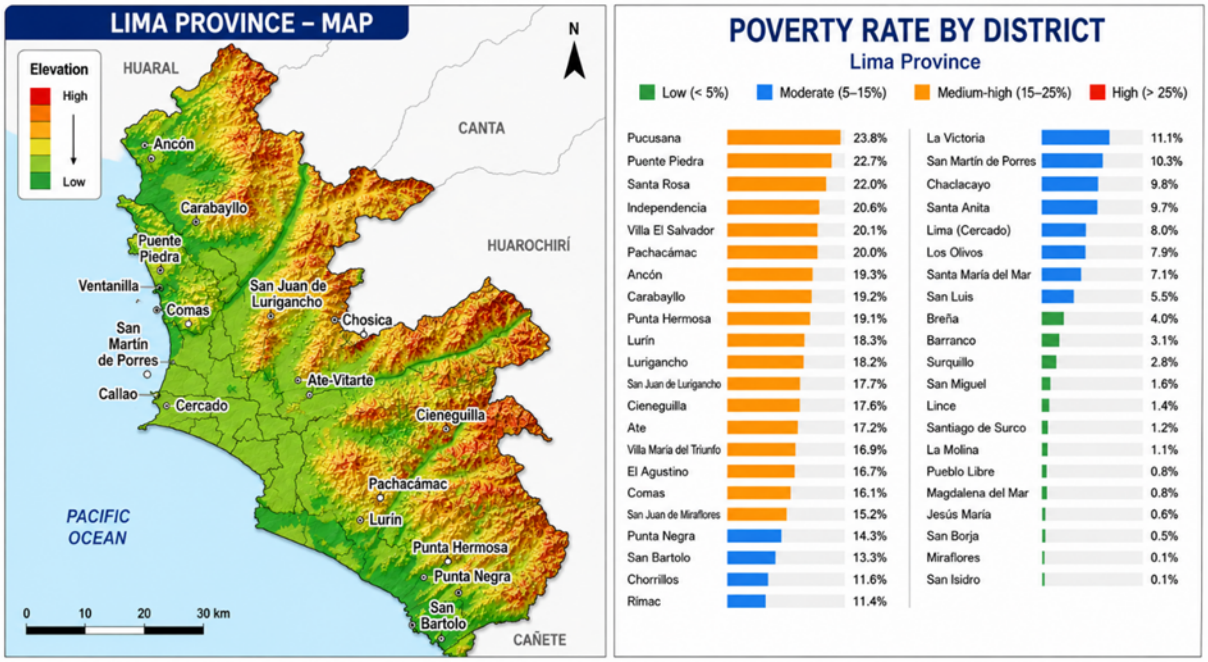
Countries also have their own national poverty thresholds, calculated according to their own criteria. One of these countries is Peru, where, according to the criteria of the INEI (Instituto Nacional de Estadística e Informática, 2026), which are based on the minimum monetary amount required to cover the basic basket of goods, the poverty line would be 462 soles per month per person, with 25.7% of the population living below this line. Chile and Argentina also have their own methods for measuring monetary poverty. As we can observe, there are different ways to calculate poverty.

Next, we have the definition of poverty commonly used by international organizations in their policies, which no longer focuses on the amount of financial resources people possess, but rather on the lack of conditions that allow individuals to fully develop their potential. In this sense, poverty could be defined as the deprivation of essential services for development, such as education, healthcare, and decent employment. In summary: "poverty is not only an economic issue; it is a multidimensional phenomenon that includes both the lack of income and the lack of basic capabilities necessary for living." (Office of the United Nations High Commissioner for Human Rights, 2012, p. 2).

As we can observe, poverty has multiple definitions based on different criteria, ranging from monetary aspects to those related to human development. It could be argued that there are different types of poverty depending on the various needs of human beings. For this project, we will focus on poverty related to geographic isolation and the negative effects it generates on the human development of people living under these conditions. The concept of “geographic tax” is not widely used in academia, but it refers to how factors such as geography and topography affect access to and the cost of goods and services in the same way that a fiscal tax does. An example of this can be seen in transportation systems, where bus routes do not reach remote areas of cities, forcing people to rely on more expensive alternative means of transportation, which in the long term increases poverty.

The relationship between poverty, territory, and geographic conditions can be observed in the city of Lima, as shown in the following diagram.

Figure 1. *Monetary Poverty Incidence by District-Province of Lima, 2018*



Note. The map represents the geographic distribution of the districts in Lima Province and their corresponding poverty levels (Instituto Nacional de Estadística e Informática, 2020).

From the previous figure, it can be inferred that most districts located in hilly areas (Carabayllo, Puente Piedra, Pachacamac) have a high percentage of poverty compared to those located in more favorable terrain, such as San Martín de Porres and San Bartolo, which show moderate poverty levels. This suggests a possible relationship between geographic conditions, accessibility, and poverty levels in the province of Lima.

Why

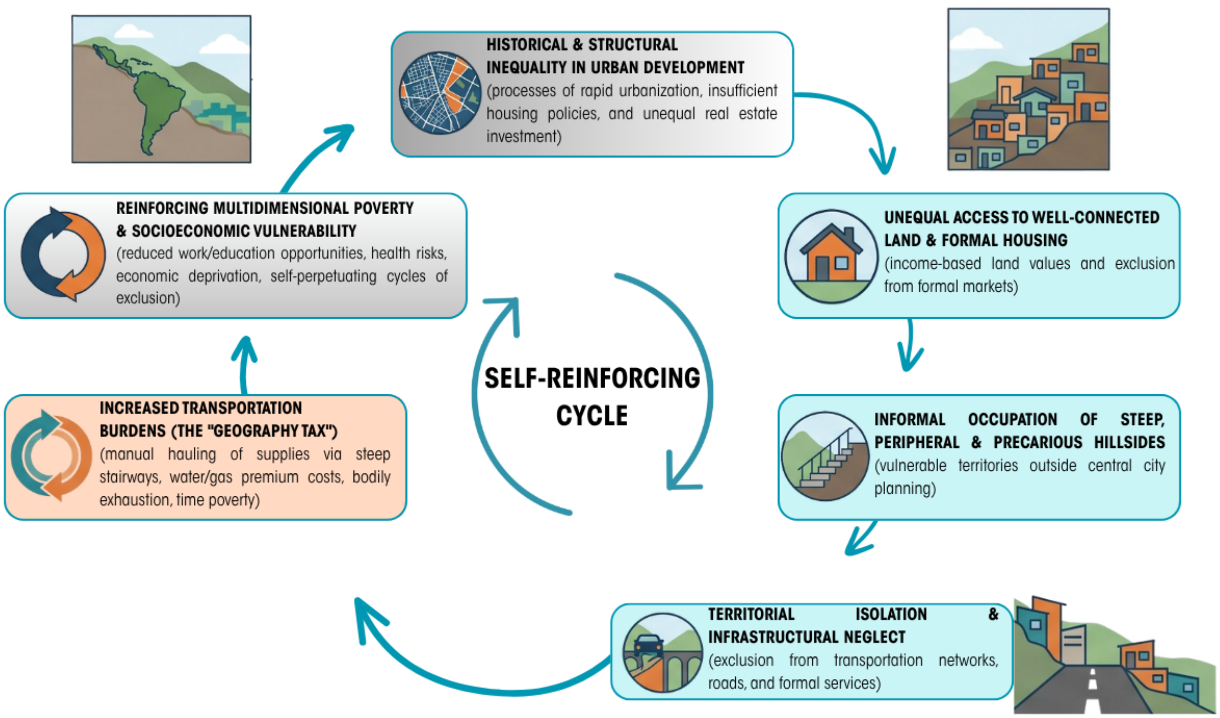
Urban inequality in Latin America has historically been shaped by processes of spatial segregation, unequal infrastructure distribution, and exclusion from formal urban development. According to Chilean urban sociologist Francisco Sabatini (2003), spatial segregation is not simply a geographic reflection of social inequality, but an active structural mechanism that reproduces poverty by isolating vulnerable populations from opportunities, services, and urban integration. In this context, informal hillside settlements emerge not as accidental urban formations, but as the material consequence of historically uneven urbanization processes across the region.

During the second half of the twentieth century, accelerated demographic growth and rural-to-urban migration transformed Latin American cities at a pace that exceeded the capacity of governments to provide affordable housing and integrated urban infrastructure.

As formal land markets became increasingly inaccessible for low-income populations, large sectors of the urban poor were progressively displaced toward peripheral and geographically precarious territories, particularly steep hillsides excluded from formal planning systems. According to UN-Habitat (2022), informal settlements continue to expand throughout Latin America due to persistent housing deficits, territorial inequality, and fragmented urban growth.

This process generated a pattern of territorial marginalization in which geography became directly connected to socioeconomic vulnerability. In cities such as Lima, many hillside settlements developed without adequate transportation systems, emergency accessibility, sanitation infrastructure, or institutional investment. As urban theorist David Harvey (2008) argues, cities are shaped through uneven processes of development in which infrastructure, investment, and public resources are asymmetrically distributed across urban space. Consequently, difficult topography becomes socially significant not because hillsides are inherently poor environments, but because urban systems systematically fail to adapt mobility and infrastructure networks to these territories.

Figure 2. *Conceptual Framework of the Spatial Segregation Cycle and the Geography Tax*



Note. Adapted from Sabatini (2003) regarding urban segregation mechanisms and integrated with the multidimensional "Geography Tax" framework analyzed in this study.

The consequences of this spatial exclusion extend into multiple dimensions of everyday life. Limited accessibility increases the effective cost of transportation and essential goods, restricts emergency response capacity, complicates access to healthcare and education, and intensifies the physical burden associated with manually transporting resources across extensive stair networks. Residents frequently carry water containers, cooking gas cylinders, food supplies, construction materials, and medicine through steep pathways that require substantial physical effort and time investment. These burdens disproportionately affect elderly residents, informal workers, women responsible for domestic logistics, and households with limited economic resources.

Over time, these conditions contribute to the reproduction of multidimensional poverty through what this paper defines as the "Geography Tax": a structural condition in which territorial isolation systematically increases the physical, economic, and social costs of daily life for already marginalized populations. In this sense, poverty is not experienced solely through low income, but through the unequal distribution of accessibility, infrastructure, and mobility within the city itself.

The persistence of these conditions also reveals the limitations of conventional urban infrastructure paradigms in informal vertical settlements. Existing mobility solutions such as electric elevators, escalators, and cable car systems generally depend on stable electrical grids, centralized maintenance systems, long-term public investment, and continuous technical support. However, these conditions are often absent in low-resource hillside communities. Environmental factors such as humidity, unstable terrain, coastal corrosion, and component theft frequently accelerate infrastructural deterioration and increase operational costs. As a result, many large-scale mobility projects become financially unsustainable or operationally fragile over time.

Table 1. *Comparative vulnerabilities between electric infrastructure systems and decentralized mechanical systems.*

Conventional Electric Systems	**Hillink Mechanical System**
Requires electricity	No electricity required
High maintenance costs	Low maintenance
Risk of cable/component theft	Simple replaceable parts
Requires municipal technical support	Community-manegeable
High installation costs	Low-cost infrastructure
Operational dependency	Decentralized operation

Note. Created by the authors.

Therefore, the Geography Tax should not be understood as an isolated geographic phenomenon, but as the material expression of historically unequal urban development and infrastructural exclusion. The persistence of spatial poverty in hillside settlements demonstrates that conventional urban infrastructure models frequently fail to respond to the territorial realities of marginalized communities. This structural limitation reveals the need for locally adaptable, low-cost, and low-dependency mobility systems capable of operating sustainably within resource-constrained environments.

When

Geography, urban conditions, and territory significantly influence human well-being. According to the economist Carmen Magaly León Segura (León Segura, 2011) “territory constitutes a highly important variable for local development processes.” Its importance is not limited only to economic or monetary factors, but also extends to the social sphere, since it is the space where a large number of social relationships develop among actors such as neighbors, companies, and organizations that share a specific place and form a sense of collective identity.

For this reason, geographic isolation and poor urban conditions can cause significant harm in multiple areas. Geographic taxes represent a major barrier preventing people from directly accessing a wide range of essential services, while also affecting many daily activities of local residents. As a result, people are often forced to improvise solutions in order to adapt to the difficult context in which they live.

One of the main difficulties that people face daily concerns mobility within these areas. A clear example of this can be observed in the settlements located on the outskirts of Lima. Due to the steep geography of these areas, mobility is highly limited, and there are zones where urban infrastructure such as sidewalks and bus stops is absent, as shown in the following figure.

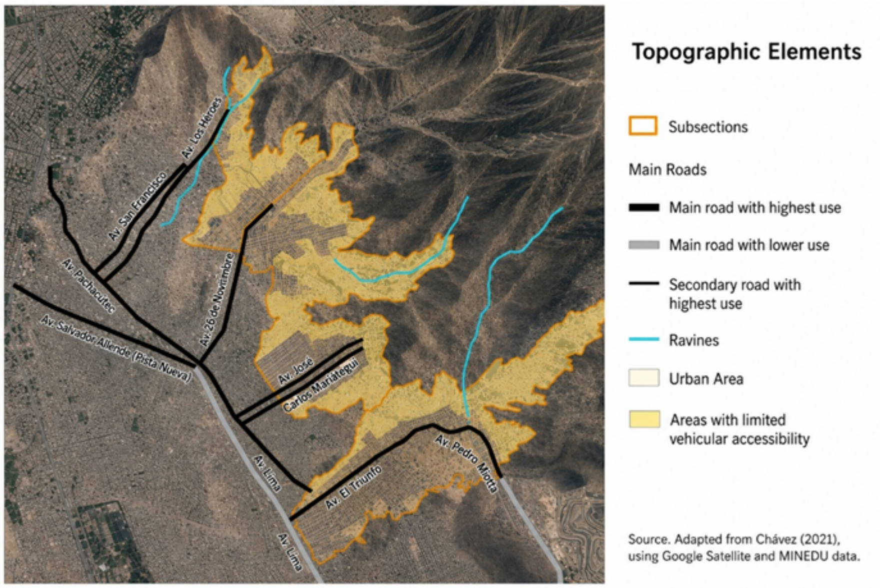
Figure 3. *Slopes and Sandy Areas in Pachacútec*

Note. © César Ponce (julio 2021).

The safety conditions of these roads are far from adequate. Dirt roads and sandy pathways do not meet the necessary conditions to be considered fully accessible or safe for transit. People who travel through these areas often get dirty, slip, or even trip and injure themselves, as explained by different studies on urban mobility in peripheral settlements (Ponce, Román García, & Chávez Arana, 2022).

Access routes to these districts are also limited by topographic conditions. According to the research conducted by Karina Chávez (Chávez, 2021), the urban configuration of these areas closely matches the physical characteristics of the hills of Lima. The main avenues and access roads to these districts are primarily located along the slopes of ravines, where the terrain is flatter. In contrast, access from other sides, where the terrain is much steeper, is completely blocked. Consequently, there is no road connecting the hills from one side to the other. Instead, neighborhoods are mainly structured vertically, from the top downward, as shown in the following map.

Figure 4. *Topographic Elements*



Note. Adapted from Chávez (2021), using Google Satellite and MINEDU data.

These conditions also affect the availability of transportation. As previously established, the worse the topographic conditions of an area are, the poorer the infrastructure becomes and the less adapted it is for vehicle access. For this reason, people often rely on local means of transportation such as mototaxis or simply travel on foot. These alternative forms of transportation are characterized by being significantly more expensive, costing up to 12 or even 15 times more than the average transportation fare, according to the report (Ponce, Román García, & Chávez Arana, 2022).

The report also highlights that, in the most vulnerable areas, residents must travel long distances because bus routes do not pass near these zones. As a result, people are often required to take more than one route segment in order to reach their destination, which clearly forces them to make greater efforts simply to move around the city.

In summary, geography and topographic conditions can be harmful in countless contexts, especially in matters related to transportation and mobility, where there is no optimal urban design adapted to these types of territories. Terrain directly influences the quality of urban conditions, as shown in the table, which consequently impacts the daily lives of residents.

Table 2. *Analytical summary according to study areas.*

Study Zones Analysis Variables		Pachacútec	Independencia	VMT
		Relief		
		Relatively flat	Sloped	Sloped
Infra-structure	Lack of sidewalks	X	X	X
	Lack of lighting	X	X	X
	Lack of transit stops		X	X
	Improvised stairways		X	X
Distance	Night-time schedules with reduced transit service	X	X	
	Routes with 1 to 3 transfers per segment	X	X	X

Note. Adapted from Ponce, Román García, & Chávez Arana (2022).

Where

The territorial conditions that shape vertical informal settlements across Latin America are deeply connected to broader processes of uneven urbanization, peripheral expansion, and socio-spatial segregation. According to Clichevsky (2000), contemporary Latin American cities have experienced increasingly fragmented urban growth patterns associated with informality, unequal land access, and the progressive displacement of low-income populations toward geographically precarious territories. Rather than existing outside the urban system, informal settlements constitute structurally produced spaces that emerge from historical inequalities in housing provision, infrastructure distribution, and territorial planning.

These processes are especially visible in cities characterized by mountainous and hillside geographies, where accelerated metropolitan expansion has historically concentrated vulnerable populations in steep peripheral areas with deficient infrastructural integration. Across cities such as Lima, Medellín, Rio de Janeiro, La Paz, Valparaíso, and Quito, hillside settlements frequently develop through gradual self-construction processes under conditions of limited state presence, fragmented accessibility networks, and unstable territorial consolidation. Although these territories differ politically and geographically, they share common spatial characteristics: steep slopes, irregular circulation systems, deficient mobility infrastructure, and unequal access to urban services (Clichevsky, 2000; Sabatini, 2003).

Recent urban morphology research demonstrates that informal hillside settlements in Latin America evolve through progressive processes of occupation, transformation, and territorial extension that intensify urban fragmentation over time (Martínez Muñoz & Maroto

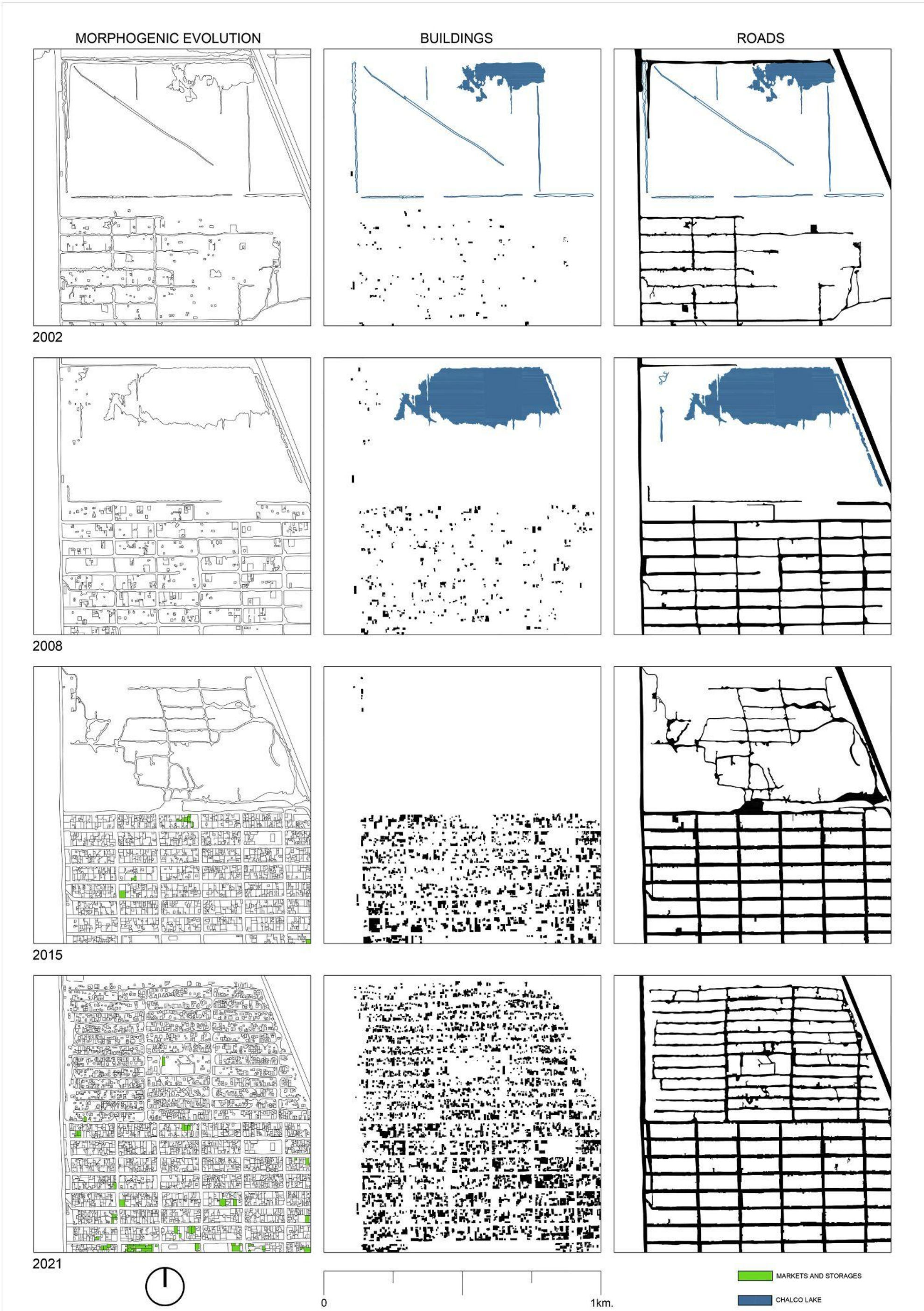
Ramos, 2024). According to their comparative analysis of settlements in Lima, Medellín, Mexico City, and Santiago de Chile, early-stage infrastructural neglect frequently generates long-term spatial discontinuities that become progressively more difficult to reverse as settlement density increases. In these contexts, urban accessibility networks often emerge incrementally and without integrated planning, producing highly vulnerable mobility systems dependent on stair circulation, narrow pedestrian paths, and fragmented territorial connectivity.

This pattern is particularly evident in Lima, Peru, where peripheral urbanization accelerated dramatically during the second half of the twentieth century due to rapid rural-to-urban migration and the inability of formal housing systems to absorb demographic growth. As low-income populations were progressively excluded from the formal land market, thousands of households occupied steep peripheral hillsides surrounding the metropolitan area through processes of incremental self-construction and informal territorial consolidation. According to Lambert (2021), these settlements should not be understood as spontaneous or chaotic urban forms, but rather as complex territorial assemblages shaped through interactions between informal practices, institutional limitations, speculative land dynamics, and uneven state intervention.

State-led urban management in Lima has historically oscillated between large-scale planning experiments and progressive institutional neglect. As documented by Martínez Muñoz and Maroto Ramos (2024), two major public interventions during the late twentieth century illustrate this volatile trajectory: the Proyecto Especial Huaycán (PEH) and the Proyecto Especial Ciudad Pachacútec (PECP). The PEH initially stood out as a highly organized, self-managed alternative driven by the Municipality of Lima, introducing Communal Housing Units (UCV) that operated under innovative cooperative models for urban equipment (Gyger, 2019; Ricou, 1988). Similarly, the PECP represented one of the most ambitious state-driven relocation programs in the 1990s, deploying multiple government agencies to distribute populations across the peripheral desert margins (Sierra & Ortiz, 2012). Nevertheless, both public projects ultimately succumbed to systemic institutional abandonment, leaving these communities with heavily fragmented infrastructure and severe connectivity deficits.

This legacy of state withdrawal directly shapes contemporary vertical informal settlements, with the Sector Virgen de Lourdes in Villa María del Triunfo (VMT) serving as a paradigmatic example of unmanaged peripheral growth since the 2000s. Unlike the planned boundaries of the PEH or PECP, the morphogenic evolution of VMT's southern hillsides has occurred almost entirely through incremental self-construction in extreme topographies (Martínez Muñoz & Maroto Ramos, 2024). In these steep terrains, the complete absence of integrated public planning has caused accessibility limitations to become permanently embedded within the physical urban fabric. Consequently, everyday mobility in VMT is dictated by highly precarious pedestrian pathways and disjointed stair networks, transforming spatial isolation from a mere geographical trait into a structural mechanism of daily social exclusion.

Figure 5. *Morphogenic Evolution and Territorial Fragmentation Processes in Villa María del Triunfo, Lima*

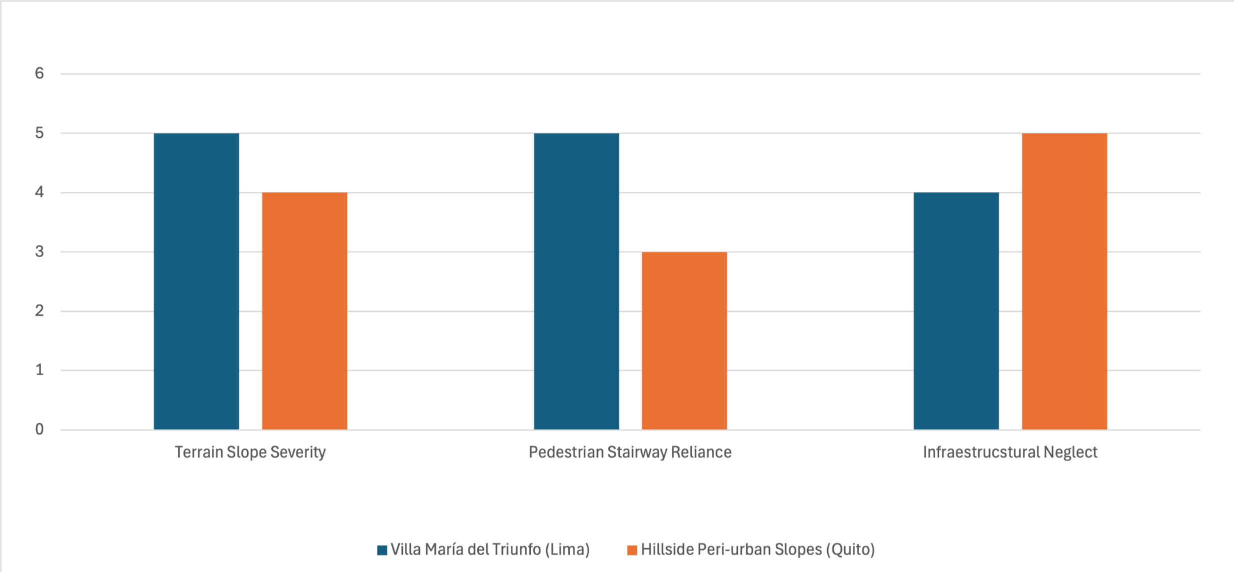


Note. Adapted from Martínez Muñoz and Maroto Ramos (2024).

The territorial conditions observed in VMT are not exclusive to Peru. Research on Andean hillside urbanization in Quito similarly demonstrates that peri-urban slopes frequently become spaces inhabited by populations historically marginalized from formal urban development processes (Amoroso Lavayen, 2025). According to Amoroso Lavayen (2025), the absence of territorially specific planning strategies in Andean hillside environments has contributed to deficient urban development, infrastructural vulnerability, ecological degradation, and the systematic disconnection of local communities from formal urban governance structures. These findings reinforce the broader regional pattern in which hillside urbanization produces forms of multidimensional territorial exclusion extending beyond purely economic poverty.

The morphology of hillside settlements directly conditions mobility, accessibility, and the circulation of essential resources within everyday life. Many sectors remain accessible exclusively through extensive stair systems and narrow pedestrian pathways that restrict vehicle circulation, emergency accessibility, and infrastructural maintenance operations. Residents frequently transport cooking gas cylinders, water containers, food supplies, medicine, and construction materials manually across steep terrain under physically demanding conditions. In high-density settlements with fragmented circulation systems, these territorial limitations significantly increase transportation burdens, reduce accessibility to healthcare and employment opportunities, and intensify everyday physical exhaustion.

Figure 6. *Spatial Accessibility Limitations in Hillside Informal Settlements*



Note. Prepared by the authors.

The variables represent a qualitative standardization (scaled 1-5) of the structural boundaries and transport obstacles described by Martínez Muñoz and Maroto Ramos (2024) regarding the concrete stairway dependencies in Villa María del Triunfo (Lima), and by Amoroso Lavayen (2025) concerning the institutional planning gaps on the Andean slopes (Quito).

These comparative territorial conditions demonstrate that hillside informal settlements cannot be understood merely as geographically isolated communities, but rather as territorially fragmented urban environments where topography, infrastructural inequality, and socio-spatial exclusion interact dynamically to reproduce long-term vulnerability. Consequently, mobility constraints within these settlements are not isolated logistical inconveniences, but structural manifestations of historically uneven urban development across Latin America.

Crucially, this specific terrain, the network of narrow pedestrian paths and long concrete stairways that completely prevent cars from entering, defines the exact "Where" of this project. While traditional urban planning often views the extreme slopes of sectors like Virgen de Lourdes in Villa María del Triunfo as inaccessible areas that justify state neglect, this research uses these exact physical conditions as the starting point for a new solution. The straight, continuous lines of the community staircases provide the perfect space to install a low-cost mechanical system.

Ultimately, the physical reality of this location directly determines the design and scope of *Hillink.* Because the terrain lacks stable electrical grids and faces constant resource scarcity, the intervention cannot rely on complex, motorized engineering. Instead, it demands a decentralized, manual, and non-electric mechanism that can be easily managed by the local community. By aligning the technical solution with the precise shape of the hills, this project proves that the vertical margins of the city are not just places of poverty, but the exact spaces where simple mechanics can break the cycle of exclusion and restore daily mobility to its residents.

Who

The population affected by the Geography Tax is not unique to Lima or Peru. Across Latin America, millions of low-income families inhabit informal hillside settlements, peripheral flood-prone areas, and isolated rural-urban margins where geography directly increases the cost of daily survival.

In Brazil, favela residents in Rio de Janeiro and São Paulo navigate similar conditions: steep slopes, lack of formal transportation, and the physical burden of carrying water, gas, and food over long stairways. In Chile, poblaciones in the cerros of Valparaíso and Viña del Mar present the same pattern of territorial exclusion. In Argentina, Villa Miseria in Buenos Aires and “barrios populares” in Córdoba face analogous challenges: narrow pathways, flood risks, and dependence on informal delivery systems.

The following figure provides a geographical overview of these affected areas across the region, showing the spatial distribution of informal hillside settlements in each country.

Figure 7. *The Geography Tax Across Latin America*

Note. Prepared by the authors. The icons represent villas (Villa Miseria).

Despite national differences, the affected population shares common characteristics: predominantly low-income families, high rates of informal employment, limited educational attainment, and precarious access to basic services. Women and elderly residents bear the greatest physical burden, as they are primarily responsible for domestic logistics.

Table 3 synthesizes these characteristics across the four countries, allowing a direct comparison of terrain, transport access, affected groups, employment conditions, basic services, and reliance on informal delivery.

Table 3. *Characteristics of populations affected by the Geography Tax in Latin America.*

Characteristic	Brazil (Favelas)	Chile (Cerros)	Argentina (Villa Miseria)	Perú (Peripheries)
Terrain	Steep slopes	Steep hills	Flood-prone / narrow pathways	Steep slopes
Formal transport access	Very low	Low	Very low	Low
Main affected group	Women, elderly	Women, elderly	Women, children	Women, elderly
Informal employment rate	High	High	Very high	High
Basic services access	Precarious	Precarious	Very precarious	Precarious
Reliance on informal delivery	High	High	Very high	High

Note. Compiled by the authors based on secondary sources: for Brazil, IBGE (2024); for Chile, CASEN (2022); for Argentina, INDEC (2022); and for Peru, INEI (2022) for informal employment data, INEI (2025) for basic services data, and authors' fieldwork (2026) for terrain, transport access, affected groups, and informal delivery.

In conclusion, the map and the table demonstrate that the Geography Tax is not an isolated phenomenon but a regional structural condition affecting millions of families across Latin America. Understanding who these residents are across different countries, in structurally similar contexts, is essential for designing a solution that is not only locally relevant but regionally scalable.

This demographic and territorial profile informed the sampling strategy for the field visit described in Section 5, which focuses on Villa María del Triunfo as a representative case of the Peruvian peripheries.

Field Visit

The location was the Villa María del Triunfo district (V.M.T.), specifically in the areas near San Gabriel Alto. This area is known for being one of the poorest in all of Metropolitan Lima, as can be seen from the National Registry of Municipalities (RENAMU) in the following respects. The full RENAMU indicators, including own-source revenue, waste management, and building permits, are presented in Appendix 2 (Figures A1-A3).

Municipal Fiscal Dependence

On average, the Lima Metropolitan Area relies on government transfers for only 38% of its total funding. This figure is significant because Villa María del Triunfo tells a very different story. In V.M.T., the municipality depends on the central government for 75% of its funding (INEI, 2025). In other words, three out of every four soles spent by the local government come from external transfers, not from taxes collected within the district itself. (See **Appendix 2, Figure A1** for the complete comparison of own-source revenue between VMT and Metropolitan Lima).

The implications of this fiscal dependence are profound. A municipality with low own-source revenue has limited capacity to invest in infrastructure, maintain public spaces, or respond to emergencies without waiting for central government approval or budget allocations. This creates a cycle of dependency: without local revenue, the district cannot improve its services; without better services, economic activity remains stagnant; without economic growth, tax collection does not increase.

In conclusion, while a middle-class district like San Miguel or Pueblo Libre funds most of its budget through its own tax revenue, VMT relies on funds allocated by the central government. A poor district cannot support itself. This fiscal reality is the first and most fundamental expression of the Geography Tax at the municipal level: the poorer the territory, the less autonomy it has to change its own condition.

Limited Garbage Collection Services

Garbage collection is one of the most basic public services, yet in V.M.T. it operates at a significantly lower standard than in the rest of Metropolitan Lima. While most districts receive daily or every-other-day collection, in V.M.T. garbage trucks arrive only twice per week (INEI, 2025). (See **Appendix 2, Figures A2** for the complete data on waste sent to landfills and recycling rates).

The consequences extend beyond discomfort. Accumulated waste in public spaces becomes a health hazard, particularly for children who play in the streets and for elderly residents with weaker immune systems. During the rainy season, uncollected garbage mixes with mud and rainwater, clogging drainage systems and creating additional flooding risks. Residents reported that the irregular collection schedule forces them to coordinate with neighbors or risk having their waste left behind.

Residents of VMT have their trash on the street for longer (it is collected less often), and a larger proportion of it ends up in inappropriate places. Poverty becomes visible through the deterioration of public space and the irregularity of basic services. The irregularity of this essential service is not a minor inconvenience; it is a daily reminder of how territorial exclusion translates into lower-quality public services.

Urban Development Constraints

Construction activity is a reliable indicator of economic dynamism and private investment, when families and businesses invest in building or improving properties, it signals confidence in the neighborhood's future and the presence of disposable income. In Villa María del Triunfo, this indicator reveals a stark reality. (See **Appendix 2, Figure A3** for the complete data on building permits in VMT compared to the Metropolitan average).

Construction activity in VMT is less than half that of the average district in Lima. Private investment in housing —measured through building permits for single-family homes— is significantly lower than the metropolitan average (INEI, 2025). Even more telling is the complete absence of permits for multifamily buildings, which in other districts signals the emergence of a real estate market and upward mobility.

The reasons for this are multiple. Steep slopes increase construction costs significantly, as foundations must be reinforced and materials must be carried manually or by small vehicles. The lack of formal land titles in many areas discourages long-term investment, since families cannot guarantee that the land they improve will remain theirs. And the absence of reliable public services —water, sewage, electricity, garbage collection— reduces the incentive to build beyond the most basic shelter.

Private investment in construction serves as an indicator of wealth. In this context, limited construction activity reflects constrained private investment, insecure tenure, difficult geography, and weak public infrastructure. In VMT, the scarcity of building permits is not a matter of individual choice but a structural constraint imposed by the very conditions that define the district: difficult geography, insecure land tenure, and insufficient public infrastructure. Breaking this cycle requires interventions that reduce the cost and risk of improving homes in hillside communities.

Results

To complement the secondary data from RENAMU, the team conducted semi-structured interviews in five different communities. A "community" was defined as a distinct hillside unit (cerro) comprising several households sharing similar access conditions, stairway networks, and exposure to the Geography Tax. Rather than seeking statistical representativeness, the sampling strategy aimed to capture the diversity of experiences across different elevations and locations within San Gabriel Alto. Each interviewed household represents one cerro, allowing the team to identify common patterns across spatially distinct but structurally similar contexts.

The interviews aimed to capture residents' perceptions of their quality of life, their relationship with the government, their experiences carrying heavy loads (water, food, gas, construction materials), accidents related to this activity, and their openness to the proposed mechanical transport solution. The main findings are summarized in the following table.

Table 4. *Responses from interviews conducted with various communities in San Gabriel, in the Villa María del Triunfo district.*

Topic	Responses
Regarding the area	Residents have been living in the area between 8 and 22 years. The zone lacks basic services: water, sewage, electricity. Stairs are a mix, some built by residents themselves, others by the municipality. In upper areas, there are no stairs at all, only sand and dirt, which becomes slippery mud during rain. One resident noted that even municipal stairs have problems: water pools on them, making them hazardous.
Regarding the government	All five residents stated they receive no support from the government. When asked about the last public work, only the staircases were mentioned. One resident said: *"The authorities need to remember those who live in higher areas. We need basic services to live with dignity."* Another noted that municipal stairs were built, but only in certain areas — above that, residents had to build their own.
Regarding the carrying of objects and/or food	All households transport goods manually. Trip duration ranges from 10 to 20 minutes one way, depending on the location. Load weight ranges from 5 to 15 kg per trip. Some residents shop daily (buying 5-6 kg per day), others shop weekly (10-15 kg at once). Women and elderly residents bear the greatest burden. One resident stated: *"When you're young you don't feel it, but when you reach a certain age, it gets harder and harder."*
Regarding gas	Gas cylinder prices range from S/ 50 to S/ 70, depending on the brand and delivery distance. One resident pays S/ 50, others pay up to S/ 70. Gas is delivered by motorcycle up to a certain point, but not to the doorstep. The delivery cost is higher than in lower areas — what costs S/ 40-50 below can cost S/ 70 in the hills. This is a direct manifestation of the Geography Tax.

Topic	Responses (continued)
Regarding accidents	Several residents reported accidents. One said: *"Several times, neighbors and also myself have fallen on the unfinished part of the stairs."* Another mentioned that before stairs existed, accidents were common. Rain makes stairs slippery and turns dirt paths to mud. One resident noted: *"When it rains, if there are no stairs, you slide all the way down."* Another added that stairs lack railings, increasing danger.
Regarding the community and the individual	Mutual support among neighbors is limited. Most residents said: *"Very little, everyone fends for themselves."* However, during emergencies (such as a death in the family) or community work (faenas), neighbors do collaborate. One resident noted that when there is a major task, *"we all pitch in"*, but daily help is rare because everyone is busy working.
Regarding our solution	The question was asked in three of the five interviews (Interviews 1, 2, and 5). In all three cases, residents expressed strong interest and approval. One resident said: *"Yes, I've thought about those little machines that help us several times."* Another stated that quality of life would improve, *"especially for the elderly, because it's quite a struggle for them to carry things."* A third acknowledged that implementation is difficult given the narrow stairs but remained hopeful.

Note. Authors' fieldwork, San Gabriel Alto, Villa María del Triunfo, 2026.

This limited mutual support identified in the interviews informed the design of Hillink's operational model. Rather than relying on voluntary neighbor collaboration, the system is structured around paid Station-stores with designated Hillink Agents. This ensures daily reliability without depending on informal community solidarity.

A video compilation of the interviews, including testimonies on load-carrying burdens, accidents, gas prices, and receptiveness to the proposed solution, is available in Appendix 3.

The interview results reveal a consistent and troubling pattern across all five households. First, the State is largely absent from residents' daily lives, none of the interviewees reported receiving any form of government support, and public works are rare, incomplete, or limited to staircases that often lack railings and proper drainage. This institutional abandonment forces communities to rely on their own limited resources.

Second, the physical burden of the Geography Tax is real and measurable. Residents spend between 10 and 20 minutes carrying loads of 5 to 15 kilograms up steep staircases and dirt paths, multiple times per week. This daily effort produces chronic pain, particularly in hips and backs, and becomes increasingly debilitating with age.

Third, the economic dimension of the Geography Tax is most visible in the price of gas. A cylinder that costs S/ 40-50 in lower areas can cost S/ 70 in the hills, simply because informal delivery workers must climb the stairs. This price penalty is paid almost exclusively by the poorest residents, who can least afford it.

Fourth, accidents are frequent and predictable. Unfinished stairs, lack of railings, and slippery conditions during rain create a hazardous environment. Several residents reported falls, and some noted that before stairs existed, accidents were even more common. These are not isolated incidents but structural consequences of neglected infrastructure.

Finally, residents are receptive to solutions. In all three interviews where the question was asked, residents expressed strong interest in a mechanical transport system. They recognize that such a system could reduce physical strain, save time, and improve quality of life, particularly for the elderly. However, they also understand that implementation faces real challenges, including narrow staircases and lack of government support.

Figure 8. *View from Above in One of the Communities of San Gabriel Alto, Villa María del Triunfo*

Note. Authors' fieldwork, 2026.

The photograph above illustrates the physical conditions that residents navigate daily. Unpaved streets, exposed soil, and steep slopes are not merely aesthetic features of the landscape, they are active constraints on mobility, safety, and quality of life.

Figure 9. *Villa Maria del Triunfo Avenue*

Note. Authors' fieldwork, 2026.

The image above reflects the broader context of Villa María del Triunfo: a district where basic infrastructure remains incomplete, and where the visible deterioration of public space mirrors the institutional abandonment that residents described in their testimonies. This is the territory where the Geography Tax is paid daily, on unpaved streets, steep staircases, and the bodies of those who climb them.

Given these results, we reflect on the reality these people face and their disconnect from the municipality, the mayor's office, and the government. We hope to bring about positive change in these people and their communities through our solution, but it is also necessary to learn from our mistakes; therefore, we will present the previous solutions and explain why they did not resolve our current problem at the time.

Past Solutions & Why They Failed

Electric elevators

Electric elevators are one of the solutions that have been implemented to improve mobility in the hills of Latin American cities. Among the most iconic are the elevators of the city of Valparaíso, Chile, a system of elevators that connects the flat coastal area with the surrounding hills. The oldest of them is the Concepción Elevator, inaugurated in 1883, which originally operated through a complex hydraulic system that "worked by means of water tanks located at both ends of the route, whose function was to counterbalance the load of the cars, made of wood at that time, in order to produce the ascent and descent of each one" (Migone & Pirozzi, p. 55) Its operation relied on a steel cable capable of withstanding heavy loads. This system was later replicated on other hills, leading to the construction of a total of 30 elevators in Valparaíso. However, most of these elevators are currently out of service due to a wide range of problems.

Figure 10. *Concepción Elevator*

Note. Museo Histórico Nacional.

One of the main issues affecting this service is its financial sustainability. The elevators are not profitable due to their high maintenance and repair costs, while the low fares charged to users are insufficient to cover operating losses. For this reason, in 2012 the Chilean government decided to acquire ten of these elevators because of their great cultural significance and strategic role in the city's mobility system. However, to date, only two of the ten elevators have been restored, while the remaining ones remain abandoned (La Tercera, 2024).

The delay in repairing the elevators is largely due to their age. Finding replacement parts is extremely difficult, and only a small number of companies possess the expertise required to provide maintenance services. The modernization of the elevators has also faced a series of technical challenges. According to engineer Humberto Miranda, quoted by *The Clinic* (The Clinic, 2023), “Attempts are being made to automate machines that are decades old, and in some cases more than a century old. An electronic control board is replicated and made operational, but the system has no way of detecting imbalances. Automation cannot guarantee that the car will not overshoot its destination.” The same report also points out that younger operators often lack the training needed to manage such old mechanical systems.

Even the elevators that remain in operation are not free from problems, as they have experienced a number of technical failures that have resulted in serious accidents. One notable example involved the historic Concepción Elevator, where five people were injured after the directions of the two cabins, or funicular cars, were inadvertently reversed. As a result, one car crashed into the upper station while the other slid downhill, as reported by the news outlet *Emol* (Emol, 2020).

Figure 11. *Damage Caused by the Accident*

Note. From Emol *(Emol, 2020).*

Cable cars

Cable car systems have been proposed or implemented in several informal hillside settlements across Latin America as a solution to mobility problems. The most prominent examples include Medellín's Metrocable in Colombia, which inspired similar projects in Caracas, Venezuela, and Rio de Janeiro, Brazil. However, when evaluated as a solution for low-resource, low-density, and low-infrastructure communities such as Villa María del Triunfo, cable cars present multiple structural limitations that make them unviable for the Geography Tax problem.

First, cable cars require high upfront investment. Construction costs include towers, cables, stations, electrical systems, and specialized rolling stock. In Colombia, Metrocable lines cost between 20 and 40 million dollars per kilometer (Henao, 2015).

Second, cable cars rely on stable power grids. Communities located on hillsides frequently experience power outages due to illegal connections, overloaded transformers, and lack of maintenance. In other words, without electricity, a cable car system becomes unusable.

Third, maintenance costs are often too high for community management. Cable car components require specialized technicians, regular inspections, and replacement parts from manufacturers. The Teleférico do Alemão in Rio de Janeiro perfectly illustrates this problem. Opened in 2011 at a cost of 253 million reais, the system closed in 2016 for what was supposed to be a six-month maintenance period. By 2021, the stations were in poor condition, the machinery was rusted, and residents feared that the abandoned cables might fall onto their homes (Extra, 2021).

Figure 12. *Deteriorated Cable Car Structure in Complexo do Alemão*

Note. Adapted from Extra (2021).

Fourth, cable cars are vulnerable to component theft and corrosion. This problem is exacerbated in informal settlements where insecurity is a constant presence among residents. In the case of Alemão, abandoned cable cars deteriorate rapidly, becoming dangerous and, over time, unusable. By 2021, the state government had repeatedly considered reactivating the system, but fiscal constraints have prevented any progress (G1, 2021).

Figure 13. *Deteriorated Cable Car Structure in Complexo do Alemão*

Note. Adapted from G1 (2021).

Fifth, cable cars only serve specific routes. Most cable car systems connect a station on the mountainside with another in the valley, but they do not reach private homes, precisely where the Geography Tax exists. Residents still have to walk from the cable car station to their homes, which may be hundreds of meters away and accessible only via steep stairs.

Finally, cable cars are not designed to transport goods. They are built for passengers, specifically for tourism, not to carry water, gas cylinders, construction materials, or bulky goods. In other words, it is inefficient for a resident with a 15 kg gas cylinder or a bag of cement to use a cable car designed for standing passengers. This type of infrastructure does not solve the geographical constraint that defines the Geography Tax.

Our Solution: Hillink

Hillink is a low-cost, cargo-only, non-electric, modular overhead transport system designed to move essential goods through steep and infrastructure-constrained settlements. Its technical purpose is specific: to reduce the effort, time, risk, and informal cost associated with carrying water, food, cooking gas, medicine, groceries, and construction materials through stairways, slopes, and narrow pedestrian routes.

The system is built around three non-negotiable design constraints derived from the fieldwork in Villa María del Triunfo. First, it must operate without electricity. Second, it must be installable and maintainable with locally available tools, materials, and technical knowledge. Third, it must preserve the stairway as a pedestrian circulation and emergency evacuation route. These constraints define the system architecture more directly than any fixed model or universal installation geometry.

As discussed in the previous section, conventional electric elevators and cable car systems often fail in low-resource hillside contexts because they depend on stable power supply, centralized maintenance, specialized technical support, and costly components. Hillink is designed to bypass these vulnerabilities through mechanical simplicity, local manufacturability, decentralized maintenance, and a cargo-only operational logic.

The system operates through manual mechanical advantage. Its basic components include galvanized steel carrier cables, an independent traction cable, a rolling trolley assembly, a suspended cargo container, manual winches, and terminal stations. These components are commercially available or locally manufacturable, allowing the system to be adapted to different terrain conditions without deep civil works or complex automation.

System Architecture: Spatial Separation and Clearance Requirements

Hillink is organized around a spatial separation principle: cargo movement occurs above the pedestrian corridor, while stairways remain available for circulation and emergency access. The carrier cables and rolling trolley operate at overhead level, the cargo container travels suspended below them, and the manual winch remains fixed at station level.

The minimum protected pedestrian clearance is defined as 2.30–2.50 m between the stairway surface and the lowest point of the moving cargo container. In inhabited stairway sections, this generally requires carrier cable installation at approximately 3.20–3.50 m above the walking surface. In open hillside segments without pedestrian circulation beneath the route, the cable height may be reduced to approximately 1.50–2.00 m, reducing post height, bending demand, and material use.

This clearance-based logic allows the system to adapt to local terrain instead of relying on a single fixed geometry. Post height, cable elevation, station position, and suspension geometry are therefore defined by the route profile and by the need to preserve safe pedestrian passage.

Structural and Mechanical Components

The Hillink system is composed of four main subsystems: the carrier cable structure, the rolling trolley and suspension assembly, the manual propulsion system, and the cargo container with terminal stations. These subsystems separate load support, movement, handling, and operation into distinct mechanical functions.

Structural System

Two parallel carrier cables support the suspended load and distribute forces across the route. The dual-cable configuration improves lateral stability and creates redundancy relative to the nominal operating load. The traction cable is independent from the carrier cables and performs only the propulsion function. This separation is a passive safety feature: if the traction cable fails, the container remains suspended by the carrier structure rather than falling from the system.

Terminal zones include passive impact absorption using replaceable bumper elements. Their function is to dissipate residual kinetic energy if an uncontrolled downhill movement reaches the lower station. Routine inspection therefore focuses on traction cable wear, pulley condition, anchor integrity, cable tension, and bumper positioning.

Trolley and Suspension Assembly

The trolley assembly rolls along the carrier cables and transfers the suspended load to the container. Upper pulleys support movement along the carrier lines, while lower retention rollers reduce the risk of disengagement under wind, uneven loading, or vibration. A rigid yoke connects the trolley frame to the container suspension, reducing longitudinal oscillation during acceleration and braking.

The container is suspended through a central pivot and compact dual-chain geometry. This arrangement keeps the cargo floor approximately horizontal across slope variations and reduces pendulum amplitude during operation.

Manual Propulsion System

Cargo movement is generated by a manually operated self-braking winch connected to the traction cable. The internal ratchet mechanism locks the system if the operator releases the crank, preventing uncontrolled rollback on steep routes. The winch is positioned at station level within an ergonomic operating range and protected inside a locked enclosure when not in use.

Route segments are limited to approximately 50 m to control operator effort, cable sag, drum growth, and anchoring demand. Under normal operating cadence, a segment of this length can be completed in approximately two to three minutes, depending on slope and cargo weight.

Cargo Container and Terminal Stations

The standard cargo container measures approximately 60 x 60 cm and is designed for routine household logistics, including LPG cylinders, water containers, groceries, medicine, and small construction materials. The mesh enclosure reduces weight, allows visual inspection, improves drainage, and limits wind resistance.

Terminal stations concentrate loading, unloading, winch operation, and routine inspection. Their handling platforms are positioned at approximately waist height to reduce vertical lifting. Station geometry must preserve the pedestrian corridor and should preferably use widened stairway landings, open edges, or existing commercial nodes when available.

Operational Safety and System Resilience

Hillink's safety logic is based on fault tolerance rather than automation. Load support and propulsion are mechanically separated, operating speeds are low, transported mass is limited, and the system can stop passively through the self-braking winch. These features reduce the consequences of traction failure, load shifts, or temporary obstruction.

Structural resilience depends on corrosion-resistant components, distributed load paths, adjustable tensioning hardware, and accessible inspection points. In humid or coastal environments, cable condition, pulley wear, anchor integrity, and tension loss should be monitored through routine maintenance. Gradual cable elongation does not necessarily compromise structural safety, but it can alter the clearance profile and must be corrected through periodic tension adjustment.

In seismic or unstable hillside contexts, the system avoids large suspended structures and concentrates loads in a lightweight, segmented architecture. While detailed seismic performance requires pilot validation, the proposed configuration limits kinetic energy, separates critical functions, and supports predictable failure behavior. The main validation requirements are long-term cable behavior, wind response of the suspended container, component wear, route throughput, and maintenance intervals under real operating conditions.

Deployment Typologies and Terrain Adaptation

Hillink is deployed through morphological variations rather than through a single fixed layout. The same mechanical core can be adapted to different terrain conditions by changing route alignment, station placement, support height, and anchoring strategy.

Type A: Confined Stairway Corridor

This configuration applies to narrow hillside stairways bordered by houses, walls, or dense built edges. The transport path remains above the stairway, and the compact container preserves the required pedestrian clearance. Type A is the most restrictive case and serves as the baseline for the current design.

Type B: Open-Edge Stairway

This configuration applies where one side of the stairway faces an open slope or ravine. The route can shift toward the open edge, reducing interference with facades and improving clearance flexibility.

Type C: Unbuilt Slope Span

This configuration connects a lower access point to an upper destination across open hillside terrain. Because no active pedestrian corridor lies beneath the route, longer spans may be possible if cable sag, wind exposure, anchoring capacity, and operator effort remain within acceptable limits.

Type D: Vertical Adaptation

This configuration addresses abrupt level changes, blocked entrances, narrow passages, walls, or other entry constraints that cannot be solved through a simple inclined route. Because it introduces additional mechanical complexity, it should be used only when required by site-specific conditions.

Type E: Rooftop-Level Network

This configuration shifts the cargo path to rooftops, terraces, or elevated built surfaces in ultra-dense areas where stairway installation is impractical. It requires structural assessment of host buildings and stronger local coordination before implementation.

These typologies expand Hillink from a single-site proposal into a terrain-adaptable method. The mechanical core remains standardized, while alignment, height, anchoring, and station design respond to local morphology.

Project Implementation

Implementation Phases

Due to the social, technical and territorial factors described in the previous sections, Hillink will be implemented through a phased strategy rather than through an advanced prototype from the outset. This approach allows the project to move progressively from diagnosis to measurement, feasibility assessment, community validation, pilot testing and impact evaluation.

Table 6. *Implementation Phases.*

Phase	Objective	Expected Output
Field Diagnosis	Understand the real problem within the community	Interviews, photos, videos, critical routes, pain narratives, perceived costs and local barriers
Baseline Metrics	Convert the diagnosis into measurable pre-intervention data	Cost, time, load, frequency, pain, exhaustion and accessibility indicators
Applicability & Feasibility	Assess whether the site is suitable in different ways	Territorial typology, technical checklist, materials, corrosion risks, permits and constraints
Community Validation & Governance	Confirm acceptance, operation and maintenance capacity	Local responsibilities, use rules, maintenance plan and community ownership
Pilot Implementation	Test the module in a specific route or stairway	Initial operational evidence, usage records and technical limitations
Impact Evaluation	Compare pre- and post-pilot conditions and build a replication argument	Before/after comparison, impact indicators, lessons learned, and replication criteria

Note. Made by the authors.

Field Diagnosis

Phase A follows a process evaluation logic: before testing Hillink's impact, the project must verify whether the problem has been correctly diagnosed. The burden created by difficult access is not experienced uniformly; it varies according to local routes, household routines, gender roles, age, informal delivery systems and community governance. Therefore, the first phase is designed to assess whether all affected groups have been identified and whether the proposed intervention addresses the real constraints faced by residents.

This approach is supported by process evaluation literature, which warns that weak problem analysis or misdiagnosis can lead to misleading conclusions about whether an intervention works or fails. 3ie emphasizes that process evaluation helps identify how and why an intervention produces results, whether the original diagnosis was appropriate, and whether implementation is shaped by contextual, institutional or external factors (Dixon & Bamberger, 2022).

To address this, Phase A will focus on qualitative assessment through active community immersion and direct field research during the case study in Villa María del Triunfo, Lima. This follows Gu Dai's recommendation that Hillink should first understand the real struggles of the community before moving toward advanced technical design. The phase will be organized around two core activities:

Semi-Structured Community Interviews: engaging in open dialogue with neighborhood assembly representatives, local leaders and community cooperative heads to map existing governance, historical mutual-aid systems, informal transport arrangements and practical expectations.

Everyday Life Experience Mapping: speaking directly with vulnerable and operationally relevant groups, especially elderly residents, women, caregivers and informal delivery workers, to collect testimonies on daily transport burdens, physical strain, chronic pain, time loss, informal delivery costs and dependence on third parties.

This phase is also consistent with stakeholder engagement and development planning guidance. The IFC manual supports early and context-sensitive consultation with affected communities, while UNDP identifies inadequate stakeholder involvement as one of the common reasons why programmes and projects fail. UNDP also recommends stakeholder analysis to identify risks, conflicts, opportunities, vulnerable groups and actors who are often excluded from planning processes (International Finance Corporation, 2007; United Nations Development Programme, 2009).

For Hillink, this means that interviews and route observation are not preliminary anecdotes. They are the empirical basis for defining the project's technical requirements, social risks and baseline indicators. The field diagnosis will help identify who carries goods, who pays for informal transport, who depends on others, which routes are most critical, and which groups experience the greatest physical, temporal and economic burden.

This step is also important for future scalability. A strong documentation method allows Hillink to distinguish between what is specific to Villa María del Triunfo and what may be transferable to other contexts. Process evaluation literature supports this logic because it emphasizes the role of context, institutional structures and external factors before drawing conclusions about impact or replication (Dixon & Bamberger, 2022).

In summary, Phase A provides the qualitative foundation required to design locally valid baseline indicators in Phase B. It does not measure Hillink's impact yet. Instead, it identifies which variables actually matter for the community and prevents the project from imposing externally defined metrics that may not reflect local reality.

Baseline Metrics

Phase A identifies which burdens matter to the community. Phase B measures those burdens in a structured and comparable way by converting qualitative evidence into baseline indicators. The output is a baseline table describing the current burden of essential-goods transport before the pilot, which will serve as the reference point for later comparison after Hillink is tested.

Table 7. *Documentation Methodology.*

Method	Evidence Produced	Output for Phase B
Semi-structured interviews	Testimonies from residents, vulnerable groups and informal delivery actors	Variables for cost, time, pain, effort and accessibility
Stakeholder & governance mapping	Local leaders, community organizations, affected groups and municipal actors	Stakeholder matrix for validation, permissions and maintenance
Everyday life & route mapping	Routines, goods carried, stairs, slopes, access gaps and critical routes	Routes and logistics categories to measure
Visual documentation & basic measurements	Photos, videos, time, steps, load estimates and frequency	Initial baseline values and before/after metric-card material

Note. Made by authors.

Table 8. *Proposed baseline indicators for Phase A.*

Indicator	Measurement
Frequency	Goods transport recurrence
Cost	Informal carrying or delivery expense
Time	Route duration
Load	Weight carried
Route difficulty	Physical barriers
Physical strain	Pain or exhaustion
Dependency	Need for help

Note. Made by authors.

The World Bank and IDB impact evaluation framework supports this sequence. It states that baseline data should be collected before implementation to establish the initial condition of the outcomes that the intervention expects to change. It also emphasizes that evaluation should be connected to a theory of change, results chain and clearly defined indicators. UNDP reinforces this logic through its results-based management framework, which links expected results to indicators, baselines, targets, means of verification and risks (Gertler et al., 2016; United Nations Development Programme, 2009).

Phase B will not attempt to measure every possible effect of Hillink. Instead, it will define a minimum viable set of indicators that can be realistically collected in the field and later compared with post-pilot data. This avoids excessive data collection, reduces respondent fatigue and improves the quality of the baseline, consistent with World Bank and IDB recommendations.

The proposed Phase B baseline indicators are presented below.

Table 9. *Proposed baseline indicators for Phase B.*

Indicator	Measurement	Metric	Source from Phase A
Transport frequency	How often households carry essential goods	trips/week	testimonies; routines; frequency records
Informal transport cost	Amount paid to carry or deliver goods	local currency/month	testimonies from residents and informal delivery actors
Transport time	Time required to move goods from access point to home	minutes/trip or hours/week	route mapping; time records; resident testimonies
Manual load	Approximate weight carried by residents	kg/week	goods carried; load estimates; testimonies
Route difficulty	Physical barriers along the path	steps, slopes, access gaps, critical routes	route mapping; photos; videos; step counts
Pain and exhaustion	Self-reported physical strain after carrying goods	0-10 scale	testimonies from vulnerable groups
Accessibility dependency	Need for help from others to transport goods	yes/no or times/week	testimonies from elderly residents, women, caregivers and vulnerable groups
Governance feasibility	Local actors relevant to operation and maintenance	stakeholder matrix	local leaders, community organizations and municipal actors

Applicability & Feasibility

While Phase B measures the current burden of essential-goods transport, Phase C uses these results to assess whether a specific route or site is suitable for Hillink implementation. In short, Phase B measures severity; Phase C evaluates applicability and feasibility. A route may show high social need through high costs, long travel time, heavy loads or strong dependency on others, but this is not enough to justify a pilot. The site must also meet minimum conditions of technical safety, environmental durability, institutional authorization and local maintenance capacity.

For this reason, Phase C proposes the use of a Multi-Criteria Decision Analysis (MCDA). MCDA is a decision-making approach used when alternatives must be evaluated through several criteria at the same time. This is appropriate for Hillink because site selection cannot depend on a single variable: one location may have high social need but weak technical feasibility; another may be technically viable but serve too few households; another may have severe physical barriers but high regulatory risk.

In operational terms, the MCDA will be implemented as a route-level composite applicability index. This distinction is important: MCDA describes the broader decision-making framework, while the composite index is the practical scoring model used to compare candidate routes. This approach is consistent with UNECE guidance on composite indicators, which describes composite indicators as tools for combining multiple dimensions into a single measure through a structured process involving conceptual definition, selection of dimensions and variables, data processing, weighting, aggregation, robustness checking and communication. For Hillink, this means that physical, social, technical, environmental and institutional variables can be normalized, weighted and combined transparently, while still allowing the weights to be adjusted and tested through sensitivity analysis.

Deciding where to test the system requires combining heterogeneous data, such as terrain, population served, accessibility, environmental risks, technical restrictions and local permissions. In this sense, Phase C transforms the baseline indicators from Phase B into a transparent route-selection framework. This also connects with Tsinghua's 5W1H+ Toolkit, which emphasizes multi-actor and multi-institutional collaboration in poverty-reduction processes; therefore, a transparent methodology is essential to support coordination, comparison and future replication.

The connection with Phase B is therefore essential. Without baseline indicators, Phase C risks selecting sites based only on visual perception or social urgency. With Phase B data, frequency, cost, time, load, physical difficulty, exhaustion and dependency become measurable inputs for route comparison. When field evaluation is not yet complete, Phase C can also use open-data estimates. Digital elevation models, gridded population datasets, road-network maps and built-up area data can estimate slope, elevation gain, distance to accessible roads, urban density and potential population served. Sources such as Copernicus DEM, WorldPop, GHSL and OpenStreetMap can provide a first analytical layer to prioritize routes and reduce field investigation costs. These tools to estimate do not replace community validation or direct measurement, and increase costs as well. But they can be helpful enough for not being cited and the geospatial data analysis toolkit can be a interesting future plan consistent with Hillink's scope.

In this sense, Phase C prevents Hillink from advancing to a pilot based only on social need. A site should advance only if it combines a relevant baseline burden with minimum conditions of technical safety, institutional feasibility, environmental durability and community maintenance capacity. The final output of this phase will be a structured route decision: advance, advance with adaptations or do not advance at this stage.

Community Validation & Governance

While Phase C assesses whether a route is technically and territorially suitable for Hillink, Phase D verifies whether that route can be implemented through clear stakeholder collaboration. Technical feasibility alone is not sufficient: a route should not advance to pilot implementation if affected residents reject the installation, if public authorization remains uncertain, if no local operator is defined, or if maintenance responsibilities are unclear.

Stakeholder engagement is the central mechanism through which this stage establishes community validation and governance. This proposal uses the IFC handbook *Stakeholder Engagement: A Good Practice Handbook for Companies Doing Business in Emerging Markets* as a methodological reference. At this stage, the objective is not to define the full operational strategy; more concrete plans regarding stakeholder roles, engagement methods, and implementation procedures will be developed in Section 8. Therefore, this section presents stakeholder engagement only as a methodological foundation for community validation and governance.

Following the IFC definition, stakeholders are understood as individuals or groups directly or indirectly affected by the project, or able to influence its outcomes (International Finance Corporation [IFC], 2007, p. 10). For Hillink, the basic stakeholder structure has already been established in the previous sections. However, depending on the local context, this structure should remain open to additional actors, including NGOs, universities, funders, landowners, risk-management authorities, or other institutions whose approval, expertise, or support may affect implementation.

Rather than treating participation as a one-time consultation, we propose following the approach presented in the IFC handbook, where stakeholder engagement is framed as a broader, more inclusive, and continuous process across the project cycle (IFC, 2007, p. 2). This process is crucial to reduce the risk that technically valid infrastructure may become unsustainable due to weak maintenance, unclear responsibilities, institutional dependency, or limited local ownership.

Continuing from the IFC framework, Hillink should adopt the following basic premises, followed by brief practical suggestions for their application.

- **Information disclosure:** explain Hillink early, in simple language, including expected benefits, limitations, risks, costs, responsibilities, and what is still open to change.

  - Our suggestion: a simple one-page visual brief explaining what Hillink is, what it carries, what it does not carry, expected risks, basic rules, costs, and what is still open to community input.

- **Stakeholder consultation:** collect feedback from affected residents, vulnerable users, operators, delivery workers, local leaders, technicians, and public authorities before finalizing the pilot.
  - Our suggestion: hold small, targeted consultations instead of one large meeting: residents on the route, vulnerable users, operators, delivery workers, technicians, and local government.

- **Negotiation and partnerships:** define agreements with local operators, station-shops, municipalities, NGOs, universities, funders, or technical partners when implementation depends on shared responsibility.
  - Our suggestion: Create simple agreements with station-shops, Hillink Agents, municipalities, technicians, NGOs, universities, or funders, depending on who will authorize, operate, maintain, or support the system.

- **Grievance management:** create a simple channel for complaints, safety concerns, unfair pricing, misuse, maintenance failures, or conflict during the pilot.
  - Our suggestion: Set up a basic complaint system: WhatsApp plus a physical logbook at the station-shop. Record the issue, date, responsible person, response, and resolution status.

- **Stakeholder involvement in project monitoring:** involve users and local actors in checking whether the system is safe, accessible, fairly managed, and actually reducing transport burden.
  - Our suggestion: Include residents, operators, and technicians in short periodic checks on safety, fair pricing, stairway obstruction, maintenance, misuse, and actual usefulness.

- **Reporting to stakeholders:** communicate what was decided, what changed after consultation, what problems were found, and what actions will be taken next.
  - Our suggestion: share short updates on what was changed after feedback, how often the system was used, what problems occurred, how maintenance funds were used, and what will be adjusted next.

- **Management functions:** assign responsibility for tracking commitments, maintaining records, coordinating actors, updating rules, and ensuring that stakeholder engagement continues during the pilot.

- Our suggestion: assign one Hillink team member to track consultations, commitments, permits, complaints, maintenance records, and stakeholder follow-up.

The practical rule is that each stakeholder should have a clearly defined function: validate, authorize, operate, maintain, monitor, report, finance, or raise concerns.

Finally, the IFC handbook also emphasizes that the government should be recognized as a key stakeholder (IFC, 2007, p. 23). For Hillink, this means identifying the minimum institutional pathway required for each pilot site. This point should not be understood as making government the central actor of the model, since Hillink is designed for territories where public presence may be weak or inconsistent. Rather, the purpose is to clarify the minimum public authorization required for each implementation scenario.

Pilot Implementation

The output of Phase D is a prerequisite for Phase E. As described above, without prior acceptance, authorization, use rules, operator definition, and maintenance responsibility, the pilot would only demonstrate a mechanism, not an implementable infrastructure model. These constraints clarify who is allowed to operate it, what loads are permitted, how risks and complaints will be handled, and when the test must be stopped or redesigned.

Given the early stage and time constraints of the project, this phase should be structured as a pilot-implementation stage rather than a final engineering deployment.

To support this stage and Hillink project in general, a preliminary 3D model was developed in the software *Rhinoceros 8*. The model translates the preliminary engineering implementation suggestion described in Section 7 into a visual and measurable pilot configuration. The model is not used as a certified engineering design, and it does not replace structural calculations, anchoring verification, fatigue analysis, supplier load ratings, or professional engineering approval. Instead, it helps in describing the pilot implementation logic and gives better understanding for later sections.

By organizing the model into material groups, the project can estimate first-order quantities such as carrier-cable length, traction-cable length, station height, tube length, platform footprint, container size, and clearance distance. These quantities support a preliminary bill of materials and identify the main cost drivers of a pilot installation. More importantly, they define the physical baseline for Phase F: impact and scalability can then be assessed not only through user outcomes, but also through route geometry, implementation cost, maintenance demand, and replicability across terrain typologies.

Impact Evaluation

Finally, Phase F differs from Phase E by shifting the focus from controlled pilot implementation to impact evaluation and replication criteria. While Phase E verifies whether a minimum Hillink module can operate safely under real route conditions, Phase F asks a

Table 10. *Pilot model elements and material assumptions.*

Model element	Pilot function	Material assumption	Quantity from model
Carrier cables	support suspended load	galvanized steel cable	length
Traction cable	move trolley	thinner galvanized steel cable	length
Station frame	support/operation point	galvanized steel tube	tube length
Trolley	rolling support	welded steel frame + pulleys	unit
Cargo container	cargo-only transport	steel angle + mesh	size/area
Winch	manual propulsion	self-braking manual winch	unit
Platform	loading/unloading	concrete/steel	footprint

Note. Made by the authors.

narrower and more rigorous question:

Did Hillink reduce the Geography Tax burdens after pilot implementation?

The results of a single pilot should not be used to claim that Hillink represents a universal solution to poverty. Instead, it tests whether Hillink reduces a measurable burden in a specific place. Phase F should be understood as a pilot-level impact assessment rather than a definitive causal evaluation.

The most direct evaluation strategy for this phase is a comparison before and after pilot implementation. After the pilot, the same indicators used on previous phases are measured again among users and affected households. The comparison does not prove universal causality, but it allows the project to test whether the pilot implementation changed the burdens it was specifically designed to reduce.

To conduct this evaluation, we propose a set of guiding questions and quantitative indicators to measure social impact and support the pre/post comparison:

- Before Hillink, residents had to carry essential goods repeatedly through difficult routes. **After the pilot, did Hillink manage to reduce the number of manual carrying trips? Was there a significant difference?**
  - indicator: average number of manual carrying trips per household per week before and after the pilot.
- In many cases, basic goods became more expensive because delivery workers had to climb stairs, slopes, or inaccessible paths. **Did Hillink reduce this extra cost? How much?**

  - Indicator: average household savings in delivery or carrying costs, measured by comparing the cost of moving the same goods before and after the pilot.

- Residents used to spend significant time carrying goods from the last vehicle-accessible point to their homes. **Did Hillink reduce this time? How much time is saved?**

  - Indicator: average time required to move one standard load from the access point to the household before and after the pilot, including loading and unloading time.

- Geography Tax made transportation to interrupt work, study, care, or rest. **The residents are now able to do their activities with less burden?**

  - Indicator: qualitative post-pilot interviews comparing perceived routine disruption before and after Hillink.

- Residents had to carry heavy loads such as gas, water, groceries, medicine, or construction materials manually**. How much does this carry reduce with Hillink?**

  - Indicator: total kilograms transported through Hillink per cycle of implementation and estimated kilograms no longer carried manually by residents.

- Many routes had an increased risk and exhaustion because of lack of infrastructure. **Has Hillink made transportation safer?**

  - Indicator: number of reported safety incidents, near-falls, complaints, and obstruction events.

- The field diagnosis identified fatigue, pain, falls, and other health-related burdens associated with repeated manual carrying. **After Hillink, to what extent did residents report a reduction in these physical and health-related burdens?**

  - Indicator: data collection on local health-post or municipal records on falls, injuries, or musculoskeletal complaints related to load carrying.

A pilot route will be considered to show high social impact if post-pilot evidence demonstrates improvement in at least four core dimensions. The evaluation should maintain a clear focus on vulnerable groups, including elderly residents, pregnant women, and women responsible for household supply logistics.

If continuous post-pilot evaluation shows consistent improvement and high social impact, the pilot can justify a second implementation cycle with technical refinement and site-specific adaptation. This should not be interpreted as immediate large-scale expansion,

Table 11. *Pilot social impact classification.*

Classification	Condition
Low impact	Improvement in only 1 indicator
Moderate impact	Improvement in 2–3 indicators
High impact	Improvement in 4+ indicators **AND** no accidents

but as the basis for a minimal scalability plan. Such a plan is necessary to reduce future engineering costs through modularization, prepare stakeholder engagement for different community and institutional contexts, and test whether Hillink can reduce the Geography Tax under varied conditions while preserving safety, affordability, and local ownership. This broader discussion will be developed in the *Social Impact and Scalability* section.

Costs, Maintenance & Financing

As described in the technical section, Hillink is intentionally designed as a low-cost, non-electric, and mechanically simple infrastructure. However, a module that is inexpensive to build but difficult to inspect, repair, or maintain would not be appropriate for low-income hillside settlements. For this reason, cost and maintenance must be treated as a single engineering problem: the more demanding the route and the higher the operating frequency, the greater the required reserve for maintenance. Because of this, the problem introduces another variable: financing strategies, which will be further discussed in the stakeholder engagement and financing section.

At this stage, Hillink's cost model should be treated as a preliminary engineering estimate, not as a final budget. Following the AACE International *Cost Estimate Classification System*, the estimate will be classified according to the maturity of project definition deliverables, since cost accuracy depends on scope definition, design information, assumptions, and risk analysis rather than on a single fixed value (AACE International, 2016, pp. 3–5).

For Hillink, this is relevant because each route may require different terminal anchoring conditions, cable lengths, station layouts, slope adaptation, access conditions, and maintenance needs. The 3D model can support the first estimate by extracting approximate route geometry and material-driving quantities. However, these outputs remain conceptual until supplier quotations, detailed drawings, and pilot data are available. Therefore, the estimate should be understood as a route-based cost structure rather than as a final bill of quantities.

Cost viability should then be tested through a simple lifecycle check. A pilot or future implementation should only be considered feasible if, within a defined service period, the available revenue, collective funding capacity, or maintenance fund can cover the initial investment plus operation, management, maintenance, and replacement costs. This does not imply premium pricing for residents. It means that Hillink must preserve safe operation without depending on uncertain external support.

Modularization is the main engineering strategy for reducing long-term cost. Hillink includes repeated components that can be standardized across routes, such as:

- Cargo container;
- Pulley assembly;
- Winch unit;
- Cable system.

Site-specific elements, such as foundations, anchoring points, support spacing, post height, and route alignment, should be adapted to each location. This reduces design and procurement costs over time without assuming that one fixed geometry can fit all hillside settlements. This modular strategy also improves maintenance. If repeated components are standardized, the community does not need a different maintenance logic for every installation. The same inspection checklist, spare parts list, lubrication routine, and replacement procedure can be reused across routes.

To move from a conceptual design to a financially accessible pilot, a transparent route-based cost basis is required. The current 3D model is therefore used to extract preliminary quantities from the proposed pilot configuration. These quantities do not yet constitute a final bill of quantities, but they help transform the estimate from a generic prototype price into a route-specific cost structure. The estimate made from the model is described in Table 12.

Table 12. *Preliminary route-based cost estimate for the Hillink pilot configuration.*

Line item	Category	Quantity	Unit	Unit cost key	Unit cost (USD)	Direct cost (USD)	Notes
Carrier cables (2 lines + 10% allowance)	Standard core	53.83	m	Carrier cable 3/8 in galvanized	$4.50	$242.24	From Rhino carrier span; allowance for fixation/tensioning
Traction cable (+20% allowance)	Standard core	30.22	m	Traction cable 3/16 in galvanized	$1.80	$54.40	From Rhino traction path; allowance for winding/connections
Station structural steel	Site-specific interface	29.94	m	Structural steel tube/profile for stations	$8.00	$239.52	Approximated from visible station members in model + 15% allowance
Station platforms / handling surfaces	Site-specific interface	2.68	m^2	Station platform / steel plate equivalent	$35.00	$93.80	Two terminal stations, approximated from Rhino bounding box
Cargo container frame	Standard core	5.90	m	Cargo container steel angle/frame	$5.00	$29.50	Frame length from model bounding box + 20% allowance
Cargo container mesh	Standard core	1.00	m^2	Galvanized mesh panels	$12.00	$12.00	Container surface estimate from Rhino bounding box
Pulleys / rollers	Standard core	8.00	unit	Sealed-bearing pulley/roller	$12.00	$96.00	4 rolling pulleys + 4 retention rollers; preliminary count
Manual self-braking winch	Standard core	1.00	unit	Manual self-braking winch	$85.00	$85.00	One lower station winch unit

Line item	Category	Quantity	Unit	Unit cost key	Unit cost (USD)	Direct cost (USD)	Notes
Anchors / foundations	Site-specific interface	2.00	set	Anchors/foundation set	$120.00	$240.00	Base and top station sets; high uncertainty
Connection hardware kit	Standard core	1.00	kit	Fasteners, clamps, thimbles, turnbuckles	$80.00	$80.00	Cable clamps, thimbles, turnbuckles, bolts
Safety kit	Standard core	1.00	kit	Safety stops / bumpers / signage	$60.00	$60.00	Terminal bumpers/stops and visual signage
Local welding and fabrication labor	Implementation support	1.00	lot	Welding, cutting, assembly, and local fabrication labor	$600.00	$600.00	–
Installation tools and consumables	Implementation support	1.00	kit	Electrodes, cutting discs, drill bits, grease, PPE, and minor tools	$350.00	$350.00	–
Implementation contingency	Risk reserve	20.00	%	Contingency applied to direct components, labor, and tools	–	$436.49	–

The estimate can be summarized as follows:

$$C_{\text{pilot}} = C_{\text{direct}} + C_{\text{labor}} + C_{\text{tools}} + C_{\text{contingency}} \tag{1}$$

where:

- C_{pilot} represents the preliminary pilot implementation estimate.
- C_{direct} represents the subtotal of direct components listed in the route-based cost table.
- C_{labor} represents local welding, fabrication, cutting, assembly, and installation labor.
- C_{tools} represents installation tools, consumables, protective equipment, and minor assembly supplies.
- $C_{\text{contingency}}$ represents the implementation contingency reserve.

Using the values from the preliminary estimate:

$$C_{\text{direct}} = 1{,}232.46 \tag{2}$$
$$C_{\text{labor}} = 600.00 \tag{3}$$
$$C_{\text{tools}} = 350.00 \tag{4}$$

The contingency value is calculated as:

$$C_{\text{contingency}} = r_{\text{cont}} \left(C_{\text{direct}} + C_{\text{labor}} + C_{\text{tools}}\right) \tag{5}$$

For this preliminary estimate, the contingency rate is defined as:

$$r_{\text{cont}} = 0.20 \tag{6}$$

Therefore:

$$C_{\text{contingency}} = 0.20 \left(1{,}232.46 + 600.00 + 350.00\right) \tag{7}$$
$$C_{\text{contingency}} = 0.20(2{,}182.46) \tag{8}$$
$$C_{\text{contingency}} = 436.49 \tag{9}$$

The total preliminary implementation estimate is therefore:

$$C_{\text{pilot}} = 1{,}232.46 + 600.00 + 350.00 + 436.49 \tag{10}$$
$$C_{\text{pilot}} = 2{,}618.95 \tag{11}$$

This gives a preliminary implementation estimate of USD 2,618.95. At this stage, the value should not be interpreted as the final price of a Hillink implementation, but as a preliminary route-based cost structure. Its main function is to identify which components dominate cost, which quantities are sensitive to route geometry, and which items must be protected by a maintenance reserve.

The inclusion of labor is important even if part of the work is provided through community support. Community labor may reduce cash expenditure during a pilot, but it still represents an economic contribution that must be made visible for future replication. If Hillink is later implemented in another community, the same work may need to be paid directly or replaced through municipal, NGO, university, or partner support. For this reason, local welding and fabrication labor must remain included in the estimate.

The same logic applies to installation tools and consumables. Welding electrodes, cutting discs, drill bits, grease, safety equipment, clamps, temporary supports, and minor tools may appear secondary compared with cables or winches, but they are necessary for safe installation. Excluding them would make the system appear cheaper than it actually is and would weaken the credibility of the implementation estimate.

The same logic applies to maintenance. Standardized components should use standardized inspection routines, spare parts, lubrication procedures, and replacement criteria. The maintenance reserve should prioritize the traction cable, pulleys, bearings, winch mechanism, suspension chains, anchors, braking elements, and terminal impact absorbers. If these items are not included, the estimate understates the real cost of safe operation.

Cost viability should then be assessed through a lifecycle check. A pilot or future implementation should only be considered feasible if, within a defined service period, the available revenue, collective funding capacity, or maintenance fund can cover the initial investment plus operation, management, maintenance, and replacement costs. This condition can be expressed as:

$$R_{\text{life-cycle}} \geq C_{\text{initial}} + C_{\text{operation}} + C_{\text{management}} + C_{\text{maintenance}} + C_{\text{replacement}} \tag{12}$$

where:

- $R_{\text{life-cycle}}$ represents the total resources mobilized during the evaluation period.
- C_{initial} represents the initial implementation cost.

- $C_{\text{operation}}$ represents routine operation costs.
- $C_{\text{management}}$ represents local coordination, administration, or governance costs.
- $C_{\text{maintenance}}$ represents preventive maintenance costs.
- $C_{\text{replacement}}$ represents expected replacement of wear components.

This does not imply premium pricing for residents. It means that Hillink must preserve safe operation without depending permanently on uncertain external support. Cost viability should therefore be assessed by comparing lifecycle costs with each local realistic funding capacity. If the system cannot finance maintenance over time, the route should not advance, even if installation appears financially feasible.

In this sense, the spreadsheet is not only a cost table. It becomes a governance tool. It makes visible which costs are fixed, which costs vary by route, which costs recur over time, and which responsibilities must be assigned before implementation. As supplier quotations, pilot data, and maintenance records are added, the estimate can be updated and used to compare routes, refine modular components, negotiate partnerships, and define whether a future implementation is financially and technically ready.

The engineering objective is not the cheapest possible installation, but the simplest safe system that can be inspected, repaired, and adapted locally. Maintenance should therefore be cycle-based rather than only time-based. Routes with higher daily use require shorter inspection intervals, even if the calendar time is the same.

A monthly operating-cycle estimate can be defined as:

$$N_{\text{cycles/month}} = N_{\text{daily}} \times 30 \tag{13}$$

where:

- $N_{\text{cycles/month}}$ represents the estimated number of operating cycles per month.
- N_{daily} represents the average number of cargo runs per day.

Monthly maintenance cost can be represented as:

$$C_{\text{maint/month}} = C_{\text{inspect}} + C_{\text{lub}} + C_{\text{wear}} + C_{\text{adjust}} \tag{14}$$

where:

- $C_{\text{maint/month}}$ represents the estimated monthly maintenance cost.

- C_{inspect} represents inspection labor or supervision.
- C_{lub} represents lubrication of exposed mechanical interfaces.
- C_{wear} represents the reserve for replaceable wear components.
- C_{adjust} represents cable tension adjustment, alignment correction, or minor route recalibration.

Maintenance should be designed as a preventive, cycle-based routine. Higher daily use increases operating cycles and should shorten inspection intervals. Therefore, the engineering strategy is to standardize visible and replaceable components, preserve safety factors, and adapt only the site-specific elements. Although Hillink's premise is to keep it as simple as possible, it still requires disciplined maintenance. Affordability therefore depends on designing the system to be locally maintainable from the beginning.

Stakeholder Engagement and Financing Strategies

This section explains how Hillink can engage local, municipal, and private-impact stakeholders to make pilot financing credible. The two primary references are the IFC/World Bank handbook "*Stakeholder Engagement: A Good Practice Handbook for Companies Doing Business in Emerging Markets*" and Valenzuela Inga et al.'s engineering study *"Design of a Portable Freight Ropeway for Transporting Construction Materials on Hillside"*.

This strategy is appropriate because Hillink remains at a preliminary stage and still depends heavily on local acceptance, municipal permission, technical validation, and a credible maintenance arrangement. Therefore, financing should not be approached as a simple request for money. It should be approached as a process of reducing risk for potential funders.

The IFC handbook argues that stakeholder engagement has moved from a short-term requirement for consultation and disclosure to a longer-term strategy for relationship-building, risk mitigation, and business identification (International Finance Corporation [IFC], 2007, p. 1). This is directly relevant to Hillink because the project operates in socially sensitive urban areas.

For this reason, Hillink's financing strategy should be organized around three stakeholder levels: local stakeholders, municipal stakeholders, and private impact funds. Each group reduces a different type of risk. Local stakeholders reduce demand and operation risk. Municipal stakeholders reduce authorization and institutional risk. Private impact funds reduce capital constraints, but only if the project can demonstrate that local demand, technical plausibility, and governance conditions have already been addressed.

The first financing strategy is to reduce stakeholder uncertainty before seeking capital. Hillink should map not only the directly affected households, but also the actors able to authorize, block, operate, maintain, or legitimize the pilot. This includes community representatives, municipal authorities, local NGOs, technical partners, manufacturers, and potential funders. This mapping converts stakeholder engagement into a risk-reduction tool for financing.

Before requesting funding, Hillink should prepare a short disclosure package explaining the proposed pilot, expected benefits, technical limits, operational risks, and unresolved uncertainties. This document should not overpromise implementation readiness. Instead, it should show that the project is transparent, reviewable, and open to stakeholder input.

The financing strategy should be partnership-based. Hillink should not approach funders as a stand-alone student invention, but as a pilot supported by a local implementation coalition. Each stakeholder reduces a different financing risk: the community reduces demand risk, the municipality reduces authorization risk, engineers reduce technical risk, NGOs reduce social risk, manufacturers reduce cost uncertainty, and funders reduce capital constraints.

The success of Hillink's launch depends on its technical design, community acceptance, municipal permits, and sustainable funding. However, fieldwork conducted in San Gabriel Alto revealed that mutual support among neighbors is limited; residents explicitly stated that "it's very scarce, everyone fends for themselves." Voluntary collaboration among neighbors is desirable, but Hillink's operational model does not depend on it. The system is structured around economic incentives and clearly defined paid roles, not unpaid neighborhood solidarity.

Local Level (Community-Based but Not Voluntary)

Local stakeholders in the Hillink context include directly affected residents, households near the proposed route, informal community leaders, neighborhood associations, women, elderly residents, people with mobility limitations, delivery workers, local shop owners, builders, welders, mechanics, and possible operators of the system. As discussed earlier, the most vulnerable groups should receive priority. Hillink depends on daily use. The system is not useful if the community does not trust it, if users do not understand the load limits, if access rules are unclear, or if residents near the route feel exposed to risk.

The project team should document what goods residents carry, as shown in the Field Visit section. This is the most effective way to determine how often manual carrying occurs, who carries the loads, how much time is spent, and where the most difficult route segments are located. This avoids presenting Hillink as a generic device and instead frames it as a response to a documented local problem.

Community representatives should then be selected, but with caution. The IFC handbook warns that relying on representatives without checking whether they actually reflect community views can create conflict and damage stakeholder relations (IFC, 2007, pp. 20–21).

Consultation should be used as an essential design input for both the system and the stakeholder engagement strategy. For Hillink, community meetings should explain the system in simple language and disclose the project clearly. Hillink should prepare a short visual document explaining the proposal, rules, risks, maintenance needs, and remaining uncertainties as clearly as possible. This should not be treated as a symbolic gesture: the IFC recommends early disclosure, objective information, accessible language, and clarity about which elements of Hillink are fixed and what can be adapted through consultation (IFC, 2007, pp. 28–30). A relevant success case is Sasol in Mozambique, where a Background Information Document used non-technical language, maps, and figures to explain the project and invite stakeholder participation (IFC, 2007, p. 32).

This helps transform the pilot from an external proposal into a locally adjusted infrastructure experiment with local operating agreements. Those agreements should define who can use Hillink, what loads are allowed, who operates the winch, how use is scheduled, who reports damage, and when the system must stop. This is important because community support must become operational responsibility. Without this step, local approval remains too vague for funders.

A basic grievance mechanism should be presented as part of the financing proposal. Even for a small pilot, residents must know how to report unsafe use, obstruction, damage, unfair access, or operational problems. This increases accountability and shows funders that social risk is being actively managed. The IFC handbook states that grievance procedures should be accessible, culturally appropriate, written, publicized, and proportional to the project's risks (IFC, 2007, pp. 69–76). For Hillink, this can be simple: a WhatsApp contact, a notebook with a local operator, a QR form, or a designated community focal point.

Municipal Level

Municipal stakeholders include the local government, urban planning department, public works department, mobility or transport authority, civil defense, social assistance agencies, health posts, schools, local council members, and any public authority responsible for public stairs, slopes, informal settlements, risk areas, or infrastructure authorization.

The Villa María del Triunfo municipality is responsible for granting permits and authorizing installations on public stairways. Although the municipality lacks fiscal resources (as shown in Section 5.1), its endorsement is necessary for implementation. The municipal strategy is necessary because Hillink can affect shared urban space. Even if the system is small or installed in areas where government presence is limited, it still involves safety, route authorization, maintenance responsibility, public liability, and possible land-use restrictions. As discussed in Section 8.1, Phase D, government is a key stakeholder because public authorities may have regulatory responsibility, established relationships with communities, and the ability to convene or facilitate discussions between projects and affected groups. In the Hillink case, however, government participation may be limited or inconsistent.

Nonetheless, consultation and transparency are not symbolic gestures. Hillink must still be presented clearly, with emphasis on its potential social impacts rather than only on its engineering mechanism. Before requesting funding, the project should request non-financial municipal support. At the proposal stage, the municipality may not be able to pay for the pilot. However, technical feedback, public data, authorization guidance, and institutional legitimacy can increase transparency and reduce implementation risk.

Government stakeholders can connect Hillink with valuable and organized data that can improve the system beyond a single location. This is a powerful way to increase scalability and credibility. As discussed earlier, government should remain a key stakeholder. Institutional legitimacy and credibility are important for risk minimization and for the search for financing.

Beyond the Villa María del Triunfo municipality, Hillink should seek cooperation with other locations. This could include other districts of Lima, such as San Juan de Lurigancho, as well as international partners. City governments in Rio de Janeiro and São Paulo have experience with informal settlement interventions and could serve as partners for the adaptations that Hillink provides.

Private Impact Funds

To bridge the funding gap left by the government, Hillink can turn to private impact investors focused on social innovation.

Presentation is again an essential factor, but in this case it should focus on the staged implementation process described in Section 8.1. Because implementation is staged, funding requests can also be staged. This reduces funder risk because each stage has a clear deliverable. The HAI (Hillink Applicability Index) presented earlier can support the case for technical plausibility with these actors. However, even a robust MCDA model may reproduce algorithmic bias: vulnerability cannot be fully standardized mathematically, and populations that score just below arbitrary thresholds cannot be ethically abandoned.

The calculator must therefore be framed as a preliminary sorting guide for reducing risk, while the final decision must always incorporate flexible, qualitative social criteria to ensure that no vulnerable household is left behind by a rigid algorithm.

Synthesis

The financing strategy should always be based on risk minimization. Local stakeholders demonstrate whether the system is needed and acceptable. Municipal stakeholders clarify whether the system can be authorized and publicly legitimized. Private impact funds can then finance staged validation and pilot implementation. With these stakeholders aligned, Hillink can be positioned as a financially and operationally viable response to the impacts of the Geography Tax.

Social Impact and Scalability

Social Impact

The previous sections established that the Geography Tax is not an abstract concept, but a measurable burden experienced in daily life. In Villa María del Triunfo, residents reported carrying loads of approximately 5 to 15 kg through steep routes, spending between 10 and 20 minutes per trip, paying higher prices for cooking gas because delivery workers cannot reach the doorstep, and facing repeated risks of falls on unfinished stairs, dirt paths, and slippery routes during rain. These findings show that territorial exclusion affects households through cost, time, physical effort, safety, dependency, and reliability of access.

The social impact of Hillink should therefore be evaluated through the extent to which it reduces those burdens. Impact should not be defined only by community acceptance or by the technical operation of the system, but by measurable changes in everyday logistics. The core indicators should include the number of manual carrying trips per week, kilograms transported manually, time required to move goods from the last accessible point to the household, informal delivery costs, reported exhaustion or pain, and the frequency of accidents or near-falls. This is consistent with impact-evaluation and results-based management frameworks, which emphasize baseline measurement, indicators, targets, and means of verification before claiming social impact (Asian Development Bank, 2006; Gertler et al., 2016; United Nations Development Programme, 2009).

The new evidence added by the transport and health literature reinforces the relevance of these indicators. Studies on domestic transport of water, fuel, and household supplies show that manual carrying can consume substantial amounts of time and energy in low-infrastructure contexts, producing a form of time poverty that limits education, income generation, care, and rest (Malmberg-Calvo, 1994; Ho et al., 2021; Isoto et al., 2024). Literature on Intermediate Means of Transport (IMTs) also shows that mechanical or semi-mechanical systems can reduce transport bottlenecks by increasing the amount of cargo moved per trip and lowering the labor required to move bulky goods (Acheampong, 2004; Riverson & Carapetis, 1991). Hillink adapts this logic to dense hillside settlements by targeting the final segment of cargo movement, where the Geography Tax is most concentrated.

The impact is also physical and health-related. Research on head-loading and domestic transport documents associations with musculoskeletal pain, spinal stress, fatigue, fall risk, and long-term health consequences, especially for women and children who often perform a disproportionate share of household logistics (Ho et al., 2021; Porter et al., 2013). In the context of Hillink, this evidence helps explain why repeated trips with gas cylinders, water containers, groceries, medicine, or construction materials should be treated as a health burden, not merely as an inconvenience. The body becomes the transport infrastructure, and the cost accumulates through repetition.

The gender dimension is equally important. Domestic transport burdens are frequently distributed unequally within households, affecting women, girls, caregivers, elderly residents, and informal workers more intensely (Malmberg-Calvo, 1994; Ho et al., 2021; Isoto et al., 2024). This connects directly with the field visit findings, where women and elderly residents were identified as especially affected by carrying tasks. Reducing manual carrying may therefore generate effects beyond logistics: lower physical exhaustion, less dependence on informal help, improved safety, and more time for education, paid work, care, or rest. These effects should not be assumed automatically, but measured through post-pilot interviews and before/after indicators.

Hillink may also produce economic and local-development effects. The clearest example from the fieldwork is the price of cooking gas: when upper areas are harder to reach, residents pay more for the same basic good. This creates a regressive cost structure in which poorer households pay an additional territorial surcharge.

Therefore, Hillink can contribute to many goals of the United Nations 2030 Agenda for Sustainable Development. Its most direct contribution is to **SDG 1: No Poverty**, because it addresses a concrete dimension of multidimensional poverty: the additional cost imposed by difficult terrain on low-income households. It also relates directly to **SDG 3: Good Health and Well-being**, by seeking to reduce physical strain, fall risk, and repeated load-carrying burdens; **SDG 5: Gender Equality**, by addressing gendered domestic transport responsibilities; **SDG 9: Industry, Innovation and Infrastructure**, by proposing low-cost and locally adaptable infrastructure; **SDG 10: Reduced Inequalities**, by targeting territorial exclusion; and **SDG 11: Sustainable Cities and Communities**, by improving last-segment accessibility in informal and peripheral settlements. Indirectly, the project may also support **SDG 4: Quality Education**, **SDG 8: Decent Work and Economic Growth**, and **SDG 13: Climate Action**, insofar as reduced time poverty, local logistics roles, and low-energy mechanical operation are verified during pilot evaluation (United Nations, 2015).

Table 14. *Physical, Socio-Economic, and SDG Dimensions of the Geography Tax*

Category	Physical and Health Impact	Socio-Economic Effect	SDG Alignment
Physical and Health Risks (Manual Carrying)	Musculoskeletal risks, chronic injuries such as scoliosis and pelvic damage, and extreme physical exhaustion from head-loading or manual portage. Manual hauling accounts for 80–92% of total transport effort in low-infrastructure contexts.	Reduced productivity and diminished capacity to work or study; households suffer from physical disruption and a perpetuation of structural poverty; high energy expenditure limits the ability to handle health emergencies.	SDG 1 (No Poverty), SDG 3 (Good Health and Well-being), SDG 8 (Decent Work and Economic Growth).
Time Poverty	Long walking hours, including 2–18 hour workdays, leading to fatigue, reduced energy for other activities, and restricted time for rest, self-care, or childcare. Significant time loss, up to 50%, for cultivation and housework.	Limits opportunities for education and non-farm wage employment; prevents children, especially girls, from attending school; hinders the development of efficient marketing systems and economic diversification.	SDG 1 (No Poverty), SDG 4 (Quality Education), SDG 8 (Decent Work and Economic Growth).
Gendered Labor Distribution	Women and daughters face disproportionate musculoskeletal stress and physiological risks, such as pelvic damage, while carrying 70–96% of domestic loads, including water, wood, and produce.	Triple burden of work, reproductive, productive, and community, results in extreme time impoverishment; reinforces subordinate social positions and limits access to capital, credit, and resources.	SDG 4 (Quality Education), SDG 5 (Gender Equality), SDG 10 (Reduced Inequalities).

Continued on next page

Category	Physical and Health Impact	Socio-Economic Effect	SDG Alignment
Economic Surcharges (Geography Tax)	Physical exhaustion from traversing difficult terrain, steep hillsides, or deteriorating gravel tracks, particularly during rainy seasons; high post-harvest losses due to perishability.	Residents in isolated areas pay 15–40% more for basic goods such as water and gas, and for services; high marginal costs for increasing output; depressed producer prices due to seasonal inaccessibility and lack of market competition.	SDG 1 (No Poverty), SDG 2 (Zero Hunger), SDG 9 (Industry, Innovation, and Infrastructure), SDG 10 (Reduced Inequalities), SDG 11 (Sustainable Cities and Communities).
Infrastructure Gaps	Physical strain from long-distance hauling of water and firewood due to a lack of piped services or electricity; exposure to water-related diseases.	Restricts social intercourse and limits access to emergency health services; prevents modernization of agriculture; forces trade-offs between leisure and basic subsistence tasks.	SDG 6 (Clean Water and Sanitation), SDG 7 (Affordable and Clean Energy), SDG 9 (Industry, Innovation, and Infrastructure).
Food Processing (Grinding Mills)	Arduous labor of hand-pounding crops; carrying heavy grain loads over long distances to and from processing sites.	Significant time cost, 40–242 hours per year per household; acts as a barrier to diversifying family diets and improving local nutrition.	SDG 2 (Zero Hunger), SDG 5 (Gender Equality).

Scalability

Any scalability plan should be based on a socio-technical readiness assessment.

Engineering modularization should begin with load classes or terrain classes. A light module can serve groceries and medicine; a medium module can serve water containers and food baskets; a heavy module can serve gas cylinders and construction materials. Each class changes the required cable strength, pulley diameter, braking system, anchoring design, and maintenance interval.

Hillink's scalability should be understood as modular adaptation, not as the identical reproduction of the same equipment. What can be replicated is the method: local diagnosis, baseline measurement, maintenance-fund assessment, local operation, monitoring, and impact evaluation. Engineering must vary according to slope, route length, soil type, available materials, anchoring form, corrosion, climate, permissions, and local maintenance capacity.

Limitations

Hillink has several limitations that must be acknowledged before any pilot implementation. First, the current proposal remains at a conceptual and preliminary engineering stage. The 3D model, cost estimate, and mechanical configuration are useful for feasibility discussion, but they do not replace certified structural calculations, anchoring verification, fatigue analysis, supplier load ratings, seismic assessment, or professional engineering approval.

Second, the fieldwork was limited in scope. The interviews conducted in Villa María del Triunfo provide valuable qualitative evidence about the Geography Tax, but they are not statistically representative of all hillside settlements in Lima or Latin America. Future work should expand the sample, include more households, compare different routes, and collect baseline measurements before and after a pilot.

Third, Hillink is not appropriate for every terrain. Some stairways may be too narrow, too irregular, too exposed to wind, or too socially contested for safe installation. Routes with weak anchoring conditions, high pedestrian conflict, unclear land rights, or insufficient maintenance capacity should not advance to pilot implementation without redesign.

Fourth, the system depends on governance as much as engineering. Even a simple mechanical system can fail if no operator is defined, if maintenance funds are absent, if rules are unclear, or if local authorities do not authorize the intervention. For this reason, Hillink should be treated as a socio-technical infrastructure model rather than as a stand-alone device.

Finally, the project does not claim to solve poverty as a whole. It addresses one specific dimension of multidimensional poverty: the cost, time, effort, and risk of moving essential goods through inaccessible terrain. Its value depends on whether future pilots can demonstrate measurable reductions in those burdens.

Conclusions

Hillink began from a simple but often overlooked observation: poverty is not only measured by income, but also by the physical conditions under which daily life becomes more expensive, slower, heavier, and less accessible. In hillside settlements, informal peripheries, flood-prone areas, isolated villages, and dense neighborhoods unreachable by conventional vehicles, geography itself becomes a mechanism of exclusion. This project defined that burden as the **Geography Tax**: the additional physical, economic, temporal, and health-related cost imposed on low-income communities because of where they are forced to live.

The proposal does not claim that infrastructure alone can solve poverty. Poverty is multidimensional, historically produced, institutionally reinforced, and shaped by income, housing, land tenure, public services, gender, health, education, and political representation. For this reason, Hillink should not be interpreted as a universal solution to poverty, nor as a replacement for public investment, urban reform, road access, housing policy, or social protection. Its contribution is narrower, but still significant: Hillink addresses one concrete and repeated dimension of poverty — the difficulty of moving essential goods through territories where formal infrastructure does not reach.

The central value of Hillink is that it transforms a daily burden into an engineering problem that can be measured, tested, adapted, and improved. Instead of proposing an expensive, electric, centralized, or highly technical system, Hillink is intentionally designed as a low-cost, cargo-only, non-electric, modular mechanical infrastructure. This design choice is not merely technical; it is social. A system intended for low-income communities must be affordable, maintainable, locally operable, and adaptable to different territorial conditions. A technically sophisticated solution that residents cannot repair, finance, authorize, or govern would fail the very population it intends to serve.

The phased implementation strategy reinforces this logic. Phase A identifies the real burdens experienced by the community. Phase B converts those burdens into measurable baseline indicators. Phase C evaluates technical and territorial applicability through structured criteria. Phase D verifies whether the route can be socially accepted, locally governed, and institutionally authorized. Phase E tests the system as a pilot rather than as a final deployment. Finally, the impact and scalability stage compares pre- and post-pilot conditions to determine whether Hillink actually reduces time, cost, effort, physical strain, and dependency in the movement of essential goods. This sequence prevents the project from relying only on intuition, visual urgency, or abstract engineering feasibility.

The project also recognizes that scalability does not mean copying one fixed design everywhere. The same mechanical principle may be useful in many territories, but each application requires local adaptation. A steep stairway in Lima, a favela pathway in Rio de Janeiro, a flood-prone corridor, a rural hillside trail, or a dense informal passage may require different anchoring strategies, materials, operating rules, maintenance routines, and governance arrangements. Therefore, Hillink's scalability depends less on universal standardization and more on a modular kit logic: a common mechanical core combined with site-specific engineering, community validation, and institutional negotiation.

This recognition of limitations is not a weakness of the proposal. On the contrary, it is what makes Hillink more credible. No serious poverty-alleviation project should claim to work in every place, under every condition, for every group, without adaptation. By acknowledging technical, social, regulatory, financial, and cultural constraints, Hillink creates space for iterative improvement. Routes that are unsafe should be rejected or redesigned. Communities that do not accept the system should not receive a forced intervention. Sites without minimum maintenance capacity should not advance to pilot implementation. Contexts with weak authorization, high conflict, or unsuitable geography require different strategies. These limits protect the project from overpromising and make future replication more responsible.

At the same time, the existence of limitations does not reduce Hillink's global potential. The Geography Tax is not exclusive to one city or one country. Across the Global South, millions of people live in territories where the final segment of access depends on human strength: carrying water, gas, food, medicine, construction materials, and household supplies through difficult terrain. Even a modest reduction in this burden may produce meaningful improvements in time use, physical exhaustion, delivery cost, health risk, and access to basic goods. Hillink's potential lies precisely in targeting this specific daily friction point with a system that is simple enough to be realistic and flexible enough to be adapted.

For these reasons, Hillink should be understood as a practical infrastructure tool for poverty alleviation, never as a complete solution to poverty itself. Its promise is not to eliminate structural inequality, but to reduce one of its most concrete territorial expressions. If tested carefully, governed locally, maintained sustainably, and adapted intelligently, Hillink can become a replicable model for reducing the Geography Tax in vulnerable communities around the world. Its strength lies in its simplicity: mechanical, community-driven implementation, measurable impact, and territorial adaptability where applicable. The project deliberately avoids unnecessary technological complexity, not because advanced technologies are inherently unsuitable, but because development is often associated with digital sophistication while simple solutions are underestimated or made invisible. In territories shaped by infrastructural neglect, the priority is not to introduce new forms of technical dependency, but to develop systems that can be understood, repaired, governed, and sustained locally. Simplicity is therefore a core philosophy of this project. With further refinement, Hillink can become a simple yet robust system for poverty alleviation.

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Appendix

Appendix 1 “Field Visit: List of questions”

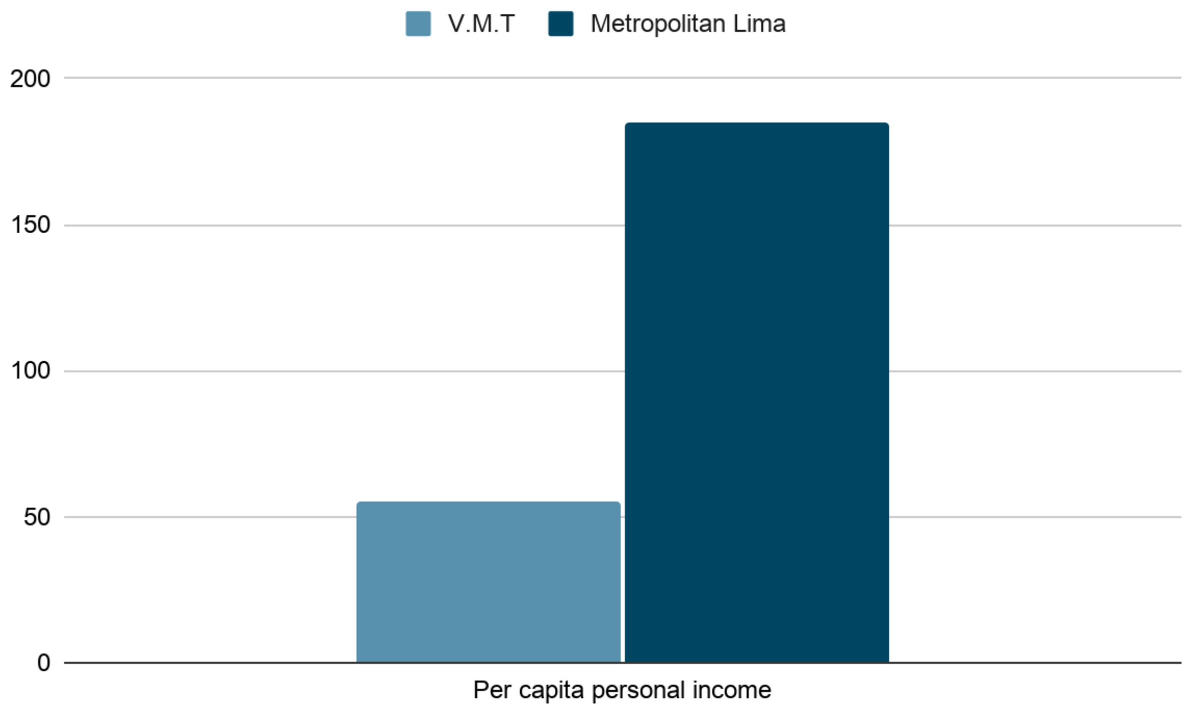
	Questions	Purpose
Regarding the area	1. How long have you been living in your current home? 2. Do you feel that your surroundings have changed over the years? 3. How has the neighborhood changed? 4. Do you have access to basic services?	To establish the resident's level of rootedness and assess perceived changes in access to basic urban services over time.
With regard to the State	5. Do you feel that you receive support from the government? 6. What was the last public works project the government carried out in your area? / Was the last project the staircase?	To gauge the perceived presence and effectiveness of government intervention in the community, and identify the last point of public investment.
Regarding the loading of objects and/or food	7. Do you go grocery shopping every day or once a week? 8. How long does it take you, roughly, to carry your groceries upstairs? 9. How much do your groceries weigh, approximately?	To quantify the frequency, time cost, and physical weight involved in the daily task of carrying supplies upstairs.
With regard to the impact on cargo	10. Do you find it really hard to carry your groceries upstairs? 11. When another family member does it, do you notice they look tired? 12. Do you end up with aches and pains all over your body?	To assess the physical toll that load-carrying imposes on residents and their families, documenting bodily exhaustion as a measurable dimension of poverty.

	Questions	Purpose
Regarding natural gas	13. ¿How much do you usually pay for gas? 14. Do you feel like you're being overcharged because of the altitude? 15. Do they deliver the gas cylinder to your home?	To document the economic penalty associated with altitude — higher prices, informal delivery, and limited access — as evidence of the Geography Tax.
Regarding accidents	16. Have there been any accidents while you were loading your groceries? 17. Have there been any accidents in rainy conditions?	To identify safety risks associated with load-carrying on steep stairways, particularly under adverse weather conditions.
With regard to the community and the individual	18. What do you think is one of the biggest problems they face? 19. Do you feel that neighbors support one another?	To evaluate social cohesion and collective resilience as a foundation for the cooperative governance model.
Regarding our solution	20. What if those weekly groceries could be delivered right to your doorstep, or somewhere nearby? Would you like that? 21. Do you think your quality of life—and that of your children and husband—would improve if that were implemented?	To test community receptiveness to Hillink and gauge perceived impact on quality of life.

Appendix 2 RENAMU Indicators for Villa María del Triunfo

Figure A.1. *Own-Source Revenue: VMT vs. Metropolitan Lima (Total Soles)*

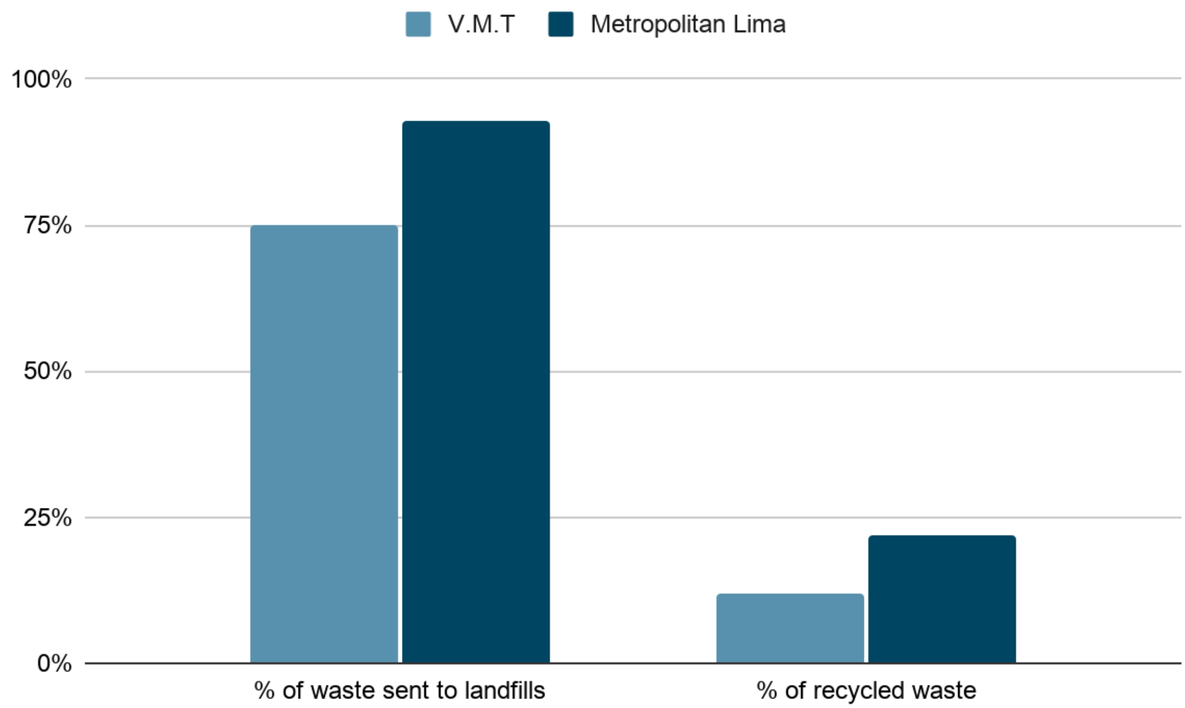
Per Capita Own-Source Revenue: VMT vs. the Average for Metropolitan Lima



Note. *Prepared by the authors using data from the 2025 National Registry of Municipalities (INEI, 2025). VMT = Villa María del Triunfo. Values represent total municipal own-source revenue in soles. Metropolitan Lima excludes the district of VMT.*

Figure A.2. *Waste Management: VMT vs. Metropolitan Lima*

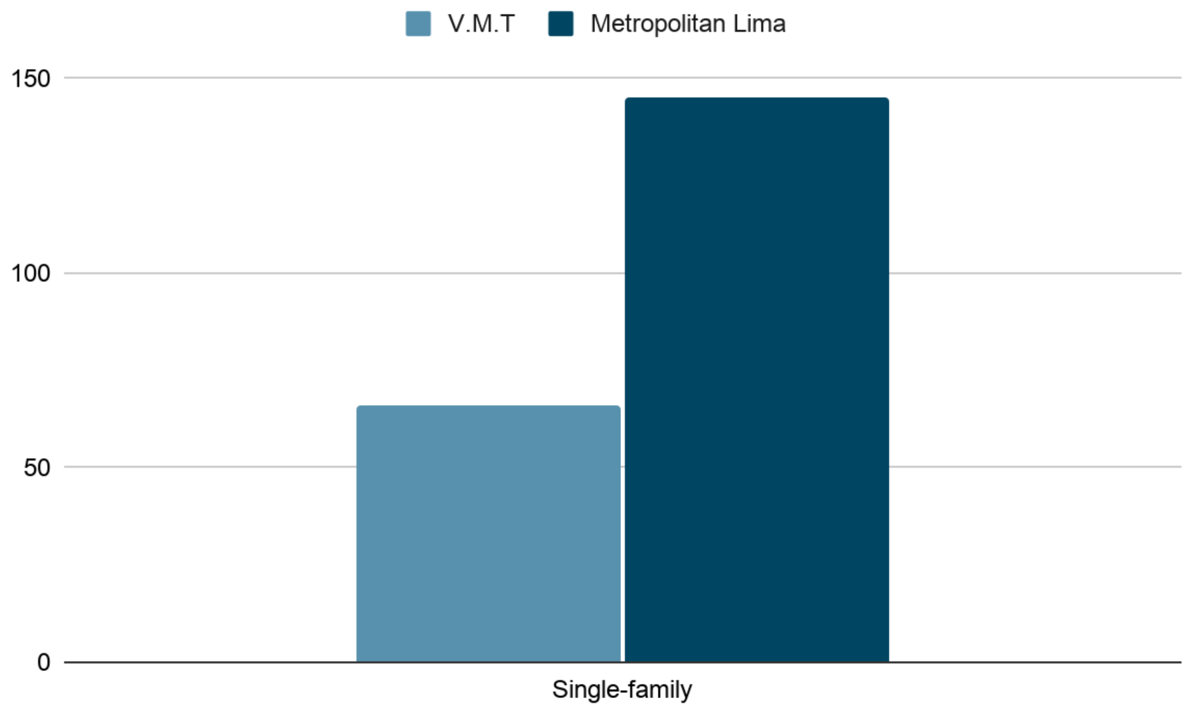
Average Percentage of Waste Sent to Landfills and Recycled Waste: VMT vs. Metropolitan Lima



Note. *Prepared by the authors using data from the 2025 National Registry of Municipalities (INEI, 2025). VMT = Villa María del Triunfo. Metropolitan Lima excludes the district of VMT.*

Figure A.3. *Building Permits: VMT vs. Metropolitan Lima*

Average Percentage of Building Permits for Single-Family: VMT vs. Metropolitan Lima



Note. Prepared by the authors using data from the 2025 National Registry of Municipalities (INEI, 2025). VMT = Villa María del Triunfo. Metropolitan Lima excludes the district of VMT.

Appendix 3. Video Compilation of Interviews

https://youtu.be/c5dJGw_S8Ws

Note. The video includes testimonies from residents regarding their daily carrying burdens, accidents, gas prices, and their views on a potential mechanical transport solution. All participants were informed about the purpose of the recording and gave their verbal consent.

Authors' fieldwork, 2026.