

Approaches, Strategies, and Policy Frameworks for the Sustainable Development of Underground Urban Spaces in the Urban Planning of Addis Ababa City - The case of Transforming Addis Ababa's Light Rail Transit (LRT) into an Underground System

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ABSTRACT

The high pace of urbanization of Addis Ababa has exerted a lot of strain on land use, movement, and environmental sustainability. The Light Rail Transit (LRT) is the pioneer in Sub-Saharan Africa but the operations and spatial limitations of its existing above-ground structure, such as intersection congestion, poor land use, and urban landscape disruption, require resolution. It is against this background that the conversion of LRT into an underground system comes in as one of the strategic avenues to the realization of sustainable urban development. This paper will look at the methods, strategies and policy frameworks that would be needed to implement such an overhaul in the broader urban planning agenda in Addis Ababa. The engineering, environmental, and socio-economic aspects of underground urban spaces have been brought to the fore, based on international experience of other cities with well-developed underground transport systems. It suggests the strategic interventions that include underground transit integration with multi-modal networks, use of smart city technologies, and adoption of novel financial tools, including public-private partnership. The policy analysis also highlights that there is a necessity of clear underground zoning policies, revised safety and regulation policies, and good institutional coordination between local and national governments. Its results indicate that though underground LRT development involves high initial expenses, it will have long-term returns in decongestion, reclaimed urban land, improved mobility, and the resistance to the forces of urban growth. The paper concludes the study with the recommendation of gradual implementation, effective financing plans, and principles of design to be sustainable. Finally, the LRT conversion in Addis Ababa is not only a solution in transportation, but it is an opportunity to redefine the future of the city as producing a stronger, habitable, and competitive city in the world.

Keywords: Addis Ababa, Light Rail Transit, underground urban spaces, sustainable development, transport policy, urban planning.

SAMRIDDHI : A Journal of Physical Sciences, Engineering and Technology (2025); DOI: 10.18090/samriddhi.v17i03.05

INTRODUCTION

The blistering development of urban areas in Africa has put the available infrastructure, urban form, and land resources under a very high pressure. The capital and largest city of Ethiopia, Addis Ababa, has been an ideal example of these pressures, with high population growth rate and sprawling urban areas (World Bank, 2015). As the land supply is low and demand of transport is rising, solutions to sustainable urban planning are urgently required so that the solutions can be efficient, resilient, and inclusive. The inefficiency of the Light Rail Transit (LRT) system is among the most severe challenges confronting the city since, though innovative in concept, it

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How to cite this article: Alemayehu, A.Z. (2025). Approaches, Strategies, and Policy Frameworks for the Sustainable Development of Underground Urban Spaces in the Urban Planning of Addis Ababa City - The case of Transforming Addis Ababa's Light Rail Transit (LRT) into an Underground System. *SAMRIDDHI : A Journal of Physical Sciences, Engineering and Technology*, 17(3), 40-52.

Source of support: Nil

Conflict of interest: None

has been restricted in its performance because the system is going above ground (Kassahun, 2021).

The Addis Ababa LRT was supposed to reduce regular traffic jams, ease traffic movement and offer an alternative mode of transportation that is sustainable and does not involve the use of roads. Nonetheless, its shallow integration has caused a wave of disruption to traffic, wasted precious land, and has not satisfied passengers with efficiency and convenience (Abebe, 2020). These constraints point to the need to re-envision the opportunities of urban transport, and underground development is a promising avenue of sustainability.

Underground urban areas in the world have been recognized because of their ability to maximize the use of limited land areas by maximizing mobility systems and promoting overall urban sustainability goals (Bobylev, 2016). Cities like Tokyo, London, and Singapore have over time depended on underground infrastructures to ensure that the population growth is matched with urban effectiveness and that, at the same time, the environment is taken care of (Zhang and Yang, 2014). In the case of Addis Ababa, several advantages may be generated through taking up comparable strategies: re-appropriating surface areas to green and social areas, alleviating traffic jams, and promoting economic efficiency.

This paper will look at the solutions, plans, and policy lines that need to be undergone to turn the LRT of Addis Ababa into an underground system. Using comparative lessons based on international best practices and basing analysis on the local challenges the city faces, the research creates a roadmap to sustainable underground development in Addis Ababa.

Literature Review

The sustainable development of underground urban spaces has gained increasing global attention as cities confront challenges of land scarcity, congestion, and environmental degradation. Scholars in urban planning, transportation, and environmental design emphasize that underground infrastructure provides an innovative pathway to optimize limited surface land, improve urban mobility, and create resilient city systems. This section reviews key strands of literature relevant to Addis Ababa's case: global practices in underground transit development, theoretical foundations of sustainable urbanism, and the contextual lessons from existing studies on Addis Ababa's Light Rail Transit (LRT).

Global Practices in Underground Transit and Urban Spaces

International experiences demonstrate how underground transit systems can simultaneously address mobility demands and urban land constraints. The London Underground, as one of the oldest systems, has evolved into an integrated transport backbone that supports high-capacity urban mobility while freeing surface land for economic and

social functions. Similarly, the Tokyo Metro illustrates the value of underground infrastructure in densely populated contexts, where limited surface land requires vertical urban development. In Singapore, underground planning is guided by a national underground master plan, which integrates transport tunnels with subterranean utilities, retail hubs, and pedestrian corridors.

Research on these systems highlights critical success factors: long-term government commitment, robust financing mechanisms, advanced tunneling technology, and institutional frameworks for safety and regulation. These cases also show how underground infrastructure contributes to sustainable urban development by reducing congestion, minimizing environmental impact, and enabling multi-functional use of land above ground.

Theoretical Foundations of Underground Urbanism

The literature sites underground transit within broader theories of sustainable urban development and transport-oriented development (TOD). Sustainable urban development emphasizes balancing environmental protection, economic growth, and social equity. Underground infrastructure supports this balance by reducing surface-level carbon emissions, reclaiming land for green spaces, and facilitating compact urban growth.

Transport-oriented development theory provides an additional lens, stressing the importance of integrating high-capacity transit with mixed-use, walkable neighborhoods. Underground systems complement TOD by providing mobility without disrupting land use at street level, thereby strengthening urban density and accessibility. Moreover, the urban resilience framework highlights how underground spaces can protect critical infrastructure from external shocks, such as extreme weather or rapid demographic shifts (Ahern, 2011). Collectively, these theoretical perspectives underscore the relevance of underground urbanism as a multi-dimensional planning approach.

Addis Ababa's LRT and Local Urban Challenges

Addis Ababa's LRT was inaugurated as a flagship project to modernize public transport and reduce reliance on informal road-based systems. Initial assessments praised its affordability and accessibility, particularly for low-income commuters. However, studies have documented several limitations. At-grade crossings at busy intersections exacerbate traffic congestion rather than alleviate it (Taffese & Abebe, 2018). Elevated sections have consumed valuable central land, disrupting commercial activity and limiting opportunities for alternative urban functions. Furthermore, the system has struggled with technical reliability, operational funding, and integration with buses and taxis.

Local scholarship emphasizes that while the LRT is a pioneering step for African cities, its above-ground model is poorly suited to Addis Ababa's evolving urban dynamics.

Rapid population growth, increasing motorization, and competing demands for land require innovative approaches that extend beyond surface-based transit (Asfaw, 2020). In this context, underground LRT development is increasingly viewed as a sustainable alternative that could mitigate current inefficiencies while positioning the city for future growth.

Research Gaps and Emerging Directions

Despite a growing body of literature on Addis Ababa's LRT, there is limited research on the feasibility, strategies, and policy frameworks for transitioning to underground systems. Most studies have focused on operational performance, commuter behavior, and economic costs of the current LRT. There is a lack of integrated analysis that connects underground urbanism with Ethiopia's sustainable development agenda, urban policy frameworks, and financing options. Moreover, comparative insights from global cities are underutilized in informing Addis Ababa's planning processes.

This gap highlights the need for research that bridges theory and practice by aligning underground transit development with local realities. The present study addresses this by examining approaches, strategies, and policies for sustainable underground urban development, using the LRT transformation as a case study.

Current Situation of Addis Ababa LRT

The Light Rail Transit (LRT) system in Addis Ababa stands as one of the most significant public infrastructure projects in the city's history. Designed as a response to growing traffic congestion, environmental concerns, and the need for modern mass transit, the system comprises two primary lines spanning approximately 34 kilometers. These lines traverse major economic and residential corridors, connecting the city's eastern, western, and southern zones with the central business district (Taye, 2016). The LRT was envisioned as a

cost-effective, environmentally friendly alternative to the city's overburdened road network and informal minibuss transport system (Kassahun, 2021).

In practice, the LRT has provided important mobility benefits. It offers affordable fares compared to private vehicles or minibuses, thus remaining accessible to low- and middle-income groups (Kumsa & Dilla, 2020). The system has also contributed to reducing reliance on fossil fuel-driven transport by shifting a portion of daily commuters to electric-powered mobility (Sekasi & Martens, 2021). However, the current above-ground configuration has created significant challenges that limit its efficiency, sustainability, and integration into Addis Ababa's broader urban planning goals (Teklemariam & Shen, 2020).

Congestion and Traffic Conflicts

One of the most persistent issues arises from at-grade intersections where LRT trains share road crossings with vehicles. Instead of alleviating congestion, the trains frequently block intersections, causing delays and traffic buildup (Kassahun, 2021). Elevated tracks, while reducing some conflicts, have introduced new constraints by occupying central road corridors and narrowing carriageways (Sekasi & Martens, 2021).

Land Use Inefficiencies

The LRT alignment consumes large swathes of valuable urban land in core areas. Commercial zones, green spaces, and pedestrian pathways have been constrained by the system's physical footprint. This has led to competition for scarce land resources, reducing opportunities for mixed-use urban development in prime areas (Teklemariam & Shen, 2020).

Environmental and Social Impacts

While electric traction has environmental advantages,

Table 1: Comparative Lessons from Global Underground Transit Systems vs. Addis Ababa LRT

<i>Feature / Indicator</i>	<i>London Underground</i>	<i>Tokyo Metro</i>	<i>Singapore MRT</i>	<i>Addis Ababa LRT (Current)</i>
System Age & Scale	Oldest, >400 km	Extensive, >300 km	Dense, >200 km	Young, 34 km
Design	Fully underground with integrated above-ground lines	Predominantly underground	Integrated underground with utilities & retail	Above-ground (elevated & at-grade)
Land Use Impact	Surface land reclaimed for other uses	Minimal disruption of surface land	Multi-use integration with retail & services	Occupies central corridors; land conflicts
Congestion Management	Reduces vehicular reliance	High efficiency in dense population	Seamless multi-modal integration	Intersections congested by at-grade crossings
Urban Aesthetics	Enhances city design	Preserves surface space	Blends with urban landscape	Elevated structures disrupt aesthetics
Policy & Planning	Strong long-term policy support	National coordination	Master plan approach	Limited integration in urban master plan
Key Lesson for Addis Ababa	Institutional resilience and financing are crucial	Suitability in dense urban areas	Integration with multi-use planning is key	Transition underground needed to resolve inefficiencies



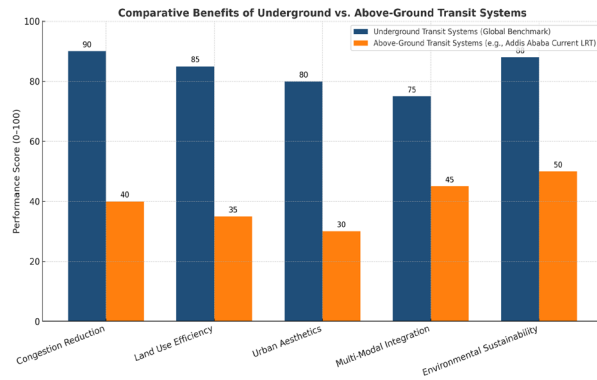


Figure 1: A graph shows the comparative benefits of underground vs above-ground systems

surface-level alignments concentrate noise, vibration, and localized air pollution from adjacent traffic along the LRT routes (Sekasi & Martens, 2021). Elevated tracks have disrupted the city's visual aesthetics and, in some cases, created physical barriers between neighborhoods. Socially, land acquisition for stations and track alignments displaced residents and small businesses, generating tensions over compensation and urban equity (Taye, 2016).

Institutional and Operational Challenges

The LRT system faces ongoing operational difficulties, including inadequate maintenance capacity, inconsistent power supply, and limited integration with other transport modes (Kumsa & Dilla, 2020). The absence of a unified metropolitan transit authority has further complicated coordination between buses, taxis, and rail (Kassahun, 2021). Financial sustainability is also a recurring issue, with fare revenues falling short of covering operational costs (Sekasi & Martens, 2021).

Implications for Future Planning

The current situation demonstrates that while Addis Ababa's LRT represents a landmark achievement in modern African urban transport, its design and operation present fundamental challenges to sustainable development. The system's above-ground structure consumes valuable surface land, increases congestion in certain corridors, and weakens urban aesthetics. Moreover, limited institutional capacity and poor integration reduce its potential as a backbone for the city's mobility network.

These realities provide strong justification for considering underground transformation as a strategic long-term solution. By relocating the LRT below ground, Addis Ababa could mitigate congestion conflicts, reclaim valuable urban land for economic and social uses, and align transport planning with global best practices in sustainable urbanism. In a nutshell, this section:

- Provides historical context (why LRT was built).
- Highlights benefits and limitations.
- Includes a major table summarizing characteristics + challenges.

- Concludes with implications for planning (transition toward underground).

The development of underground urban spaces represents a transformative approach to addressing the constraints of surface-level infrastructure in rapidly growing cities. For Addis Ababa, where limited land availability, urban congestion, and fragmented urban form have posed persistent challenges, moving infrastructure underground offers both practical and strategic benefits (Broere, 2016). The approaches to developing such spaces must, however, be carefully framed around technical feasibility, urban planning integration, environmental sustainability, and social acceptability (Von der Tann et al., 2020).

Integrated Urban Planning Approach

A successful transition to underground development requires embedding underground transit planning within the broader framework of citywide master planning. This means treating subterranean spaces not merely as engineering projects but as integral components of the urban fabric (Pankratova et al., 2019). An integrated approach emphasizes the creation of multi-functional spaces that accommodate transport, utilities, commercial activities, and public amenities. For Addis Ababa, this entails linking underground rail infrastructure to above-ground transit hubs, commercial districts, and pedestrian networks, ensuring seamless connectivity and accessibility (Kassahun & Bishu, 2018).

Transit-Oriented Development (TOD) Synergies

One of the most promising approaches involves aligning underground development with Transit-Oriented Development (TOD) strategies. TOD emphasizes high-density, mixed-use developments centered around transit hubs, encouraging compact and walkable urban growth (Teklemariam & Shen, 2020). By situating LRT stations underground, Addis Ababa can unlock surface-level land for TOD, creating vibrant commercial and residential clusters that reduce car dependency while enhancing the city's economic competitiveness (Sekasi & Martens, 2021).

Phased and Adaptive Implementation

Given the scale and cost of underground projects, a phased approach is essential. This entails identifying priority corridors with the highest congestion, land-use conflicts, or redevelopment potential, and transitioning them underground first (Von der Tann et al., 2020). A phased strategy allows for lessons learned from early stages to inform later expansions, while also distributing financial burdens over longer timelines. Adaptive implementation further ensures that design and construction practices can adjust to technological advancements, changing demographics, and evolving urban policy priorities (Pankratova et al., 2019).

Engineering and Design Innovations

Engineering considerations lie at the heart of underground urban development. Advances in tunnel-boring technology,

Table 2: Key Characteristics and Challenges of the Addis Ababa LRT

<i>Category</i>	<i>Current Status / Characteristics</i>	<i>Challenges Identified</i>
Network Length	~34 km, two lines (east–west, north–south)	Limited coverage; insufficient to meet rising demand
System Design	Predominantly above-ground (at-grade + elevated)	Road congestion at intersections; disruption of urban corridors
Passenger Capacity	Tens of thousands daily (below projected demand)	Overcrowding during peak hours; declining reliability
Land Use Impact	Occupies prime central corridors	Restricts commercial use, pedestrian flow, and green spaces
Environmental Effects	Electric-powered (low carbon emissions)	Concentrated noise/vibration; surface-level pollution exposure
Urban Aesthetics	Elevated tracks dominate city landscapes	Visual disruption, reduced attractiveness in commercial areas
Institutional Framework	Operated by Ethiopian Railways Corporation	Weak integration with buses/taxis; limited financial sustainability
Social Impact	Provides affordable mobility to low-income groups	Displacement of small businesses and households; limited inclusivity

structural engineering, and geotechnical analysis provide a foundation for safe and efficient construction (Broere, 2016). In the context of Addis Ababa, with its varied topography and sub-surface geology, customized engineering solutions will be required to minimize risks (Taye, 2016). Design innovations such as modular station architecture, energy-efficient ventilation, and flood-resilient systems are critical for long-term sustainability. The incorporation of digital technologies, including Building Information Modeling (BIM) and smart monitoring systems, can also enhance planning, execution, and maintenance (Von der Tann et al., 2020).

Environmental and Sustainability Considerations

Underground development must be environmentally responsive. Subterranean infrastructure can significantly reduce surface-level carbon emissions, noise, and visual intrusion (Broere, 2016). However, the construction phase often carries environmental risks such as soil displacement, groundwater disruption, and energy-intensive operations (Von der Tann et al., 2020). Approaches to mitigating these impacts include eco-friendly construction materials, energy-efficient tunnel lighting and ventilation, and green energy integration, such as solar-powered station facilities (Sekasi & Martens, 2021). A sustainability-driven approach ensures that underground spaces contribute positively to Addis Ababa's climate resilience agenda.

Institutional and Governance Frameworks

The success of underground development depends heavily on governance capacity. Establishing a dedicated metropolitan authority for underground planning, operation, and regulation ensures accountability and efficiency (Kassahun, 2021). Such institutions must coordinate across sectors, integrating transport, land management, energy, and

housing policies (Kassahun & Bishu, 2018). Equally, financing models whether through public-private partnerships (PPPs), international development loans, or municipal bonds must be structured to ensure financial sustainability without imposing excessive burdens on citizens (Kumsa & Dilla, 2020). Transparent governance frameworks build public trust, which is essential for long-term acceptance and support of subterranean infrastructure (Sekasi & Martens, 2021).

Community and Stakeholder Engagement

Finally, community involvement is indispensable in underground development approaches. Stakeholder consultations with residents, businesses, and civil society organizations provide insights into local needs and help mitigate social disruptions during construction (Pankratova et al., 2019). Public participation not only fosters inclusivity but also enhances legitimacy and public ownership of transformative projects. For Addis Ababa, where displacement and land-use conflicts have historically accompanied major infrastructure projects, a participatory framework is particularly critical (Kassahun, 2021).

Strategies for Transforming Addis Ababa's LRT into an Underground System

Transforming Addis Ababa's Light Rail Transit (LRT) from an above-ground system into an underground network requires a multi-pronged strategy that balances technical feasibility, financial sustainability, social acceptance, and long-term urban development goals. While the benefits of underground systems are clear, the pathway to realizing them involves deliberate planning, phased execution, and institutional innovation (Sekasi & Martens, 2021). The strategies outlined below highlight the core pathways through which this transformation can be effectively pursued.



Technical and Engineering Strategies

The priority is to establish a robust technical foundation. A comprehensive geotechnical survey is necessary to understand soil conditions, groundwater dynamics, and seismic risks across Addis Ababa's urban landscape (Tesfaye Demdime, 2012). Based on these findings, tunnel-boring machines (TBMs) and cut-and-cover methods can be selectively applied depending on corridor-specific conditions. Additionally, employing modular station designs and advanced ventilation systems will ensure both cost efficiency and adaptability. Engineering resilience against flooding, seismic activity, and long-term wear must remain central to the transformation strategy (Mohamed et al., 2020).

Phased Corridor Prioritization

Transforming the entire LRT at once would be financially and logistically unfeasible. A phased corridor prioritization strategy is necessary. High-demand corridors such as the east-west line passing through Meskel Square and key business districts should be prioritized due to their acute congestion and land-use conflicts (Kassahun & Bishu, 2018). Subsequent phases can target peripheral areas, integrating lessons learned from initial underground conversions. This sequencing minimizes disruption while maximizing early benefits (Sekasi & Martens, 2021).

Financing and Investment Models

Transforming to an underground LRT system requires significant capital investment. Public-private partnerships (PPPs) offer an avenue for mobilizing private sector expertise and finance, while international development loans and grants can complement domestic resources (Ababa, 2006). A value-capture financing approach where land and property values around underground stations are leveraged can also provide a sustainable revenue stream. Transparent financial governance is essential to avoid cost overruns and ensure accountability (Molla et al., 2019).

Policy and Institutional Strengthening

An enabling policy environment is vital. Establishing a dedicated Urban Rail Authority with clear mandates for underground planning, implementation, and operations would strengthen governance (Kassahun & Bishu, 2018). Policies should encourage integration of the underground LRT with buses, non-motorized transport, and future metro systems, ensuring a multimodal urban transport framework. Regulatory frameworks must also address safety standards, environmental compliance, and land-use planning, ensuring that underground transit aligns with broader sustainable development goals (Authority & Ababa, 1997).

Environmental and Social Safeguards

Given the potential for environmental and social disruption during underground construction, safeguards must be embedded into the strategy. Environmental Impact

Assessments (EIAs) should be mandatory for all corridors, with mitigation measures for soil erosion, groundwater disruption, and waste management (Authority & Ababa, 1997). Social safeguards include fair compensation for displaced individuals, alternative livelihood programs for affected businesses, and public engagement to build trust and minimize resistance (Mohamed et al., 2020).

Public Engagement and Communication Strategy

Transforming the LRT into an underground system requires broad social acceptance. A transparent communication strategy should inform the public about benefits, timelines, disruptions, and long-term gains. Participatory forums, stakeholder consultations, and awareness campaigns can build ownership among residents, ensuring that the transformation is viewed not as an elite-driven project but as a collective urban achievement (Tesfaye Demdime, 2012).

Technology Integration and Smart Systems

The transition presents an opportunity to integrate advanced technologies. Smart ticketing systems, real-time passenger information displays, and digital monitoring platforms can enhance efficiency. Using Building Information Modeling (BIM) during design and construction, coupled with Internet of Things (IoT)-enabled monitoring for maintenance, will ensure long-term operational resilience (Mohamed et al., 2020).

Policy Frameworks for Sustainable Underground Development in Addis Ababa

The successful development of underground urban spaces in Addis Ababa requires more than technical and financial strategies; it necessitates a robust policy framework that guides planning, implementation, governance, and long-term sustainability (Mohamed et al., 2020). Policy frameworks provide the legal, institutional, and regulatory scaffolding necessary to ensure that underground transit and related infrastructure operate efficiently, equitably, and sustainably (Authority & Ababa, 1997). This section outlines the key policy dimensions relevant to transforming the city's Light Rail Transit (LRT) into an underground system.

Legal and Regulatory Frameworks

Clear legal structures are essential to define property rights, land acquisition processes, and the permissible uses of underground space. Underground zoning regulations must specify corridors for transit, utilities, and commercial development while balancing public access and private rights (Molla et al., 2019). Environmental regulations and safety standards must also be codified to address the unique risks associated with subterranean construction, including soil stability, groundwater management, ventilation, fire safety, and emergency evacuation procedures (Authority & Ababa, 1997).

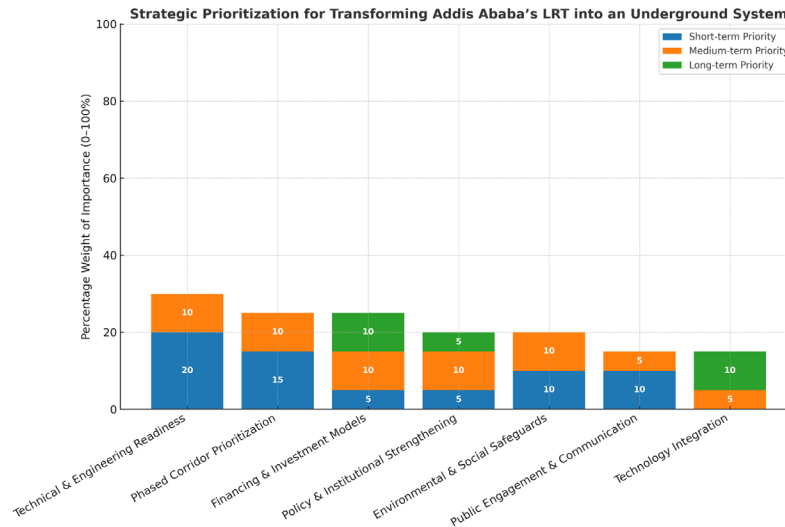


Figure 2: Comparative Strategic Prioritization for Transforming Addis Ababa's LRT into an Underground System

Institutional and Governance Structures

Effective governance requires the establishment of a dedicated authority responsible for underground planning, implementation, and operations (Kassahun & Bishu, 2018). Such an institution should coordinate across municipal agencies, federal ministries, utilities, and transport operators. A centralized oversight body can streamline permitting, standardize safety and technical protocols, and ensure alignment with Addis Ababa's broader urban development plan. Furthermore, integrating underground planning into existing metropolitan and regional urban strategies can prevent conflicts with above-ground development initiatives (Ababa, 2006).

Financing and Economic Policy Instruments

The scale and complexity of underground transit demand innovative financing policies. Public-private partnerships (PPPs), municipal bonds, and international development loans are critical instruments (Sekasi & Martens, 2021). Economic

policies should also enable value capture, where increases in land and property values surrounding underground stations help finance infrastructure construction and maintenance. Transparent financial reporting and regulatory oversight are essential to safeguard public resources and encourage private investment (Mohamed et al., 2020).

Environmental and Sustainability Policies

Policies must embed environmental sustainability at every stage of underground development. This includes mandating Environmental Impact Assessments (EIAs), promoting energy-efficient station designs, integrating renewable energy sources, and ensuring waste and water management practices minimize environmental disruption (Authority & Ababa, 1997). Urban policies should also promote the reuse of surface space reclaimed from underground transit corridors for green spaces, pedestrian pathways, and public amenities, thereby contributing to climate resilience and livability (Molla et al., 2019).

Table 3: Key Policy Dimensions for Sustainable Underground LRT Development

Policy Dimension	Key Actions / Measures	Expected Outcomes
Legal & Regulatory Framework	Define underground zoning, property rights, safety codes	Clear legal foundation; risk mitigation
Institutional & Governance	Establish dedicated Underground Transit Authority; integrate with urban planning	Streamlined coordination; policy alignment
Financing & Economic Instruments	Enable PPPs, municipal bonds, value capture, international loans	Financial sustainability; investment mobilization
Environmental & Sustainability	Mandate EIAs, renewable energy integration, reclaimed land use	Reduced environmental impact; climate resilience
Social & Community Policies	Implement displacement compensation, public participation, equitable access	Enhanced public trust; social legitimacy



Social and Community Policies

Social policies play a vital role in mitigating displacement, ensuring equitable access, and fostering public acceptance. Frameworks should address compensation for affected residents and businesses, safeguard vulnerable populations, and encourage participatory planning (Tesfaye Demdime, 2012). Community engagement ensures that projects are not only technically and financially viable but also socially legitimate, enhancing long-term sustainability (Mohamed et al., 2020).

Case Study Analysis: Addis Ababa's LRT Transformation

The transformation of Addis Ababa's Light Rail Transit (LRT) into an underground system presents a unique case study in urban sustainability, mobility modernization, and infrastructural innovation in Sub-Saharan Africa. This section examines the feasibility, potential benefits, and strategic considerations for such a transformation, drawing on both local realities and comparative global experiences (Sekasi & Martens, 2021).

Feasibility Assessment

The feasibility of undergrounding the LRT depends on technical, financial, environmental, and social considerations. Geotechnical surveys indicate that Addis Ababa's variable topography and soil composition require careful alignment planning (Taye, 2016). Corridor sections with stable substrata are suitable for tunnel-boring methods, while cut-and-cover approaches may be needed in areas with shallow urban infrastructure. Financial feasibility is contingent on mobilizing a combination of public funds, private investment through PPPs, and international development assistance (Kassahun & Bishu, 2018). Early modeling suggests that phased implementation along high-density corridors can mitigate costs while delivering early benefits.

From an operational perspective, underground systems can integrate with existing above-ground and surface transit modes, creating a seamless multimodal network (Abreham, 2015). Safety and emergency management protocols, including fire suppression systems, flood mitigation, and real-time monitoring, are critical feasibility components (Kedjela, 2015).

Expected Benefits

Transforming the LRT underground is projected to deliver multiple benefits across urban, social, and environmental dimensions (Sekasi & Martens, 2021):

- **Congestion Reduction:** By eliminating at-grade crossings and freeing road space, underground transit can significantly reduce traffic congestion in core urban corridors.
- **Urban Land Reclamation:** Surface land currently occupied by elevated tracks and at-grade routes can be redeveloped for commercial, residential, and green

spaces (Taye, 2016).

- **Environmental Sustainability:** Underground transit reduces urban noise, vibration, and localized pollution, while supporting climate-resilient infrastructure.
- **Enhanced Mobility:** Faster, uninterrupted train operations improve travel times, reliability, and commuter experience.
- **Economic Opportunities:** Redevelopment of reclaimed surface land encourages investment, urban densification, and job creation (Kassahun & Bishu, 2018).

Comparative Insights

Global case studies from London, Tokyo, and Singapore highlight lessons relevant to Addis Ababa. These include phased construction to manage costs, integrated station designs that combine commercial and transit functions, and robust institutional coordination to ensure operational efficiency (Sekasi & Martens, 2021). Local adaptation is critical, however, to account for unique geographic, social, and economic conditions.

Key Implementation Considerations

- **Corridor Selection:** Prioritize high-demand urban routes with severe congestion or land-use conflicts.
- **Phased Rollout:** Begin with pilot underground segments to demonstrate feasibility and build public trust (Abreham, 2015).
- **Financing Structure:** Utilize a mix of PPPs, municipal funding, and international financing with transparent management mechanisms (Kassahun & Bishu, 2018).
- **Policy Alignment:** Ensure compatibility with urban zoning, environmental regulations, and social equity standards.
- **Community Engagement:** Conduct participatory consultations to minimize displacement impacts and enhance public acceptance (Kedjela, 2015).

Policy Recommendations

The transformation of Addis Ababa's Light Rail Transit (LRT) into an underground system requires a set of actionable policy recommendations to ensure long-term sustainability, operational efficiency, and urban integration. These recommendations are informed by the preceding analysis of technical feasibility, urban planning considerations, and global best practices, and are designed to provide a strategic roadmap for policymakers, urban planners, and stakeholders (Sekasi & Martens, 2021).

Strengthen Institutional Frameworks

A dedicated Underground Transit Authority should be established with clearly defined responsibilities for planning, construction, operation, and regulation of underground infrastructure. This body should coordinate across municipal agencies, federal ministries, utilities, and private partners (Kassahun & Bishu, 2018). Policies should empower the

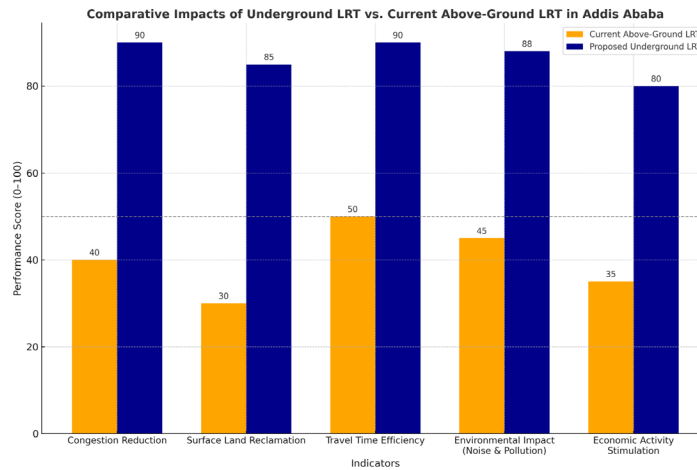


Figure 3: The graph shows the Comparative Strategic Prioritization for Transforming Addis Ababa's LRT into an Underground System

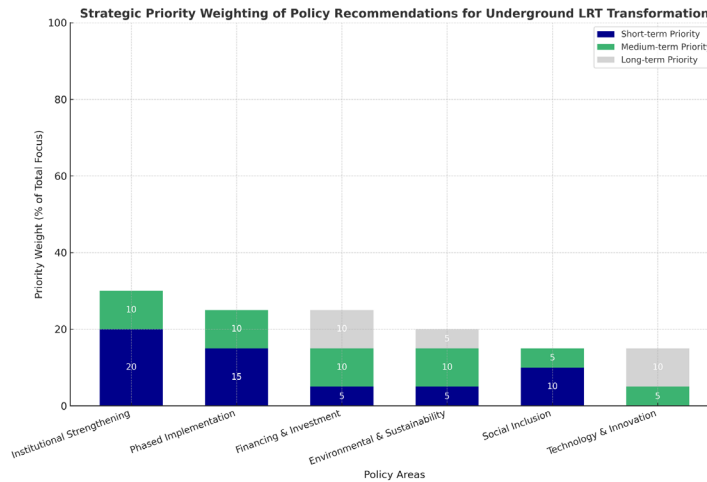


Figure 4: The graph shows the Strategic Priority Weighting of Policy Recommendations for Underground LRT Transformation

authority to manage funding, monitor project milestones, and oversee safety and operational compliance.

Develop Phased Implementation Policies

Underground LRT development should be executed in phases, beginning with high-demand corridors where congestion and land-use conflicts are most severe. Policies should define priority areas, sequencing strategies, and monitoring frameworks to evaluate performance at each phase (Abreham, 2015). Phased implementation reduces financial risk, enables adaptation based on lessons learned, and allows early benefits to be realized while subsequent phases are under construction.

Enact Financial and Investment Policies

Policy frameworks must enable innovative financing mechanisms, including public-private partnerships

(PPPs), municipal bonds, value capture financing, and international development assistance (Sekasi & Martens, 2021). Policies should promote transparency in budgeting, cost management, and revenue generation to ensure long-term financial sustainability. Tax incentives or development rights around underground stations can further mobilize private investment while enhancing urban development outcomes (Taye, 2016).

Integrate Environmental and Sustainability Policies

Sustainability-focused policies should require Environmental Impact Assessments (EIAs) for all underground construction projects, mandate energy-efficient design and renewable energy integration, and establish protocols for waste, water, and noise management (Assefa et al., 2021). Reclaimed surface land should be allocated for public green spaces,

Table 4: Key Policy Recommendations for Addis Ababa Underground LRT Transformation

<i>Policy area</i>	<i>Recommended actions</i>	<i>Expected outcomes</i>
Institutional Strengthening	Establish Underground Transit Authority; coordinate agencies	Streamlined governance; efficient decision-making
Phased Implementation	Prioritize high-demand corridors; monitor phased progress	Reduced financial risk; early benefits realized
Financing & Investment	Enable PPPs, value capture, municipal bonds	Financial sustainability; mobilized investment
Environmental & Sustainability	Mandate EIAs, renewable energy, reclaimed land use	Climate resilience; reduced environmental impact
Social Inclusion	Community engagement, compensation, equitable access	Public trust; reduced displacement impacts
Technology & Innovation	Implement smart monitoring, BIM, digital ticketing	Operational efficiency; long-term adaptability

pedestrian infrastructure, and mixed-use developments to maximize urban sustainability and climate resilience (Kedjela, 2015).

Embed Social Inclusion Policies

Policies must ensure equitable access and mitigate potential social impacts. This includes fair compensation for displaced residents and businesses, participatory engagement with affected communities, and measures to promote accessibility for low-income populations (Kassahun & Bishu, 2018). Public communication strategies should be institutionalized to maintain transparency and build trust throughout the project lifecycle.

Promote Technology and Innovation Policies

Policies should encourage the adoption of smart infrastructure solutions, including digital monitoring systems, real-time passenger information, and Building Information Modeling (BIM) for construction and maintenance. Innovation policies should incentivize research and development in underground engineering, energy efficiency, and sustainable urban design (Abraham, 2015).

CONCLUSION

The long-term urbanization of underground urban spaces in Addis Ababa, especially the revitalization of the current Light Rail Transit (LRT) system, also offers a strategic chance to urgently solve existing urban mobility, land-use, and environmental issues. Although innovative, the existing overground LRT of the city is limited in its ability to manage congestion, land use, operating performance, and visual integration (Abebe, 2020; Kassahun, 2021). These problems highlight the importance of having a visionary city planning approach that uses underground transit networks as a tool of sustainable urban development.

The international experience shows that such cities as London, Tokyo, and Singapore have managed to use underground transit not only to make urban movement as

efficient as possible but also to reestablish the use of surface land by developing it as a mixed-use area, combining many modes of transportation, and improving the environment and social results (Tan, 2017; Zhang and Yang, 2014). The concept of underground infrastructure as a source of multifunctional gains, such as fewer carbon emissions, a better accessibility experience, and enhanced urban resiliency to socio-environmental shocks, is also supported by the theoretical frameworks of sustainable urbanism, transit-oriented development, and urban resilience (Bobylyev, 2016; Teklemariam and Shen, 2020).

The feasibility analysis suggests that undergrounding Addis Ababa LRT can be realized using a combination of specific-engineering solutions, a step-by-step approach, and a powerful monitoring system (Taye, 2016; Abraham, 2015). High-demand corridors have to be prioritized, tunnel-boring and cut-and-cover methods should be used, and smart technologies must be incorporated to guarantee efficient operations, safety, and flexibilities (Kedjela, 2015). Economically, the project can be supported in terms of its economic sustainability using a mix of public-private partnerships, value capture systems, municipal bonds, and international funding, whereas the staged implementation will reduce the risks and enable the realization of the benefits in the early stage (World Bank, 2015; Sekasi and Martens, 2021).

Policy frameworks are essential to guide the transformation process. Institutional strengthening, legal clarity, environmental safeguards, social inclusion measures, and technology integration form the backbone of a comprehensive governance strategy (Kassahun & Bishu, 2018; Authority & Ababa, 1997). Ensuring community participation and transparent communication enhances public trust and social legitimacy, while environmental and sustainability policies safeguard the city's climate and urban ecosystems (Huang et al., 2018; Molla et al., 2019).

The expected benefits of the underground LRT extend beyond mobility. Congestion reduction, reclaimed urban land, faster and more reliable travel, improved urban aesthetics, and economic stimulation collectively contribute to Addis

Ababa's long-term development objectives (Carmona, 2019; United Nations, 2019). By aligning technical strategies with policy measures and participatory governance, the city can achieve a sustainable, resilient, and modern transit system that serves as a model for other rapidly urbanizing African cities (Broere, 2016; Von der Tann et al., 2020).

The transformation of Addis Ababa's LRT into an underground system represents a convergence of innovative engineering, strategic urban planning, and inclusive policy-making. It offers a transformative pathway to a more efficient, sustainable, and livable city, ensuring that Addis Ababa's urban infrastructure meets the mobility and developmental needs of its growing population while aligning with long-term sustainability goals (Zhang & Yang, 2014; Pankratova et al., 2019).

The transformation process requires policy frameworks that will steer the process. The foundation of an all-encompassing governance strategy is institutional strengthening, legal certainty, environmental protection, social inclusion, and integration of technologies (Kassahun and Bishu, 2018; Authority and Ababa, 1997). Securing both community engagement and clear communication strengthens the levels of social legitimacy and trust toward the city, and environmental and sustainability policies help protect the city climate and urban ecosystems (Huang et al., 2018; Molla et al., 2019).

The mobility is not the only potential asset of the underground LRT. Reduction in congestion, reclaimed urban space, increased speed, and reliability of travel, improved aesthetic appearance of the city, and economic growth are all aspects of the long-term developmental aims of Addis Ababa (Carmona, 2019; United Nations, 2019). Instead, the city can implement a sustainable, resilient, and modern transit network that integrates technical strategies with policy actions and participatory governance and become one of the models of urbanizing rapidly urbanized African cities (Broere, 2016; Von der Tann et al., 2020).

To conclude, the process of transforming LRT to an underground system in Addis Ababa could be seen as the combination of innovative engineering, strategic urban planning and inclusive policy-making. It provides a redefining route to a more sustainable, efficient, and habitable city, so that Addis Ababa can satisfy the mobility and developmental demands of her expanding population, in line with long term sustainability objectives (Zhang and Yang, 2014; Pankratova et al., 2019).

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