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Integrating Underground Urban Spaces into the Sustainable Urban Development Agenda of Addis Ababa: Challenges and Opportunities

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Abstract

The city of Addis Ababa, Ethiopia is one among the rapidly growing cities in Africa and is starting to face problems associated with high-speed urbanization and development, land shortage, congestion, and environmental degradation. The more the city expands, the greater the need to find new, sustainable spatial solutions. This paper will discuss the integration of urban space underground as an agenda of sustainable development in Addis Ababa, as well as the opportunities and challenges that these offer. It discloses the place of underground growth, maximization of restricted surface land, movement, and resilience of the environment.

The research points to the following challenges as the main aspects: complicated geological settings, expensive constructions and maintenance, poor institutions, and poor awareness of people. It also stresses the necessity to legalize the underground land ownership and use, and to coordinate interagency and reform policies. There are proposed technological innovations, collaboration between the government and the private sector (PnPs), and involvement of the community as the important keys to the successful implementation.

More so, the article proposes the implementation of a three-dimensional urban planning structure on the Master Plan of the city and the building on the basis of environmentally friendly construction activities, geotechnical mapping, and community engagement. Through the imitation of the best practices in other nations and modifying them to the local realities, Addis Ababa can extract the untapped potential under the surface. One of them is underground space, and the integrated management of the latter provides a revolutionary possibility to build a small, resilient, and environmentally friendly urban future - turning Addis Ababa into an example to the other fast-growing cities in the African continent.

Keywords: Underground Urban Spaces**;** Sustainable Urban Development**;** Addis Ababa**;** Urban Planning**;** Public-Private Partnerships (PPPs)**;** Infrastructure Innovation

1. Introduction

The capital and the biggest metropolitan area in Ethiopia, Addis Ababa, is a city of contrasts: the city symbolizes the process of fast modernization; on the other hand, there is a powerful sense of history. The city has been experiencing a level of urbanization that has never been witnessed before, making it demand more land, housing, transportation, and government infrastructures within the last few decades. Even though this growth can be regarded as a sign of economic progress, it has created a cord of urban conflicts, including congestion, slums, lack of green areas, and environmental decay. Sustainable urban development has become one of

the major agendas in the future of Addis Ababa as urban planners and policy makers endeavor to strike a balance between economic development and the environment.
In this respect, Underground Urban Spaces (UUS) are a new and sustainable method of solving the problem of space limitations and improving a more stable and efficient urban ecosystem. The experience of cities such as Tokyo, Helsinki, Montreal, and Singapore has demonstrated to the world how underground development can not only take the pressure off surface land, but also reduces the environmental impact as well as optimize the functionality of cities. In the example of Addis Ababa, the topography is in line with the development of the city and the population density, so that the exploration and use of underground space can restructure the way the city can develop.
This paper will explore how the underground urban spaces can be incorporated into the sustainable development plan of Addis Ababa. It discusses the opportunities, challenges, and strategic directions that can enable the policymakers, urban planners, as well as stakeholders in this city to harness this new strategy in developing a livable, resilient, and inclusive city.

1.1. Addis Ababa Sustainable Urban Development Overview.

The sustainable urban development in Addis Ababa aims at striking the right balance between economic growth and environmental management as well as social equity. The city has, over the years, incorporated numerous urban renewal and development of infrastructure to enhance the increasing demands of the already huge population in the city, which is already estimated with over 5 million people. The priorities of the Ethiopian government include modernization of urban infrastructure, sustainability, and green development: the Growth and Transformation Plans (GTP I and II) and the Ten-Year Development Plan.
But there are major limitations to Addis Ababa. Geographic growth in the city has been mostly horizontal, and this has eaten up precious agricultural and green lands at the edges of the town. As a result of this uncontrolled sprawl, there is increased road commuting, road congestion, poor land use, and higher government service delivery costs. In addition, the city's topography, including hilly terrain and irregular landforms, creates engineering and environmental challenges for above-ground expansion.
This means that sustainable development in Addis Ababa will entail a paradigm shift away from traditional urban development models towards compact, resource- and environmentally friendly ones. This includes re-invention of use of space, both above and below ground. The underground areas would be also a good way of reducing the land shortages and the sustainability of the city as it would allow the incorporation of transport facilities, utility, parking, commercial areas, and even green spaces.
Also, sustainable development models advance the 3E: Economy, Environment, and Equity. These values meet the idea of underground urbanization because it promotes good land use (economic), the minimization of ecology footprint (environmental), and accessibility and livability to citizens (equity). In such a way, underground development can be incorporated into the sustainable urban planning in Addis Ababa, as this will enhance the capacity of the city to overcome climate change, streamline the infrastructure and ensure sustainable inclusive growth.

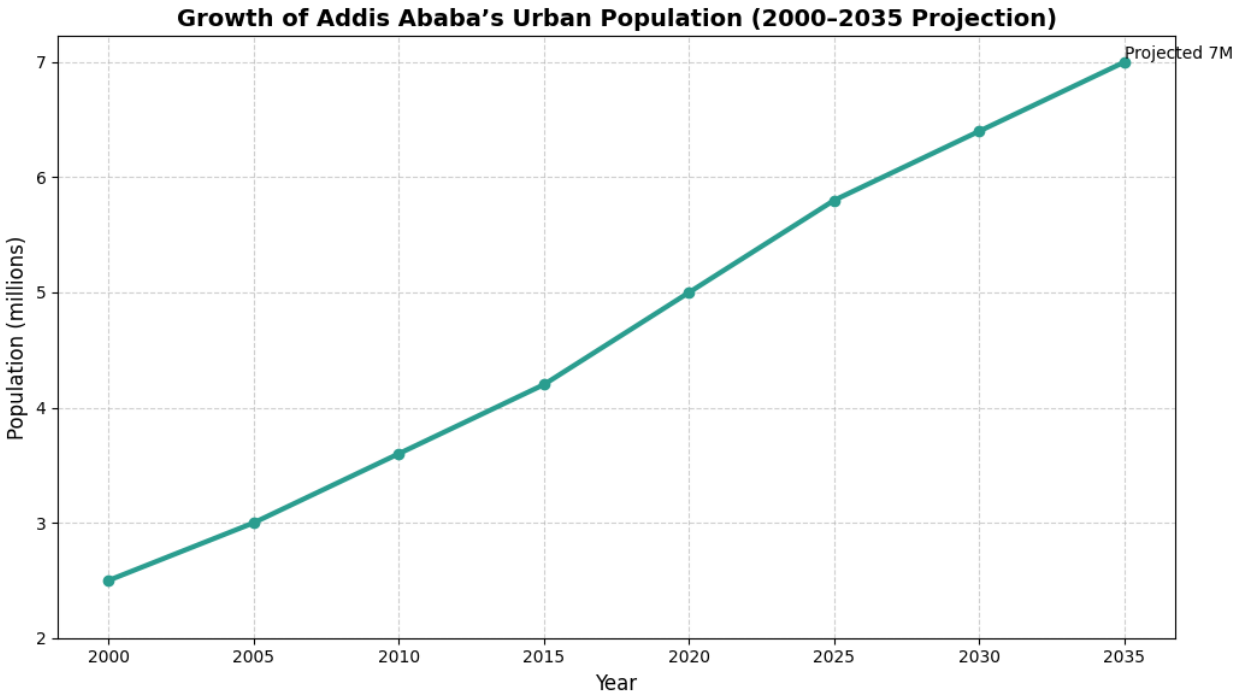

Figure 1. Growth of Addis Ababa's Urban Population (2000–2035 Projection)

1.2. The Growing Importance of Urban Underground Spaces.

Underground urban space is being identified worldwide as the fourth dimension of urban development, alongside traditional horizontal and vertical growth. They are applied in diverse applications- underground subway, utility tunnels, car parks, shopping centres, cultural centres, and even in data storage centres. This kind of underground development not only decongests the surface area, but also offers climate controlled and energy efficient areas.

The open spaces of Addis Ababa can be used to change the city by making strategic use of the underground spaces. The scarcity of land on urban areas, combined with the increased number of people in cities, has resulted in urban land becoming one of the most valuable commodities due to the lack of space on the surface and the increase in demand for space due to the development of infrastructure. The fact that the underground space can be developed means that the city can expand without additional invading of natural ecosystems and farmlands. It also relieves the overburden on the surface infrastructure that enables the city to allocate more space to social amenities, green space, and pedestrian space.

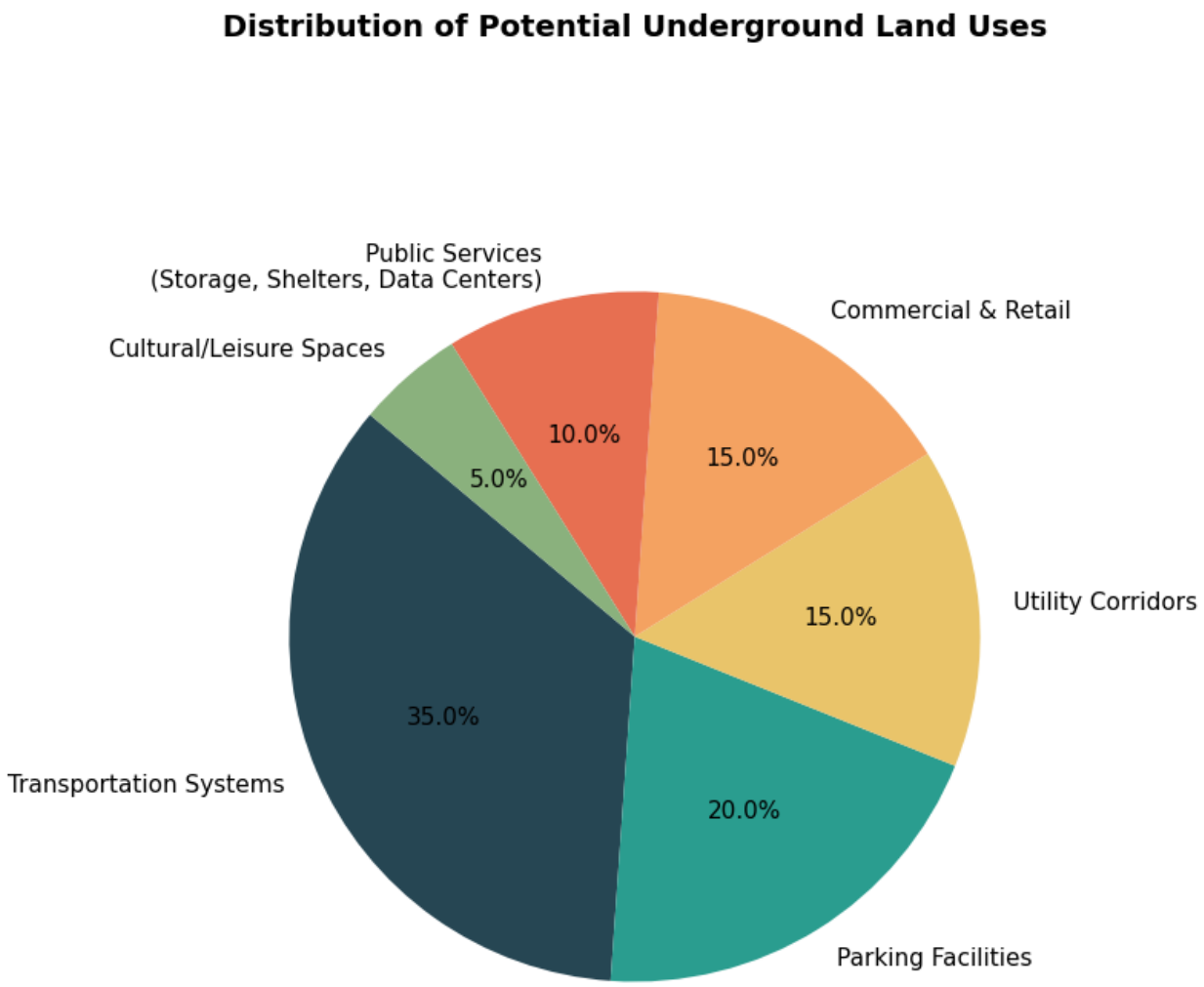

Figure 2. Distribution of Potential Underground Land Uses

Moreover, the underground systems might be critical towards improving movements within the city. The light rail transit (LRT) in Addis Ababa is a historic project, although, the majority of lines are overhead, which contributes to visual congestion and prevents flexibility in the land allocation. The transportation system in cities can be more effective when a greater number of underground transit corridors, tunnels, and utilities are opened, improving the connectivity, reducing the travel time, and favouring a more efficient transport system.

Underground construction can also assist in environmental friendliness by extreme temperatures insulation, less energy consumption in cooling and heating, and saving treasured surface ecosystems. Also underground storm water systems and reservoirs would decrease the flooding that is common in the city during the rainy seasons.

However, the augmented importance of underground spaces also elicits some feeling of rule, security, and social acceptability. Addis Ababa needs to embrace a holistic model to coordinate underground development and surface planning, promote private investment, and leverage technical expertise to make the city a success. The planners of the town must not consider underground urbanization as a single project but as part of a long-term sustainable urban development.

Table 1. Comparison of Surface vs. Underground Urban Development

Criteria	Surface Urban Development	Underground Urban Development
Land Use Efficiency	Limited — competes with green and residential spaces	High — frees up surface land for other uses
Environmental Impact	Contributes to heat islands, air pollution	Reduces surface congestion, preserves green space
Construction Cost	Moderate	High (requires advanced technology)
Maintenance	Easier access, lower cost	Complex ventilation, drainage, and monitoring
Safety & Comfort	Exposed to weather and traffic risks	Controlled environment, weather-resistant
Aesthetic Integration	Often visually dominant	Allows more natural and green surface design

1.3. Relevance and Purpose of Research.

The primary justification of research on the underground urban integration in Addis Ababa is to know how underground spaces can contribute to attainment of sustainable development agenda of the city and address the challenges of space and environment. The significance of the given study lies in the fact that it draws attention to one of the comparatively underexplored areas of city planning that can change the way in which the cities are formed, work, and sustain themselves.

Land shortage, urban sprawl, overcrowding, and lack of effective infrastructural problems are just some of the key challenges to the realization of Addis Ababa as a metropolitan city in Africa. Conventional urban growth practices are not effective in handling such concerns sustainably. Thus, the so-called underground development as part of the city planning agenda may become a game-changer, encouraging space optimization, energy efficiency, and environmental safety.

The study can be applicable for several reasons:

- Urban Innovation and Adaptation: It fosters the introduction of new urban solutions which would be befitting in the specific geographic and socio-economic environment in Addis Ababa.
- Sustainability and Climate Action: It is aligned with the Ethiopian commitments on the United Nations (SDGs) Sustainable Cities and Communities (SDG 11) and Climate Action (SDG 13).
- Policy and Planning Guidance: It provides information to the policy makers and planners on how they can incorporate the use of underground space in Master Plan and the long term development plans of the city.
- Socioeconomic Relevance: It is concerned with the establishment of employment, the enhancement of technology, and enhanced strength in the city as the potential outcomes of underground integration.

Lastly, the study will be added to the wider debate of sustainable urbanization in Africa and how the urban centers like Addis Ababa can be both cost-effective and at the same time, encouraging environmental stewardship. The use of underground spaces is not only a brilliant engineering exploit but also a phase on long term development plan of the city, a step towards a more efficient, inclusive, and sustainable city environment.

2. Underground Urban Spaces (UUS)

2.1. Definition and Scope of Urban Spaces, which are underground.

Underground Urban Spaces (UUS) are the designed and practical use of underground recesses in a city to serve various urban functions, including transport systems, utilities, storage, parking, commercial complexes, and even residential uses. Their symbolism is that they are the continuation of the urban realm into a different plane — below the surface — where cities can grow without taking over more surface space. Essentially, UUS is concerned with rethinking how cities use space by exploring the possibilities of the space under our feet.

Underground spaces that are considered in sustainable urban development are not regarded as stand-alone engineering endeavors but as part of the overall city planning. They are used to supplement on-ground functions and host the required but outwardly unattractive or land-consuming infrastructure, such as sewerage, power, transit, and storage systems. Such incorporation frees surface land into green space, social facility, and housing zones, thus enhancing living and environmental conditions in the city.

The use of underground space has been on the worldwide rise due to increasing population density, land space challenges, and environmental strains in the cities. Underground urbanization is a sustainable alternative to solve spatial and environmental challenges, which have been demonstrated to work in cities such as Tokyo, Helsinki, Montreal, and Singapore. Such cities have turned underground spaces into active, livable spaces that coexist well with the surface city.

Underground space concept has not been fully generated in Addis Ababa yet, since it is restricted to tunnels, basements, and selected segments of transport infrastructure. But as the city keeps developing at a very fast rate, and there is no additional land to be developed, and the people are further packed together in town, it is clear that the time has come to look into the restructuring of underground development. Sustainable development of Addis Ababa depends on the implementation of new practices, including UUS that can take the best use of space, minimize the impact on the environment, and help the urbanity to be resilient.

The implementation of the underground development should be a multidisciplinary process with incorporating urban planners, engineers, architects, geologists, environmental scientists and economists. The coordination between such professionals renders the use of underground utilities safe, effective, and context-related. More to the point, underground development must be considered in a systems-based perspective, where underground and surface developments are in harmony with each other as constituent parts of the same urban ecosystem. Such a comprehensive perspective will mean that underground urbanization does not just contribute to space efficiency but also to environmental sustainability, social inclusivity, and economic sustainability.

2.2. Cosmopolitan and Development of UUS.

Underground Urban Spaces have been changing as people adapt to an expanding urban environment, driven by growing populations and space constraints. Traditionally, underground areas were employed for practical and defensive purposes. The civilization of Millennia past in Cappadocia used to construct large underground dwellings to protect itself, and the Romans had to create catacombs and aqueducts as part of the city's infrastructure. The examples from the early years show that the concept of the underground as a means of urbanization is not new; it has merely been developing alongside advances in engineering and technology, as well as in urban architecture.

Rapid industrialization, urbanization, and environmental issues became a major concern in the modern period of the 20 th century with the underground development. Japan was the first in that area. Japanese cities, including Tokyo and Osaka experienced scarcity of surface space and frequent natural calamities and started establishing underground shopping, pedestrian walkways and transportation systems. The dug-up food stores are not just constructed in order to be functional but are safe as well with advanced engineering that will support earthquake and other natural occurrences.

Correspondingly, Helsinki, Finland, is a world leader in underground planning. The city has developed an official underground master plan that allocates certain areas beneath the city to utilities, parking, sports facilities, and even data storage. This legal and planning framework guarantees the systematic and long-term utilization of the underground space, eliminates the conflicts of land use, and preserves the surface and underground environment.

Another outstanding example is Montreal, Canada. It has a vast underground network, named RESO, that links metro stations, offices, hotels, and shopping centers over 33 kilometers. It is built to shield its inhabitants from the harsh winters in the city, but it has become an efficient and social centre that adds to the city's economy. Singapore has also used underground development as one of its long-term sustainability visions. It has underground fuel storage caverns, deep sewerage systems, and underground science parks as part of its efforts to conserve the limited surface land available for housing and green areas.

In the global context, the underground development is currently considered a response to the city problems rather than an empty fancy. The success of these cities is because of strategic governance, scientific research and technological development. In the case of Addis Ababa, the research on these foreign experiences could be a priceless lesson on how to incorporate underground development into local urban planning. Although each geological, financial, and social context is unique, the general principle remains the same: to make effective use of all the layers of the city to make it more sustainable, livable, and resilient for an urban future.

2.3. Establishing typologies and functional uses of Underground Spaces.

The underground area in the cities is multifunctional and can be divided into types. Transportation systems, utility networks, commercial areas, public facilities and environmental infrastructures are the most popular typologies. All have specific roles but are aimed at the city's general functionality and sustainability.

Most of the underground developments rely on transportation systems. Subways, road tunnels, and walkways are effective means of movement in high-density urban environments and alleviate congestion on the surface. In the case of Addis Ababa, the development of an underground light rail system would not only ease traffic congestion but also enable new business and social contacts at transit nodes.

Other factors that should also be considered include utility and infrastructure networks. The city of the future is becoming more and more dependent on the underground tunnels to transport water, garbage, electricity and telecommunications. Through maintaining such systems underground they are easily maintained, safe and not prone to environmental hazards. It also enhances the surface's aesthetic and ecological value by removing overhead lines and gnarled infrastructure.

The below-the-surface commercial and recreational spaces are also established. Underground shopping malls, films, and restaurants have become part and parcel of the Japanese and Canadian city cultures and economies in such places as Tokyo and Montreal. The spaces are usually climatic, energy saving and directly connected to transport centres and this elevates convenience and accessibility to the residents and visitors.

They may also be constructed underground in libraries, museums, and hospitals, which are usually located in high-density regions in the country. The approach enables the conservation of important surface land used in green space, residential and social plaza. Secondly, one can also find underground environmental and emergency facilities, stormwater reservoirs, disaster shelters, and waste recycling to improve the urban resilience and sustainability.

When it comes to the Addis Ababa, the biggest attraction is to give high priority to the underground typologies that satisfy the most pressing urban needs of the city. Introduction of underground parking can be proposed in congested places like Bole or Piassa to minimize traffic on the surface and maximize the use of land. On the same note, installation of underground utility networks can also be used to upgrade the old infrastructure without much inconvenience to the normal operations during the upkeep. With the city slowly adapting and investing in technology, it can be expanded to use more underground space, with more advanced and integrated systems that improve the life of the city and make it more sustainable.

2.4. Global Cities experience of UUS (Tokyo, Helsinki, Montreal, Singapore).

The analysis of the experience of cities that have managed to develop underground spaces offers a guide to Addis Ababa. The example of Tokyo demonstrates the functioning of underground systems as a component of city resilience. In the geologically hardened territories, the underground complexes in the city are designed with a thoughtful approach to the issue of earthquake safety and ventilation and accessibility, which proves that the underground development under such circumstances can be successfully supported by innovation and vision. Addis Ababa can learn this by integrating geological risks and disaster preparedness into the city's initial planning processes.

Helsinki is an example of both legal and institutional organization. Its Underground Master Plan establishes strict guidelines for what should be done to the land beneath the surface to ensure proper coordination among the different urban activities. Such a model will motivate Addis Ababa to come up with its own underground planning framework that is geared towards its general city master plan. Creating ownership, rights of use, and development priorities will assist the city in its future problem avoidance and provoke the actions of the private-sector.

The underground city of Montreal, on the other hand, talks of how the level of design grounded underground can improve the comfort of the climatic conditions and the city. Its tunnels connect major state and privately owned establishments and individuals can pass easily through them even during extreme winters. The concept can be restructured around Addis Ababa to provide covered walking paths that shield citizens from rain and ensure year-round mobility.

Singapore is quite successful because it has been integrating technology and pursuing a long-term strategic vision. The Deep Tunnel Sewerage System and underground science parks demonstrate the ability of highly developed engineering to be environmentally responsible. The innovation and sustainability that the city centers on provide lessons for Addis Ababa on the consistency of planning, financial investment in research, and cross-agency cooperation.
The major lesson these cities convey is that underground development is not simply about building new infrastructure; it is about changing how cities operate. In the case of Addis Ababa, such a way of thinking will need clear policy guidance, financial creativity, and enlightenment. Underground spaces would become one of the pillars of the city's development when oriented toward sustainability; this is their ability to make the city grow up, out, and down in accordance with the surrounding space and the people living in it.

3. Urbanization and Spatial Limitation in Addis Ababa.

3.1. The Urban Growth Trends and Patterns.

Addis Ababa is also one of the most fast-evolving cities in Africa; it has transformed itself over the past 3 decades to become an energetic city. The city has turned into a big and expansive metropolis of over five million people as opposed to its days as a small administrative center. One of the factors that lead to the mushrooming is partly due to the rural-urban migration, economic expansion and political/diplomatic position of Ethiopia as an African hub. The city of Addis Ababa has become multi-ethnic and international in its urban landscape because of the establishment of the African Union headquarters and other international bodies in the city.
Such a rapid expansion has, however, placed a gigantic strain on the already limited land resources in the city. Horizontal growth as opposed to vertical and underground growth, has characterized a good aspect of the development of Addis Ababa. The city has continued to encroach the outer regions of the surrounding farmlands and this has caused the rural communities to be displaced, fertile soils to be lost and natural habitat to be invaded. The result has been an unsustainable trend of residential sprawl, whereby the development of infrastructures is failing to match population growth.
The development of the city has also contributed to the population that is made up of informal settlements that constitute a considerable portion of the population of the city. They are not well cleaned, are poorly developed and do not have access to simple services. The central districts are experiencing high demand in land prices and therefore, it is not affordable to many residents. This enhanced inequality highlights why new strategies of land use that will ensure that development, sustainability, and inclusivity are balanced should be developed.
Although the Addis Ababa City Administration has demonstrated a certain level of initiative to promote sustainable urban planning over the last few years, it has implemented some projects and programs to achieve this objective, including the Addis Ababa Master Plan or the Integrated Development Plan. These frameworks are oriented towards small-scale development, infrastructure development and green space development. However, there is slow implementation and the gap between policy and practice is apparent. The city's horizontal development trend continues amid population pressures and limited space.
It is against this background that underground city building becomes more relevant. This restructuring of the part of the urban activity underground may assist Addis Ababa in tackling land shortage better, reduce the congestion on the surface, and avoid urban development over

valuable ecological reserves. The challenge is not, then, the thought put into it but the cultivating of the power, the management and the dream of making it real.

3.2. Scarcity of the Land and Increasing Infrastructure Pressures.

Land scarcity has emerged as a characteristic of urbanization in Addis Ababa. The city is located in a relatively limited geographical area, with topographical features of hills that restrict horizontal growth, making construction difficult. With population growth, new housing areas, infrastructure, and green areas are becoming smaller. This scarcity has also driven land prices up sharply, creating a speculative real estate market that further makes the urban core unaffordable to the poor and middle-income earners.

These demands have been added to by the growing demand to have infrastructure like roads, transport, utilities even amenities for the people. The existing infrastructure is not able to match the fast growth of the city. The streets tend to be congested streets, parking facilities are minimal, and transport facilities are insufficient to meet demand. Overcrowding in the core areas like Bole, Piassa, and Mexico Square has become critical, whereby expansion or upgrading of necessary services is hard without necessarily kicking out the already existing buildings.

In addition, the growing demand for modern amenities, including waste disposal centers, water supply systems, and telecommunications systems, contributes to the pressure on space. These services require a significant amount of surface area to install and service, and hence, they compete for space within the city. This leads to a situation where infrastructure growth often sacrifices green spaces or residential areas, thereby diminishing the quality of urban life.

Urban development underground is an option to such challenges. Addis Ababa can use surface space by moving infrastructure to underground areas such as utility channels, parking lots and transport systems, and thus convert them into more productive and livable spaces. The approach can be useful to not only solve the problem of land shortages but also to increase the efficiency and resilience of cities.

Nevertheless, such projects must be planned and invested in to be realized. Geological surveys ought to be conducted cautiously to identify locations where underground building can be done. The city must also come up with legal provisions that outline the ownership, access and safety provisions of underground spaces. Properly developed infrastructure ground level can significantly contribute to the increase of the city space and result in a more sustainable, properly structured urban environment.

3.3. Dilemmas in Informal Settlement and Urban Sprawls.

Among the most evident aspects of the rapid and unproportional urbanization of the city of Addis Ababa, informal settlements can be singled out. Over 60 percent of the population of the city dwells in unplanned places that are mostly located at the outskirts of the city or in flood prone regions that are also exposed to environmental degradation. Low-quality housing, lack of clean water, bad sanitation, and deficiency of social facilities are typical of these settlements. Increase in informal settlements does not only strains the resources of the people, but it also makes it difficult to plan and develop the urban areas.

Urban sprawl has also contributed to these problems. As the size of city increases, facilities such as roads, power, and sewerage systems have to extend further increasing the costs and reducing the efficiency. This is not a sustainable trend of development in terms of economics

and the environment. It results in the depletion of agricultural land, interference with the natural drainage system, and air pollution due to the rise in vehicular traffic.

The decline of informal settlements underscores the urban expansion and inability to manage it. Despite the government's resettlement and accommodation programs, including the condominium program, they have not kept pace with population growth. Most people cannot afford to have formal housing, or they are forced to relocate to far-off suburbs with no proper transport and employment.

There might be indirect solutions to these problems by developing the urban areas underground. The city can provide more affordable housing and community areas by building new infrastructure underground, including systems of public transport, utility tunnels, and storage areas. This would allow an urban form to be more compact, as well as necessitate an outward expansion.

Moreover, underground facilities should be incorporated into the redevelopment projects, which may improve the informal settlements' infrastructure, without mass displacement. As an example, the installation of sewage and waste management systems underground might advance the condition of living as well as the conservation of the current communities. Through this, underground urbanization would facilitate inclusive development that would deal with both spatial and social disparities in the Addis Ababa urban environment.

3.4. The Urban Land Use under Socioeconomic and Environmental Pressures.

Socioeconomic and environmental factors interact with each other and effectively determine the land use in Addis Ababa. The rise of the economy has catalyzed huge investment in real estate, infrastructure, and industry, which has led to intense competition over urban land. In the meantime, population density and migration remain active due to their tendency to increase the demand for housing and social services. This leads to land distribution policies that put more emphasis on economic benefit rather than social justice and environmental continuity.

This has been an imbalance that has led to the increase in socioeconomic disparities. The wealthy people and investors are found in the most prime urban locations and the poor are left to be in the fringe or end up being shanty-town inhabitants. This geographical distance reinforces social disparity and denies access to job opportunities, education and healthcare. Urbanization can further increase such divides without the inclusion of land-use policies.

The pressures in the environment are complicated. The urbanization of the city in sensitive ecological regions has led to deforestation, soil erosion and destruction of the natural drainage system. It has resulted in flooding which has become common in particular seasons, resulting in damage to property and structures. The construction work, traffic emission, and bad waste management also increase air and water pollution.

The Addis Ababa sustainable use of land should, therefore, change to integrated urban planning where the economic development is taken seriously, as opposed to the environmental and social factors. The power of underground city available spaces can play an instrumental role in this change. Surface congestion in the city can be removed through the underground relocation of activities that normally consume large amounts of land, natural landscapes, and improvement of the quality of the environment.

Incidentally, a decrease in flooding underground can be achieved through underground storm water reservoirs and underground storm water drains, a decrease in pollution and visual clutter underground power substations and waste buildings. Moreover, underground development

promotes compactness of the city, effective utilization of the public transport, reduction of energy consumption and general sustainability of the built environment.

4. The Urban Strategic value of Urban Underground spaces in Addis Ababa.

4.1. Improving Land Use Efficiency and Urban Compactness.

The availability of urban land is one of the greatest problems facing Addis Ababa. With the city's growth, there is an alarming rate of consumption of valuable agricultural land and green spaces. This uneven horizontal growth has led to poor land use and higher infrastructure costs. To solve this, Addis Ababa should have learner approach to urbanism, which maximizes the surface as well as underground spaces. The underground urban space (UUS) is one of the solutions offered to increase land-use efficiency and maintain the ecological balance.

The underground dimension offers opportunities for reallocating urban functions. Subsurface transfer of land-based elements like parking lots, transport corridors, warehousing units and utility systems can help Addis Ababa to reuse surface area to other productive purposes. This would comprise of increased green areas, walking-friendly zones and affordable housing projects. Dense city form also encourages mixed-use development where residential, business and recreational activities co-locate within close proximity to each other - decreasing travel, energy consumption and carbon emissions.

In addition, underground growth supports the idea of three-dimensional city planning, combining the vertical (up and down) and horizontal aspects of the city. The underground does not just constitute an area of technical infrastructure in such a model. Still, it is a dynamic component of urban life — it can include communal facilities, transport networks, and even cultural facilities. For example, the establishment of underground parking centers around key transport stations would relieve congestion on the surface, whereas underground shopping centers could boost economic activity in the city center.

Such a strategy can only be implemented through a change in city planning philosophy. The planners of Addis Ababa need to embark on mapping and controlling the underground area just as they do the surface plots. These include the identification of the right geological location to excavate, assessment of the environmental impact, and the establishment of proper property rights over the use of the underground location. When used correctly and planned, underground spaces can lead the city to the state of growth, habitation, and sustainability.

Lastly, underground development as a solution to space limitation is not only a reaction to space limitation, but also a possible solution to sustainable urbanization. Using this model, Addis Ababa will be a greener, denser and stronger city that can sustain the increasing population without the need to destroy nature.

4.2. Urban Infrastructure and Urban Services.

As the number of people residing in Addis Ababa is constantly growing, so does the need in the urban services, including transport, water, energy, waste management and communication. Regrettably, most of the current city infrastructures are aged, disjointed, and overstretched. The horizontal acquisition of these systems on the ground is also becoming more difficult due to land scarcity and congestion. Here, strategic exploitation of the underground space would be significant in bringing the proper provision of the infrastructure and services.

The city of Addis Ababa can revolutionize the way it handles the infrastructure using underground corridors when integrated into the utilities. Such systems can be focussed on

underground utility tunnels instead of laying water mains, power cables and telecommunications cables across the city. They are less affected by environmental risks and can be easily maintained and less susceptible to natural disasters. They also minimize the disturbances over the surface during the maintenance process such that day-to-day activities of the city are not interrupted.

Another sensitive field where underground solutions can have a substantial influence is transport infrastructure. Although there has been increased mobility with the current Light Rail Transit (LRT) system, it is mainly above ground, thereby consuming surface land and contributing to traffic congestion at road crossings. Other LRT or future metro would increase the efficiency and aesthetic of the system, besides enabling the surface space to be used by green boulevards, walking tracks, and bicycle tracks.

In addition, the parking issues that have evolved in the city over the years, including lack of parking space, would be minimized using underground parking units. In the business districts such as Piassa and Bole where there are high densities, underground parking complexes would be helpful in minimizing on-street parking, easing traffic issues, and promoting pedestrian safety. There may be need to promote the construction of underground parking materials as well as building permits to enable the general public to construct their buildings, malls, and hotels.

Outside transport and utilities, waste management, and water storage systems can be housed underground. An example is stormwater tunnels could be used to control the flood during the rainy season and underground reservoirs could be employed to increase the water security by storing excess rainfall to be used during the dry seasons. The facilities can be integrated into the overall environmental management plan of the city and in so doing, enhance resilience and sustainability.

Addis Ababa has an advantage of building a livable, more organized, and efficient city through underground integration to maximize the use of infrastructure and the provision of social services to the people. It generates not only better utilization of space but also a better quality of life for residents, lower maintenance expenses, and improved resilience of cities to both environmental and social challenges.

4.3. Adopting Transit-Oriented Development and Mobility.

Mobility is the blood of any modern city, and Addis Ababa is not an exception. However, the city has been marked by traffic jams, low capacity of roads, and lack of integrated transportation making transport one of the most crucial issues. The expansion of underground cities is the once-in-a-life chance to promote Transit-Oriented Development (TOD). The model combines transport systems and mixed use cities in order to develop efficient, accessible, and sustainable cities.

This vision has a central role that is played by the transport infrastructure (underground). Addis Ababa could improve its mobility network greatly by building subways and underground walkways and linking metro stations to each other. This is not only a way to cut down the surface traffic, but also a favourable high-density development of transit hubs. This, in its turn, promotes walkability, minimizes the use of personal cars, and decreases greenhouse gas emissions.

The economic activity can also be triggered by the integration of underground stations with commercial and residential developments. An example of this is underground transit hubs that

can incorporate retail areas, cafes, and other communal facilities, and turn what was once a transit hub into an exciting urban environment. The development of such facilities makes the commuting process more convenient to the commuters and also provides more income to the city authorities.

In addition, underground corridors will be able to link major urban knots, namely Piassa, Megenagna, and Meskel Square, to enable free movement of pedestrians regardless of the high traffic or the presence of rain. Not only would this system of underground walkways enhance accessibility, but it would also offer safe and comfortable modes of mobility to both residents and visitors of the network.

Nevertheless, in order to achieve a strong underground transit-oriented approach, Addis Ababa needs to make sure that there is coordination in the planning of transport, urban planners, and private developers. The city should also consider such long-term financing approaches, like the public-private partnerships (PPP), in order to finance these capital-intensive projects. In the long run, it will be successful to incorporate underground mobility systems with the rest of the transport and land-use system into the city so that there is a complement between the two.

The mobility change in Addis Ababa may be supported by underground city spaces. They offer the physical and spatial base of a more connected, efficient, and sustainable urban transport system that should correspond to the principles of smart and resilient city design.

4.4. Encouraging the Combat of Climate Change and Green Infrastructure.

Climate change offers more and more risks to urban centers in the global society, and Addis Ababa is not an exception. The city is also affected by frequent flooding, temperature increase, and uncertain rainfall patterns, all of which burden the city's systems and endanger its sustainability. The development of underground urban areas as part of the city development agenda can contribute significantly to increased climate resilience and facilitate the development of green infrastructure.

Underground areas have natural insulation against temperature variation, which can be used to minimize heating and cooling of buildings. As an example, underground business zones or communal premises may keep their internal temperatures constant, which reduces the necessity of artificial climate regulation and helps in saving energy. This especially applies to Addis Ababa, where the energy demand is steadily increasing due to the urbanization of this city.

Another option that they can apply is the underground stormwater management systems as a compulsory approach to curbing flooding- a problem, which is common among the low-lying housing areas during the rainy season. Through construction of underground drainage tunnels and retention reservoirs, the city would be in a position to absorb extra rainwater and divert it to unnecessary areas without risking the susceptible places. This water that has been stored can be utilized later in the future to irrigate or otherwise use it non-drinking purposes, and thus be able to manage the water resources sustainably.

Green infrastructure can be used to improve the ecological balance of the city by integrating both underground and green infrastructure. As an illustration, overhead areas over amenities to be constructed underground may be fitted with parks, gardens or walkways. The dual use will guarantee the highest level of the land-use efficiency and enhance the green cover and biodiversity in the urban regions.

Furthermore, the underground development can also be designed to utilize renewable energy, including geothermal heating and cooling, ventilation based on the use of sunlight, and the

collection of rainwater to guide development. These innovations align with the general environmental goals of Ethiopia and sustainable development agenda of climate-resilient green economy (CRGE) strategy.

5. The Prospective Advantages of underground Urban Development at Addis Ababa.

5.1. Enhancing Urban Density and Land Use.

The land scarcity within Addis Ababa could be resolved by urban agriculture because underground urban development will provide the city with the fresh chance to solve the limited land existing in the area. This has been augmented by the fact that the population of the city has been on the rise straining its housing, infrastructure and other amenities. It is nearly completely developed though with surface land in the city boundaries; room to expand is barely available without encroaching on agricultural and sensitive environmental land. The underground spaces are an effective strategy that would contribute to the enhancement of land-use efficiency and enable the city to reach the next stage of urbanization without the degradation of the quality of life and the environment.

Addis Ababa can reclaim some valuable top space by moving underground space land-eaters, such as parking garages, utility tunnels, shopping malls and even transportation corridors. As an illustration, the city can use proxemic areas above car parks to create parks, playgrounds, or walking streets to enhance the green areas of the city, as well as to promote social well-being. This two-purpose practice will give a chance to optimize space in places with high surface density like Bole, Piassa, and Mexico Square that are congested.

Also, the underground development is consistent with the concept of compact city, which promotes vertical development, land-use integration, and efficient provision of services. The development features of compact cities are lower costs of infrastructure per capita, better accessibility and the minimization of environmental effects. In the example of Addis Ababa, this type of model may be introduced through underground spaces that will be used to control suburban sprawl and the development of informal settlements into peri-urban regions.

Urban resilience is also supported by underground development through the diversification of the spatial resources. It generates another level of urban functionality that can accommodate essential services in case of an emergency or disaster. For example, underground shelters and storage facilities, along with transport corridors, can provide protection and sustain services during a natural or artificial crisis.

Addis Ababa needs to incorporate underground land into its official urban planning to enjoy these benefits fully. This involves extensive underground mapping, zoning laws as well as legal frameworks on the ownership of land and the authority to use the land under the ground. By utilizing the available untapped potential in the underground and surface space in an integrated manner that is not hierarchical, the city is able to make use of the potential and manage it in an integrated non-hierarchical manner, which will lead to a more sustainable, efficient, and fair urban space.

5.2. Growing Economic Growth and Investment Opportunity.

When the underground urban development is implemented as a sustainability strategy of Addis Ababa, it can increase the growth rate and the rate of attracting investments, both local and foreign. Addis Ababa is the capital city of one of the fastest growing economies in Africa, which is why it is a business, tourist and innovative hub. The economic development in the city is,

however, limited by the space constraints, bottlenecks in the infrastructure, and underdeveloped commercial infrastructure. The only avenue of coming out of these restrictions is to increase the underground space and open up new avenues of diversification and investment in the economy.

Underground areas may be exploited in commercial shopping malls, entertainment centers, restaurants, as well as office complexes. There are other cities like Helsinki and Montreal that have developed an underground built up that supports a completely healthy business ecosystem, they have climate-regulated zones running throughout the year, irrespective of the weather. Addis Ababa can emulate this by coming up with underground commercial centers related with key transport centers like Meskel Square or Megenagna. This would be more convenient to consumers and would in addition increase the growth of retail and create new employment opportunities.

Cost of construction and running of the underground facilities also lead to a lot of economic activity. These projects need the skills of engineering, architecture, geology, and construction, which demand the expertise of skilled labor and build up the technological growth in the construction business. In addition, the ability of the government to fund and operate these projects through public-private partnerships (PPP) without implying a heavy load on the government but functioning effectively may be essential.

Another economic benefit of underground urbanization is that it raises the value of land and property revenue. By effectively doubling the land area of its towns (both overground and underground) that can be put to use, the city can grow its property tax base and can increase its municipal revenue. This can in turn be used in recycling infrastructure and residential development and social services and this is a virtuous circle of city growth and prosperity.

In addition, the underground spaces will increase the position of Addis Ababa as a world conference and tourist destination. Through creation of underground exhibition spaces, convention centers and cultural spaces, international events and visitors will be increased hence increasing the local economy.

5.3. Enhancing Mobility in Cities and Congestion.

The traffic jams are one of the most visible persistent issues in Addis Ababa. Poor gridlocks have also been caused by the few roads in the city, the poor number of transportation facilities, and the rising population of the personal vehicles on the roads, especially during the rush hours. This is a waste of time and fuel besides polluting the air and wasting money. The solution to these mobility issues that is feasible and long term is the urban underground because it will offer more transport infrastructure and will ensure that the maximum traffic is underground.

The implementation of underground metro or the extension of the existing Light Rail Transit (LRT) network may transform urban mobility. Subway trains are faster, stable and are not influenced by congestion on the surface. They are also applied to interlink different parts of the city making them more accessible and minimizing the use of personal vehicles. Introduction of underground stations into residential and commercial buildings can also result in new transit oriented communities and hence the encouragement to use public transport instead of cars.

Along with underground railways, the underground road tunnels must also be built which will help to decrease the traffic on the surface. Major road networks, like the Bole International Airport to Mexico Square and the city centre would be improved with the help of tunnels to avoid road crossing where traffic is usually high. Such tunnels can have a certain transport

system lane, emergency services, and provision system, which enhance the control of the traffic.

One more significant aspect is underground parking facilities. The poor parking as we see it reduces drivers to the sidewalks and shoulders of the roads, thereby creating more congestion, as well as exposing pedestrians to danger. This pressure can be relieved by positioning underground parking structures strategically under shopping centers, office and other areas of the population. The maximum use of automated or multi-level underground parking can be applied in locations where there are high foot traffic.

Additionally, pedestrian footways linking key transport and shopping centers and office buildings can contribute to significant improvements in urban walkability, as they are underground. These routes provide secure, weather-sheltered, convenient ways of moving that reduce surface congestion and promote non-motorized movement.

The adoption of these underground mobility systems is very expensive and needs proper planning. But the long-term advantages — saved travel time, reduced emissions, and improved living standards — far outweigh the costs. Addis Ababa can take a step closer to realizing its vision of a modern, sustainable city with connected, livable infrastructure by integrating underground mobility infrastructure into its sustainable urban development agenda.

5.4. Climatic Adaptation and Environmental Sustainability Empowerment.

The increasing population of Addis Ababa has made green urbanization a problem. Air pollution, flooding, and loss of green spaces are on the rise in the city and all of this poses threats to the stability of the urban ecosystem and their health. The underground urban development is an opportunity that can help enhance environmental sustainability and adjust to climate change.

It is also one of the most important environmental advantages of underground spaces because it helps to decrease the urban heat island effect. The surface development may lead to increased heat intake due to asphalt, concrete, and fewer vegetation. The underground buildings, in their turn, stabilize the temperatures and do not use many energy resources to heat or cool down, which decreases the greenhouse gas emissions.

In addition, environmentally friendly infrastructure including storm water storage systems, waste water treatment facilities and renewable energy can be located in underground areas. Indicatively, rainwater can be collected and stored in underground water retention systems to reduce flooding effects during wet seasons and also be used as water resources during dry seasons. On the same note, underground waste treatment plants can reduce surface pollution, odors, and aesthetic impacts, and free up land for green and recreational areas.

Moreover, green roofs, vertical gardens, and surface parks placed over underground development can be integrated to enhance biodiversity and air quality. The two-layer urban structure enables the metropolitan area to increase its capacity for green areas while maintaining urban density functionality.

Underground construction also promotes low-impact development of the city due to the limitations it places on surface disturbance. Well planned and controlled underground projects can be used to conserve the cultural heritage sites, mitigate deforestation and safeguard the natural habitats.

Addis Ababa can strengthen its dedication to sustainable urbanization by pursuing a different approach to urban development underground urban development in accordance with the

Climate-Resilient Green Economy (CRGE) strategy of Ethiopia. The underground facilities, waste management and recycling of water would also be powered with renewable energy sources, which would make the city a prototype of environmentally friendly development in Africa.

6. Challenges of Incorporating Underground Spaces in the Development Agenda of Addis Ababa

6.1. Technical, Geological, and Geological Limitations.

The geological and technical limitations of the city are one of the largest challenges in the underground urban space development of Addis Ababa. The soil in Addis Ababa is not uniform as the cities, which are located on solid, homogeneous geological grounds, and has complex structures, volcanic rock structures, irregular topography, and heterogeneous soil. Such geological factors render the excavation as well as underground construction both technical, costly, and time-consuming.

The highland location of the city and the fact that some of its areas have soils rich in clay also make it more complicated. The rainy season increases the soil moisture that exposes it to erosion, landslides and structural instabilities that can be an issue to underground projects of construction. Before engineers can start any kind of excavation, they are supposed to carry out intensive geotechnical research to know the conditions that are found below the ground. This involves drilling boreholes, seismic, soil tests and ground water level analysis - which involve special skills and resources that are not in abundance in Ethiopia.

Another relevant issue is the infiltration of water. The rising and falling groundwater level in Addis Ababa can lead to seepage issue in underground tunnels, parking buildings, and cellars. Waterproofing, drainage systems and moisture-control technology are essential to have the long term durability and integrity of underground facilities. Nevertheless, lack of these sophisticated construction technologies and availability of domestic materials raises the level of imports hence making these projects highly expensive.

Moreover, absence of experience in the city on the large scale underground construction may imply that local contractors and engineers do not possess the technical expertise to design and execute complex underground projects. This is aggravated by the absence of standard construction codes and technical guiding principles as far as underground development is concerned. To be better off in this aspect, Addis Ababa will require capacity building and development by creation of training, international partners, and technological transfers.

Finally, lastly, the seismic activity is possible. Even though Addis Ababa is not situated in the most seismically active area, Ethiopian tectonic environment of the East African Rift System requires the inclusion of the earthquake resilience. Underground constructions need to counter movement of the ground floor and as such it implies that the international engineering standards are followed.

To sum up, underground construction in Addis Ababa might be challenged by geological and technical issues, but not overcome. The city can address these obstacles through effective site analysis, establishment of new construction technology, and geotechnical engineering practice and establish a groundwork of safe and effective underground urbanization.

6.2. Expensive initial expenditure and Maintenance expenses.

It is a major financial activity, and in most cases, underground urban development is costly in contrast to construction above ground. This is quite a challenge to Addis Ababa, where the already tight urban development budgets are contested with other competing agendas such as housing, transport, and social services. The initial expenses of underground construction, ground stabilization, waterproofing and ventilation, and security systems are very expensive, which means the underground projects are capital-intensive and need long-term planning and funding.

As an illustration, the engineering of underground tunnels or car parking can cost up to two or three times that of the equivalent construction on the surface due to the complex engineering and safety considerations involved in the construction. Initial costs of construction are high as well as the maintenance costs of underground structures are high. The air quality, lighting, humidity, structural integrity and others have to be constantly checked in order to make sure that the users are in a safe and comfortable environment. This will entail advanced ventilation and drainage systems, and frequent maintenance thus very expensive to run.

This is also worsened by two factors: First, there are no systems of domestic financing of large infrastructure projects. Ethiopia has most risk-averse banks that find it easy to get short-term and low risk loans as opposed to the long term infrastructure investments. This renders it difficult to fund underground projects by the developers. Part of this hole might be occupied by foreign capital. Nevertheless, it requires a predictable regulatory environment and clear legal and institutional structures of the underground property ownership connections that Addis Ababa does not have.

One solution to the financing dilemma is in Public-Private Partnerships (PPPs). This is because the PPPs can bring about a collective opportunity where both the public and the private sector can share the risks and costs of developing the underground projects thus making it practicable to construct them. Nevertheless, the PPPs experience in Ethiopia is still low in the infrastructure sector, and its institutional capability to absorb the same is still at the infancy level.

Besides that, underground developments have a longer payback period compared to the surface developments. Their profitability will be the location, accessibility, and integration with the adjacent land uses. Lack of strategic planning and proper demand forecasting can make projects face the danger of being underutilised and incurring losses.

However, in the long run, underground development could be an economic payoff. Less surface congestion, higher land value and greater urban functionality will bring about long term economic sustainability. Addis Ababa must foster financial incentives in order to attain such benefits, which includes tax incentives, low-interest loans, or land concessions to attract the involvement of the private sector and make sure that the subterranean projects are economical.

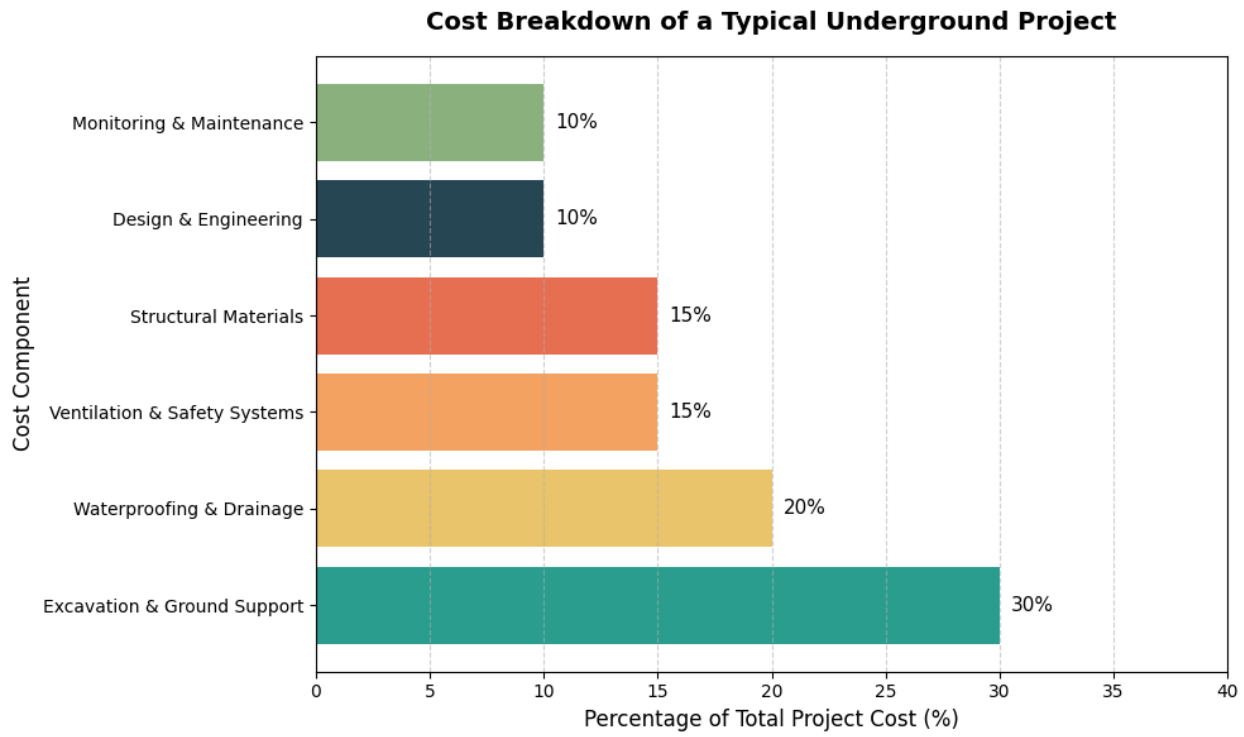

Figure 3. Cost Breakdown of a Typical Underground Project

6.3. The Institutional Framework and Policy Integration Weaknesses.

The absence of a clear institutional and policy framework is one of the greatest challenges to the adoption of the underground spaces in the urban agenda of Addis Ababa. Although the city has achieved progress in coming up with urban plans, the strategies mostly concentrate on the land use on the surface without much emphasis on the underlying spaces. Current Addis Ababa Master Plan and related urban policies lacks the provisions that may govern the underground land ownership, regulation and use.

The gap in the policy places the investors, developers, as well as government agencies in an uncertain position. The remaining questions of who owns the rights to the underground space, the extent to which property rights should go, the safety and environmental standards to be used are all left unanswered. There is a lack of clear legal guidelines in the society and thus the underground construction projects face the problem of bureaucratic bureaucracy, overlapping mandates and the existence of conflicting interests among the stakeholders.

Besides this, even coordination is complicated by the institutional fragmentation. Both governmental and non-governmental organizations, such as the Addis Ababa City Administration (AACA), the Ministry of Urban and Infrastructure Development, and Ethiopian Roads Authority share land use, infrastructure, and construction issues. But this does not mean that a body or inter-agency mechanism is in place that manages underground urban development.

It is hence important to design an all inclusive underground land-use policy. Being an urban strategy, it must create property rights beneath the soil, come up with technical and safety rules, and include underground spaces in the urban space and economic plans. It also must have the

procedures and mechanisms of environmental impact assessment, as well as the social participation practices, ensuring transparency and participation.

International experience can teach some useful lessons. Indicatively, cities like Helsinki and Montreal have developed Underground Master Plans that are useful in planning underground uses as they exist, possibly developing zoning of these uses and working in conjunction with other sectors. Addis Ababa would be advised to emulate them by introducing subsurface planning as part of urban development agenda in the city.

Besides policy reforms, the capacity of institutions should also be built. Based on the design, engineers, policy makers and urban planners need specialized training on underground infrastructure, geotechnical assessment and design. Such topics need to be taught in universities and other technical institutions to create a solid base of local talent.

Addis Ababa has a huge potential of underground urbanization but this cannot be achieved without the presence of institutional mechanisms of governance. The successful implementation of the well-coordinated policy framework will not only assist in streamlining the activities in the project implementation process but will also ensure that, in the long term, the implementation of underground development will be helpful in achieving the objectives of sustainability and resilience of the city.

6.4. Public Awareness and Social Acceptance Issues

Beyond technical and policy issues, the social aspect of underground development is also very important. The success of the underground urban projects is determined by the public perception and acceptance. Though underground space is new to the majority of the population in Addis Ababa, skepticism or cultural resistance could exist of living, working, or spending time underground.

Caves tend to be associated with blackness, claustrophobia or pain. These psychological impediments may influence usability and popularity of underground facilities like parking garages, shopping centers and transportation tunnels. In order to overcome these perceptions, one needs to design well with regard to the comfort, safety, and aesthetic of the user. Underground spaces can be converted to various environments with the use of natural lighting systems, ventilation, greenery and open plans that provide immaculate living spaces that are safe and comfortable.

Offers must educate the people about the benefits of the underground urbanization such as less congestion, increased green swaths and more resilience in case of a disaster. Trust and familiarity may also be built with demonstration projects. To illustrate a case in point; by coming up with small scale underground developments like pedestrian tunnel, car park or utility tunnel, the viability and safety of such developments can be found out first before one goes to larger developments.

Community participation is also another significant factor. The community is supposed to be involved during the early stages of planning and decision-making. Local communities are engaged to promote ownership and limit opposition. Transparency in terms of the purpose of the project, safety standards, and projected benefits will contribute to overcoming the misperceptions and gaining the favor.

Moreover, one should take into consideration the affordability and availability of underground spaces. When underground development is only expected to serve the high income segments or even commercial businesses, it is likely to contribute towards further increase in the social

gap. Planning should be inclusive, i.e., the underground structures (e.g., markets, public transport, or recreational spaces) should be advantageous to the wide cross-section of the society.
Lastly, there should be respect of issues on culture and environmental heritage. There is a history and diversity of cultural identities in the built environment of Addis Ababa. The heritage sites must not be disturbed and the ban on building underground structures in archaeological sites or heritage buildings should be imposed. The suitable design, including the application of Ethiopian architectural styles and public art, can be used to make underground spaces more familiar to the local users and make them more appealing to them.

Table 2. Key Challenges of Underground Development in Addis Ababa

Category	Description	Impact
Geological Constraints	Volcanic soil, unstable terrain	Increases construction complexity
High Capital Costs	Expensive excavation and waterproofing	Limits private investment
Institutional Gaps	Lack of regulatory frameworks	Causes planning delays
Social Acceptance	Limited public awareness	Reduces utilization
Technical Expertise	Insufficient local capacity	Depends on foreign expertise

7. Sites: Successful Underground Urban Projects.

7.1. Helsinki's underground master scheme (Finland).

Helsinki is one of the most inspiring success stories of how underground spaces can be successfully integrated into a sustainable urban development plan. The Finnish capital had a detailed Underground Master Plan (UMP), adopted in 2011 and subsequently supplemented, that systematically maps and regulates the use of underground space throughout the city. This proposal encompasses more than 400 subterranean facilities, including car parking, shopping malls, data centres, and even sports arenas - all of which have been planned to make the best possible use of scarce surface land while leaving the city's green and open spaces intact.
The Helsinki underground development has successfully been planned, administered and its success heavily relied on thorough geological studies. The city possesses 3-dimensional cadastral system that captures the ownership, land use and geological features explaining why the planners can easily allocate underground resources. Moreover, the ground of the city of Helsinki is composed of cool climate and hard granite, which will form a great base of underground construction which will decrease the cost of long-term maintenance and increase the energy efficiency.
From an environmental point of view, the UMP enables minimizing surface congestion and urban sprawl through the possibility of multi-level urban growth. Moreover, green building is effective in fighting climate change as it offers tough space that can withstand extreme weather. Notably, the plan was created in the most transparent and socially accepted manner the citizens were consulted during the public hearings and exhibitions.
For Addis Ababa, the experience of Helsinki shows that by integrating underground infrastructure into urban master planning, cities can achieve the greatest land-use efficiency,

preserve their heritage sites, and build a climate-resilient city. The codification of underground property rights, geological mapping, and participatory planning could be game changers in urban development in the Ethiopian context.

7.2. Montreal's RESO (Canada)

The RESO Underground City or the Réseau d'Étude de la Structure d'Outre-Montreal (RESO) is one of the largest and most interconnected underground constructions in the world. Operating on over 33 kilometers of tunnels in between shopping malls, offices, hotels and the metro stations, RESO represents a union between city transport, business and climate change adjustment. The project was initially created as a solution to extreme weather circumstances in the winter of 1960s; however, it became a comprehensive underground ecosystem which is presently used by over a million people daily.

The genius of RESO is that it is multi-functional and integrated with the public transportation network. The Montreal Metro, built alongside RESO, is its backbone and allows commuters to move around the city without facing the freezing temperatures. More than that, the network also provides platforms for economic activity by housing retail, food, and entertainment outlets, as well as cultural facilities in the underground - thus proving that the underground can be a living place, where humans can be at the centre of space rather than just a conduit for utilities. Sustainably, RESO takes the burden off the surface, increases the number of people walking, and lowers the carbon footprint of the city. This is also attributed to incremental development, which is developed over several decades due to the pressure of demand and feasibility instead of a major investment at once. Addis Ababa can learn a lot about this flexibility because phased, low-risk implementation can contribute to the creation of public trust and financial sustainability.

Moreover, the model of Montreal focuses on the use of PPPs (public-private partnerships) to fund and run underground projects. A PPP regime would be a desirable method of mobilizing investment in the African cities, particularly Addis Ababa where the technical expertise required in overcoming the technical challenges associated with underground engineering was required. RESO is an outstanding example of an anthropocentric, user-friendly city planning that is also incorporated in the public transport and may be used as an example in the inclusive and climate-sensitive urban planning.

7.3. Underground Space Development in Singapore

Singapore, usually regarded as a pioneer of the three-dimensional city built, has intentionally resorted to underground building as an answer to the drastic lack of land. The Urban Redevelopment Authority (URA) provides the City-state with a multidimensional strategy of space utilisation at ground, above ground, and below ground through the City-state Underground Master Plan which will ensure efficient and sustainable land management. The Jurong Rock Caverns, the Underground Ammunition Facility, and underground pedestrian networks are some of the major projects through which Singapore has been able to strike a balance between safety, innovation, and economic efficiency in the construction underground. The Jurong Rock Cavern (JRCC) that is the first underground hydrocarbon storage facility to be built in southeast Asia is an engineering marvel, located 130 metres beneath the sea floor. Shifting hazardous storage to underground position, Singapore released the surface land, which is so valuable in the city-state, to urban and industrial growth, as well as enhanced the safety and environmental concerns. Furthermore, underground pedestrian networks, which connect

shopping malls, MRT stations, offices, and others, in the city center, also provide the last-mile links in the city, which offer energy-efficient and climate-controlled mobility solutions.
Singapore's success is supported by sound policy, research, and technology. Again through the advancement of new technologies in tunnelling, the ongoing enhancement of detailed geological mapping and the design of transparent regulatory frameworks governing rights to land underground, underground development has not only become a possibility but also an attractive opportunity. The government also actively participates in encouraging the multi-agency coordination i.e. planners, engineers and environmental experts are drawn in and coherent execution is achieved.
The case of Singapore demonstrates the relevancy of the concept of strategic foresight and governance to underground city planning, which should be highlighted with regard to the case study of the Addis Ababa case. The Ethiopian capital must look at having a multi-sectoral coordination to reduce the risk of landslides and investing in geological data infrastructure. By so doing, Addis Ababa would be able to plan and develop sustainable underground areas, such as transport stations, storage as well as business zones, with regard to long-term urban resilience goals.

7.4. Lessons to Addis Ababa and Cities of Africa.

The cases of Helsinki, Montreal and Singapore present valuable lessons to Addis Ababa and other rapidly rising urban African cities that aim at integrating underground spaces in their sustainable development plans. The lesson that we have acquired is that of thorough underground master planning. Just as Helsinki did with its subsurface assets and Singapore with a legal and technical framework, Addis Ababa also needs to start by developing a three-dimensional urban plan, supported by geological surveys and cadastral mapping.
The other conclusion realized is that of climate adaptation and resilience. Montreal and Singapore can both show that underground infrastructure will help the citizens to withstand extreme weather and minimize carbon emissions through energy-saving systems. Addis Ababa has a high rate of urbanization that usually causes congestion, informal settlements, and surface crowding; thus, underground spaces should be used to minimize the pressure on the available land and to make this city more habitable.
Addis Ababa can pursue the public-private partnership model that has proven very effective in Montreal given that there is expertise and funds in the private-sector that can be used to finance the complex engineering projects. Moreover, the inclusion of the community is the only way the people can trust and accept underground development (as in Helsinki).
Lastly, the African cities must embrace context-sensitive innovation. The geological and economic conditions in Addis Ababa demand proper solutions (in contrast to the countries of the temperate climate zone): the low-cost technology of tunnelling, adaptive construction materials and gradual scaling of the project. It is through such global precedents that Addis Ababa will be able to plan a viable and sustainable vision that will spearhead the underground urbanism in Africa to make the environment more viable, efficient, and inclusive.

8. Approaches and Suggestions for Implementing Underground Urban Development in Addis Ababa

8.1. Including Underground Urban Planning in City Master Plan.

The first and most important step in integrating underground spaces into the agenda of sustainable urban development in Addis Ababa is to incorporate underground urban planning into the city's Master Plan. Currently, the Master Plan is mainly concerned with surface land use, transportation networks, housing, and the distribution of green space. However, it ignores the huge potential of subsurface land as a spatial and economic resource.

The city is supposed to adopt a three-dimensional (3D) planning framework that considers and manages the vertical and horizontal dimensions of land use. In this manner, planners will be able to assign special uses to underground floors, as they do to surface and high-rise spaces. As an example, the parking, retail stores, and pedestrian tunnels can be stored on the first underground level, the transportation systems, metro lines, and utility tunnels can be placed on the second level, and the long-term storage, infrastructure, or even data centers can be located at the levels that are deeper.

In addition to this, the underground in the Master Plan of the city would require a comprehensive system of underground mapping. This involves the collection of geotechnical, geological and hydrological data in order to identify safe and proper sites to excavate. Upon mapping of underground conditions in the city, the construction risks would be reduced, the cost would be less and the situation would be made more understandable to the investors and the developers.

Moreover, zoning regulations should be revised to establish the rights to underground land use, the depth, and the responsibilities for developing this land. For example, for underground extensions, it may be possible to allow developments to be constructed within certain depth limits where safe conditions and environmental impacts are met. This would clarify the ownership of what and would assist in preventing any struggles over underground rights.

Lastly, the use of underground spaces in the Master Plan must be in line with the overall vision of Addis Ababa of developing compact urban spaces that are sustainable. It must follow up on the current initiatives, as well as the Addis Ababa Integrated Development Plan (IDP), and the Climate-Resilient Green Economy (CRGE) strategy. This city by institutionalizing the expectation of underground planning will make sure that all urban growth in the future will be space efficient and environmentally and economically viable.

8.2. Enhancing Institutional Coordination and Law.

Underground urban development demands institutional and legal reforms to help it succeed. On the contrary, Addis Ababa has different agencies dealing with urban infrastructure and urban construction management that have different mandates. Subsequently, fragmentation is likely to bring about inefficiency, redundancy of duties, and accountability.

To counter this, the city needs to set up an independent Underground Development Authority (UDA) or an independent department in the already existing city Planning Commission. This body would take the coordination of all the underground development activities such as development of policies, project clearance, monitoring and compliance with safety. All the investors, developers, and citizens would come to the UDA to streamline the bureaucratic procedures, and there would also be uniformity in the projects.

There should also be a strong legal system which will control land use underground. This framework should be clear in outlining the property rights of underground areas, depth of ownership, environmental, and safety regulations. It must also consist of clauses concerning

acquisition and leasing of the underground land and also dispute resolution with regard to the subsurface development.

The international case law is the most appropriate. Indicatively, the Underground Deposits Utilization Act of Japan and a similar legislation, the Underground Space Planning Regulations of Finland, have given a good guideline on the matters concerning ownership of underground land, construction safety and environmental protection. Addis Ababa can make these models localized but at the same time provide legal certainty and investor confidence.

Moreover, it is important also to have inter-agency coordination. There is a need to have diverse government institutions like the Addis Ababa City Administration, the Ministry of Urban and Infrastructure Development, and the Ethiopian Roads Authority to have one umbrella. Such a partnership will make sure that underground infrastructure projects such as transport tunnels, sewage network and utility corridors are in tandem with that of the city as a whole.

Meanwhile, institutional capacity needs to be established. Planners, engineers and policymakers can be given the technical and managerial skills to handle such projects underground through training programmes, workshops and collaborating with universities and international organizations. This development will not only see the city develop underground but also sustain it to the future generations.

Table 3. Recommended Policy and Institutional Actions

Action Area	Recommendation	Expected Outcome
Legal Framework	Develop underground land use rights legislation	Legal clarity and investor confidence
Institutional Reform	Establish Underground Development Authority (UDA)	Coordinated management
Financial Policy	Introduce tax incentives and PPP frameworks	Increased investment
Urban Planning	Integrate subsurface mapping in Master Plan	Informed spatial development
Capacity Building	Train local engineers and planners	Enhanced technical expertise

8.3. Applications of Technology and Innovation.

The success of a development underground in the city is centered on technology and innovation. To achieve move forward on the same, Addis Ababa might be required to implement modern technologies in areas of planning, construction, monitoring, and management. The innovations are not only efficient, safe and minimizing in cost and environmental impact of construction.

Two tools that can transform the planning of the underground are BIM and GIS. BIM can be used to visualize underground buildings in 3D and allow the designers to simulate spatial relations and recognize the possible conflicts before the construction is underway. GIS technology on the other hand takes geological, hydrological, and infrastructure data and makes them available on one platform to enable informed decision-making and risk evaluation.

Technologies, which have been applied in the field of construction, include Tunnel Boring Machines (TBMs), ground-penetrating radar, and smart sensor systems, which will help to enhance precision, decrease excavation time, and increase safety. An example of this is to construct large underground structures in complex geological settings in cities like Singapore and Seoul using TBMs. Such technologies would also mean investing in Addis Ababa, but would significantly increase the speed of projects.

Also, sustainable construction practice should be emphasized. Environmental impact of underground projects can be minimized by the use of environmentally friendly materials, recycling of excavation wastes, energy saving ventilation and lighting systems. Besides recycling air, new cooling technologies can be used to minimize energy expenditure in underground areas based on the use of geothermal power and natural air circulation.

Digital innovation can also be applied to support underground operation and administration. IoT sensors can be used to monitor the air quality, humidity, and structural stability in real-time and contribute to keeping users safe and minimizing the maintenance costs.

Lastly, local start-ups, universities, and international technology partners should be able to work together to create a strong innovation ecosystem. The growing technological community in Addis Ababa (which is concentrated in localities, like Kazanchis and Bole) can be central to the design and execution of digital solutions to underground urbanization.

Through embracing technological improvements, Addis Ababa will be able to become a key participant in the sustainable development of cities, both underground and on the surface.

8.4. Providing a Push to Public-Private Partnerships (PPPs) and Financing Models.

Due to the high capital cost of underground projects, it is time that Addis Ababa should consider new forms of financing, particularly the Public-Private Partnerships (PPP). PPPs also allow the state to collaborate with the private investors in distributing risks, expenses and benefits in the construction of the major infrastructure works.

An example can be to have the government supporting it with land rights and regulation issues, and the investors on the ground will provide the financing, design, and construction experience. User fees, leases or management contracts would in turn be revenue to the private partners. This simulation has been successfully applied to cities such as Hong Kong and Dubai for the construction of underground transport systems and business centres.

The City Government of Addis Ababa can set up an Underground Infrastructure Investment Fund which will be appealing to both the domestic and foreign investors. This fund is capable of being used to lend, grant and co-finance strategic projects such as underground parking systems, metro lines and utility tunnels. Aid in the form of facilitating feasibility studies and starting capital investments could also be done with the help of development banks like the African Development Bank (AfDB) and the World bank.

Additional incentives, such as tax incentives, low-interest loans, and land concessions can also be used to encourage participation of the private participants. A clear legal and financial system of PPPs is also an important factor to attract investors and accountability.

In addition, value-capture mechanisms can make the underground projects financially sustainable. When underground projects enhance the values of the lands above ground, i.e. whereby a new metro station will raise property prices in the vicinity; the city can tax or levy development taxes on the value added. This money can be re-invested in more underground infrastructure and this will result in a self-sustaining financial cycle.

To be effective, PPPs need a proper financial management and governance. By implementing accountability, equitable distribution of risks, and effective project delivery, Addis Ababa will be in a position to gain investor confidence and expedite her path to an integrated underground city in the 21st century.

8.5. Participation in Community Building and Communication.

Underground infrastructure building requires the collaboration and involvement of the people. However good or bad may be the technical merits of the projects, without acceptance by the community they could be opposed or not utilized. Hence, Addis Ababa must not disregard the people, education and involvement in every level of underground development.

The awareness should be conducted to highlight the tangible advantages of underground urbanization, which include curbing the congestion, building better public spaces, and the better adaptation to climate change. It is possible to demonstrate to residents how underground space can add to their quality of life with the help of graphic models, simulations, and pilot projects to illustrate it.

Moreover, participatory planning processes also have to be institutionalized. This would involve using community representatives, civil society organizations as well as local community associations in consultations and decision making. Their contribution can make underground projects reflect the local needs and values as well as make the citizens feel like they own the project.

Transformation can also come from education. Universities and schools have the option of adopting a curriculum that concentrates on the science and design of underground spaces and educating the population of the future of urban planners and engineers.

It is also very crucial that one is culturally sensitive. The architecture of the underground areas must be based on the identity of Ethiopians and incorporate the materials, colors, and forms of art found locally. Such developments can be made more relatable and appealing by developing underground cultural areas, such as galleries, group art installations, common spaces, etc. through which one can experience belonging and cultural understanding.

9. Conclusion

The need to incorporate underground urban spaces in the sustainable development plan of Addis Ababa is also a challenge and an opportunity. With the city expanding at an alarming rate, land space is becoming limited, the infrastructure is overloaded and the strain on the environment is increasing. In this regard, underground development provides a strong solution: new space of transportation, infrastructure, commerce and recreation.

The implementation of this vision however needs a paradigm shift in the way the city looks at urban planning. It entails a transition of two-dimensional thinking, as opposed to three-dimensional thinking in which the sub-surface is no longer viewed as a hidden emptiness, but as a resource of value and strategy. It will need technical innovation, effective policy structures, institutional coordination and above all the trust of the people.

Addis Ababa can observe the best practices of the city of the world and implement them to local conditions; in case it does, Addis Ababa can become an innovative example of the underground urbanization in Africa. The town is about to experience a new wave of urban frontier- one where development is not only northwards and outwards but also southwards

towards a new future which is not only spatially efficient, environmentally healthy and socially inclusive..

Suppose the city of Addis Ababa can adopt this vision. In that case, it is possible to turn its challenges into opportunities and develop a modern, resilient city that would flourish above and below ground.

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