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SUSTAINABLE DEVELOPMENT OF UNDERGROUND URBAN SPACES: LESSONS FOR ADDIS ABABA FROM GLOBAL BEST PRACTICES

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Abstract
The need to find sustainable solutions to the congestion of cities, the lack of land, and the environmental issues is gaining momentum as cities are becoming larger and larger around the world. The Underground Urban Development is an option that has proven viable, enabling the cities to utilize the space more efficiently, enhance mobility and resilience, and reserves the upper land to housing, green spaces and cultural activities. This article discusses the concept of sustainable underground urbanization in Addis Ababa through the lens of global best practices (cities such as Tokyo, Helsinki, Montreal, Singapore and Beijing), and understanding of relevance to the practice to Addis Ababa. The case studies illustrate how underground infrastructure can play a role in efficient land use, energy savings, climate change adaptation and improvement of the quality of life.
With rapidly growing population, increasing congestion and pressures on the environment, underground development can help offer a paradigm shift in the urban strategy of Addis Ababa. Although there is one obstacle, including the increased cost of construction, technical risks and the implementation of different cultures and life styles is a challenge, the opportunities of creating new jobs, advancing economic growth, and introducing smart cities, underground spaces are part of the future planning. With a well-understood governance structure in place, a master plan, pilot projects, Addis Ababa can enjoy a robust organizational future in regards to sustainable, inclusive and resilient urbanization. This paper finds that underground urbanization applied under the guidance of the best practices in the world and depending on the local conditions can make Addis Ababa become a pioneer in the new and sustainable urban development in the African continent.
Keywords: Sustainable urban development**;** Underground infrastructure**;** Addis Ababa urban planning**;** Smart city integration**;** Climate resilience**;** Global best practices

1. Introduction

The growth of cities is one of the most significant problems in the world, and how to grow without depleting the limited resources of the world. Sustainable urban development is thus not a buzzword or key to survival and prosperity of modern cities. For a fast growing city such as Addis Ababa, which is growing in population and infrastructure, the choices taken today will have a great impact on the quality of life of millions of its citizens in the coming decades. The thought of taking a look underneath the hood is a great idea on how to balance growth and sustainability. Subterranean urban space has become a promising solution to the problems of

congestion, pollution and land scarcity, and has the potential to be at the forefront of change in the urban future of Addis Ababa.

1.1. Need for Sustainable Urban Development

Sustainable urban development refers to the idea of developing the cities in a manner that fulfills the needs of the current generation without undermining the future generation to fulfill their requirements. This incorporates the prudent use of resources such as land, water and energy and safeguarding the environment and enhancing social well being. This especially applies to urban cities that have the tendency to develop at rapid pace: in case the growth of urbanization is not appropriately planned, it is likely to be accompanied by congestion, informal settlements, traffic problems, and air quality deterioration.

A sustainable city is a small healthy economically viable city which is less environmentally-intensive. As the increasing and constant demand in housing, transportation and green spaces, Addis Ababa is in dire need of establishing an exemplar of development that can strike a balance between the requirements of present day development and future requirements. Underground development offers an alternative to surface land development that does not harm important environmental and cultural values. Rather, it is a complement to above-ground development which enhances it and makes the city more balanced and resilient.

1.2. Increased demand of space in the fast developing cities.

One of the 21st -century trends is urbanization. Each week millions of citizens of the world go to the city in pursuit of an improved opportunity. The United Nations suggests that by 2050, the population of the world would be nearly 70 percent urban. With this population increase comes massive requirements for land, infrastructure and services. In a city, where there is shortage of land or expensive land required to build a house, it has been found that the pressure often translates into vertical development resulting in high-rise buildings. However, most functions cannot or should not be placed on the surface.

Likewise, underground car parks, utilities, road and transport systems, shopping malls can function well in the subsurface. In this way, quality surface space is available for housing, green space and community space. Cities as different as Tokyo, Helsinki and Montreal have already shown how this can be achieved by moving key facilities underground. In a city with a rapidly expanding population like Addis Ababa, where there are serious constraints of land and congestion, underground development may offer the remedy.

1.3. Why the Underground Urban Space is of Importance

Underground development is not a new concept but its relevance has grown as cities are facing increasing sustainability challenges. Underground urban environments are significant due to a number of things:

Land Efficiency - Because of the underground infrastructure's compact size, cities can use their precious surface areas for living, farming, and leisure instead of roads, parking lots, etc.

Environmental Protection - Underground facilities help to reduce urban sprawl, conserve natural ecosystems and contribute to mitigation of climate change through increased levels of energy efficiency.

Improved Quality of Life - The cities have all improved their congestion, air quality and urban design, making the cities healthier and better places to live.

Safety and Resilience - Underground facilities can be used to provide a safe refuge during an emergency, and also, they can be used to protect critical infrastructure from the dangers of the environment.
In other words, underground development in Addis Ababa is not just a means of providing solutions for the congestion of today; it is a means of attempting to design a future with even less land available to build on, even more climate pressures, and even larger populations to build for. By also analyzing best practice worldwide and appropriate adaptation to the local situation, the city will be able to create an innovative growth model based on environmental sustainability and adapted to local needs.

2. Exploring Underground Urban Spaces.

2.1. Meaning and Definition of Underground Urbanization

Underground urbanization: refers to the planned and systematic use of the underground environment. It is the construction of infrastructures, services, and even living spaces underground as part of the general planning strategy of a city. As opposed to normal basements or single tunnels, underground urban spaces are made as integrated parts of the city; that is, they are a functional extension of the town. They can include transportation networks such as subways and underground highways, commercial spaces like malls and restaurants, storage facilities for energy and water, pedestrian paths, and, in some cases, even living and recreational spaces. The scope of underground urbanization is thus tremendous, and includes everything from small-scale utility networks to large-scale underground cities.
It is no longer simply a matter of sinking when it is convenient to do so; instead, the underground is to be used strategically. Just as land on the surface is carefully planned for housing, business, and agriculture, so too the underground must be mapped, allocated, and regulated for different purposes. This not only renders the underground urbanisation not only an engineering issue, but also a planning and a governance issue.

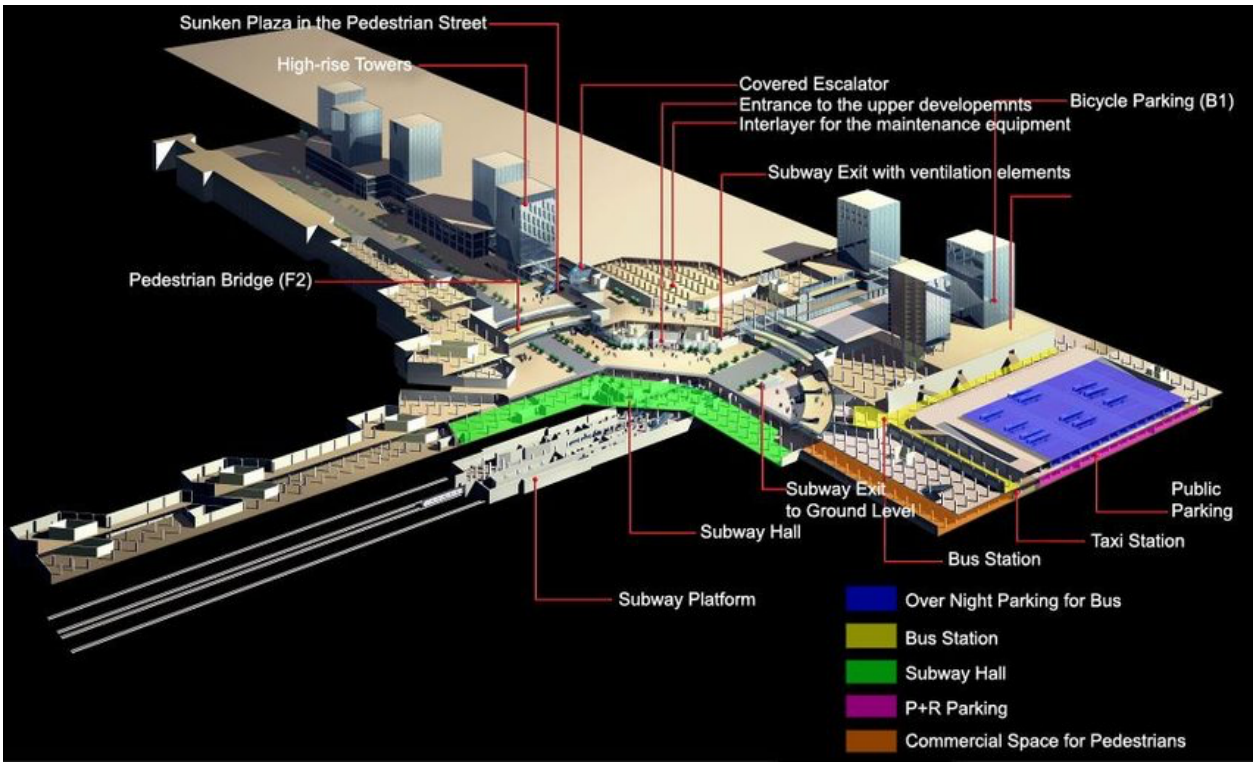

Figure 1. Underground complexes in Beijing city

2.2. Historical Background and Early examples.

Although such a term as underground urbanization can seem modern, the idea is several thousands of years old. As we are aware, underground environments have been used since time immemorial as a source of shelter, security and storing resources. One of the oldest and most famous of the past is the underground cities of Cappadocia in Turkey which they carved out of the soft volcanic rock. These were multi-level settlements where thousands of individuals used to live with living quarters, ventilation systems and places of worship. In communities of other regions, like ancient Rome, and underground tunnels in Paris and the catacombs, were constructed to both move buried and to move secretly within cities.

During the Cold war in China, Beijing had constructed a complete underground city to house millions of people in case there was an attack. Similarly speaking, the underground bunkhouses and shelters built during the World War II contributed to a high degree of safety of the civilian population on the European continent. With these illustrations, it can be said that underground spaces have been in use since time immemorial, as a means of survival and protection. Nevertheless, they were not the part of the daily economic and social life of a city as it is in the present time.

2.3. Modern Trends in underground infrastructure

The underground development has grown to be more than an emergency use to a mainstream approach of urban planning in the new age. In places like Tokyo, the cities have built large underground shopping malls connected to the metro stations, which render underground living a way of life to them. Montreal has developed the well known Underground City - a 33km system of shopping centers, offices and residential blocks located under the downtown center. The city of Helsinki is special in that it has a formal Underground Master Plan which illustrates what will be included in all its parts of the underground; utilities, parking, sports arenas, and even cultural spaces.

These developments are driven by the technological advancements in tunneling machines, ways of building the tunnels, and safety mechanisms. There are also underground spaces which today can be fitted with light simulators, the complex ventilation systems, and climate control in order to be as comfortable as those in the above-ground facilities. Cities are no longer restrained by the conventional engineering dilemmas; rather, they are trying to enter the underground spaces through their endeavors to attain sustainability.

2.4. Important Values: Space Optimisation, Sustainability, Integration

The success of underground urban development is based on three principles. The first is space maximization. With the increasing restriction on the availability and cost of land, underground construction enables cities to relocate non-essential surface uses, such as parking areas, utility corridors, and, in some cases, major commercial areas, below ground level. This allows for surface land to be used for housing, parks, and public facilities.

The second principle is sustainability. The insulation of underground spaces is naturally a low level and therefore, it implies that heating and cooling are not required. They also assist in reducing urban sprawl thus enabling conservation of agricultural lands and natural ecosystem around cities. Together with intelligent technology and energy sources, underground infrastructure may dramatically decrease the environmental footprint of a city.

The third principle is integration. Underground development cannot be regarded as an individual entity with regard to the city above, but as an entity. Subway stations, foot paths, and shopping centers must be close to the overground facilities. Effective integration ensures that there is convenience, safety and effectiveness to the residents of the city.

These principles put together create a formidable instrument in the creation of strong and habitable underground cities. In such a location as Addis Ababa, where rising urban dissatisfaction, land pressure, and other challenges are causing ground-based development to be a significant alternative, these foundations are important before the large-scale development can be pursued.

3. Urban Underground Space is needed in Addis Ababa.

The capital city of Ethiopia is Addis Ababa which is a fast growing urban city. The city has a very huge population of about six million people and is expected to continue growing by the next few decades, the city poses an enormous burden to accommodate even more people, companies, and infrastructures. Similar to most other rapidly developing African cities, Addis Ababa deals with a lack of land, housing, traffic jams and environmental destruction. In a bid to come up with sustainable future of the city, the planners and policymakers should address the issue of alternative solutions to traditional surface growth. The greatest opportunity is strategic development of the underground space of the city.

3.1. Problems of Urbanization and Population Growth.

Addis Ababa is one of the most urbanized African areas. Each year, tens of thousands of the population leave the countryside to move to the capital in search of a better job, education, and healthcare. This constant inflow exerts enormous burden on housing, transport and government services. This has resulted in the increase of these informal settlements with significantly no infrastructure such as sewage power and provision of water. The city has a chance to end this cycle with the new solutions, when the development results in the growth of congestion, poverty, and lowering the quality of life.

The city underneath can offer an avenue of relieving this pressure. The town may then reclaim surface land that is of value to it in terms of housing and other necessities by moving part of its functions underground e.g. transport hubs, shopping malls or utility corridors. This way, underground building could become an escape valve to the surging city population.

3.2. Housing Demand and Supply of land.

There is already a lack of land to expand in Addis Ababa. The surrounding land areas are mainly agricultural and this is essential in the food security of the country. Scouting off implies the loss of arable land and causing of communities to be displaced and this is not sustainable as well as socially just. The rising housing requirements also shoot up the price of land thus making it more and more harder to afford a home by low-income families.

Subterranean spaces are another way out. Addis Ababa may grow up and down as opposed to horizontally. The parking garages, storage rooms, and shopping malls could be built beneath the ground, thus minimizing the competition of the limited space on the surface. All this would free up space for residential buildings, greenery, and essential above-ground infrastructural needs.

3.3. Traffic jam and pollution

Traffic congestion is one of the most prominent metropolitan problems in Addis Ababa. The city has a low road capacity and with the rising cases of personal vehicles on the road, the city has been experiencing congestion and gridlock every day, wasting time and lowering productivity and causing air pollution. Despite the support provided by light rail system, this is not enough to cater to the demands of an expanding city.

This could be of critical importance with regards to underground solutions. The construction of additional underground metro systems, pedestrian tunnels or underground parking of facilities would put less burden on the surface road infrastructure. It would ease the traffic as well as lower the vehicle emission, making the area a safer and safer place to live.

3.4. Reducing Green Spaces and Environmental Problems.

The city is growing very fast and green spaces are being lost at rapid rates. Development of cities usually takes the form of urban forests, parks, and open recreational facilities being the initial victims. However, such spaces are important in terms of preserving the ecological equilibrium, decreasing air pollution, and providing social and recreational value to people who use them.

Addis Ababa will conserve the small green cover by putting infrastructure underground. To cite an example, when the city wants to construct a parking lot or an office building, and the only land available is to do landscaping, why not construct this underground and the remaining surface areas should be left to be used by the community as the green area instead of paving over the parks to make way to such new constructions? This approach will be in line with the global Sustainable Development Goals and will increase the livability of the city.

3.5. Potential of the Underground Solutions to Addis Ababa.

In the case of Addis Ababa, underground development is no longer a fantasy in the future, but it is a real necessity. The issues of overpopulation, lack of land, congestion and the environmental stress are not the issues of superficial development. Using underground solutions, the city may become more balanced in terms of its urban space with houses, green spaces, and social well-being as its center of interest, making the city also address the economic and infrastructural needs.

Using the best practice examples the world over, Addis Ababa can develop a new model of urbanization in Africa which transcends the model of traditional growth and exploits the latent potential lying under the ground. When well incorporated in the planning of the city, the underground spaces contribute in making Addis Ababa a forward-looking and sustainable city instead of an overstretched and congested city.

4. Best Practices of Underground Urban Development around the World

The cities in the world have resorted to the deployment of underground urban development as a solution to the problem of land scarcity, human population, and sustainable living. Although the issues are specific to each city, some cities have been the first to think of underground spaces as a form of integrated development strategy. Having some knowledge about their practices, Addis Ababa will be able to seek available solutions and modify them according to the local environment.

4.1. Tokyo, Japan - Malls and Transport Hubs

Tokyo is a city where there is never enough space. With a population of more than 37 million in its metropolitan area, the city has been compelled to innovate. One of its most effective strategies has been the construction of massive underground complexes adjacent to train stations. Such places are not only subways, but shopping malls, restaurants and entertainment areas. An example is the Shinjuku and Shibuya area which hosts one of the busiest transport infrastructure in the world with under the area being occupied by huge underground shopping malls which receive millions of people every day.

What makes the underground development of Tokyo so unique is how easily it blends in. A commuter can get in by train, do his shopping, eat, and even walk several blocks without ever coming to the surface. The result of this is less congestion on the roads, safeguarding of individuals against the extreme weather conditions and the maximum use of the land.

4.2. Helsinki, Finland: Underground master plan.

Helsinki has been systematic in doing underground projects unlike other cities which do them project by project basis. The town has come up with Underground Master Plan, which clearly shows the use of underground space in the long run. This also encompasses transportation and parking not only, but also the sports arenas, utility tunnels, and emergency shelters.

The underground swimming hall and ice hockey arena are also among the greatest accomplishments by Helsinki, cut out of solid rock. These buildings are nature friendly and energy efficient, they are naturally insulated and linked to the larger city infrastructure. With a well-planned structure, the city of Helsinki is successful in avoiding the conflict of various underground applications and in making sure that the city develops in a systematic and sustainable way.

4.3. Montreal, Canada - The Underground City.

Montreal has a good reputation with the RÉSO (La Ville Souterraine), also referred to as the Underground City. It covers 33km below the downtown area and links shopping centers, offices, hotels and residential complexes. It is also one of the largest underground pedestrian networks in the world. It is a very important aspect of the normal life of the city especially at the harsh winters in Canada.

The case of Montreal shows that the underground infrastructure may also promote economic activity. The retail business is advantaged by the year-round availability of customers whereas

the residents have easy access to services without the worry of snow, rain or the extreme cold weather. Though the climate conditions of the city of Addis Ababa are different, the city of Montreal has something to teach the city of Addis Ababa concerning the success in using underground networks as a means of transportation and as a source of economy.

4.4. Singapore - Scarcity and Resiliency Planning.

Singapore is among the least land-bound nations in the globe. To make the most out of space, the government created an Underground Master Plan that extends beyond transportation. It encompasses underground science parks, oil depots, and even underground living quarters. With the transfer of such functions to the underground, the country of Singapore manages to get more surface to house and green space.

The strategy of Singapore is particularly applicable to Addis Ababa since it focuses on the necessity of long-term planning and innovation. The city-state applies the advanced 3D digital mapping to control its underground areas and develop them in the future. It is also a mixture of underground infrastructure and smart city infrastructure, in which the infrastructure is secure, effective, and resistant to climate hazards.

4.5. Beijing, China- Metro Networks and Underground Housing.

Other cities that have resorted to the underground in efforts to accommodate the boom are Beijing. It has one of the largest metro networks in the world which is served by millions of people daily. Besides transport, Beijing has been trying out underground accommodation which poses the issue of safety and living conditions.

The lesson from Beijing is all about the scale and ambition. The city has illustrated how efficient underground transport systems can be in alleviating the traffic jam on the roads and enhancing movement in a city of more than 20 million. As an example, Addis Ababa has already light rail system that can be developed further through underground means.

Table 1. Comparison of Global Best Practices in Underground Development

City	Key Features of Underground Development	Benefits for the City	Lessons for Addis Ababa
Tokyo	Underground malls & transport hubs	Reduces congestion, integrates shopping & transit	Build transit-linked underground commercial centers
Helsinki	Underground master plan (utilities, arenas, parking)	Organized growth, resilience	Develop a coordinated underground master plan
Montreal	RÉSO underground city (33 km network)	Winter mobility, economic growth	Use underground networks for commerce & tourism
Singapore	Underground science parks, energy storage	Land efficiency, climate resilience	Use underground space for utilities & research
Beijing	Metro networks, underground housing	Massive commuter capacity	Expand Addis rail network underground

4.6. Major Lessons to be learned by Addis Ababa

The examples of Tokyo, Helsinki, Montreal, Singapore, and Beijing in the world have a few valuable lessons. First, underground development must be viewed as part of a long-term vision, rather than a short-term solution. Second, there must be integration - underground infrastructure needs to be harmonized with the other transport infrastructure on the surface (housing and commercial infrastructure). Third, all the projects should be guided by sustainability and resilience, which means that underground spaces should allow adjusting to climate changes and saving energy.

In the case of Addis Ababa, the above lessons may entail the development of underground shopping complexes linked to light rail stations, introduction of underground parking as one of the solutions to ease congestion, and a master plan on how the underground spaces are to be used within the next 20 to 30 years. With experience of other cities in the world and adjusting its strategy to its needs, Addis Ababa can afford to make large steps in developing a sustainable, habitable and progressive city.

Table 2. Potential Underground Development Sites in Addis Ababa

Proposed Location	Potential Underground Use	Justification	Expected Impact
Meskel Square	Underground parking, commercial center	Congested hub, central location	Reduced surface congestion
Piassa District	Cultural market, pedestrian tunnels	Historic area with tourism potential	Economic revitalization
Mexico Square	Metro station expansion	High commuter density	Improved mobility
Bole Road Corridor	Utility tunnels, service conduits	Infrastructure strain due to development	Efficient urban services
Addis Ababa Stadium Area	Event facilities, transport hub	Frequent large gatherings	Increased safety and accessibility

5. Underground Urban Development and its Environmental and Social Benefits

The creation of the underground urban spaces does not concern solely the creation of additional space to accommodate infrastructure, but is also an establishment of healthier, greener, and livable cities. In the case of such a city as Addis Ababa where excessive development has already resulted in overcrowding, disappearance of green areas and more pollution, the environmental and social outcomes of underground development would be life-transforming. The resettlement of a portion of the urban activity of the city underground will enable the city to guarantee the safeguarding of the natural environment of the city, improve the life quality of people living there, and gain sustainability to confront future issues, including climate changes.

5.1. Optimal Land Utilization and Reducing Urban Runaway

Another major problem of concern that is looming in Addis Ababa is the emergence of informal settlements and urban sprawl. The housing demands as a result of an increase in population into the city are seen to push the urban areas to the agricultural land and natural habitats. This uncontrolled growth is unsustainable and this results in the loss of the food producing areas

and overstretching the urban infrastructure. In order to counter this, underground development assists in the development of cities vertically, and not horizontally.
With the relocation of infrastructure such as transport facilities, car parking garages, and utility systems, underground, the city of Addis Ababa will have the potential to keep the ground-level real estate to house, farm and provide social services which are in high demand. By so doing, it is a planned and systematic way of growing as opposed to being unintentional and accidental. It also reduces the conflicts associated with land utilization since underground space can be used specifically as utilities, commerce or transportation and it will not compete with the residential or environmental demands.

5.2. Conserving Green areas and Ecosystems

Green spaces play a crucial role in the health of any urban area as they are used not only as recreational facilities but also as a natural component that helps to maintain air quality, stormwater, and cool the city. It is a shame that, due to the ever-increasing size of Addis Ababa, most of its few parks and open spaces are already at risk of being turned into a road, a building or a house. Underground development provides one way for this to free up surface land for green spaces instead of using it.
An example of this is, in case the parking facilities or the shopping complexes were moved underground, the large spaces would be turned into parks or community gardens. This would not only be more aesthetically pleasing to the city but also enhance the physical as well as mental health of people living there. Ecosystems protection is also an important aspect of the city that ensures the biodiversity and environmental stability despite the climate pressures.

5.3. Conservation of Energy and Response to Climate Change.

Climate change already has a serious effect on the cities around the world and Addis Ababa is not an exemption. The major issues are the increase in temperature, unreliable rainfall and floods. Subsurface infrastructure can be an important factor in improving climatic resilience. The insulating nature of the underground facilities means that these buildings do not need a lot of energy to be able to maintain a comfortable temperature and therefore operate at a lower energy consumption than the older surface-level buildings.
In addition, the underground storm water management systems would be able to enable cities to survive the heavy rainfall and thereby prevent flooding. This is particularly critical to the Addis Ababa which is characterized by seasonally flooding areas. Thus, underground infrastructure can be climate-proofed, which could reduce risks and energy expenses.

5.4. Better Quality of Life among Urban Dwellers.

Along with positive environmental effects, underground development may contribute greatly to the everyday life of urban residents. A capital city to which the traffic jams are solved by parking the cars under the earth, where the shopping malls are linked directly to the light rails stations located beneath the earth, and where the family members spend more time in the parks than engaging in the battle to get the space on the overcrowded roads. It is not an illusion but a reality that has been attained in cities like Tokyo and Montreal.
Underground development facilitates the creation of healthier living conditions by aiding in the enhancement of air quality, decreasing of noise, and the green space. It also improves mobility, making it easier for residents to get around and engage in activities such as playing, shopping, or socializing without wasting hours stuck in traffic. These improvements combine

to create stronger social cohesion as people spend more time together in community-friendly spaces than in isolated areas within congested environments.

5.5. Building a Stronger City for the future

The benefits of underground city growth are not restricted to the time. In the case of Addis Ababa that is expected to keep growing at a tremendous pace, the underground solution is a future investment. The city can be able to secure long term sustainability by addressing the issue of congestion, land use and pollution issues, and also planning future problems like climate change and population explosion.

In brief, the underground development is not only technical solution, but also social and environmental strategy. It gives Addis Ababa a chance to make a bigger but more green, healthier and more resilient city, a city where growth does not compromise livability.

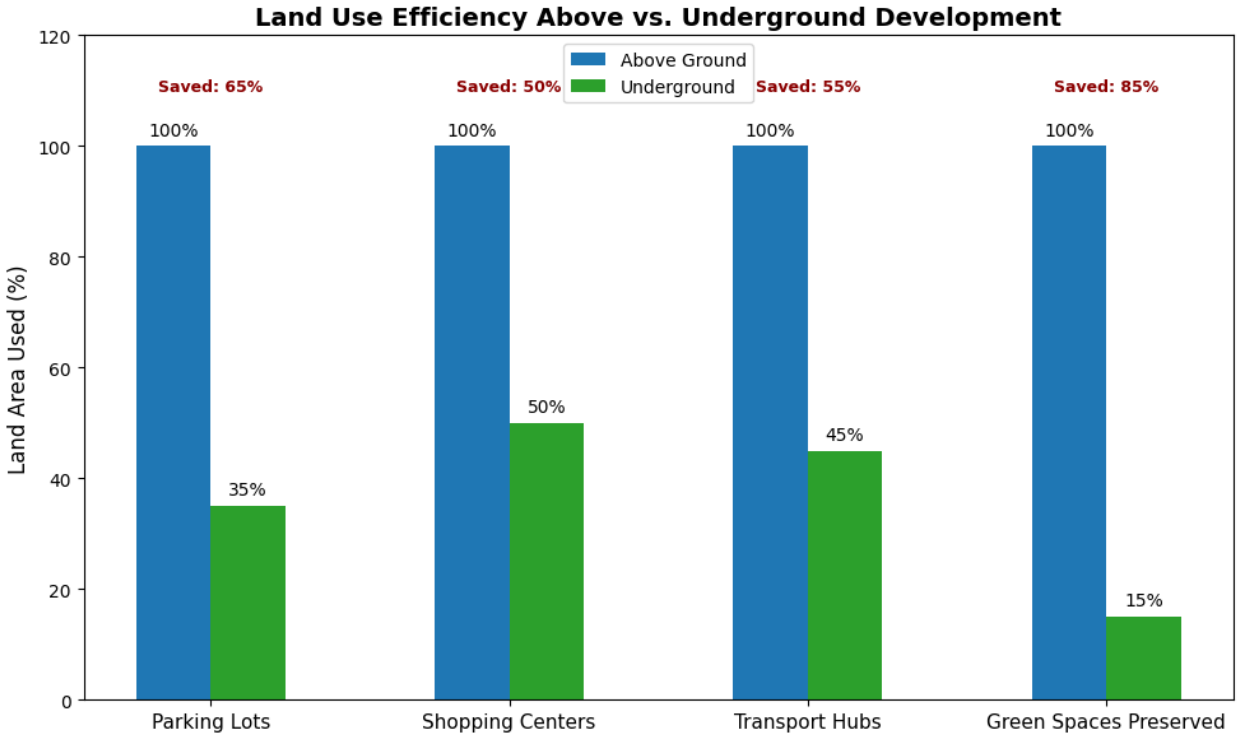

Chart 1. Land Use Efficiency Above vs. Underground Development

6. Economic Opportunities of Underground Urbanization.

The environmental and social benefits of underground urban development are a popular topic, although its economic potential should also be mentioned. In the case of Addis Ababa, the political capital of Ethiopia, as well as its economic and cultural hub, sub-ground areas might be considered the effective drivers of economic development. The underground infrastructure will be able to provide new employment, enhance real estate possibilities, boost tourism, and enhance the financial stability of the city in the long term with the help of strategic planning.

One of the short term economic benefits of underground development is job creation. Underground constructions require professional workforce, such as engineers, architects, construction workers, and employees doing maintenance. Major construction projects, particularly underground ones, also provide a chance to educate the locals in new tunneling and a construction methods, which could then be exported to other African cities. This

knowledge transfer is advantageous to not only Addis Ababa but also causes Ethiopia to become an innovation hub in underground construction within the region.

Other areas that are bound to benefit are real estate and commercial development. With dwindling and costlier surface land in Addis Ababa, the developers have an increasing challenge to create cheap and lucrative projects. The new dimension in the real estate market is underground urbanization. The construction of shopping centers, offices, entertainment facilities, and parking lots underground will contribute to the increase in the value of the surrounding land and will enable the release of the surface area to be used as a housing facility or as green areas. To developers, it is a higher payoff in terms of returns on investments, whereas to the city it is efficiency in land use.

Another major economic opportunity is from tourism. Underground attractions have been converted into special tourist attractions around the globe. The underground city of Montreal, in its turn, receives millions of visitors annually, and the underground arenas of Helsinki, as well as the underground complexes of Singapore, are attractions throughout the world. Addis Ababa, already a significant African conference and tourist cultural destination, can also improve the attractions by building the modern underground attractions, like museums, art galleries, or cultural centres, which would provide visitors with a unique experience.

Finally, underground development helps to achieve economic stability in the long-term. Cities with only superficial infrastructure are susceptible to disturbances brought about by the increase in population, climatic change or natural calamities. Addis Ababa is able to reduce these threats by ensuring that it develops infrastructure in a more balanced way and in different locations. For example, underground transport hubs could keep the city running even if it floods or is congested by a massive amount of surface traffic. Likewise, underground utility corridors can provide a more reliable supply of electricity, water, and internet services, which are essential factors for economic stability in this digital era.

Regarding it as an investment, as opposed to a cost, underground urbanization is one way of creating short-term and long-term economic positive impacts to Addis Ababa. It has the ability to drive growth, create employment and make the city an innovator in the innovative city planning in Africa.

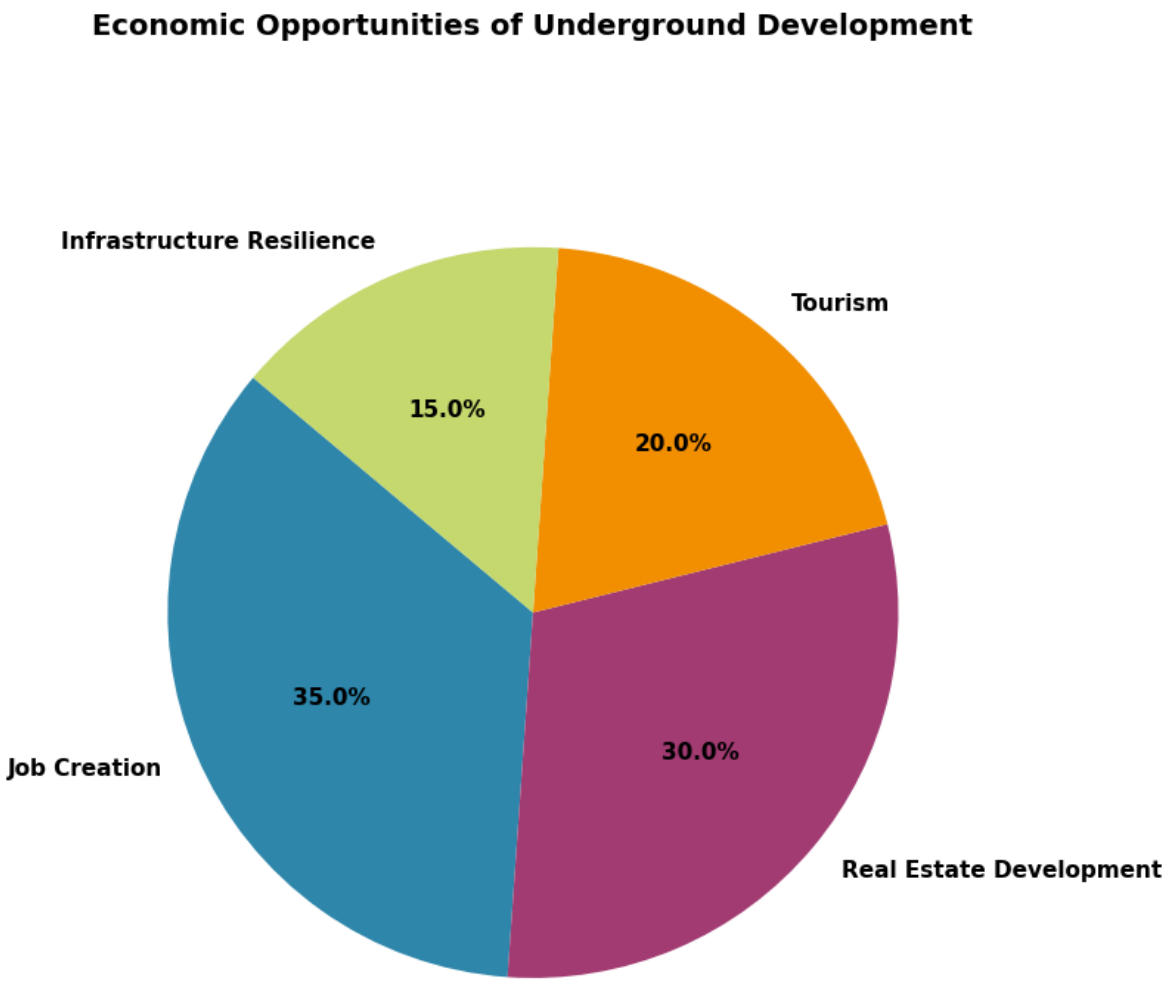

Chart 2. Economic Opportunities of Underground Development

7. Development of underground driven by technological Innovations

New underground urbanization would be impossible without significant technological progress. In recent decades, the development of tunneling, engineering, and digital systems has seen construction underground become a more precise and efficient practice than it has ever been before. Addis Ababa must embrace these technologies in order to facilitate underground development to occur hence making this development successful.

Technology in excavation and tunneling has been one of the greatest innovations. The techniques were tedious, time-consuming and accident prone. Tunnel Boring Machines (TBMs) may nowadays drill through rock and soil at incomparable speed and precision. These machines save time in construction and also need minimal disturbances in the surface thus underground systems can be constructed under the thick urban areas without interfering with the urban life.

The enhancement of ventilation, lights and climatic control is also significant. The air circulation and lighting of underground spaces should be properly managed so as to make them safe and convenient to users. The newer models are fitted with energy-efficient LED lights, light simulated by solar energy, and intelligent ventilation that regulates the flow of air according to real-time information. Such innovations allow achieving an equally habitable

environment in the underground as in the above one, as well as to consume less energy in the process.

The use of digital mapping and 3D modelling has also led to a revolution in underground development. Some cities like Singapore have also invested in sophisticated underground master plans, which are supported by digital twins - virtual models of underground infrastructure, which enable planners to visualise the use of spaces. Other systems in the same fashion within the city of Addis Ababa will contribute towards avoiding land use conflicts, easing the construction process, and improving long-term planning and building.

The adoption of smart city technologies, including the Internet of Things (IoT), Artificial Intelligence (AI), sensor-based systems, is the most exciting one. These technologies are able to track facilities in the underground in real time, air quality, stability, and potential dangers. They are also able to increase user experiences, e.g. directing the pedestrians via underground routes or help the drivers find parking spots via the mobile applications.

In the case of Addis Ababa, these technologies cannot be invested in, but need to be. In their absence the underground development can be risked to developing inefficiently or facing safety issues. Nevertheless, the city could overcome the conventional hurdles with the help of appropriate tools and pursue the most modern solutions that guarantee durability, safety, and reliability in the long term. Through innovation, the city of Addis Ababa can be able to brand itself as a contemporary African capital that will incorporate technology at the core of its city future.

8. Problems of Underground Urban Planning

On the one hand, the enormous advantages of underground urbanization exist; however, this is not an issue without problems. In the case of Addis Ababa, identification and anticipation of such issues will be as significant as exploitation of the opportunities. Unplanned underground development is a liability financially, technically or socially and not a solution.

Among the most obvious issues, there is high cost of construction. Underground construction is costly in a sense that it involves special machineries, skilled labor as well as sophisticated technologies and all these are quite costly to use in the first place. Also, it is difficult to start a massive underground project, with the financing sources usually not easily accessible in developing nations. These projects would need innovative financing mechanisms, including public-private partnerships (PPPs) and international development loans to make it work in Addis Ababa.

The other high barriers are technical and engineering challenges. Topography, soil conditions and seismic activity of a place have to be properly explored before any underground construction can be started in Addis Ababa. Projects are also at risk of having to deal with dangerous conditions without carrying out proper geological studies, like unstable soil, flood risks and collapsing of the ground.

Safety and security are other important factors. The spaces underground should have high fire protection and emergency exit and disaster management facilities. E evacuation is more complex on the ground-level in case of natural disasters or accidents. Underground infrastructure safety and effective communication is therefore a precondition to develop the trust of the people to the underground infrastructure.

Last, cultural acceptance is a field that is easily left out. Individuals in most societies might not be at ease spending long durations of their lives at the underground locations either as their homes or recreational places. Much of Addis Ababa lacks underground residents so the first reaction could be suspicious of public perception. The eventual goal is to develop underground spaces, but this can be addressed by creating awareness campaigns and gradually introducing the spaces—starting with transport hubs and commercial centers—that would familiarize people with the concept.

Table 3. Challenges and Mitigation Strategies

Challenge	Impact	Mitigation Strategy
High construction cost	Limits large projects	Public-private partnerships, phased development
Technical difficulties	Risk of flooding/instability	Detailed geological surveys
Safety concerns	Low user confidence	Strong safety codes, transparent communication
Cultural acceptance	Resistance to underground life	Awareness campaigns, community-driven designs

9. Policy and Governance Setting for Underground Development.

A successful urban project that is placed below the earth surface cannot be achieved without proper governance and clear policies. Nevertheless, ground areas cannot be governed the same way as surface land because of some peculiarities: property rights, safety standards, and long-term planning are the issues that need to be controlled. In the case of Addis Ababa, the development and creation of a strong framework of governance will be a major point in the success of underground development.

At the most fundamental level, the city would need a legal framework to govern the use of underground land. Questions of 'who owns the underground space?' and 'how far can you go with private property?' must be well clarified. Many cities around the world only grant property rights for a certain depth, and the underground area belongs to the state. Addis Ababa would need to adopt similar rules to manage conflicts between private developers and public interests.

Sustainability and integration is also a matter of policy. The underground development is to be conducted based on a master plan that is in line with the overall strategy of the city of Addis Ababa. This is in the form of knowing where it would be most appropriate to put underground transport, commercial or utility functions and making sure that there is a smooth transition of these with the surface infrastructure. The city can easily fail to coordinate which may lead to the establishment of incomplete projects that do not yield the long-term value.

Investment strategies and financing are also very critical. The projects that are underground are expensive and it will not suffice to rely on the government funds. Examples of successful public- private partnerships (PPs) have been witnessed in cities like Singapore and Tokyo where governments offer regulatory assistance, with the projects being funded and operated by their respective private investors. The city of Addis Ababa can take the same models to encourage both foreign and local investment, and still have a state check.

Ultimately, the rule of government requires inclusive decision-making in a certain sense. Residents must be involved in the planning process to create trust/acceptance. On the one hand, the cultural resistance can be eliminated via the open debate on benefits, risks, and safety standards. The city of Addis Ababa can have a chance to establish a governance system to make underground development equitable, efficient, and sustainable through citizen involvement, involvement of the policymakers, private developers, and international partners.

Table 4. Policy and Planning Frameworks Supporting Sustainable Underground Development

Policy Framework	Global Example	Key Objective	Relevance to Addis Ababa
Helsinki Underground Master Plan	Finland	Integrate subsurface into city planning	Basis for Addis 3D zoning plan
Tokyo Metropolitan Infrastructure Policy	Japan	Disaster resilience and safety	Flood and seismic risk mitigation
Urban Redevelopment Authority (URA) Underground Master Plan	Singapore	Optimize land use for sustainability	Supports compact growth
Environmental Impact Assessment Act	China	Regulate underground environmental effects	Needed for Addis planning reform
Smart City Framework	EU	Technology-driven underground management	Enables Addis' digital urban management

10. Environmental Hazards and Environmental Control.

Although underground spaces are linked to positive environmental effects, they have risks which are to be controlled with caution. The challenge in Addis Ababa is to reduce these risks and at the same time balance the land development in such a way that can allow the underground development to be sustainable.

The most imperative is the disruption of groundwater systems. The construction underground can cause floods, water deficits or soil erosion because it interferes with the natural circulation of water. Nonetheless, large-scale undertakings are impossible without comprehensive hydro geological investigations. Some of the mitigation measures include waterproof building methods, artificial drainage systems, and constant checking of the groundwater levels.

The other threat is carbon footprint of building. Challenges pertaining excavation, tunneling and construction consume high energy and materials. Unless construction is undertaken in a sustainable manner, the environmental costs would outshine the other associated benefits of underground construction in the coming years. Addis Ababa can deal with this problem by

using construction materials that are environmentally friendly, machinery that would use less energy and renewable energy systems in underground setups.
Another issue is that of waste management. Assuming a real-life construction, underground facilities can produce significant volumes of construction waste and garbage after being in operation due to commercial activities. They must also possess efficient recycling and waste management systems installed in them during the construction.
Lastly, the Addis Ababa city must be equipped to deal with natural calamities, which will include earthquakes or torrential floods. The underground places should be designed as a strong structure that is not affected by earthquakes and with the most modern draining systems and clearly laid down evacuation methods. Although this will make the construction expensive, it will make the building safe and reliable in the long run.

11. Smart City Solution and Digital Infrastructure.

To be successful in the underground urban development in Addis Ababa, underground urban development should not be regarded as an independent project, but as a section of the whole smart city transformation. A smart city is a blend of the two components of physical infrastructure and digital technologies to make it more efficient, sustainable, and comfortable to live. Underground spaces can also form an essential component of this ecosystem in case it is used in combination with the appropriate digital solutions.
One of the most important is real-time monitoring with the help of IoT (Internet of Things) sensors. Underground areas, irrespective of the purpose of the area like transport tunnels, commercial centers, utility spaces, etc need to be consistently monitored on air quality, temperature and humidity and the stability of the structures. The IoT devices could be utilized to keep track of real-time data and feed it directly into the central control systems to be safe and provide predictive maintenance opportunities as well. The city should also prevent risk management to save money and at the same time give reliability because the city can react to breakdowns or accidents.
Another important part is digital navigation systems. The rooms that are underground are usually lost and lonely. Nevertheless, underground transport hubs, shopping malls, and walkways are easily oriented by residents and visitors, with the application of the smartphone and interactive digital maps. Such systems already exist in Tokyo and Montreal, and they are deployed to direct millions of commuters on a daily basis. For Addis Ababa, this would be a great way to open up the underground infrastructure to a far wider audience, particularly to novices.
It also requires renewable energy systems to be able to integrate it. The power source of underground lighting and ventilation could be solar panels placed on the surface, and underground geothermal systems which supply a natural heating and cooling system. There have been efficient processes of distributing energy using smart grids in such a way that the underground facilities are cost effective and friendly to the environment.
Lastly, Addis Ababa might want to implement digital twin technology over the city, a virtual city that includes underground infrastructure as well as above-ground infrastructure. City planners are able to experiment with different situations by simulating traffic, energy use, and environmental conditions, thereby saving them costly investment. Singapore and Helsinki are

already operating this technology and its adoption would provide Addis Ababa with a strong competitive edge as far as planning and development is concerned.

12. Social Acceptance and Culture View.

Whatever the level of advancement and effectiveness of the underground projects, it can only be effective when people are ready to utilize it. The social acceptance is, then, a significant considerate of the underground urban development. Most of the population in Addis Ababa is not used to spending hours and hours underground so the cultural perception should be taken into consideration.

One of the challenges is the psychological comfort. Many people associate underground spaces with darkness, , confinement, and danger. To beat this, the designs of underground facilities should be user-friendly. These spaces can be made to seem less tunnel-like and more friendly public spaces by spacious corridors, lots of natural light, natural ventilation, and open plans. Also, art installations, cultural symbols and traditional design features could be associated with a sense of familiarity and belonging.

Another problem is public faith in safety. People might not feel comfortable using underground transportation or shopping malls, say, because of accidents, floods, or lack of sufficient ventilation. The use of CCTV and fire doors is an example of how transparent communication around safety features—fire escapes, surveillance systems, and disaster preparedness — can help build confidence. People can also become more comfortable with the idea by the means of public awareness campaigns, consulting the local communities, and providing the open tours of the underground sites during the construction stages.

There is also the issue of cultural values. The culture of community is also a great tradition in Addis Ababa that is reflected in open markets, coffeehouses and squares. These social practices should not be lost underground. Instead, underground spaces could be designed to represent Ethiopian cultural identity, for instance, by featuring local art, traditional marketplaces, and areas for socializing. This would help residents to view underground facilities less as foreign and imposed entities, but as natural extensions of their cultural life.

At the end of the day, social acceptance is not only about design - it is about inclusivity. When underground spaces are not open to all citizens, but only to those who are higher in the society and the citizens with low incomes, it is likely to result in a spreading social inequality. Affordability, inclusivity, and cultural sensitivity of these facilities will be the answer to high levels of acceptance in Addis Ababa.

13. Addis Ababa in the Comparison with the World Leaders

Therefore, the present condition of Addis Ababa is best understood in comparison with that of international leaders such as Tokyo, Helsinki, Montreal, and Singapore, for which underground urban development shows great potential. Addis Ababa is quite far in the process, but gaps can offer a developmental roadmap.

Addis Ababa has already a light rail system- the first in the Sub-Saharan Africa, as far as transport infrastructure is concerned. However, it is narrow in scope and only above ground. Instead, cities like Tokyo and Beijing have massive underground metro networks that can be used by millions of individuals daily. In the case of Addis Ababa, underground lines may play an important role in congestion release and transport improvement.

There is no underground master plan in Addis Ababa in terms of urban planning. Nevertheless, the cities of Helsinki and Singapore have already developed underground development into the national urban strategy. This implies that the development is organized in a manner that does not allow it to be compromised into little fragments and also it is long term sustainable. Addis Ababa will not be able to construct piecemeal projects that are not well interconnected without having a clear master plan.

Addis Ababa is behind in matters of technological development. As complex cities across the world are implementing digital twins, smart ventilation, and IoT monitoring, the Addis Ababa is still building rudimentary infrastructure. But this gap is also an opportunity. As countries in Africa have abandoned landline telephones in favor of mobile technology, Addis Ababa could seize the opportunity to bypass legacy technology and leapfrog to modern technology.

The community life in Addis Ababa is rich and, therefore, can be an advantage. Addis Ababa could develop a more locally focused, community-oriented, and culturally oriented underground space unlike the life that is often very isolating in cities. It might allow the city to create a truly Ethiopian paradigm of underground existence, instead of imitating and replicating international trends.

In short, though Addis Ababa is nowhere near the level of other cities of the world as far as underground development is concerned, it has also the advantage of learning its lessons about the achievements and mistakes. The city has the potential of setting a model of both modern and unique city because of combining global best practices with local cultural strengths.

14. Plan to Addis Ababa: Concrete Measures to be taken.

Addis Ababa requires a roadmap in order to make the vision become a reality. Underground development is a long-term, complicated project, though, properly taken, it can be made feasible and attainable.

The initial one will involve carrying out extensive feasibility studies. This deals with geological surveys, environmental impact assessments, and economic analyses to find out areas where underground development could be done and their functions to be given priority. Without this basis, projects will be unsafe or uneconomic.

The second step will be to prepare a comprehensive underground master plan. Such a plan must strategize potential underground uses over a 20-30 year period, and conform to the overall plans of the urban development of Addis Ababa. It must create clearly, where transport hubs, commercial complexes, utility tunnels and the locations of public facilities will be situated so that they blend with the surface level development.

Third, Addis Ababa should also possess a policy and governance structure. A better understanding of the regulations of the underground land ownership, safety, and building will give the investors and citizens a sense of certainty. Public-private partnerships should be promoted to raise the required financing; however, such alliances could also be facilitated by international development agencies.

Fourth, the city should begin with pilot projects. Addis Ababa could also commence with targeted projects rather than putting up big projects to make gigantic underground towns at once, which may include underground parking stations at large markets, underground shopping malls at light rail stations or underground storm water catchments. Such smaller projects would

give an opportunity to accumulate experience, earn the trust of people, and show them the advantages of underground development.
Finally, but not the least, Addis Ababa should prioritize the community involvement and the cultural assimilation. The elements of community based design, open consultation and public education program will see to it that underground spaces are locally expressive and adopted by the society.
In this manner, Addis Ababa can gradually build its underground future following this roadmap. It will be a slow process that will need time, money and creativity but the end results of economic growth, sustainability and the better quality of life will justify the process.

15. Conclusion

Sustainable development of underground urban space is no longer a futuristic vision, it is a feasible requirement of the cities whose population grows fast, where the land area is limited and in the circumstances of environmental pressure. Cities (in Tokyo and Helsinki) as well as cities (in Montreal, Singapore and Beijing) are already showing how underground infrastructure can be used to promote mobility, land-use optimization, economic development, and help to improve the quality of life. These are lessons that Addis Ababa should use in the future.
The possible revolution underground development can have in the capital of Ethiopia. The redevelopment of the land in the center of the city- relocating the necessary functions including transport hubs, parking zones, and utility networks underground- can provide the surface space to be occupied by housing, parks, and culture. Another way through which the city can enhance its ability to withstand climate change is by installing underground storm water management systems and energy efficient buildings. More to the point, the move can assist Addis Ababa in preserving its cultural identity and simultaneously modernizing the city, giving its people not only additional space, but also healthier, safer, and easier to access spaces.
Of course, the difficulties are great. High building costs, risks of technical and social acceptability should be considered. Nonetheless, through an appropriate regime, new funding mechanisms and participative planning, these issues can be turned into opportunities. This is because, in its quest to be the first to achieve underground urbanization in Africa, Addis Ababa has a high probability of succeeding by adopting the best practices in other regions across the world and adapting them to local demands.
The trick lies in being strategic- and beginning with feasibility studies, master plan, pilot projects, and expansion by increments. In the process, Addis Ababa can create not only a larger city, but also a smarter, greener, and more resilient one. The future of Addis Ababa may not be limited to above-ground developments, but also underground, where there is potential to be tapped into.

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