A New Concept towards Addis Ababa’s Utility distribution methods

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“The country [Ethiopia] is rapidly developing; the demand for new houses and settlements is enormous. This goes hand in hand with the accelerated infrastructural expansion corresponding to the needs of a steadily growing population. Now is the time to make the right choices and to set the course..... “

Peter Reinhardt, Addis Ababa, June 8, 2009

Introduction
According to United Nations Human settlement program projections, The state of African Cities; in 2025, Ethiopia’s population is expected to be more than 125 million and over 170 million in 2050. Today, 83% of the population is living in rural areas, creating their income from agriculture and relying on a limited resource-land. Because of the limitation of this income source, a major shift from the rural to the urban is likely to happen, as other examples around the globe have demonstrated already.
Given the possibility and believing prognoses of the UN, that in the very near future more than 50% of the population is going to live in urban settlements. The question is how to prepare for such an incredible demand for water, food, energy, security, hygiene, shelter, jobs, infrastructures, social networks, education, and also capital.

Addis Ababa alone, as the biggest urban centre in Ethiopia, will need to house approximately 4 million more people in 2025 than it does today (2012), if UN predictions are correct. In order to be prepared for such a wave of new urban settlers, new urban settlements need to be planned
and developed. The government of Ethiopia has recognized the need to develop hundreds of new urban centers and shows its desire to its implementation. 

*(Building Ethiopia: Sustainability and Innovation in Architecture and Design: ZegeyeCherenet, HelawiSewnet, 2012)*

As a result of the Government’s effort to meet these demands, since 2004 its investment in roads, housing, dams etc had Ethiopia’s economy grow rapidly with a visible construction boom and urban expansion in Addis Ababa and other major cities of the country. But, although the government is actively trying to meet the housing demands, the rapid increase in population and rapid growth of Addis Ababa also had its impacts on infrastructure mainly roads, power, water and sewage. Because these demands had not been recognized, the severe strains on the infrastructure had been debilitating to the city and its inhabitants.

The new Addis Ababa Master Plan*(2013-2023)* has recognized this and stated on its report “the lack of integrated and sustainable provision of public infrastructure and services, lack of efficient and reliable transport service, water and electricity, and waste management; adequate and affordable housing; and public spaces and parks are pressing challenges that need concerted efforts for redress. Diseconomies due to lack of coordination among public service providers and absence of strategic infrastructure investment plan have rendered interventions inadequate. In the coming plan period, the city needs to be prepared to accommodate and serve a larger population. Moreover, in view of transforming its global, continental, regional and domestic roles and its competitiveness,
radically improving both the quantity and quality of public infrastructure and services is required.”

The Master plan (2013-2023) of the city had come to effect with a new vision of the city to be more densified in an organized manner, paying a special emphasis on provision of open and green areas while revolving on concepts of efficiency and sustainability in its approach.

Accordingly, plans and projects are being undertaken based on these objectives. Just a few months ago the Prime Minister was unveiling the “La Gare” new urban complex; one of its kind in its size are stature. And a few weeks ago, it was revealed that new some 20 Billion birr projects are planned to develop major rivers and rivers sides of the city with the Prime Minister’s office announcing a trial project is already being started accordingly. All these efforts indicate to a revolutionary approach to the development and radical upgrading of the city.

However, if the city is to meet this vision and its ever increasing population demands, the infrastructure system needs a new and revolutionary concept and approach.
A need for new Concept towards Infrastructure

Infrastructure can be defined as the physical components of interrelated systems providing commodities and services essential to enable, sustain, or enhance societal living conditions. It is composed of physical improvements such as roads, bridges, tunnels, water supply, sewers, electric grids and telecommunication.

Basic infrastructure elements in Addis Ababa and most Ethiopian cities include Roads and Railways, Water supply, Sewage facilities, Power Supply and Telecom.

Besides roads, almost all systems stated above use pipes and cables in underground burial or overhead lines (except for sewage) which have been the most widely adopted solution for placing and distributing utilities in Addis Ababa and prominent cities of Ethiopia. But when considering utility distribution, open-cut excavation (i.e. trenching) and overhead line systems are not as effective as they were 20 years ago. In previous decades, the ground surface were undeveloped, suburban and urban areas was primarily unpaved and considerably less dense than today. Allied to this, the installation of electric lines overhead and potable water networks below ground were considered effective economically since future disruptions would have been assumed minimal as there were smaller rates of development, urbanization and expansion. Moreover, labor and construction material costs were relatively smaller; while social and environmental costs were less well-defined and either ignored or simply not considered important enough to offset the rapid economic, financial and social changes that would soon follow.
Consequently, trenching and overhead line utility distribution systems, as an engineering method, has seen little change in their fundamental approach since the early days. The primary improvements are use of much durable materials such as concrete or steel poles instead of wooden poles for overhead lines and significant improvement to pipe material quality in trenched water supply lines and improvement in material quality in electrical cables.

However, in recent years, because the local contexts have changed rapidly, currently Addis Ababa’s infrastructure have all been strained to the point of collapse. Almost all roads of the city are relentlessly congested, while safe water accessibility is 98%, availability estimated at less than 50%, frequent power outages are rigorously common, Telecom and internet services below the demand and sewage facilities can be considered non-existent. Moreover, frequent and uncoordinated disruptions to maintain and sustain these facilities are sources of major social distress. The current system also affects public walkway ground surfaces which are now predominantly paved or built over with tiles both in suburban and urban areas of the city. Servicing and maintenance of the city’s utility services often causes damage to the pavements.
Conversely, the number of utility lines underground is growing; there are now many more utility types installed underground (e.g. stormwater drainage, electric cables, telecommunications cables, street lighting cables etc), and in the not too distant future, as the city continue to grow, significantly more utility types could be prevalent (e.g. non-potable water networks such as firefighting lines, fiber optics etc.) In addition to these, additional fast technological innovations and advancements suggest other network based systems such as wireless internet networks are worthy of consideration when planning for the future.

In addition, if further attention is paid to contemporary international infrastructure placing, practices suggest that everything we do regarding utility placement, needs to take into account current and future costs related to a much broader spectrum than direct economic costs alone (i.e. indirect economic costs, and costs to society and the environment). If the current complications, stated above are considered and the costs are being recognized for utility placement (e.g. traffic disruption, deleterious environmental effects, health and safety hazards, premature deterioration of paved surfaces, and major risks of damage to adjacent infrastructure), there could be a strengthening argument against trenching and overhead lines being the predominant form of utility installation and renewal.

For example, a frequent and repetitive trenching of a road and road side pavement by different municipal, power and telecom institutions for laying of pipe (cable) simply costs 3-4 times in excavation costs (without considering the pavement costs) as each are separately operated and managed. This shows that due to the adoption of short-term planning cycles and the requirement for lowest initial construction costs, the conventional method for utility installation and maintenance are
failing the demands of the city. And when taking a long-term sustainability perspective these methods can be considered socially disruptive, environmentally damaging and significantly more expensive, i.e. unsustainable.

Figure 5 Typical walkway trenching for utility placement/ upgrading in Addis Ababa

It is also true that these constraints and limitations create social, economic and financial costs that are far reaching than the direct costs if further research and analysis are applied.

Taking all the problems stated above into account, these modern difficulties call for new concepts of efficiency and sustainability. And one long-term solution to these problems could be the adoption of Multi-Utility Tunnels (MUTs).
Multi Utility Tunnels (MUTs)

An MUT (Multi-utility Tunnel) is a tunnel that co-locates more than one utility underground, facilitating their subsequent upgrading, repair and renewal while eliminating the need for continuous surface excavation. MUTs offer the advantage of hosting multiple utility services’ inside an accessible and safe space, and of allowing regular inspections, maintenance and easy replacement. Also, very high safety results are obtained by moving inside tunnels the aerial electricity lines that are present in streets.

MUTs has been implemented since many decades in Europe (e.g. Berlin, Helsinki, Stockholm, Madrid and Barcelona), and more recently in North America and Asia. MUTs are mostly used for transporting water, sewage, electricity, telecommunication cables, etc.

Compared to traditional trenching and overhead systems, Multi-utility tunnels represent a sustainable solution, avoiding the recurring street
works that have become routine for the streets of Addis. Initial investment costs are higher than trenching but, considering the life time costs of utility lines and number of utility numbers accommodated, they are quickly compensated by very low costs for maintenance and repair. Moreover, the solution is incomparably safer from any point of view: ruptures, fires, earthquake and also more convenient for interventions after natural disasters.

For Addis, where many infrastructures are still directly buried (like pipes for water, sewage, cables) or are aerial (like electricity and telecommunication cables) the utility tunnel represents a unique innovation that is guaranteed by previous experiences. In using MUTs, the streets will no more be involved in recurrent excavations (that impact traffic and pedestrian movement), regular activities of the commercial buildings, residences, office buildings at street sides will not be halted and there will be no pavement and air pollution for inhabitants. Once installed excavations will not be need; repairs and new installations of cables/ pipes require less working time and material use. Furthermore, when and where significant urban renewals are foreseen, suitable planning for utility services will be easily implemented.

However, there should be further studies on the matter as there is a lack of research to show where the economic tipping point between the traditional (Trenching and overhead) and MUTs occur. And further study is needed to compare on how the two systems might be influenced by urban conditions of Addis, utility type, pipe number (i.e. density), pipe diameter, number of excavation and replacement procedures avoided, location (i.e. suburban and urban areas), etc.
Advantages vs Disadvantages of MUTsand Open Cut(Trenching)

Figure 9visual Section of medium sized MUT

The main advantages of MUTs is that it eradicates the need for repeated excavation and reinstatement (E&R) procedures over its lifetime (60–100 years) and therefore eliminates many of the longer-term costs relating to sustainability.

For example, maintenance works are carried out within the MUT therefore reducing significantly the size of working areas (above ground) and requirements for equipment (e.g. heavy machinery), labour and materials. Moreover, associated impacts on local businesses and residents (e.g. closure and damage to pavements, stairs, noise, loss of public space and business) are minimized.

Another of the biggest advantages is its accessibility which allows for improved inspection and condition assessment. According to “Sustainable utility placement via Multi-Utility TunnelsD.V.L. Hunt, D. Nash, C.D.F. Rogers)” faults and breakdowns to utility services are reduced by approximately 80–95% and asset life is extended by approximately 15–30%, improving the quality of service to the
consumer whilst reducing costs for the utility provider. MUTs facilitate renewal and decommissioning (or perhaps even re-use for a purpose other than which it was intended) and upgrading of utility services. This is particularly relevant to the Telecom industry where technological evolution constantly requires the networks to be changed. Allied to this is the introduction of new utilities which are being, or could be, adopted in the not too distant future.

MUTs require a smaller combined area than the equivalent utilities installed via trenching (open-cut) thereby allowing for more organized planning of underground space for which there are many other uses. Additionally, one of the greatest advantages is public safety as accidents caused by electric lines and open ditches are avoided.

The following table compares the features of utility networks in single purpose buried trenches vs. the features of MUTs:

<table>
<thead>
<tr>
<th>MUTs</th>
<th>Trenching and Overhead</th>
</tr>
</thead>
<tbody>
<tr>
<td>Higher initial capital cost for construction of tunnels</td>
<td>Cheaper initial capital cost of burying individual infrastructure</td>
</tr>
<tr>
<td>Easy location of infrastructure, Fast</td>
<td>Difficult location of infrastructure, Slow</td>
</tr>
<tr>
<td>Easy and access maintenance &amp; replacement</td>
<td>maintenance and replacement and roads constantly need to be ripped up for maintenance</td>
</tr>
<tr>
<td>No manholes on roads, Single manhole for all infrastructure</td>
<td>Increased roadworks and traffic, large amounts of manholes for individual infrastructure</td>
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<td>------------------------------------------------------------</td>
<td>----------------------------------------------------------------------------------</td>
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<tr>
<td>Easy to coordinate between different infrastructure, easy upgrading and expansion of infrastructure</td>
<td>Hard to coordinate projects between infrastructure providers, huge labor costs for re-burial</td>
</tr>
<tr>
<td>Dramatically reduced future-maintenance costs</td>
<td>Long term costs unjustified</td>
</tr>
<tr>
<td>shared initial capital costs between infrastructure providers</td>
<td></td>
</tr>
<tr>
<td>No overhead power lines and reduced impact from outages, increased public safety</td>
<td>Increased risk of disruption, increased chaoticness</td>
</tr>
<tr>
<td>The low thermal conductivity of air in tunnels allows heat transmission with less insulation and cheaper standoffs.</td>
<td></td>
</tr>
</tbody>
</table>
Increased cooperation and collaboration with infrastructure providers (if private)

**Approach Towards Multi Utility Tunnels (MUTs)**

Based on concepts of efficiency and sustainability, contemporary thinking suggests that the total cost (TC) for utility placement methods should be considered as the summation of Direct, Indirect and Social and environmental costs calculated in terms of sustainability.

**Comparisons on Costs**

According to “Sustainable utility placement via Multi-Utility Tunnels D.V.L. Hunt, D. Nash, C.D.F. Rogers)”, the total sustainability costs should consist of three distinct pillars of sustainability:

\[ C_{SUSTAINABILITY} = C_{ECONOMIC(direct+indirect)} + C_{SOCIAL} + C_{ENVIRONMENTAL}. \]

For example, currently total costs (TC) of trenching (open cut) for Water, Electric and Telecom cables and Overhead poles Electric and Telecom lines and the considerably nonexistent Sewage system which predominantly uses the rivers of Addis; can be considered as the summation of the direct investments by city municipal, Power and Telecom institutions (costs directly related to actual construction (e.g. earthworks, excavation, concrete, metal and woodworks, material, labour, equipment etc)), Environmental costs (e.g. land, water, noise and air pollution), Social costs (e.g. traffic troubles, delays and loss of business income, safety, productivity etc.)
Whilst design decisions will impact significantly upon life cycle costs including social and environmental for the project, traditionally they were not considered in utility distribution projects. However, for anyone who lives in Addis the cost effects of these factors are visible every day. The lifetime element, which is crucial within the overall decision-making and construction process should also be considered. It can be considered over the short-term (i.e. days to years), and long term bearing in mind impacts which may last significantly beyond the lifetime of the assets (i.e. 50 or even 100 years). When comparing MUTs with the current trenching system, the longterm lifetime conditions will be a significant factor. A broader discussion related to each pillar of sustainability is given in the sections below.

**Economic costs**

In MUTs major pre-construction costs include design, ground investigations and survey work required before the physical construction of the utility takes place. Similarly, in the current trenching and overhead practice, design, ground investigations and survey works for electric, telecom, and water and sewage systems are seemingly being carried out independently by their own institutions based on the institutions’ priorities and criteria. On the second stage are excavation and earthworks. In MUTs as an integral part of this stage, relatively deeper excavations can cause large costs especially due to limitations associated with soil type, utility type and depth. Moreover, uncertainty in relation to soil and terrain circumstances can increase the risk of unplanned events/construction activities.
In this stage, the primary costing here is \( C_{\text{ECONOMIC(DIRECT)}} \). In the current trenching system, all utility service providers use separate channels and lines. Currently water line is buried underground while Electric and Telecom lines are mostly overhead but underground cables are also frequent recently. Traditionally, wooden poles were frequent which have a smaller cost and time span. Currently most poles are concrete or steel which are more expensive but durable. However underground power cables are also used in most city center parts and new development areas.

Traditionally, the main costs here are trench excavation/ pole distribution, manhole and cover costs, which depend on the depth of excavation but can be significantly smaller than MUTs if considered separately. However, the separate and uncoordinated costs of all water, drainage, power and telecom distributions are added together, costs will be significantly greater. Similarly, maintenance, upgrading and renewal activities are much costlier than MUTs. Moreover, because of lack of inspection, damage to these services usually cause serious indirect, social and environmental costs which usually go beyond expectations.

![Figure 10MUT costs versus open-cut costs in in years urban centers](image)

*Figure 10MUT costs versus open-cut costs in in years urban centers*
Because sewer systems are next to none in most parts of the city, currently their costs are higher in environmental than direct.

However, in MUTs, $C_{ECONOMIC(DIRECTANDINDIRECT)}$ can vary considerably between projects due to the influence of specific local factors: speed of construction; utility type (i.e. diameter and material); and depth of excavation. With respect to the last of these influences deeper excavations may require shoring (e.g. sheet piling) as opposed to sloping work and large-scale installations may require road closures and detours. The slower speeds of construction (MUTs could take about 3 times more time than open-cut construction); can be expensive for overheads, but also more for prolonged activities such as lane occupancy.

Post-construction costs include operational costs, emergency repairs, maintenance and renewal. Costs for maintenance will be repeated to varying degrees through the lifetime of the utilities and compared to direct burial, will have significantly smaller costs.

When we come to ground pavements, it is estimated that pavement service life is reduced by 30% once a walkway or road is cut-open. Thus in trenching system, further repairs to the surfacing materials are increasingly more likely. This is attributed to the fact that as trenches are dug, stress-relief softening of the ground occurs and pavements deform progressively.

While considering the above, it can be presumed that the adoption of MUTs outweigh not only the long-term advantages or cost savings, but also the short-term advantages too.
Social costs

According to “Sustainable utility placement via Multi-Utility Tunnels D.V.L. Hunt, D. Nash, C.D.F. Rogers)”, although social costs of utility distribution are not studied richly, for developed countries (such as the UK) it is estimated that on average $C_{SOCIAL}$ is around 30– 80% of $C_{ECONOMIC(DIRECT)}$. It is believed that 50% of $C_{SOCIAL}$ is attributed to traffic delays.

When considering Addis, these numbers can only rise as traffic overcrowdings and road congestions are at incapacitating stage. These social costs include vehicular costs incurred due to increases in: traffic congestion; frequency of collisions; slower vehicular travel time; and associated operating costs which are increased significantly due to road damage.

Overhead lines are exposed to damage from natural and human factors (such as wind, trees, heavy rain, Trucks etc.) Because of these factors and increasing power demand, almost all parts of the city repeatedly suffer from power outages which cause social costs especially to commercial and industrial institutions.

Another major social costs are health and safety. For example, by trenching (open –cut) system, recently it is assumed that there had been increased rates of deaths and injuries associated with left open utility ditches and excavations in Addis especially around condominium and

Figure 11 Wakway and entrances obstructions caused by utility placement
new developing neighborhoods. Furthermore, because of lack of sanitary utilities in the city, many residents release sewages to the nearby rivers and because of that, all rivers of the city are highly polluted, unsafe and dangerous. As a result, during rainy seasons, due to river flooding and overflow, communicable disease such as Cholera have been frequent. Another social cost in the current system are Overhead electric lines which are also major hazards especially in rain seasons when power line detachment occurs.

When all these factors are accounted, MUTs are incomparably safer from any point of view: ruptures, fires, disease and also more convenient for interventions if problems occur.

Environmental costs

*Figure 12 Sight of polluted river in the city of Addis*
Because of lack of awareness, environmental factors usually neglected in the quantification of $C_{\text{ENVIRONMENTAL}}$ for utilities has received less to no attention. This is not surprising as the costs are not always considered, or their impacts are not recognized, until many years after the works have been carried out. For example, it is assumed that less than 8% of population of Addis have access to sewage lines. Many residents of the city use landfill toilets while many more release sewer to rivers. This not only did cause health coasts as mentioned above, but destroyed Addis’s river habitats and cause serious damage to the environment around.

**Conclusion**

Addis Ababa’s current problems show that lack of city wide plan in the infrastructure construction has greatly affected the city’s inhabitants, development and future. The city, with a new vision, rapid growth and wide development opportunities must meet international standard levels of quality and follow a sustainable developing approach including overall plan that spans for generations, and detailed applications methods that can be practical in everyday operations.

It is expected that in terms of utility distribution systems, sustainability, will evidently favor MUTs. An MUT during its lifetime, can provide a more economically sustainable method of utility placement as long as it is carefully planned and used in the right location and houses the right number of utilities. But it is recommended that further research should be done on the topic that would help us move progressively towards a viable end-state.