**Tianjin Daxue Xuebao (Ziran Kexue yu Gongcheng Jishu Ban)/**
**Journal of Tianjin University Science and Technology**
ISSN (Online):0493-2137
E-Publication: Online Open Access
Vol: 59 Issue: 01:2026
DOI: 10.5281/zenodo.18383248

# A GOVERNANCE-INTEGRATED SUSTAINABILITY FRAMEWORK FOR UNDERGROUND URBAN SPACE DEVELOPMENT IN ADDIS ABABA: LAND-USE OPTIMIZATION, INFRASTRUCTURE EFFICIENCY, AND ENVIRONMENTAL RESILIENCE

## ANTENEH ZERIHUN ALEMAYEHU

PhD Student, Department of Urban and Regional Planning, School of Built Environment, College of Technology and Built Environment, Addis Ababa University.

## Dr. DIPL-ING. BERHANU WOLDETENSAE

Associate Professor, Urban and Transportation Planning, Department of Urban and Regional Planning, School of Built Environment, College of Technology and Built Environment Addis Ababa University.

**Abstract**

Addis Ababa is also experiencing rapid urbanization, land scarcity, congestion and strain on the surface facilities and environmental resources. The city may have a potential solution of the problem through underground urban space (UUS) as it helps to increase the city functional capacity and still leave the surface land to mobility, green spaces, housing, and amenities. This study explores the role of underground development as a part of sustainable urban planning of Addis Ababa by analyzing policy, planning strategies, governance assessment and other city lessons. The report is founded on a mixed-methods research method, including an analysis of policy, stakeholder consultation, and case study, defining the main barriers and facilitating factors to underground development in Addis Ababa. Results indicate that the underground potential of the city is motivated by land shortage, increasing transport needs, environmental imperatives, and national development agenda. Challenges though, include regulatory loopholes, disjointed institutions, and limited funding, as well as poor public awareness. Lack of land-use rights in underground spaces and zoning and building codes are some of the issues that make it challenging to invest and cooperate among agencies. The social acceptance is also a critical factor in implementation of underground systems. Security, comfort, and cultural fit are concerns of the populace that can constrain the use of underground facilities though all these factors can be addressed by ensuring that the design factors like lighting, ventilation, and accessibility are given priority. Another finding of the study is that there is low awareness among the populace and appeals to systematic communication, consultation, and demonstration projects are needed to create trust. Based on the international experience, the research highlights that the development of underground spaces should be based on the complex master planning, backed by geology research, 3D cadastral systems, harmonized governance, bankable financing frameworks (e.g., PPPs, land-value capture), and technology-based planning (e.g., BIM/GIS, sensor monitoring). The examples of underground master planning in Helsinki and integrated underground transport and commercial system in Montreal can give some clarification. The dissertation reaches a conclusion that the city of Addis Ababa needs to initiate policy change (land-use rights, zoning), institutional change (coordinating authority), planning (subsurface mapping), capacity-building, and mobilization of the private-sector by transparent PPPs and incentives. The study is a contribution to the research on underground urbanism in African cities by providing the principles that are globally applicable and relevant to the local issues of governance and planning.

ISSN (Online):0493-2137
E-Publication: Online Open Access
Vol: 59 Issue: 01:2026
DOI: 10.5281/zenodo.18383248

## Chapter: General Discussion, Conclusions, and Recommendationserground.

## 1. PURPOSE OF THE FINAL CHAPTER

The concluding chapter is a synthesis of the key findings in the dissertation article-based manuscripts and the summarization of their implications into the consistent set of conclusions and policy, planning, and implementation recommendations in Addis Ababa. This synthesis has been explicitly placed within the dissertation structure as the gap between the article level and thesis level works and leads to an overall roadmap of sustainable underground urban development.

### Synthesis of the Findings by the Articles

The initial manuscript provides the general argument of UUS as a sustainability tool in Addis Ababa: underground development can enhance land use by relocating the chosen functions (e.g., utilities, parking, transport corridors, and some commercial activities) to the ground level, thus decreasing the surface congestion and allowing a higher level of green and people-centered urban structure. The article, however, further explains that the underground transition in Addis Ababa is not a plug-and-play transition, but it is limited by the geological complexity, high costs of capital (excavation and waterproofing), institutional voids, lack of technical expertise, and social acceptance.

One particular integration lesson is that social legitimacy is not an afterthought that should be addressed as a planning requirement. The underground assets will not be used to maximum capacity without user-centered design (light, ventilation, safety systems, comfortable wayfinding, and culturally resonant architecture) which is technically possible. The research therefore suggests demonstration projects and active education of the people to get used to underground surroundings and to decrease cultural/psychological resistance.

**Table 1: Cross-Article Synthesis Matrix (Findings → Implications → Actions)**

| Manuscript / Article | Primary focus | Core results / findings (what the article shows) | Evidence base (as used in the thesis articles) | Implications for Addis Ababa (what it means) | Priority actions (what to do) | Time horizon |
|---|---|---|---|---|---|---|
| Article 1 — Integration of Underground Urban Space (UUS) into the Sustainable Urban Development Agenda | Strategic rationale and system-level integration | UUS is positioned as a sustainability instrument to reduce surface congestion, improve land-use efficiency, and support resilient infrastructur | Literature synthesis + contextual analysis of Addis Ababa challenges/opportunities | UUS must be treated as a city system program (policy, planning, finance, coordination), not a set of one-off engineering projects. | Embed UUS in the city's development agenda; define priority UUS functions (transport nodes, utilities, parking, commercial links); adopt a phased program with pilots and scale-up logic. | Short – Medium |

**Tianjin Daxue Xuebao (Ziran Kexue yu Gongcheng Jishu Ban)/**
**Journal of Tianjin University Science and Technology**
ISSN (Online):0493-2137
E-Publication: Online Open Access
Vol: 59 Issue: 01:2026
DOI: 10.5281/zenodo.18383248

| | | | | | | |
|---|---|---|---|---|---|---|
| | | e—but only if integrated into city planning and delivery systems, not pursued as isolated projects. | | | | |
| Article 2 — Compa**2.1 Article 1: Inclusion to Addis Ababa Sustainable Development Agenda.** rative International Experience / Best-Practice Lessons (e.g., Helsinki, Montreal) | Transferable principles and implementation models | Successful UUS systems depend on: underground master planning/3D thinking, coordinated governance, strong standards and data, and user-centered design for high utilization. | Comparative case review (international cities) | Addis Ababa should adapt principles, not copy projects: planning instruments + governance arrangements + financing models must fit local legal/institutional realities. | Develop an Addis Ababa UUS concept framework (principles, typologies, safety/user standards); translate into a local policy and delivery model (PPP templates, value capture options). | Medium |
| Article 3 — Sustainable Urban Planning Approaches for UUS Development | Planning, feasibility, environmental/geotechnical considerations | Subsurface conditions are heterogeneous; some zones (e.g., basalt formations) may be more favorable, while groundwater and variability require risk-informed planning. UUS sustainability requires 3D planning, suitability screening, | Planning analysis + technical/environmental reasoning within the Addis Ababa context | Feasibility is location-specific; without subsurface data and planning tools, projects face higher risk, cost overruns, and safety/environmental exposure. | Build a subsurface data program (geotechnical + groundwater + utilities); create a preliminary suitability map and UUS zoning overlay; embed UUS checks into development control and infrastructure corridor planning. | Short – Medium |

**Tianjin Daxue Xuebao (Ziran Kexue yu Gongcheng Jishu Ban)/**
**Journal of Tianjin University Science and Technology**
ISSN (Online):0493-2137
E-Publication: Online Open Access
Vol: 59 Issue: 01:2026
DOI: 10.5281/zenodo.18383248

| | | | | | | |
|---|---|---|---|---|---|---|
| | | and integrated GIS/BIM workflows. | | | | |
| Article 4 — Governance and Institutional Strategies Supporting UUS Development | Governance performance, institutional capacity, coordination, stakeholder readiness | Governance is the binding constraint: fragmented mandates, weak coordination, unclear standards/rights, financing hesitation, and low public awareness. Quantitative indicators include 38% public awareness, 15% awareness of pilots, and 64% private-sector concern about long payback. | Policy/document review + key informant interviews (35) + FGDs + case comparison | Without clear authority, rules, and an enabling environment, UUS remains ad hoc, high risk, and unattractive to investors; low awareness threatens legitimacy and utilization. | Establish a coordinating mechanism (taskforce/unit/authority); clarify underground rights, permitting and standards; create a bankable pipeline and risk-sharing finance tools; implement public engagement and demonstration projects. | Short –Long |
| Integrated cross-article thesis conclusion (Synthesis) | What the combined evidence proves | Addis Ababa has a strong sustainability rationale for UUS, but the city is currently constrained by governance readiness, regulatory clarity, subsurface data availability, financing viability, and social acceptance. | Consolidated synthesis across the manuscripts | UUS success requires a sequenced transformation: rules + institutions + data/planning → pilots → scalable financing → networked underground systems. | Implement a phased roadmap: (1) legal/standards + coordination + baseline mapping; (2) pilots in favorable zones; (3) integrate UUS into master plan/3D overlays; (4) scale bankable corridors and nodes with PPP/value capture; (5) institutionalize monitoring and lifecycle maintenance. | Short –Long |

**Tianjin Daxue Xuebao (Ziran Kexue yu Gongcheng Jishu Ban)/**
**Journal of Tianjin University Science and Technology**
ISSN (Online):0493-2137
E-Publication: Online Open Access
Vol: 59 Issue: 01:2026
DOI: 10.5281/zenodo.18383248

## 2.2 Article 3: Sustainable Planning Approaches and Administrative-Environmental Feasibility

The third manuscript goes further to make the dissertation a question of how underground rather than why underground, that sustainable UUS application must be based on integrated planning techniques and evaluation standards, which explicitly encompass environmental protection, infrastructure performance, and the land-use performance. It justifies the fact that underground development should be integrated into master planning system by use of subsurface mapping, risk screening (e.g., sensitivity of groundwater) and multi-criteria planning frameworks through which underground functions would be in tandem with sustainability targets in the city.

**Table 2: GIS–BIM Workflow and Suitability Concept for Underground Urban Space (UUS) Planning in Addis Ababa**

| Workflow stage | GIS component (spatial planning layer) | BIM component (design & engineering layer) | Suitability / screening outputs | Decision use (what it supports) |
|---|---|---|---|---|
| 1. Data acquisition & baseline inventory | Compile spatial datasets: land use/zoning, road network, river basins, flood zones, protected areas, utility corridors, cadastral boundaries | Collect available as-built drawings, utility records, metro/transport engineering files, typical section libraries | Baseline "data availability" map; data gaps register | Confirms readiness for underground planning; identifies missing datasets before project selection |
| 2. Subsurface characterization | Geological and hydrogeological mapping (rock type, faults, groundwater depth, permeability), historical borehole locations | Geotechnical parameters used in models (bearing capacity, rock mass rating, groundwater constraints), preliminary tunnel/structure typologies | Subsurface constraint layers (high/medium/low constraint zones) | Reduces technical uncertainty; supports "go/no-go" and early risk classification |
| 3. Hazard and environmental risk screening | Flood susceptibility, groundwater protection zones, seismic/landslide sensitivity, contamination risk | Engineering risk mitigations (waterproofing, lining, ventilation, fire safety, monitoring systems) | Environmental suitability index; hazard "red flag" areas | Ensures sustainability and safety; prevents locating UUS in environmentally sensitive zones |
| 4. Infrastructure conflict mapping | GIS overlay of existing and planned utilities (water, sewer, power, telecom), | Clash detection readiness; utility relocation or protection concepts; corridor design templates | Utility conflict heatmap; preferred underground corridors | Minimizes rework and relocations; reduces cost overruns and |

**Tianjin Daxue Xuebao (Ziran Kexue yu Gongcheng Jishu Ban)/**
**Journal of Tianjin University Science and Technology**
ISSN (Online):0493-2137
E-Publication: Online Open Access
Vol: 59 Issue: 01:2026
DOI: 10.5281/zenodo.18383248

| | | | | |
|---|---|---|---|---|
| | right-of-way, metro lines, foundations | | | construction delays |
| 5. Demand and functional suitability analysis | Spatial demand mapping: congestion hotspots, transit nodes, CBD activity zones, market areas, pedestrian flows | BIM-based functional layout options (stations, underpasses, parking, retail, service tunnels) | Function-to-location matching matrix (best-fit zones for each UUS function) | Prioritizes high-impact projects; aligns underground functions with real urban demand |
| 6. Multi-criteria suitability scoring | Weighted GIS-MCDA (technical feasibility, environmental risk, land-use benefit, accessibility, social factors) | Constructability and maintainability scoring (construction methods, staging, lifecycle requirements) | Suitability classes: Highly suitable / Suitable / Conditional / Unsuitable | Produces an evidence-based "UUS suitability map" for master planning and investment programming |
| 7. Concept design and option development | Confirm alignments and corridors; protect future underground zones (3D planning overlays) | Develop concept BIM models with preliminary quantities, ventilation/fire safety, egress, materials | Concept options with comparative performance (cost, risk, disruption, sustainability) | Supports alternatives analysis and selection of pilot projects |
| 8. Costing, phasing, and constructability | Construction staging footprints; traffic/pedestrian disruption mapping; logistics and access routes | Quantity take-off, 4D scheduling (time), 5D costing (cost), safety planning | Phasing plan and budget ranges; constructability risk register | Improves feasibility and bankability; supports PPP packaging and procurement strategy |
| 9. Permitting and regulatory compliance | Spatial compliance checks: protected zones, easements, setback rules, environmental constraints | Compliance documentation: codes, standards, inspection points, safety certifications | Permitting checklist and compliance dashboard | Streamlines approval processes; increases transparency and regulatory consistency |
| 10. Delivery, monitoring, and lifecycle management | Asset registry linked to GIS for maintenance planning; incident mapping; performance reporting | Digital twin-ready BIM model for operations: inspections, sensors, maintenance schedules | Lifecycle performance KPIs (safety, uptime, cost, energy) | Ensures long-term sustainability and safety; supports continuous improvement and governance reporting |

**Tianjin Daxue Xuebao (Ziran Kexue yu Gongcheng Jishu Ban)/**
**Journal of Tianjin University Science and Technology**
ISSN (Online):0493-2137
E-Publication: Online Open Access
Vol: 59 Issue: 01:2026
DOI: 10.5281/zenodo.18383248

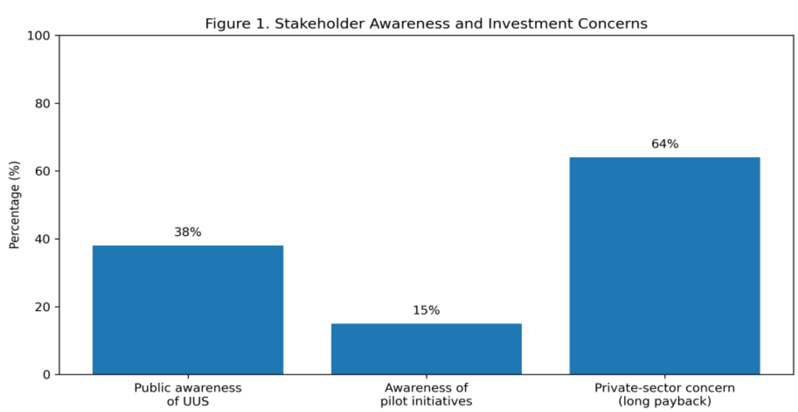
**As a practical implication, this means three planning changes to Addis Ababa:**

going beyond the superficial zoning to the 3D spatial thinking,including geological/hydrological data in day-to-day development control, andembracing technology-powered planning processes (especially BIM and GIS) that are capable of identifying the underlying conflicts at the lowest possible stage and enhance design coordination.

### 2.3 Article 4: Governance and Institutional Strategies

The governance manuscript illustrates that the underground challenge faced by Addis Ababa is essentially a rule-setting and coordination issue. Although: the policy documents mention underground infrastructure (e.g., utility corridors and metro-related objects) the city does not have a policy of the underground development with the specific property rights of the underground area, explicit zoning, and specific environment-/safety standards. The evidence of governance also brings out overlapping mandates and implementation imbalances which are some of the reasons behind slow project approvals and investor uncertainty.

The paper brings together these challenges into governance performance indicators with low public awareness (38%) and poor inter-agency coordination being the greatest obstacles but it also puts these as institutional design opportunities. In particular, the evaluation advocates having a central coordinating body or taskforce to minimize duplication, standardization, and offer a single gateway to the granting, compliance, and monitoring of projects.




**Stakeholder Awareness and Investment Concerns**

- **2.4 Comparative Lessons of Cross-Article Comparative Practice around the World**

Comparative elements of the dissertation indicate that Addis Ababa can enhance learning by pursuing the ideas of not imitating projects of cities with mature underground systems. There are two illustrations specifically educative:

**Tianjin Daxue Xuebao (Ziran Kexue yu Gongcheng Jishu Ban)/**
**Journal of Tianjin University Science and Technology**
ISSN (Online):0493-2137
E-Publication: Online Open Access
Vol: 59 Issue: 01:2026
DOI: 10.5281/zenodo.18383248

- Helsinki illustrates how a subterranean master plan, which is supported by the systematic mapping and planning controls, can ensure the protection of surface green/open spaces, as well as the strategic distribution of sub-surface functions.
- The RESO of Montreal demonstrates the possibility of connecting transport and commercial purposes through the use of integrated underground networks with high utilization rates on a daily basis when the connection and user experience are taken into consideration.

**The synthesis lesson is straightforward:** Addis Ababa needs (i) a planning tool that would render underground space visible and manageable (planning, mapping, zoning rules), (ii) an institutional tool that would render decisions coherent (a coordinating authority), and (iii) a strategy on implementation that would render the project bankable and acceptable to the society (PPP framework, incentive, and engagement, etc.).

Overall Conclusions

**In all the manuscripts, the dissertation has five consolidated conclusions:**

Developing underground is a plausible sustainability prospective of Addis Ababa in that it amplifies land-use efficiency as well as underpins resilient infrastructure, yet only when designed as a component of long-term urban plan as opposed to individual actions.

The city lacks clear underground land-use rights and development criteria, which means that they are unable to predict the flow of private capital to the city and deal with interference in the subsurface.

Reality needs to be trusting to the people and socially accepted to implement it. The lack of awareness and participatory mechanisms will limit the utilization unless it can be resolved with the help of design, communication, and inclusive planning.

Conditions of implementation such as public trust and social acceptance are required. The lack of awareness and minimal mechanisms to participate will limit the use unless it is curbed via design, communication and inclusive planning.

## 4. RECOMMENDATIONS AND ROADMAP OF IMPLEMENTATION

### 4.1 Immediate Actions (0-18 months)

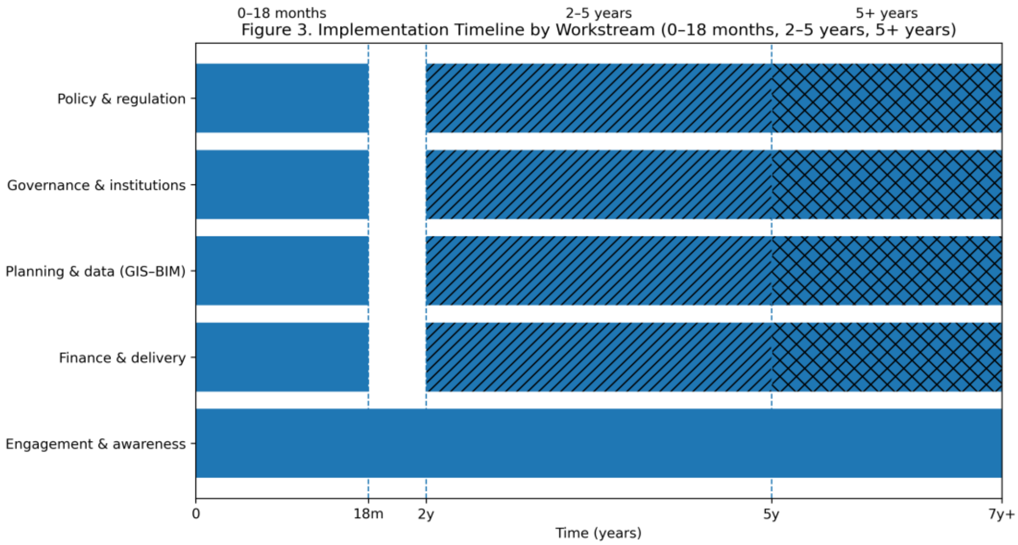
Prepare and embrace underground land-use rights and development criterion (ownership profundity, authorizing, safety, environmental standards).

Introduce a citywide subsurface information project (first GIS-based mapping that brings together the existing geological, hydrological and infrastructure data).

Create an interim inter-agency Underground Development Taskforce that is a part of the planning system that will provide the coordination of permits, standards and pilot selection.

**Tianjin Daxue Xuebao (Ziran Kexue yu Gongcheng Jishu Ban)/**
**Journal of Tianjin University Science and Technology**
ISSN (Online):0493-2137
E-Publication: Online Open Access
Vol: 59 Issue: 01:2026
DOI: 10.5281/zenodo.18383248

Identify two or three demonstration pilots (e.g. small pedestrian underpass, structured parking facility, or utility corridor) that are specifically aimed at the development of the public confidence and institutional learning.




**Implementation Timeline (0–18 months, 2–5 years, 5+ years) as a timeline chart with phases on the x-axis and workstreams on the y-axis**

### 4.2 Medium-Term Actions (2-5 years)

- Institutionalize an Underground Development Authority (UDA) or a unit of specific mandate, uniform review practice and authority of control.
- Incorporate underground mapping in the Master Plan and develop initial underground zoning overlays of priority areas and hubs.
- **Capacity building:** training of engineers, planners and regulators to eliminate the need to hire external expertise and to enhance local delivery capacity.

### 4.3 Long-Term Actions (5+ years)

Become a complete Underground Master Plan (Addis Ababa-specific), with a full 3D planning style, with space out investment program, and as well as a combined risk governance (groundwater protection, structural monitoring, and lifecycle maintenance planning).

Scale linked underground networks in strategically chosen areas (transport hubs, commercial areas) where connection can lead to high usage and financial sustainability based on global examples and contextual limitations of Addis Ababa.

### Shortcomings and Future Study

The dissertation points out limitations incomplete disaggregated subsurface infrastructure data, the difficulties of extrapolating international case studies upon the city of Addis Ababa, and the necessity to carry out even larger-scale quantitative economic models.

**Tianjin Daxue Xuebao (Ziran Kexue yu Gongcheng Jishu Ban)/**
**Journal of Tianjin University Science and Technology**
ISSN (Online):0493-2137
E-Publication: Online Open Access
Vol: 59 Issue: 01:2026
DOI: 10.5281/zenodo.18383248

Further studies are needed, in my view, to put in more cost-benefit simulation of options to finance (PPP variants, municipal bonds, and value capture), environment-specific analysis of the local impact of subsurface areas in relation to the situation in Ethiopia, and comparative research on fast-urbanizing cities in Africa (identifying transferable governance models).

New Sub Section: Dissertation Contribution to Knowledge.

## 5. ADDITION TO THE EMPIRICAL AND THEORETICAL KNOWLEDGE BASE

This dissertation will add into the field of underground urban development within the rapidly urbanizing African cities in three main ways:

Empirical contribution It integrates the evidence of various sources (policy and planning review, stakeholder perceptions, and governance performance indicators and analysis of contextual feasibility) to introduce a formal diagnosis of the reason why underground development does not become a reality in the city of Addis Ababa despite obvious urban pressures and policy ambitions.

Theoretical contribution: It builds upon a cohesive conceptualization of UUS as a governance-planning-finance-social legitimacy system, and not a technical/engineering problem. By so doing, it redefines underground development preparedness as an institutional and socio-technical competence which can be measured and reinforced.

**Methodological contribution:** It suggests a strategy of synthesis to use in article-based dissertations, where the results of articles are translated into a single explanatory framework (drivers - enabling environment - implementation capacity - sustainability outcomes), and the evidence contained in several manuscripts is used to produce only one thesis-level claim.

### Study Limitations and Future Research.

Limitations and future research directions In the future, future research directions: future research can be conducted with the objective of enhancing the intervention's effectiveness and lowering the likelihood of such an event occurring again in the future.<|human|>3.X Limitations and future research directions Future research Future research Future research can be carried out with the purpose to increase the effectiveness of the intervention and reduce the chance that an event of this kind will recur in the future.

### Limitations:

The poor accessibility and combination of overall subsurface information (utility records, geotechnical logs, groundwater data) limit the accuracy of suitability mapping and estimation of costs and risk.

The limitations of transferability arise when implementing international best practice in Addis Ababa because of the differences in the law, financing market, institutional capability, and culture of the people toward the underground use.

**Tianjin Daxue Xuebao (Ziran Kexue yu Gongcheng Jishu Ban)/**
**Journal of Tianjin University Science and Technology**
ISSN (Online):0493-2137
E-Publication: Online Open Access
Vol: 59 Issue: 01:2026
DOI: 10.5281/zenodo.18383248

Certain of these findings are relying on stakeholder perceptions and qualitative evidence which may not be comprehensive in terms of reflecting long-term behavioural adoption patterns and lifecycle cost realities.

**Recommendations in future research:**

Establish citywide 3D models of the subsurface and test the appropriateness of the classes by systematic borehole/hydrogeological datasets.

Carry out lifecycle cost-beat analysis between underground and surface options of priority corridors and nodes.

Assess institutional reforms (e.g. a single-window permitting and coordinating authority) with KPIs that can be measured, e.g. approval time, frequency of dispute, cost overruns.

Research perception change, longitudinally, in terms of safety perception, gender-intensive design requirements, outcomes of accessibility, as well as patterns of utilisation.

**Methodological contribution:** It suggests a way of synthesis that is proper to article-based dissertations, i.e. realize article-level results into one unified explanatory framework (drivers - enabling environment - implementation capacity - sustainability outcomes), making the evidence of respective manuscripts produce one and the same thesis-level argument.

The proposed theoretical framework is the Integrated UUS Sustainability Readiness Framework (I-USSRF) 4.X.

According to the synthesized results of the manuscripts, the present dissertation suggests the Integrated Underground Urban Space Sustainability Readiness Framework (I-USSRF). The framework describes sustainable underground development to be a goal function of five interdependent pillars:

**City Traffic and Pressure of Demand**

The demand of UUS is caused by growth, overcrowding, lack of infrastructure, lack of land, and enviromental sustainability.

**Potentiating Governance and Legal Foundations**

Obvious underground land-use rights, standards, permitting regulations, accountability, and institutional mandates.

**Planning Data Capability (GIS-BIM Integration)**

Underground mapping, suitability screening (MCDA), utility conflict analysis and online coordination of design and approvals.

**Finance and Delivery Capacity**

Bankable project pipeline, PPP preparedness, value-capture alternatives, risk-sharing instruments, and lifecycle financing.

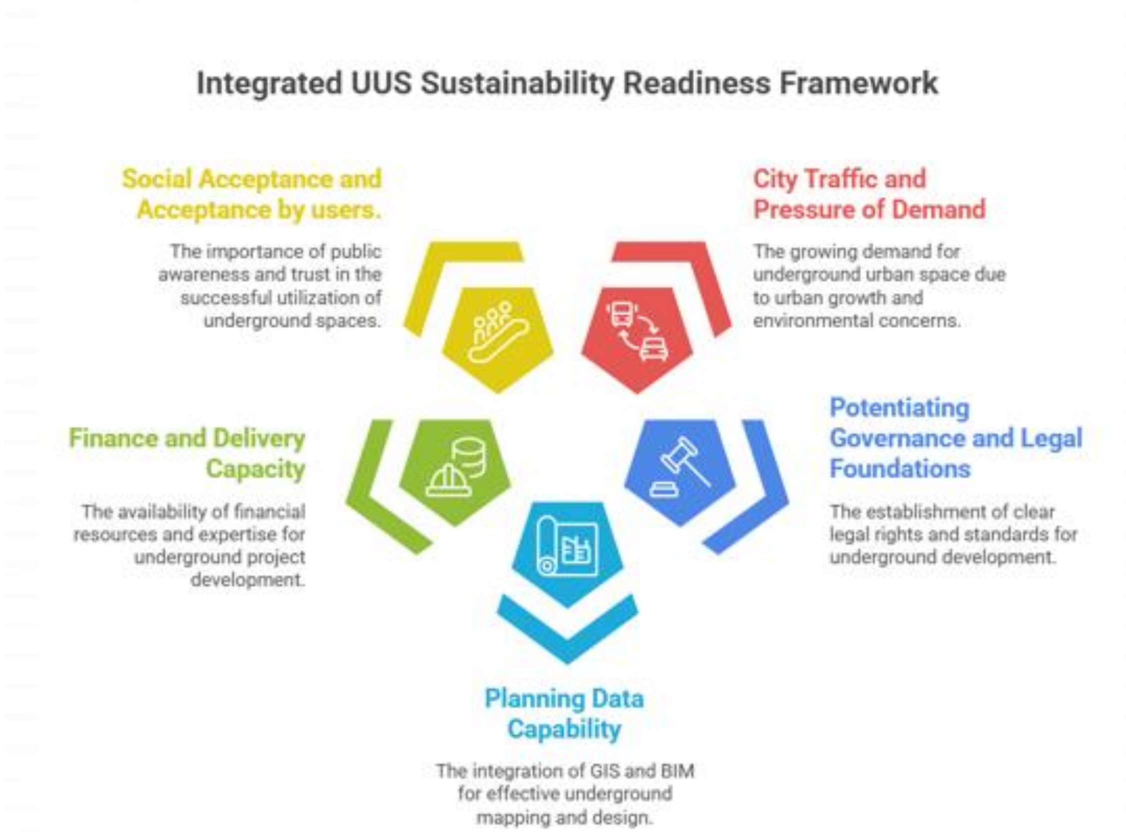
**Tianjin Daxue Xuebao (Ziran Kexue yu Gongcheng Jishu Ban)/**
**Journal of Tianjin University Science and Technology**
ISSN (Online):0493-2137
E-Publication: Online Open Access
Vol: 59 Issue: 01:2026
DOI: 10.5281/zenodo.18383248

### Social Acceptance and Acceptance by users

Social awareness, consultation, safety-based design, accessibility and long-lasting trust-building.

### Framework logic:

Urban motorists create the demand of the UUS, and success is realised when the facilitating environment (governance/legal + planning/data + finance/delivery) is fully developed and social legitimacy promotes utilisation. The presence of weakness as a pillar raises the risk, costs, and delays as well as underutilization hence compromising the sustainability outcomes.




### The outcomes of sustainability forecasted by the framework:

- Efficiency in land-use and surface liveability.
- Less infrastructure war and failure in service delivery.
- Increased resiliency and security through risk governance and oversight.
- Increased investor confidence in the form of predictive rules and pipes.
- Increased usage by user centred design and social acceptance.

**Tianjin Daxue Xuebao (Ziran Kexue yu Gongcheng Jishu Ban)/**
**Journal of Tianjin University Science and Technology**
ISSN (Online):0493-2137
E-Publication: Online Open Access
Vol: 59 Issue: 01:2026
DOI: 10.5281/zenodo.18383248

## References

1) Addis Ababa City Planning Project Office. (2017). Addis Ab...a Structure Plan (2017–2027). Addis Ababa City Administration.

2) Bobylev, N. (2009). Sustainability and underground space u.... Tunnelling and Underground Space Technology, 24(3), 362–367.

3) Bregt, A. K., Crompvoets, J., & Georgiadou, Y. (2013). Gov...of underground spatial planning. Land Use Policy, 30(1), 1–9.

4) MoUDC (Ministry of Urban Development and Construction). (2020). National Urban Development Policy of Ethiopia. Addis Ababa.

5) Parriaux, A., Thalmann, F., Jaboyedoff, M., & Forster, A. (20...of cities: The case for urban geology. Geotimes, 49(9), 20–23.

6) Sterling, R., Godard, J. M., & Bobylev, N. (2012). Urban Unde...Space Use: Sustainability, Policy and Design. ITA Working Group.

7) Teklemariam, S. (2020). Urban infrastructure development chal...n Addis Ababa. Ethiopian Journal of Urban Planning, 6(1), 44–59.

8) UN-Habitat. (2022). The State of Addis Ababa 2022: Urban Trends and Prospects. United Nations Human Settlements Programme.

9) Abidemi, A., Melo Zurita, M. L., & Munro, P. G. (2025). Under...udies, 62(3), 541–560. https://doi.org/10.1177/00420980231174996

10) Koroso, N. H., Lengoiboni, M., & Zevenbergen, J. A. (2021). ...l, 117, 102437. https://doi.org/10.1016/j.habitatint.2021.102437

11) Woldesemayat, Eyasu Markos, and Paolo Vincenzo Genovese. "Ur...o. 1, 18 Jan. 2021, p. 85, https://doi.org/10.3390/land10010085.

12) Praslova, Valentyna, and Yuliia Riabets. "Modern Trends of O... 1 June 2023, pp. 45–51, https://doi.org/10.2478/acee-2023-0014.

13) Worku, H., Azagew, S., & Zeleke, A. (2020). Accessibility of...s Research, 9(1), 26. https://doi.org/10.1186/s40068-020-00187-0

14) Tian, Ji, et al. "Urban Underground Space Geological Suitabi.... 8, 14 Apr. 2025, p. 4326, https://doi.org/10.3390/app15084326.

15) Zhang, J., Liu, H., & Sun, P. (2024). Study on underground e... City Modelling, 5(1), 22–38. https://doi.org/10.3233/JCM-247250

16) Bria

17) n, Marker. "Planning for Underground Development: Princi...4, pp. 1205–1208, https://doi.org/10.1007/978-3-319-09048-1_230.

18) Peng, F., Qiao, Y., Dong, Y., Yan, Z., & Zhu, H. (2024). Dev...ing, 26(7), 95–108. https://doi.org/10.15302/J-SSCAE-2024.07.008

19) Jiang, Ping-wei, et al. "Coupling Analysis Method of Groutin... 2024, pp. 312–330, https://doi.org/10.1016/j.undsp.2023.07.005.

20) Ma, C., Wu, W., Dong, Y., & Peng, F. (2024). Underground spa...589–606). Springer. https://doi.org/10.1007/978-981-97-1257-1_52

21) Zenga, R., & Shen, Z. (2021). Post-occupancy evaluation of t...g, 22(1), 139–154. https://doi.org/10.1080/13467581.2021.2024204

**Tianjin Daxue Xuebao (Ziran Kexue yu Gongcheng Jishu Ban)/**
**Journal of Tianjin University Science and Technology**
ISSN (Online):0493-2137
E-Publication: Online Open Access
Vol: 59 Issue: 01:2026
DOI: 10.5281/zenodo.18383248

22) Attarian, K., & Najar, B. S. A. (2019). Vernacular and histo... sustainability of cities: Case study of Dezful infrastructures.

23) Zerhouny, Mariama, et al. “Underground Space Utilization in ...lanca (Morocco).” Land, vol. 7, no. 4, 23 Nov. 2018, p. 143, https://doi.org/10.3390/land7040143.

24) Li, Xiaojun, et al. “Integrated Parameter Optimization Appro...Control Strategy for TBM Tunnelling.” Tunnelling and Underground Space Technology, 2024. https://doi.org/10.1016/j.tust.2024.105000

25) Jiang, Chao, et al. “A Comprehensive Evaluation Framework fo... Space Using Factor Analysis and AHP.” Applied Water Science, 2025. https://doi.org/10.1007/s13201-025-02421-5

26) Gong, Dandan, et al. “Sustainable Design and Operations Mana...gistics Systems: A Thematic Literature Review.” Buildings, 2023. https://doi.org/10.3390/buildings13051292

27) Magsino, S. L., Gilbert, P. H., Ariaratnam, S. T., Connery, ...ashash, Y. M. A., Hendrickson, C. T., Nelson, P. P., Sterling, R. L., & Zhao, J. (2013). Underground Engineering for Sustainable Urban Development. National Academies Press.

28) Liu, Wenque, et al. “Resilience in Infrastructure Systems: A...ol. 12, no. 6, 1 June 2022, p. 759, www.mdpi.com/2075-5309/12/6/759.

29) Sustainable tunneling and underground use. (2018). In Sustai...civil infrastructures. https://doi.org/10.1007/978-3-030-01884-9

30) Liu, Xiaotong, and Haishan Xia. “Networking and Sustainable ...g: Influence of Rail Transit.” World Transit Research, 2023, www.worldtransitresearch.org

31) Woldesemayat, Eyasu Markos, and Paolo Vincenzo Genovese. “Mo...reen Spaces Change in Addis Ababa: Directional and Zonal Analysi... Remote Sensing, 2021. https://doi.org/10.3390/rs13122345

32) Asgele, S. B. (2024). Urban Land Management System in Ethiop...lementation. Pro Publico Bono - Magyar Közigazgatás, 12(2), 103–117.

33) Kemal, F. M. (2023). Making use of leftover spaces under rai...Ababa. Advances. https://doi.org/10.11648/j.advances.20230403.13

34) Zhao, Xingxing, et al. “Enhancing Urban Landscapes through U... Perceptions.” Sustainability, vol. 16, no. 11, 25 May 2024, pp. 4501–4501, https://doi.org/10.3390/su16114501.

35) Qiu, Tong, et al. “Long-Term Urban Epidemic and Disaster Res... of a Comprehensive Underground Resilience Core.” Buildings, vol. 13, no. 5, 3 May 2023, p. 1292, https://doi.org/10.3390/buildings13051292.

36) Agyeman, Julian. “Just Sustainabilities20036Just Sustainabil...., ISBN: 1853837288 Hardback £48.00.” Management of Environmental Quality, vol. 14, no. 3, 2003, pp. 425–426.

37) World Bank Group. (2016). Addis Ababa, Ethiopia: Enhancing u... https://www.worldbank.org/en/topic/urbandevelopment/publication/addis-ababa-ethiopia-enhancing-urban-resilience

38) Abebe, M. T., & Megento, T. L. (2016). The city of Addis Aba... island”: An analysis of urban green space dynamics using remote sensing and spatial metrics. Journal of Environmental Planning and Management.

39) Agwor, A., Melo Zurita, M. L., & Munro, P. G. (2025). Underg... subterranean space in Lagos, Nigeria. Urban Studies. https://doi.org/10.1177/00420980231174996

40) Bobylev, N. (2009). Mainstreaming sustainable development in...rban underground space use. Land Use Policy, 26(4), 1128–1137. https://doi.org/10.1016/j.landusepol.2009.02.003

**Tianjin Daxue Xuebao (Ziran Kexue yu Gongcheng Jishu Ban)/**
**Journal of Tianjin University Science and Technology**
ISSN (Online):0493-2137
E-Publication: Online Open Access
Vol: 59 Issue: 01:2026
DOI: 10.5281/zenodo.18383248

41) Fan, M., Gu, Z., Li, W., Zhou, D., & Yu, C. W. (2022). Integ...h an underground complex: A low-carbon building solution for urban regeneration. Sustainable Cities and Society.

42) He, B., Armaghani, D. J., Lai, S. H., et al. (2024). A deep ...tween 2000 and 2023: A systematic review. Tunnelling and Underground Space Technology.

43) He, L., Zhang, X., & He, Y. (2022). Does the scarcity of urb...of underground space planning more sustainable? Frontiers in Environmental Science.

44) Kemal, F. M. (2023). Making use of leftover spaces under rai...s, 4(3), 93–110. https://doi.org/10.11648/j.advances.20230403.13

45) Li, G., et al. (2022). Developing a BIM-GIS-integrated metho...ement in China: A case study. Journal of Construction Engineering and Management.

46) Li, Huanqing. (2013). An Integrated Strategy for Sustainable Underground Urbanization.

47) Lu, D., Liao, Y., Zeng, J., Jiang, Y., Wang, G., Qin, B., & ...for recovery resilience of urban underground space. Strategic Study of CAE.

48) Ma, L., et al. (2023). Cases study on foundation pit design ... area. In G. Feng (Ed.), Proceedings of the 9th International Conference on Geotechnical Engineering.

49) Ma, W. X., Dong, Y. H., Ma, C. X., & Peng, F. L. (2024). Und...lanning in new urban district based on the Chinese modern garden city concept. Proceedings of the 18th ACUUS Conference.

50) Najar, S. A. N., & Attarian, K. (2019). Vernacular and histo...urban facilities and sustainability of cities. Journal of Cultural Heritage Management and Sustainable Development.

51) Peng, F., Qiao, Y., Dong, Y., Yan, Z., & Zhu, H. (2024). Dev...y for urban underground space in the new development stage. Strategic Study of CAE.

52) Wang, W. X., Dong, Y. H., Ma, C. X., & Peng, F. L. (2024). U...an district based on the Chinese modern garden city concept. Proceedings of the 18th ACUUS Conference.

53) Woldesemayat, E. M., & Genovese, P. V. (2021). Urban green s...n functional land use areas in Addis Ababa, Ethiopia, and their impact on ecosystem services. Land. https://doi.org/10.3390/land10010085

54) Xiao, Y., Zhang, J., Cao, J., & Li, C. (2021). Prefabricated...A case study on mechanical behaviour with strain monitoring and numerical simulation. Construction and Building Materials.

55) Zenga, R., & Shen, Z. (2023). Post-occupancy evaluation of t... study of Chengdu Tianfu Square in China. Journal of Asian Architecture and Building Engineering.

56) Zerhouny, M., Fadil, A., & Hakdaoui, M. (2018). Underground ...use planning of Casablanca (Morocco). Land, 7(4), 143. https://doi.org/10.3390/land7040143

57) Zhao, X., Chen, Z., Guo, D., Zhu, X., & Wu, Y. (2024). Underg... 15–24). Springer. https://doi.org/10.1007/978-981-97-1257-1_3

58) Zargarian, R., Hunt, D. V. L., Braithwaite, P., Bobylev, N., ...ility, 171(6), 324–335. https://doi.org/10.1680/jensu.15.00013

59) Design recommendations for sustainable urban underground spac...ology, 140, 105332. https://doi.org/10.1016/j.tust.2023.105332

60) A comprehensive evaluation framework for green ecological...lied Water Science. https://doi.org/10.1007/s13201-025-02421-5

61) Urban underground space: Solving the problems of today's c...ology, 55, 245–248. https://doi.org/10.1016/j.tust.2015.11.012