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Recognition of Underground Urban Spaces based on Typological Approach

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ABSTRACT: Over time, the use of underground spaces has changed and has been considered for various other purposes. Many US[1] built for a specific period with a specific purpose have been left without a specific function today. The reason for this can be considered the lack of a clear and codified plan in the face of these spaces. Therefore, the importance of underground issues related to US justifies the inclusion of UUS[2] in urban index systems. Hence, due to the depletion of activity, many US today have created bubbles lacking function under the skin of cities; with proper identification, it will be possible to use them in the service of cities and citizens. Thus, the main Goals of Current research are -Recognizing the characteristics of US -The typology of the urban US, and -Solutions to reproduce the urban US. This research is a scientific review, and the information collected is documentary-oriented. The lack of reliable sources in the fields of architecture and civil engineering in the subject of US, geographical extent, and diversity of species of these spaces on the planet show the importance of this research. Therefore, typology and solutions for reproducing urban US are presented from two methods of investigating the theoretical foundations and known projects in the field of US. The present study's findings based on the literature review and reproduction of US showed that these spaces could be defined into six categories.

Keywords: *Underground Spaces, Public Spaces, Reproducing, Typological Approach.*

INTRODUCTION

Since the beginning of human life on the planet, underground spaces have been used to create security. These spaces have seen more diverse uses over time. At the beginning of the 20th century, the idea of underground cities was proposed by Eugene Henard. Still, so far, very few resources have been published in the field of underground architecture and urban planning. Underground space is widely recognized as a valuable space, a source, and a new dimension of cities. Using underground space can help cities meet the increasing urban demand for space and remain compact)Lin et al., 2022 (. The importance of this issue causes the inclusion of UUS in the urban indicator systems to be of great importance and therefore justifies the conduct of this research.

Therefore, the main goals of this research include the following: "1. Typology of underground spaces 2. A review of the literature and experiences of updating underground spaces".

Researchers are also searching for answers to these questions: "What are the different types of underground spaces?" And which species can be used as public spaces? So, it is necessary to conduct this research.

MATERIALS AND METHOD

The Current research is a scientific review. The collection of information documents is based on the documentary. The lack of reliable sources in the US architecture fields, geographical extent, and the diversity of species on the planet shows the necessity of doing it.

This research is done in several sections. In the first part, the Typological criteria of different spaces are examined. In the second part, contemporary projects in the reproduction of underground spaces in the service of the public from three reputable websites, Dezeen, Archdaily, and MVRDV, are reviewed, and their successful experiences are reviewed. The third section proposes the typology of underground spaces based on the previous sections. In the final section, suggestions will be made on reproducing underground spaces in the contemporary era, focusing on the typological approach.

The current research, based on the evidence-based method using inferential reasoning, provides suggestions on how to

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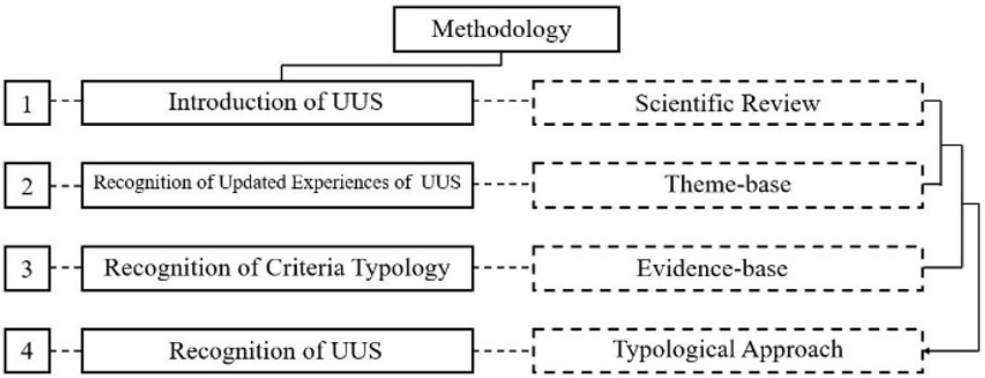


Fig 1: Methodology Framework

recognize and reproduce underground space (Fig 1).

Research Literature

Underground Spaces

Building components have various shapes below the soil surface, the most common of which is the basement. In general, underground spaces mean: "integrated into the ground," "in contact with the ground," and "built in the shape of the ground" (Watson et al., 2003, 123).

Previously, humans mostly used underground spaces as temporary shelters such as worship and retreat, protection against external factors and climatic conditions, goods depots and food storage, etc.

Sometimes being in underground spaces causes biological symptoms in a person. Even today, many people claim that using underground spaces such as parking lots and subways is associated with fear and anxiety (Godard, 2004, 5).

Suppose the underground spaces are strengthened in terms of structure and prepared in terms of aesthetics. In that case, they can act desirably in reducing physiological outputs, and satisfying people's desires can be long (Ishigaki et al., 2009).

Besner (2017, 3-6) considers the US as a sustainable urban space and, in using these types of spaces, recommends that basic and universal principles, property, urban integration, interior architecture, accessibility, safety, archaeological heritage, and building capacity be observed.

If properly selected in terms of legal and administrative, economic, social, safety and health, technical and environmental issues, and comprehensive planning for their use, US can be a good alternative to developing cities (Zaini et al., 2012, 5). This requires a comprehensive knowledge of the nature and histology of US, so that at the right time and place and with the right choice, the proper use of these abandoned spaces. Numerous studies have been conducted on the capability and potential of US and subsurface spaces in the urban development of the current society.

Molaei (2012) believes that US has a good capability in climate comfort for humans and the necessities of life. It has energy and sustainable urbanization. On the other hand, the ability to become an extensive pedestrian access network concerning urban centers such as Subway stations; Transfer of superstructure facilities and equipment to infrastructure; Reinforcement and conversion into spaces with the least amount of vulnerability in times of crisis; The possibility of creating the right of choice for users in different situations in comparison with urban spaces, etc. are other things that make the attitude to underground spaces important.

Hosseini (2015), while confirming the views of the previous researcher, Categories the potentials of the US into six parts: "Optimal use of land; Protection and separation; selection; Environmental protection; Infrastructure development and planning; Development of relief and public transport; "Management" enumerates.

He included items such as multi-purpose use; Social security and control; Long-term environmental protection; Non-interference in ecology, cityscape, agricultural lands; the creation of joint energy transfer tunnels, the creation of underground pedestrian zones, etc. are among the most important capabilities of US and the need to pay attention to these spaces in cities.

He also believes that through the criteria of "optimal land use, improved range readability, and safety" in the physical field; "Traffic flow, communication between different spaces" in the field of transportation; "Establishing social justice, participation" in the social field; "Protecting the environment, providing a comfortable climate" In the field of environment and economic profitability, it will be possible to reproduce the US and use them publicly.

On the other hand, the impact of US architecture on energy saving; Reduction of thermal conductivity and storage capacity; Soil temperature stability; Control over air infiltration; Reduction of heat received; Reducing pressure on the environment are one of the positive effects of the infiltration of spaces in the environment (Madi et al., 2018, 3-4).

The results of all research indicate the multiple capabilities of the US and the shape of spaces, so the layout of these shapes to choose the right course of action is one of the requirements for researchers.

Typology Framework

At the end of the 19th century, typology emerged as an interdisciplinary science (Jamali et al., 2011).

Urban public spaces are created following a process. The process, the introduction, and the title which is to identify the space to be discussed in the city. "Work" refers to the function of space by classifying space as streets, squares, playgrounds, etc., and Rob Krier emphasizes the form of space by describing public space in three forms: triangle, square, and circle (Behzadfar et al., 2011).

Experts from 1959 to 2008, in their definitions, have referred to the city's shape and summarized them in this regard into four main components: natural elements, artificial elements, human activities, and time are divided. Urban thinkers and urban planners recognize that the city's shape is a dynamic reality and does not refer only to the shape and body of the city (Daneshpour et al., 2012).

In the Typological analysis of urban space by Hall, they are categorized into spaces with a fixed, semi-fixed, and variable composition. They emphasize fixed design and composition characteristics, architecture and geography, and degeneration with behavior variables, respectively (Ghavami Fard, 2013). In another part of this view, Carmona et al. Have divided the types of space into four general types positive space, negative space, ambiguous space, and private space, each of which also includes other low-level spaces (Ashrafi e al., 2014 20, Memarian et al., 2014; Memarian et al., 2018). Sterling et al. (1993) classify these spaces in terms of performance, geometry, the origin of formation, site characteristics, and other project features. Each of these main groups is also classified into main and sub-subgroups. For example, functional groups include residential subgroups (single and multi-family), non-residential (industrial, religious, administrative, commercial, leisure, recreational, parking, warehousing, and agriculture), infrastructure (transportation, energy, etc.), mining, military (defense and military installations). The geometric classification includes shape subgroups (porous space - boreholes and vertical wells and miles - horizontal tunnels, diagonals and spirals - natural caves, pits, holes, and large cavities) in two natural, excavated forms.

Regarding the relationship with the surface, the relevant subgroups are subsurface, embanked, without soil on the roof, and high slopes (Carmody et al., 1993, 48). In terms of the depth of underground buildings, usually, three main categories are shallow (0-10 for buildings and 0-100 for mines), medium and deep depth, which varies according to the relevant use and the views of designers, users, and other cases. These depths range can differ for buildings, local and urban facilities, and mines.

Experiences of Reproducing in the US

Reviewing valid documentary studies presents a set of self-conscious interventions and actions in the US of architecture and urban planning with a Typological approach.

In a study conducted by Pourjafar et al. (2017), an US to reproduce and take a key role in current developments, a set of changes in the form of the following to achieve the qualities of "legibility," vitality, comfort, safety, flexibility, sense of belonging, adaptation, security, identity, accessibility, escape, moderation, homogeneity, capacity" at three levels of "intra-space, inter-space and extra-space" can be receptive.

Therefore, in the table1, notable international projects for the reproduction of the US and their use as a contemporary society have been selected; a total of 23 US projects, 14 projects are implemented, and the others are proposed.

The cases are selected from implemented and proposed projects of reputable websites (Table 1).

In general, the use of the US is often an emergency, and security, climatic and natural restrictions have been the main reasons for the emergence of these settlements and the use of these spaces. Excavating land, hills, and mountains, sheltering in the basement, and protecting users and their property has created lasting spaces throughout history.

These spaces are very attractive and memorable, especially for tourists and non-residents, due to their uniqueness in terms of form and exterior, and interior (Molaei, 2012).

Out of a total of 23 US projects, 14 projects are in the form of implemented projects, and nine projects are proposed projects. Dissemination of the studied projects in different countries of the world, including; 4 projects in China, three projects in Finland, two projects in the United States, as well as the United Kingdom, Australia, the Netherlands, Mexico, and the United Kingdom, all have an updated underground project.

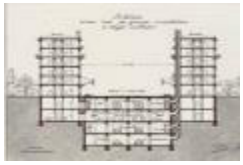
Broadcasting of these projects on the world's continents includes six projects in Europe, four in Asia, and two projects in the United States and the continents of Oceania and North America. Both have an updated global underground project. 14.2% of projects in the field of urban design, 21.4% in the field of architecture, 28.5% in the field of nature, and 21.4% of projects in the field of public transportation and also in the military sector and facilities each accounted for 7.7 percent.

US Typology

Many experts consider the US as an urban space. Lin et al. categorize the use of the US for new developments into five categories: transportation development, intensive development, urban functions, car-free urban environment, and sustainable development (Lin et al., 2022, 4 -6).

They also define six scales and forms for the US, including "public nature and urban shopping –subway lines and stations– comprehensive applications of US –facilities –underground

Table 1: Known Underground Reproduction Projects, Adapted from Archdaily, Dezeen, MVRDV

	Beijing Mega-Project		Inter-Continental Shanghai Wonderland		National Mall	**Project**
Designer: Zaha Hadid **Concept:** Fluidity and attractive connection of upper and lower floors	Transport system/ transport center / Subway ,China Beijing **Implemented Project**	**Designer:** Martin Jochman **Concept:** Connecting the natural environment and life with new Land-uses	Architecture / / Residential Hotel ,China Shanghai **Implemented Project**	**Designer:** Albert Washington and Arthur Katnemore **Concept:** proposed shopping mall and parking lot, located on a lawn area between the National Museum of Natural History and the Smithsonian Palace	Architecture /Commercial / Shopping Center USA, Washington **Implemented Project**	**Example / Evidence** **Country** **Suggested / Implemented Project**
	Underground Project131		Cross rail		Amphora	**Project**
Designer: _____ **Concept:** The Cold War-era underground city includes the offices of Mao Zedong and Lin Biao, which have been converted into a museum.	/Military / Asylum Normal China, Gaoqiao **Implemented Project**	**Designer:** _____ **Concept:** 117 km railway with new services land-uses	Transportation system / Transportation center / Railway United King-,dom London **Implemented Project**	**Designer:** The architectural firm Zwarts and Jansma **Concept:** 50 km of tunnels will be built under the canals of the city center to improve the quality of the living environment	transporta-/tion system Transporta- / tion Center Tunnel Netherlands Amsterdam **Suggested Project**	**Example Evidence** **Country** **Suggested Imple-/ mented Project**
	Temppeliaukio Stone Church		Multi-story streets		Mesa City	**Project**
Designer: Timo and Tuomo Suomalainen **Concept:** used for group wor-.ship	Architecture / Religious /Church Finland, Helsinki **Implemented Project**	**Theorist:** Eugene Henard **Concept:** place all kinds of traffic in the form of multi-story streets	Urban/ social/ multi-story street design ____ **Suggested Project**	**Designer:** Paolo Soleri **Concept:** proposed the City of Mesa Groundwater and Peak Development Plan, which forms the roof of downtown Manhattan with magnificent skylights and suspended gardens between .high-rise towers	Urban / Social/ Design underground city America, Manhattan **Suggested Project**	**Examples/ Evidence** **Country** **Suggested /Imple-mented Project**

Continiue of Table 1: Known Underground Reproduction Projects, Adapted from Archdaily, Dezeen, MVRDV

	Amox Rex		Geo –Space		Skyscraper Under-((ground City	**Project**
Designer: JKMM **Concept:** The dome-shaped underground structure of the Museum has skylights that combine with the function of the building and take on a modern style. The large domes on the roof allow natural light to enter to illuminate the museum space, creating an interactive harmony with the .urban landscape	Natural /Entertainment /Museum Finland, Helsinki **Implemented Project**	**Theorist:** Gideon Golany **Concept:** the idea of geospace, which is in three forms: shal- .low, medium, and deep	Urban /Design /Social /Space Integration Open and Underground —— **Suggested Project**	**Designer:** Architectora Group **Concept:** the idea of a scraper for the underground development of Zucala Square within the historical context	Urban / Design /Social /Underground city Mexico, New Mexico **Suggested Project**	**Examples/ Evidence** **Country** **Suggested / Implemented Project**
	Underground Bathhouse)DMZ)		Underground Street Network Beijing Finance		Underground Library Green Square	**Project**
Designer: MRDO and LaM Studios **Concept:** MRDO and LaM Studios offer an underground pool and bath. The design was inspired by the Roman baths of the Tripatorium and the Collectarium, a library, and a place full of sculptures where people .gathered	Urban Design/ Sports / Pool, Bathroom North Korea Common border with South Korea **Suggested Project**	**Designer:** SOM **Concept:** The project connects underground parking lots with 7,500 Finance Street parking spaces to surrounding streets. There are three underground pedestrian tunnels and underground car tunnels, which are .mostly two-lane	Transportation /system Public Transportation / Center public parking China, Beijing **Suggested Project**	**Designer:** Stewart Hollenstein **Concept:** The idea was to turn the former swamp area .into an underground library	Urban Design /Cultural /Artistic /Library Australia, Sydney **Implemented Project**	**Examples/ Evidence** **Country** **Suggested / Implemented Project**
	Wadi rum project Jordan		Parking Underground Katwijk aan zee		UCCA Dune Museum of Underground Art	**Project**
Designer: Rasem Kamal **Concept:** Its excavated shelters proposed a complex containing a train station, a museum, and an underground hotel in the Jorda- .nian desert	Normal /Entertainment /Hotel, Museum Jordan Dessert **Suggested Project**	**Designer:** RHDHV (Royal (Haskoning DHV **Concept:** It was designed as a dune to maintain and strengthen the relationship between the village, the beach, and the pub- .lic space	Transportation system /public parking Netherlands **Implemented Project**	**Designer:** Zhou Tingting **Concept:** a network of underground concrete galleries and art museums	Natural /Entertainment /Museum China, Beijing **Implemented Project**	**Examples/ Evidence** **Country** **Suggested / Implemented Project**

Continiue of Table 1: Known Underground Reproduction Projects, Adapted from Archdaily, Dezeen, MVRDV

	Low line park		Trampoline Cave		Houses Under the Cave	**Project**
Designer: James Ramsey **Concept:** a project which utilizes innovative solar technology to build the world's first under-.ground Park	Urban Design /Green space /Park ,New York Manhattan **Implemented Project**	**Designer:** Sean Taylor **Concept:** idea of an underground trampoline	Natural /Cave /Amusement Park ,Great Britain North Wales **Implemented Project**	**Designer:** Manuel Rocha Diaz, in collaboration with sculptor Ernesto Paulsen **Concept:** This residence has a large, convex roof covered with thousands of oak pieces and has five rooms with a specific function.	Natural/ Entertainment /Hotel, Museum ,Mexico Mexico City **Implemented Project**	**Examples/ Evidence** **Country** **Suggested/ Implemented Project**
			Onkalo Project		Auto bahnkirche	**Project**
		Designer: _____ **Concept:** to bury nuclear and radioactive waste at a depth of 400 to 450 meters in the Okalo bed	Olkiluoto Island in Eurajoki, Finland Facilities /Services /Landfill Radioactive	**Designer:** Herzog and de Meuron **Concept:** Redesign traditional places of worship to respond to their settings without religious signs and symbols.	Switzerland Architecture /Religious /Mosque, Church and Synagogue	**Example Evidence/**

logistics facilities and passage tunnels – underground parking lots" (Lin et al., 2022, 7).

A review of US research shows that most research with a local perspective has examined a type of US and focused mainly on Subway spaces (Zhou et al., 2022). However, in this study, it is important to provide a specific framework of their types and functions by analyzing the different dimensions of US. According to the authors, the US can be divided into six sections: architectural spaces, urban design, historical, transportation, military, and facilities (Fig. 2).

RESULTS AND DISCUSSION

In urban design, underground cities and villages, such as Cappadocia in Turkey, Qadamas in Tunisia, Noshabad and Meymand Kerman, Samen Malayer, Tafresh, Tahiq Khomeini, Kurd-Olia in Iran (Molaei, 2019), studio gallery, stadium, and green space are evident.

In the residential architecture section, elements such as the aqueduct, water storage, refrigerator, garden pit, padiav, Shawadan3 (in native Iranian architecture), non-residential architecture, shopping centers, and religious centers are included. Public spaces are impressive, emphasizing recreational functions, natural caves, and museums. In the transportation system and public transport network, subway tunnels, carriageways, and temporary car stops are worth considering. Other sections, such as shelters and prisons, are located in the military section and facilities, which are considered for defense, maintenance, and water supply, respectively, and in the form of shelters, warehouses, and Karis or aqueducts (Fig 3- 5).

In the meantime, some cases may include two or more categories and overlap. For example, an US should include both the role of water supply and nature (Table 2).

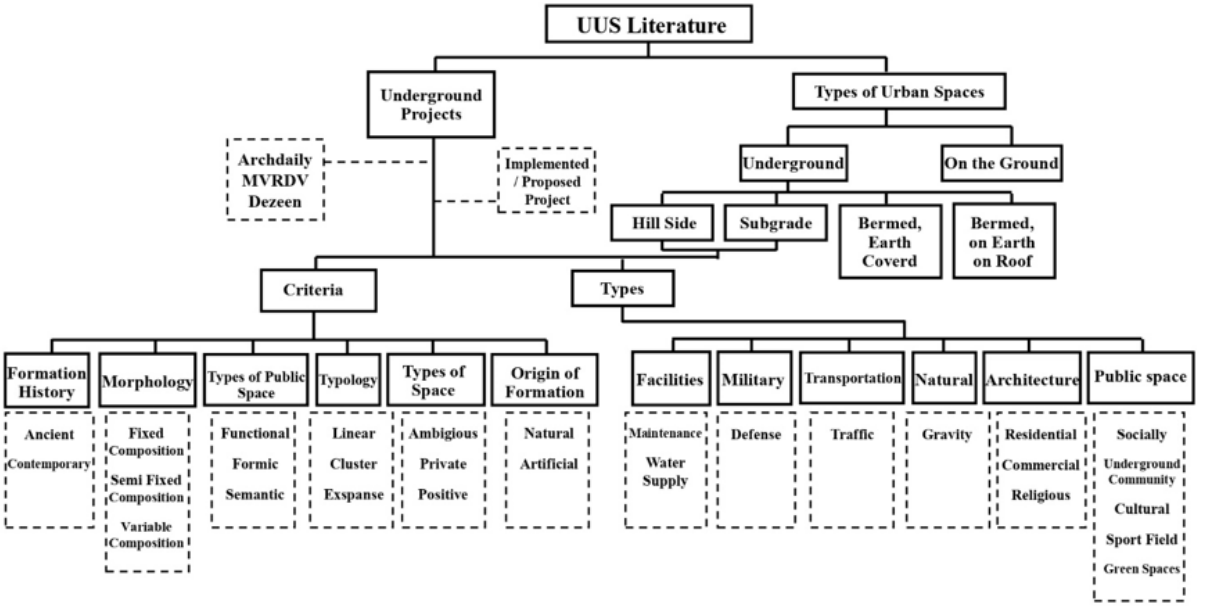


Fig 2: Theoretical Framework

Fig 3: Tahiq underground city in Khomein, Markazi province, Iran

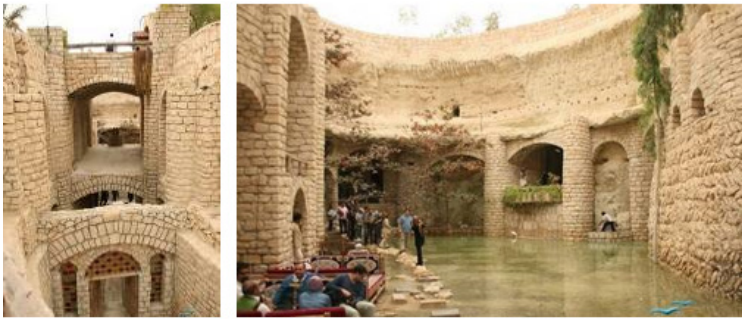


Fig 4: Karis Underground Complex, Kish, Hormozgan Province, Iran

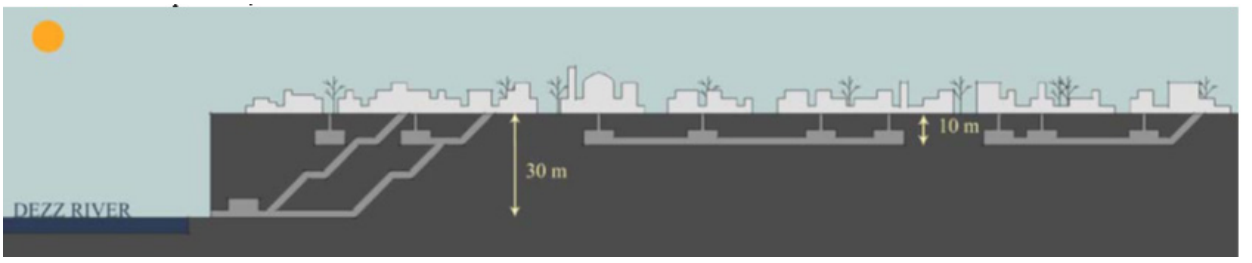


Fig 5: Shawadan and Shushtar Underground Neighborhood Units, Khuzestan Province, Iran (Safaei, 2022)

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Table 2: UUS Typology based on typological approach

Facilities		Military	Transportation			Natural		Architecture- Oriented					Public Spaces						Type	
Water supply	Main-te-nance	Defense	Traffic			Gravity		Religious	Com-mer-cial	Residential			Green Space	Sports	Cultural-artistic			So-cially	Examples	
Qantas, fog-] Karis [garas	Store	Shelters	Public Parking	Tunnel	Subway	Museum	Natural Cave	Synagogue	Malls	Sunken Courtyard	Shawadan	cistern	Park	gym	studio	Atelier	Gallery	Under-ground Community	Evidence	
																			Schematic Image	
																			Natural	Origin
																			Artificial	
																			Functional	Type of Public Space
																			Formic	
																			Semantic	
																			Ambiguous	Types of space
																			Private space	
																			Positive space	
																			Negative atmosphere	
																			Fixed com-position	Morphology
																			Semi-fixed composition	
																			Variable composition	
																			Contempo-rary	His-tory
																			Ancient	
																			linear	Typology
																			cluster	
																			expanse	

Red: Possibility or impossibility | Gray: Certainty | White: Uncertainty

CONCLUSION

The research findings showed that there are different types of underground spaces, and today, many efforts are being made in the field of their modernization at the world level. An important point is the identification of underground spaces in cities. As urban spaces are classified and planned in urban development plans, it is necessary to carry out systematic plans to identify and classify them. As the review of modernization projects showed in Table 1, underground spaces, regardless of the type and function of the "6 classifications", will have the ability to be modernized as public and collectible spaces. It should be noted that underground spaces can play a vital role in attracting tourists and sustainable development for cities. Considering the topography of Iran and the existence of natural underground spaces, which are useless, as well as many artificial underground spaces, including bunkers, shelters, and shelters, which have been left alone after the 8-year war with Iraq. There is great potential for updating them in the country, and it can answer part of the demand for space and land for the country's people.

On the other hand, the use of technology, "including in projects such as Low-Line," provides this opportunity for the city authorities to create "24-hour" underground public spaces in cities. Especially in many cold regions of Iran, such as Ardabil province, and hot regions of the peripheral provinces of the Persian Gulf, such as Sistan and Baluchistan, Hormozgan, Bushehr, Khuzestan, where social life is directly related to the climate, underground spaces can offer. It is suitable for adjusting the climate and creating public spaces all day and night. Therefore, the following suggestions are presented for the optimal use of underground spaces based on their typology.

-Identification of underground spaces in the country of Iran based on the presented classification

- Feasibility assessment of underground spaces based on the characteristics of the provinces of Iran

-Preparation of the comprehensive plan of underground spaces to update them

- Using successful experiences and technology in creating public spaces and increasing service per capita.

ENDNOTES

1. Underground Spaces

2. Urban Underground Spaces

3. In the architecture of southwestern Iran, especially Dezful and Shushtar, due to the hot and humid weather conditions prevailing there, architects use underground cold water called Shawadan, Shavadon, or Shabadan to provide climatic comfort conditions (Authors, 2023).

AUTHOR CONTRIBUTIONS

A. Molaei helped in the literature review, performed the experiments, compiled the data, and wrote the conclusion and manuscript preparation.

K. Ketabollahi performed the literature review and experimental design, analyzed and interpreted the data, and prepared the manuscript text and edition.

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CONFLICT OF INTERESt

The authors declare no potential conflict of interest regarding the publication of this work. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication or falsification, double publication and, or submission, and redundancy, have been completely witnessed by the authors.

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