Underground housing formation strategies

*R M Mahdi\textsuperscript{1}, A H Aboud\textsuperscript{2}
\textsuperscript{1}Lecturer Doctor Department of Architecture, University of Technology- Iraq
\textsuperscript{2}Assistant Lecturer Department of Architecture, University of Technology- Iraq
*Corresponding author e-mail: 90100@uotechnology.edu.iq

Abstract. This paper studied underground residential spaces as one of the most important treatments used since a long time ago until now, and despite the set of obstacles accompanying it, such as increasing costs and special construction treatments required by building, the resulting spaces remain a viable alternative to housing. The research problem is stated as a need for knowledge to determine the morphological formation of the residential underground to enhance its attachment to the surface. To solve such research problem, the most important vocabulary and indicators related to each of the morphology of the underground residential space and the physical links that work to enhance the relationship of the underground residential space with the surface have been investigated and identified. Suitable for housing depending on specialized architectural proposals. A questionnaire was conducted to demonstrate the possibilities of adopting the values of underground residential space morphology and the main element of Physical connectors between the top and bottom and indicating the degree of achievement of value resulting from the theoretical framework. The research founded that the underground residential space was considered fit for housing whenever its connection with the surface was strong depending on the functional, visual and spatial connectors.

1. Introduction
The architect "Wells" said in his statements “If the architecture that we know are positioned above the Mother Earth, the underground architecture positioned between her arms”, who called for adopting the method to invest the underground as a shelter and subsistence, the use of spaces underground was linked to the development of mankind's evolution, but the problem that limits its use is its unhealthiness, with a separated spaces nature; in addition to, the most important issue represented by the lack of a connection between the underground and its surface; therefore it is not suitable for living. The research problem is stated as a need for knowledge to determine the morphological formation of the residential underground to enhance its attachment to the surface. The research aims to close the scientific knowledge gap related to this subject of interest. The research assumption consists of the achievement of a strong connection between the Earth’s surface and its ground will be fulfilled by establishing links that enhance these connectors. The research methodology is described by the following:

- Study the history of underground housing and the levels of underground utilization importance to identify the most important patterns adopted.
- The need for knowledge to determine the morphological formation of the residential underground to enhance its attachment to the surface.
- Integrate the vocabulary of the theoretical framework for underground residential space morphology and physical connectors for underground residential space
- Conducting the questionnaire depending on the theoretical framework.
- Verify the results and state the conclusions.
2. Historical review of underground house

The utilization of the underground for the dwelling is not a new concept, as underground construction is understood to be derived out of the historical view of human domination over nature [1]. The study of the chronology of underground residential begins with the outcomes of archaeological research on habitats using shelter represented in various form of a cave, hole, crater, or natural cavities [2]. Pioneers architects adopted underground buildings as a residential area, even in places where the groundwater table rises for areas with harsh soils to meet many needs, including religious beliefs (temples or cemeteries) or for harsh climate conditions (such as dwelling holes in China and Mitmata in Tunisia, the city of Matera in Italy) as shown in Figure 1 and 2 respectively, or for protection and safety purposes, the beginnings of secret housing embedded by creating a wide range of structures for hiding in war periods. Some cities are completely underground protected, such as Derinkuyu in Cappadocia in Turkey, as seen in Figure 3.

As for semi-underground construction, it was classified into several classifications that included (pit, cliff, nest), as in the domed construction of Eskimo houses, stepped construction of the Mediterranean and the Neolithic period, underground construction, as a Roman civilization-building pattern. The continual adoption of the underground house in the recent period is due to many factors, including coping with demographic evolution, preservation from natural disasters and natural hazards. In the mid-1960s, shallow underground spaces appeared to be represented by nuclear shelters that were adapted firstly to long-term housing, secondly to strengthen the organic relationship between man and environment. Since these two patterns are converging but resulted in radically different aesthetic expressions. Malcolm Wells pointed to (conservation architecture to unify the effects of the artificial environment with nature, so the physical form appears by imparting a similar character to caves dwelling through the irregularity of the surface form [1].

In the seventies of the last century, the spaces developed vertically underground as an attempt to rectification the relation between the need for housing and conserve the environment and energy [4], as well as the development of formal configurations in the development of public space for cities and effective use of earth's face, which has a positive impact on the formation of urban design [4]. It is clear from the above that there are two types of underground construction; the first is completely underground and the second is semi-underground which is close to the surface of the earth These two patterns aiming at protecting and sheltering mankind from various environmental, social conditions and dangers. Besides, both are considered as a solution to conserve energy and provide additional spaces to accommodate the population increase and develop the general urban space depending on the formation of Underground space.

Underground spaces have developed especially in the field of housing, as one of the main goals of using these forms its ability to save energy using the earth as an insulator in addition to other energy systems such as (solar, geothermal, wind) to generate the clean energy needed for of housing inhabiting [2]. At the turn of the century, the process of developing underground residential physical structures has intensified, especially with innovations in fields of building technology, new materials and systems invented to solve the problems related to urban population density and limited space on the ground to take the forms of development as a form of Eco-friendly architecture towards merging the underground design with the sustainable environmental design and increasing the green areas, in a way that is related to the importance of the underground spaces.
3. The levels of underground utilization importance
The approach to use underground at the city level contributes to making the city more sustainable and inhabitable by the integration of functional, spatial and visual aspects and creating an enjoyable and healthy environment. The approach varies with different types; either being under a pre-built environment or as a part of rebuilding the city or being a part of the new residential facilities, whether in a space within the urban fabric or outside the city borders [5]. The use of the subterranean achieves positive visual effects on the city’s streets by creating more space for squares, parks, pedestrian traffic and public transport, providing opportunities for underground transition within the subway stations city center, this allowed to create an accessible secure channel [6].

At the building level, this approach increases the positive ecological aspects either by reducing the building’s impact on the local biological community and natural processes through underground construction or by using soil and vegetation as a cover and naturally filtering rainwater. The most profound issues facing underground housing are the consequences of non-availability of building picture, unlike the traditional buildings. The underground space has no mass or image of the building that can be perceived, architects adopted the "Kevin Lynch" image of the city in explaining the importance of the environmental image, as he is suggesting that the image of the building is a two-way process between the observer and his environment. The observer needs an identity which realized when the environment meets these essential aspects. Housing achieves three aspects through surrounding with the natural soil by adopting the principle of containment. The hidden structures under the ground aiming at redirecting the relationship between the need for construction and the need to environment protection, thus preserving the open spaces will be manipulating the natural light to create a sense of the hierarchy underground building, increasing clarity and orientation the light with the integration of vertical and horizontal light through holes allowing unified subterranean lighting that reduces the feeling of being underground while creating, stimulating underground environments simultaneously [7].
The importance of underground utility is represented within several levels that range from the city, streets, green spaces and what is provided to the public transport out of clearing the land and resource exploitation level. The importance of the building implied by reducing the ecological footprint towards the residential space underground, which is the subject of this research, and this is what the following paragraph discusses.

3.1. The importance of underground residential spaces
Residential spaces underground enhance the well-being when passes the problem of considering these spaces as attached areas with an integrated nature and neglecting the relationship between these underground spaces and the surface [8]. These spaces support the framework of successful design by creating strong physical linkages between the general space underground and the above-ground space. This can be achieved by eliminating the boundaries between the ground-level space and below-ground buildings by considering underground as a viable option [7].

The importance of residential underground spaces can be determined as follows:

- Preserving nature by merging the building with it to be considered as an integrated part, thereby achieving visual effects with aesthetic standards.
- Preserving the ground by isolating the building underground, allowing the roof to be gardens.
- Fire protection, as underground structures are made of concrete, protecting against fires and preventing their spread.
- Protection from natural disasters, as they are protected and isolated from the effects of weather and earthquakes.
- Benefits related to life cycle costs represented by lower maintenance costs, building material durability, needlessness for finishing the building [9].

The importance of underground residential spaces is summarized by preserving and protecting the land and nature from risks in addition to achieving formal effects within aesthetic standards, contradict with the general concept as being negative places, the formation of the underground residential space is important in determining the degree of relationship between the ground spaces and the underground in addition to its integration with the surrounding environment.

4. Morphology of underground residential space formation
Underground residential spaces are considered Eco friendly and the leading style of architecture in the future, an innovative living concept that becomes more integrated with the surrounding environment and a part of the nature-culture. The underground housing preserves the land resources, thus, some developed countries governments’ have issued especially strict legislation regarding the protection of natural land resources. As a result, it is not feasible to construct a new building in a previously unexploited site "Greenfield" not only to assist in protecting the environment but to achieve psychological needs by avoiding urban noise and living close to nature [10]. The study of residential underground space morphology formation, enhancing the relationship between the ground spaces and the underground are detailed into the following sub-sections.

4.1. Spaces near the surface.
The space adjunct to the surface provides a wide range of design opportunities due to its proximity to the surface to determine dealing with entry passages, natural lighting, visual model, lines of view, and facade, there are two fundamental styles of spaces close to the ground:

4.1.1. The first style. Semi underground spaces, protected areas earth that can be built above the terrain or partly underground. These structures have only one facade. Their other sides are covered by the ground [2] it is also called (berm). Walls can be used as architectural elements to form a space or as visual and acoustic barriers and surfaces [11].
4.1.2. The second style. Completely underground spaces and below the terrain level, these types provide sufficient functional needs for living by a courtyard, exposed to the open air. [2] this type is called (subgrade). The main characters of this type are disappearance and non-disruptive integration with the environment. The courtyards are embedded into the design to provide access and create lighting and ventilated spaces [11]. This pattern is suitable in the suburbs while semi-underground housing is more suitable for urban areas as it expands vertically in the underground instead of the horizontal expansion, which leads to the reduction of the floor area of buildings and land conservation reaching to achieve the environmental balance [10], as shown in Figure 4.

4.2. The deep spaces
The expansion motive for underground use to make the surface more available for natural processes and human living. Nobody recommends burying everything under the surface because it is neither feasible nor desirable, so there is a set of suitable functions for this type of construction that includes spaces, windowless functions and functions that require a high degree of environmental control has no intrinsic relationship to the surface [1] as depicted in Figure 5. The depth of space was given more attention by urban planners and architects [1] as deep spaces are virtually independent of the surface and provide access and exchange with the surface. Regarding the distinction between them lies in the degree of the functional relationship between the earth’s surface and its deep interior space that may accommodate radically different surface and underground uses, while near-surface development requires some compatibility between these uses [1]. The uniqueness of this type is within its ability to relate to terrestrial morphology through adaptation and contextualization [12]. Underground spaces were categorized as “Completely Submerged”, “Submerged “, “Partially Submerged” and “ Earth Covered” [7], the most important indicators of underground residential space morphology are presented in Table 1.

![Figure 4. Type (1&2) underground residential spaces.](image)

| Underground residential space morphology | Single facade | 
|-----------------------------------------|--------------|
| Semi underground                        | Earth cover or shallow |
| Central courtyard                       | Formative walls and surfaces |
| In urban areas                          | In urban areas |
| Completely underground                  | Central courtyard |
| In suburbs                              | In suburbs |
| Deep                                    | no surface relationship |

Table 1. Underground residential space morphology(Researchers)
The existence of clear physical connectors that would achieve a positive relationship between underground residential spaces with the surface, therefore, it is to be considered as an undivided space, this is what will be discussed in the next section.

5. Physical connectors for underground residential space

5.1. Functional connectors
The building spatial structure allows a physical connection between the ground and underground spaces by creating functional physical connectors between the internal and external activity if the depth of the buildings allows this [Ibid, p: 44], the exterior design creates a distinctive image, clarifies the building boundaries and reveal the design elements by creating functional connectors between the surface and underground activity and internal and external environments. [7], there's a set of physical properties of these connectors working on eliminating those boundaries, as a consequence; strengthening the relationship between the surface and underground, depending on the degree of communication which determined by depth, aperture, manipulation at the ground level, and spatial and geometrical structure [7] as shown in Figure 5.

5.2. Visual connectors
By clarifying and revealing the elements of building boundaries, sightlines provide a visual link between environments enhanced by the presence of natural light exterior and interior providing easy access to a clear and readable entry that can be recognized from a distance along the main tracks, in addition to the presence of a stimulating internal environment [7]. The visual communication of an underground building is related to several aspects, including social and ideological aspects, as there are several levels of visual communication, direct which is the preferred option or indirect communication [13]. The most preferred option for the entrance level of the underground housing is from the highest level, as the entrance from the ground level of the building is identified, which reduces the feeling of moving between the interior and exterior. As for access through an opening in the ground, it is characterized by concealing the identity of the building in addition to the confusion in both location and Concerning the horizontal and vertical movement inside the building, essential node navigation is created to enhance an easily distinguishable area from other internal environments, guiding and finding the way inside the building without separating the areas of horizontal and vertical movement so the activity inside this node is concentrated with providing visual stimulation and extended views inside the building orientation as clearly seen in Figure 6 [7].

5.3. Movement connectors
Represented in routs to the residential units underground building either through stairs or slopes. The spaces are gradated to create a distinct image within the building and enhance the feeling of spaciousness. In addition to defining the main paths and providing gradual transformations between levels, especially from the ground level to the first level underground [7], also designing common spaces [14] as depicted in Figure 7.

The most important major and minor indicators and substances for the physical links are identified for the residential space under the ground as detailed in Table 2.
**Figure 5.** Functional connectors.

**Figure 6.** Visual connectors.

**Figure 7.** Movement connectors.

**Table 2.** The main element of Physical connectors between the top and bottom (Researchers)

| Physical connectors between the top and bottom | The main element | The main indicator | Indicators |
|-----------------------------------------------|------------------|--------------------|-----------|
| Functional connectors between in and out      | location         | Between underground activity and above it |           |
|                                              |                  | Between indoor and outdoor environments |           |

| Visual connectors between environments        | Components       | Lines of vision    | Depth and aperture |
|-----------------------------------------------|------------------|--------------------|--------------------|
| Levels                                        | Natural light    | Direct             | Manipulation of the ground level and spatial and engineering structure |
| Specifications                                | Clear entries    | Indirect           |                     |
|                                               | A stimulating interior environment |
| Entry level                                   | From the highest level |
6. **Practical study/questionnaire**

An electronic questionnaire was designed for the extracted vocabulary related to the morphology of the formation of the underground residential space and the physical links of the underground residential space and distributing the forms to the experts, specialists and students of the fourth stage in the Department of Architecture, results were extracted depend on observations.

7. **Result**

7.1. **Results related to underground residential space morphology indicators**

Results showed that the (Semi underground) index recorded the highest percentage with indicators (morphology of residential underground space formation), at (84%) ‘Figure 8’.

7.2. **Results related to Physical Connectors for Underground Residential Space**

Results showed that the indicators (Visual connectors and Spatial activity connectors) achieved similar proportions within individual indicators (Functional connectors), Where the two indicators (Visual connectors and Spatial activity connectors) achieved by (80%), while the (functional connectors) index achieved (70%) as detailed in Figure 9.

![Figure 8. Results related to underground residential space morphology indicators.](image1)

![Figure 9. Results related to Physical Connectors for Underground Residential Space.](image2)

8. **Conclusions**

The following are the summarized concluded remarks on the present work:

- The underground residential space was considered habitable whenever attached to the surface more depending on visual-spatial and functional connectors.
- The semi-underground residential spaces and covered spaces with soils have a strong relationship with the surface, which makes it the best choice for living.
- The concepts of using underground residential spaces are immemorial in many places of the world; perpetuity application of facilities now is due to several factors, comprehensive respect to population development, to protect mankind from the natural scourge, or to keep energy and other features of those facilities.
- Many architects called to eliminate the gap between the underground and its surface to highlight the many achieved advantages. Many opportunities are ahead of the ambitious architects to inspire modern concepts to evolve the performing of underground advantages.
- Underground architecture is an endeavour to recorrect the relation between the need to build and to conserve circumference and energy.
- The principle of land clearing that most urban and architectural planners called for by increasing the area of external spaces is realized by investing the underground that leads to the development of housing underground because of the clear need for it. These spaces extended perpendicularly underground until they amount to what is called the skyscraper ground.
- Underground residential spaces are an appropriate alternative to the complexity of residential facilities, programs and functions, making underground space a habitable alternative through careful and effective planning.
- Underground residential space establishes a strong connection to its aboveground environment as preparation to developing underground space, providing a framework for improving the linkages between the above and underground spaces and making positive contributions to the public atmosphere and thus creating quality environments above and underground.

9. Recommendations

We can also state the following recommendations:

- Aiming at investing the underground spaces, to adjust with society characteristics from various environmental and social aspects in addition to providing open spaces these small housing units currently lack.
- Educating the community about the importance of the underground residential spaces and constructions and encouraging their use as positive living spaces not only for storage and parking as it is well known.
- Students of architecture departments should be trained to deal with these spaces as integrated projects to ensure efficient use in the future.
- Enriching this field, within all levels, with future research in the field of housing in addition to other fields, as it achieves functional, social and environmental efficiencies, towards achieving sustainability.

10. References

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