



The underground workspaces questionnaire (UWSQ): Investigating public attitudes toward working in underground spaces

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ARTICLE INFO

Keywords:

Underground spaces
Attitudes
Questionnaires
Office design
Indoor space
Vertical cities
Asia

ABSTRACT

Over half of the global population lives in urban areas, making the issue of space a pressing environmental factor. The development of large-scale underground complexes in (mega-)cities is a solution to healthy urban growth and many governments have already adopted the development of underground (office) workspaces (UWS). Engineering can develop such high quality spaces; yet, there is limited understanding of how the public perceives UWS. UWS are not the same as other workspaces, and thus special assessment tools are needed. Here, we present the Underground Workspaces Questionnaire (UWSQ), which measures pre-occupant attitudes towards UWS. Analysis ($N > 1000$) identified three factors with positive aspects associated with feeling protected, whereas confinement was independent of affective responses. Predictably, responses to the three factors correlated with claustrophobia but were independent constructs. UWSQ can help policymakers and architects understand how populations holistically respond to the idea of working in an underground office.

1. Introduction

The rapid growth of urban population [1] causes cities to have an unsatiated demand for land and space. As a viable solution, subterranean development not only has been put forward [2] but has been extensively adopted by cities where either the need for space is high (especially in mega-cities in East Asia) [3] or where the climatic conditions are more extreme (i.e., cities located in Canada, Russia, Nordic countries (very low temperatures), or the Middle East (very high temperatures)). Notice here that by the term “underground” we do not suggest extreme spaces such as mines or spaces where people stay underground for extensive periods of time [4,5]—though we certainly get some inspiration from these studies. In addition, we refer to only workspaces and not underground residential usages, as the latter have entirely different characteristics. Typically, an underground space refers to an enclosed environment beneath the surface of the earth [6], although this description is rather old and fails to consider differences between cut-and-cover style underground structures, basements in aboveground buildings, and rock caverns. Underground spaces are not

necessarily fully enclosed and can be designed and engineered to be equivalent to or even surpass indoor aboveground spaces. Nowadays, underground workspaces (UWS) could have greenery, well-controlled temperatures, excellent air quality, large and extensive open spaces, excellent navigation systems, and an overall pleasant atmosphere. Yet, as is also explained below, this reality might not match beliefs and stereotypes about such spaces.

UWS are a valuable opportunity for cities to increase their space and thus tackle their environmental impact, as the adoption of such spaces could increase land utilization multifold without the need for urban sprawl [3]. Pollution generated by cars or other types of transportation could be reduced since more services could be placed in the very same geographical region while conserving green spaces. Further, UWS benefit from the earth's thermal mass towards energy conservation due to the thermal properties of the soil and rock that function as a thermal reservoir for interior temperatures, thereby reducing the use of fossil fuels [7–9]. Effectively, a city without UWS has a significant disadvantage and potentially a significant impact on the environment, as, by default, it has fewer options with respect to its expansion. Thus,

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<https://doi.org/10.1016/j.buildenv.2019.02.017>

Received 23 November 2018; Received in revised form 12 February 2019; Accepted 12 February 2019

Available online 21 February 2019

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there is undoubtedly a need for systematic research on both engineering (for instance, energy efficient air quality or temperature control) and social (discussed here) aspects to ensure that this option will be sustainable, human-centric, and will favor global efforts against climate change [10–12].

In the current context, it is crucial to understand what prospective occupants think about the possibility of working in UWS. Notice that here we are *not* targeting post-occupancy or building-in-use assessment—there are already many existing tools that can reliably assess underground offices or similar spaces [13,14]; see also [15] for the relationship between office design and quality of life at work). In addition, the present study is not targeting specific architectural properties of existing or designed workspaces. On the contrary, we assess attitudes towards the prospect of working in UWS *overall*, as we want to know how the public instinctively responds to the idea of UWS—even before they visit the space. Therefore, we adopt a different approach, as the main issue with UWS is not the space itself, but a more general concern with the idea of being underground. In other words, the aim of the present assessment tool is to identify the holistic associations that the prospect of working “underground” generates, which is in accordance with previous research highlighting the need to include measures of perceived (as opposed to objective) metrics of the built environment [16]. Moreover, given that the design of public spaces affects human behavior and health [17], it is essential to incorporate and understand how the public reacts to the idea of UWS, thus aiming towards a human-centered design of such spaces [18].

Another substantial particularity characterizes the UWS and dictates the need to design a UWS questionnaire. Contrary to many other targets of attitudes, most people have limited or no experience with UWS. This means that for UWS, attitudes substantially matter, as it is much easier for misconceptions to arise. Indeed, UWS many times evoke an unjustifiable, almost stereotypic negative attitude, probably stemming from the fact that these spaces have been previously assigned with low-status uses; yet, properly designed UWS are not only acceptable but many times come with a positive premium. This research will provide insights into attitudes towards UWS and inform their communication, design, management, and organization.

Previous research (see Refs. [19–26]) has offered very valuable insights and ideas on issues related to attitudes towards UWS. Yet, various issues have arisen, such as a lack of large sample sizes, a systematic statistical approach, the relative age of the studies, or even the reliance on intuitive, practical, and first-hand observations. In fact, to our knowledge, there is no existing assessment tool examining attitudes towards UWS. We nevertheless capitalize on this valuable knowledge to develop our systematic approach further. Previous research has also shown that spatial characteristics influence individuals' perception and behavior at the workplace [27–32]. Conversely, individual differences can determine the extent to which architecture affects individuals and their work performance. For instance, individuals' proneness to distraction (i.e., screening, inhibitory ability, or perceived privacy) has been found to be negatively correlated with attitudes towards their work environment [33]. Employees' previous experience with an office setting has also been shown to contribute; for instance, workers who previously had individual offices noted a decline in perceived privacy when they were relocated to open-plan offices in comparison to those who had never had individual offices [34–36]. Again, in relation to UWS, there have been limited or no opportunities for the formation of public attitudes and opinions through direct experience, thus allowing people's imagination and preconceptions to bias their responses.

From a more applied perspective, real life examples (which also partially motivated the present research program) can help better understand the nature of the problem [37]. The first example is when a company hires somebody and then subsequently announces that his or her office will be underground. The candidate will react immediately and instinctively by generating a series of cognitive and emotional assumptions (“attitudes”) that will be activated even before s/he actually

experiences the space. The second example refers to a government or a company announcing that they are building UWS. The prospective occupants will first color the spaces with whatever beliefs they have associated with the word “underground” before they have even seen the proposed space. In other words, the value of a workspace, with whatever design properties, will be shadowed by the word “underground”; as such, there is a need to capture these holistic responses to complement them with other existing workspace design questionnaires that either capture expectations for an ideal office space or assess the perception of a current office space.

The present questionnaire (*Underground Workspaces Questionnaire – UWSQ*) aims to provide a “common yardstick” against which the attitudes, expectations, and views of various populations can be measured and compared. This would allow stakeholders to identify and predict potential problems, opportunities, and expectations related to UWS.

This paper is organized as follows. We first explain the methodological steps towards the development of the UWSQ, starting with the generation of items and continuing with the main survey and psychometric analysis. Next, we present the resulting three factors that describe the overall attitudes towards working in UWS. We then examine the relationship between these three factors and claustrophobia, which has been typically associated with UWS. We conclude by discussing implications of the present research and potential uses of the UWSQ.

2. Materials and methods

2.1. Sample

A sample of 1093 Singaporean citizens and permanent residents (women: 548 (50.1%)) using a panel recruited through a specialized market research company completed an online survey. We used stratified sampling with proportionate allocation based on ethnicity and gender. The sample was comprised of 71.6% Chinese, 14.9% Malay, 10.2% Indian, and 3.2% others, matched to the ethnic diversity of Singapore. Mean age for the entire sample was 36.07 years (SD = 11.21). Mean age of the men was 40.58 years (SD = 11.80), and mean age of the women was 37.24 years (SD = 10.35).

2.2. Sample size adequacy

A screening of data to determine the suitability of factor analysis was carried out. A Kaiser-Meyer-Olkin measure of sampling adequacy was 0.93, exceeding the minimum value of 0.60 as recommended by Tabachnick and Fidell [38] for an appropriate sample size.

2.3. Item generation

2.3.1. Overview

Within the context of determining critical factors of attitudes in relation to working in the underground environment, we first reviewed the existing literature on views about various UWS. A significant part of this review has been published elsewhere (MASKED). Based on the literature review, extensive consultations with experts, and focus groups/interviews with current users, developers, and policymakers of UWS in Asia, Europe, and the U.S., 22 attitude items were formulated. To make these items comprehensible and culturally appropriate, a sociological and cultural perspective was further applied when choosing wording, with an expert (seventh author) reviewing the items. As with most attitude scales, we employed the 7-point Likert-type scale format for the responses, which ranged from “*strongly disagree*” to “*strongly agree*”. To make the situation more realistic, participants were asked to imagine that their usual workspace was relocated to a deep basement level (level B8) and then answer to what extent they agree with each statement regarding working in that basement level workspace. For presentation of the items, positive and negative expressions were listed in a mixed and random sequence so that there were no biased responses

Table 1
Means, standard deviations, and intercorrelations for individual items.

	1	2	3	4	5	6	7	8	9	10	11
1. It decreases communication with people aboveground.	.537**										
2. I would feel suffocated.	.726**	.669**									
3. It isolates people underground from people aboveground.	.477**	.666**	.650**								
4. It is dull.	.440**	.714**	.582**	.701**							
5. I would feel like I have died.	-.094**	-.310**	-.213**	-.338**	-.304**						
6. It is an inspiring place to work.	.367**	.588**	.441**	.502**	.630**	-.170**					
7. I would feel scared.	.436**	.595**	.530**	.553**	.654**	-.207**	.773**				
8. I would feel lonely.	.321**	.450**	.379**	.405**	.535**	-.044**	.600**	.642**			
9. I would be easily distracted.	-.185**	-.362**	-.301**	-.406**	-.358**	.633**	-.280**	-.300**	-.144**		
10. It would feel pleasant.	-.244**	-.412**	-.333**	-.467**	-.414**	.580**	-.326**	-.334**	-.211**	.658**	
11. I would be enthusiastic about it.	-.185**	-.325**	-.225**	-.312**	-.379**	.352**	-.334**	-.287**	-.363**	.473**	.571**
12. It would be easy to focus on work.	.307**	.533**	.376**	.418**	.533**	-.172**	.646**	.607**	.473**	-.260**	-.284**
13. I would feel nervous.	-.139**	-.339**	-.204**	-.322**	-.347**	.419**	-.273**	-.279**	-.247**	.513**	.571**
14. It would be calming.	.278**	.459**	.333**	.370**	.501**	-.181**	.462**	.459**	.400**	-.238**	-.240**
15. It is spiritually harmful.	.259**	.491**	.386**	.503**	.458**	-.261**	.419**	.440**	.279**	-.271**	-.367**
16. The office would feel confined.	.308**	.490**	.391**	.556**	.516**	-.276**	.473**	.538**	.404**	-.332**	-.406**
17. It is a boring place to work.	.315**	.577**	.450**	.558**	.649**	-.302**	.561**	.588**	.437**	-.373**	-.418**
18. It is like staying in a tomb.	-.107**	-.238**	-.139**	-.236**	-.256**	.386**	-.221**	-.203**	-.135**	.406**	.444**
19. I would feel protected.	-.119**	-.285**	-.173**	-.264**	-.293**	.373**	-.305**	-.249**	-.250**	.429**	.480**
20. It is a secure place to work.	.265**	.478**	.364**	.415**	.497**	-.227**	.566**	.500**	.427**	-.277**	-.343**
21. I would feel unsafe.	.320**	.558**	.435**	.514**	.508**	-.232**	.461**	.481**	.338**	-.263**	-.340**
22. The office lacks air.	4.65	4.91	4.81	4.82	4.20	3.32	4.03	4.05	3.60	3.33	3.34
Mean	1.49	1.52	1.50	1.46	1.70	1.34	1.55	1.48	1.45	1.26	1.32
Standard Deviation											
1. It decreases communication with people aboveground.											
2. I would feel suffocated.											
3. It isolates people underground from people aboveground.											
4. It is dull.											
5. I would feel like I have died.											
6. It is an inspiring place to work.											
7. I would feel scared.											
8. I would feel lonely.											
9. I would be easily distracted.											
10. It would feel pleasant.											
11. I would be enthusiastic about it.											
12. It would be easy to focus on work.											
13. I would feel nervous.											
14. It would be calming.											
15. It is spiritually harmful.											
16. The office would feel confined.											
17. It is a boring place to work.											
18. It is like staying in a tomb.											
19. I would feel protected.											
20. It is a secure place to work.											
21. I would feel unsafe.											
22. The office lacks air.											
Mean											
Standard Deviation											

** : Correlation is significant at the p = 0.01 level (two-tailed).

toward one side of the scale when completing the questionnaire. The original items are presented in Table 1.

2.3.2. Data screening and descriptive statistics

The univariate skewness of all 22 items was < 0.48 and univariate kurtosis was < 0.88 in absolute value. According to Curran, West, and Finch [39]; skewness and kurtosis falling between 0 to 2 and 0 to 7, respectively, demonstrate sufficient normality. The mean, standard deviation, and intercorrelation of each variable is presented in Table 1.

3. Results

3.1. Main factors explaining attitudes towards UWS

Bartlett's test of sphericity was significant, $p < .001$, indicating the factorability of the matrix. We applied maximum likelihood analysis to extract factors [40]. Since data are relatively normally distributed, maximum likelihood is the best choice because “it allows for the computation of a wide range of indexes of the goodness of fit of the model [and] permits statistical significance testing of factor loadings and correlations among factors and the computation of confidence intervals” [40]; p. 277). For rotation, direct oblimin or an oblique rotation was applied, as it dissociates factors while minimizing cross-products of loadings. Further, the current method can handle a large range of factor intercorrelations [41].

Following Bandalos and Finney's [42] suggestions, we determined the number of factors based on a combination of standard statistical, mathematical, and heuristic judgments. Therefore, the following standards were applied for factor retention: (a) Horn's parallel analysis, (b) eigenvalues greater than 1, and (c) examination of Cattell's scree plot (for the point of modulation Cattell's [43] scree test (cited in Ref. [42])).

- (a) Horn's parallel analysis [44]: Parallel analysis program for SPSS was employed. We generated 1000 sets of random data as recommended by O'Connor [44] and Watkins [45] and compared the eigenvalues obtained in the real data file with the corresponding values from the random data results generated by the parallel analysis. If the obtained value was larger than the random value, then the factor was retained. From the analysis, six factors obtained eigenvalues greater than the random values, suggesting six factors should be retained for further analysis.
- (b) Eigenvalues: The extraction analysis found four factors with eigenvalues greater than 1, suggesting four factors should be retained for further analysis. These four factors represented 67.2% of the cumulative variance.
- (c) Cattell's scree plot: There were two inflections on the plot, indicating four factors should be explored further.

At this point, based on the results meeting all criteria, we retained four factors (explaining 67.2% of the total variance) for further interpretation.

For the interpretation of the factor solution, we followed Bandalos and Finney's [42] recommendation that the structure coefficients should be observed first, followed by an assessment of the pattern coefficients to comprehend the unique factor-variable relationships. All the items that loaded on each of the factors on both the structure and pattern matrix because of the oblimin rotation were examined further. Items that had factor loadings below 0.30 (intermediate loading) and did not semantically fit with the definition of that particular factor were excluded. Further, any factor that achieved less than three items was removed as it is considered a weak and unstable factor [46]. In total, seven items were deleted due to inconsistent loadings and definitional fit, which resulted in three factors with 16 items in total, explaining 56.94% of the total variance. The results of the final factor analysis are shown in Table 2. The three factors all had Cronbach's alpha over .80 (Factor 1: $\alpha = 0.88$; Factor 2: $\alpha = 0.87$; Factor 3: $\alpha = 0.86$) suggesting

Table 2
Factor analysis.

Factor Names	Items	Item No.	Factors		
			1	2	3
Calmness/safety	It would be calming.	14	.747		
	I would be enthusiastic about it.	11	.735		
	It would feel pleasant.	10	.705		
	It would be easy to focus on work.	12	.694		
	I would feel protected.	19	.670		
	It is a secure place to work.	20	.672		
	It is an inspiring place to work.	6	.632		
Negative Affect	I would be scared.	7		.776	
	I would feel lonely.	8		.730	
	I would be easily distracted.	9		.718	
	I would feel nervous.	13		.552	
Confinement	The office would feel confined.	16			.823
	Is like staying inside a tomb.	18			.744
	It is a boring place to work.	17			.716
	The office lacks air.	22			.584
	It is spiritually harmful.	15			.430

Extraction Method: Maximum Likelihood.

Rotation Method: Oblimin with Kaiser Normalization.

adequate internal consistency.

3.2. Independence of the factors associated with UWS and claustrophobia

UWS have been typically associated with confinement (agreeing with Factor 3 in our results), largely possibly because of an erroneous association with mining and caves. To ensure that UWSQ is related (as expected) but independent from measuring claustrophobia, we also measured claustrophobic anxiety (CSA; [47]). We first examined the correlation between responses on the three factors and claustrophobia. Not surprisingly, inter-scale correlations indicated that factor 1 (“Calmness/safety”) was negatively correlated with claustrophobia ($r = -0.13$, $N = 1078$, $p < .01$, two-tailed), whereas the other two factors (“Negative affect” and “Confinement”) were significantly positively correlated with claustrophobia ($r = 0.39$ and 0.24 , $N = 1081$, $N = 1080$, respectively, both $p < .01$, two-tailed) (note that sample size differs as participants that did not answer some of the questions of each factor were excluded for this specific analysis). This is expected for theoretical reasons, but do note that all correlations were weak (below 0.40) yet significant due to the large sample size.

To further examine the discriminant validity of the UWSQ measure, we conducted another exploratory factor analysis with the items measuring claustrophobic anxiety (4 items; $\alpha = 0.83$) to confirm if the attitudinal factors are independent of claustrophobia. Results from the exploratory factor analysis of the 16-item attitude scale with the 4-item CSA scale clearly revealed the independence of the three factors from the claustrophobia factor. Table 3 shows clearly that the CSA and claustrophobia items loaded on their respective factors.

3.3. Short interpretation of factors

The statistical analysis extracted three factors. Beyond the numerical approach, we offer a qualitative interpretation of the factors. We also further discuss the factors in the Discussion section.

3.3.1. Factor 1: Perception of Calmness and Safety

This factor had a group of items that were generally positive. Several items were related to feeling secure, such as feeling protected and calm (e.g., items 14 and 19). Other items reflected positive affect

Table 3
Factor loadings from exploratory factor analysis of 16-item attitudes toward UWS scale with 4-item claustrophobia scale.

Item	Factor			
	Factor 1	Factor 2	Factor 3	Claus
It would be calming.	0.745	0.094	0.098	0.001
I would be enthusiastic about it.	0.735	−0.054	−0.205	0.032
It would feel pleasant.	0.705	−0.076	−0.155	0.011
It would be easy to focus on work.	0.692	0.16	0.096	−0.047
It is a secure place to work.	0.673	0.106	0.09	−0.03
I would feel protected.	0.673	0.007	0.067	−0.033
It is an inspiring place to work.	0.635	−0.188	−0.207	0.045
I would be scared.	−0.062	− 0.768	0.111	0.043
I would feel lonely.	−0.034	− 0.747	0.188	−0.001
I would be easily distracted.	−0.025	− 0.706	0.004	0.032
I would feel nervous.	−0.063	− 0.527	0.213	0.067
The office would feel confined.	0.004	0.047	0.824	0.033
It is like staying inside a tomb.	−0.058	−0.153	0.735	0.043
It is a boring place to work.	−0.063	−0.109	0.710	−0.013
The office lacks air.	−0.027	−0.146	0.580	0.032
It is spiritually harmful.	0.004	−0.252	0.425	0.048
Trying out clothes in a small fitting room with the door locked.	0.057	0.053	−0.037	0.846
Entering a windowless toilet and locking the door.	−0.038	0.033	−0.022	0.835
Riding a small elevator by yourself.	−0.018	−0.088	−0.018	0.695
Riding a small elevator with the maximum number of passengers.	−0.01	0.017	0.087	0.594

Extraction Method: Maximum Likelihood.

Rotation Method: Oblimin with Kaiser Normalization.

Absolute Correlations over > |0.50 are highlighted.

and benefits associated with working in the underground environment (e.g., items 11 and 12). Factor 1 demonstrated a holistic view on positive aspects of underground spaces, combining positive affective and practical considerations.

3.3.2. Factor 2: negative affect

This factor consisted of items that reflect negative affective states. In other words, the items described how the respondent would *feel* if s/he was working in an underground office, such as feeling nervous, lonely, or distracted (e.g., items 8, 9, and 13). Thus, Factor 2 represents affective (emotional) responses towards UWS.

3.3.3. Factor 3: confinement

Confinement appears as an independent factor from other negative affective responses, which demonstrates that UWS do have a unique profile as compared to other spaces. Elements of confinement emerge, such as boredom and concern about air quality. Interestingly, some of the items represent negative cultural beliefs, such as an association with the concept of burial and evil (e.g., items 15 and 18). Factor 3 seems to reflect cognitive processes underlying the negative attitudes toward working underground, mainly pessimistic beliefs regarding the underground office.

4. Discussion

Using a large representative sample, we investigated critical factors of the attitudes toward working in an UWS. Based on the common factor analysis, three main factors emerged: *Perception of Calmness and Safety, Negative Affect, and Confinement*. Based on the results, it could be deduced that people view various positive aspects—such as their beliefs about the safety of an underground office, how comfortable they would feel in the environment, and enthusiasm to work in such space—as one solid construct, having a holistic picture over various positive experiences regarding a hypothetical underground office. On the other hand,

negative attitudes were divided into two main factors, with the first factor reflecting negative affective responses and the second factor focusing on the (many times unfounded) beliefs associated with confinement. This suggests that negative feelings about underground spaces are not necessarily based on processed thoughts (i.e., beliefs) but rather on emotional, automatic responses. This is somehow justified given the lack of real experiences with UWS. Thus, our analysis revealed that negative affect and negative belief are two separable constructs that represent negative attitudes.

As it has been the case with most attitudinal or other types of scales or psychometric instruments, the first development happens within a specific context and culture. It is common for all types of scales to be first developed in a specific population (to ensure a general homogeneity of responses) before testing the instrument in other cultures and populations. Yet, properties of the sample indicate that the results do meet generalizability concerns to a significant extent. To start with, our sample had a good representation of gender and age—parameters that will be examined in other studies. In addition, our sample was not opportunistic (such as M-Turk samples), but carefully recruited. The study population consisted of a multicultural sample of mainly Chinese, Malay, and Indian residents of Singapore, thus representing a large range of Asian cultures. This research is particularly relevant for Asia because of the rapid increase in urbanization, mega-cities, and high rates of current and projected development of underground spaces. Moreover, Singapore has specific advantages that make it an ideal space for testing this concept: it is a well-developed and modern city with moderate use of underground spaces. Thus, considering that Singapore is multicultural, located in Asia, has extensive underground spaces, relatively high population density, and modern infrastructure, we believe that the current population is at least typical, if not representative, of many other advanced Asian cities. Nevertheless, given that attitudes towards the environment are influenced by cultural factors (Milfont & Schultz, 2016), it would be essential to conduct the research in other countries with a more distinct cultural background (e.g., East Asian vs. Western) or different climates or urban structures and compare the results across these studies to generalize our findings.

Our results, to a great extent, reflect thoughts and ideas that have been raised by UWS researchers as well as users and developers of UWS but not solidly validated and examined [11,26,48]. One major factor identified in our research and in previous studies is perceived confinement. Confinement can affect navigation within the space, as a lack of landmarks to use as waypoints and visual occlusion by close walls and ceilings can disrupt route planning. This can create a lack of confidence and a feeling of uneasiness in the environment [6,49]. The absence of windows might also be a critical factor, as windows in aboveground spaces enable connection with outdoors, visual contact with nature, and interconnection of spaces [50]. Notice that the issue here might be purely psychological, as even a virtual window can reduce stress responses (as compared to a windowless space), which Fich et al. [51] attribute to a belief that windows represent possible evacuation routes. Often, a lack of natural light and ventilation make space darker, damp, and static—qualities lead to fear and avoidance in people [6,52–54]. Again, despite the fact that most of these issues are addressable with proper engineering solutions, it is rather usual for underground spaces to be often used for underprivileged purposes, such as carparks and storage, in which atmosphere and comfort are not considered crucial to design [55]. This, in turn, may contribute to further negative associations with confinement.

While there are many perceived negative aspects, positive attitudes toward underground space have also been documented. For instance, in countries with extreme outdoor conditions (e.g., extreme weather or the threat of bombardment), underground spaces often function as a shelter against such conditions and are perceived as a secure and safe place [21,56,57]. Social and cultural factors can influence these positive attitudes; for example Hane et al. [52] reported that Americans, as opposed to Japanese, chose ‘comfort’ more frequently as an adjective to

describe how they felt about staying in underground spaces. Moreover, previous experience in working underground has shown to influence one's perception of underground spaces. Carmody and Sterling [58] reported that people who were already working in an UWS were more willing to work in a new UWS compared to people who never had that working experience. In addition, underground office workers who were unsatisfied with their office environment preferred architectural improvements in their office rather than moving aboveground, whereas aboveground office workers constantly expressed their reluctance to work underground in general. This suggests that individuals' experiences are crucial factors that determine how underground space is perceived [59].

4.1. Academic and practical use of the UWSQ

It should be noted that the need for the development of the current instrument is greatly motivated from the construction industry and policymakers. Developers want to know whether building UWS will be accepted and used by the public. Towards that end, they need to understand concerns and also identify potential users that are more open to the idea of UWS—and thus accordingly change their overall strategy as well as the way the UWS are designed and promoted.

Indeed, similar to challenges that any other innovations face, it is important to target early adopters that would choose to occupy the newly built UWS [60]. UWSQ could be used to identify segments of the population that are more willing to move to UWS. By knowing their characteristics, it is possible to adapt the architecture and design of the spaces to reflect their aesthetic preferences—as opposed to developing all-purpose spaces. Specific qualities may be observed more often in one type of industry than the other. Thus, introducing UWS to certain industries first may facilitate smooth land-use change. Such knowledge will help the policymakers build the framework for promoting the future usage of large-scale underground complexes, which will work towards healthy growth of urbanization.

Like in any other cases with stereotyping, the cognitive strategy of *individuation*, in which perceivers focus on individual attributes of the concept, as opposed to *categorization*, in which perceivers see the concept through the eyes of social norms, would be crucial to reduce negative associations [61,62]. One way to do this is to let the public interact with existing underground complexes in a natural setting (e.g., by planning attractive social events similar to the fun runs and school visits organized by the Springfield Underground, which is the one of the largest underground facilities in North America [63]). Through this process, particular qualities of the underground environment will be perceived, which will slowly prevent immediate categorization of the old concept of underground and eventually reduce negative associations.

From an academic point of view, the UWSQ allows for a more systematic examination of how UWS are perceived as a function of numerous parameters. Demographics parameters, such as age, gender, and occupation, should be the first to be examined. It would be interesting to examine the suggested, but mostly untested, hypothesis that experience with indoor or very well designed UWS will change users' perceptions as well as which factors are more sensitive to these changes. Personality characteristics could also help identify workers that are particularly sensitive or resilient to UWS.

Additionally, the present instrument could help to quickly associate preferences over different architectural parameters with attitudes towards UWS. (Again, remember our aim was to dissociate architectural preferences from attitudes towards the concept of being underground). For instance, we could identify the types of office design (open-space vs partitioned), lighting, furniture, or even conceptual aspects of the design (e.g., the 'James Bond' style underground office that has been developed in Sweden [64]) that positively orient occupants' value and increase the likeability of the space. Overall attitudes could be integrated with more specifically targeted design interventions, including

thermal comfort, skylighting and air quality [65–67]. Similarly, in the case of users with negative orientations, we can identify what kind of aspects architects could improve to compensate for the fact that people have to work underground. Moreover, future research should examine the specific impact of perceptions towards UWS to other important aspects of urban life, such as walking and travel behavior, including choice of mode of transport [68].

5. Conclusion

The issue of space in cities is posing an environmental problem. A novel, but rapidly adopted, solution is to build underground spaces. UWS are a reality and provide cities with substantial space and sustainability advantages. Engineering can nowadays offer high quality underground solutions that match aboveground windowless spaces. However, a lack of understanding of how the public perceives UWS still exists. Our instrument will give the means to assess how different segments instinctively react to the idea of working in an UWS. Our instrument could also help understand who could be the early adopters as well as how to optimally design the spaces to cater to their needs. In essence, this will not only save millions of dollars by matching the design of the UWS with users' needs, but will eventually improve the everyday lives of hundreds of millions of city dwellers. Considering the key role of social dynamics in the adaptation to land-use change, the current research will be vital for creating the groundwork for healthier and human-centered urban development.

Acknowledgement

This research is supported in part by the Singapore Ministry of National Development and the National Research Foundation, Prime Minister's Office under the Land and Liveability National Innovation Challenge (L2 NIC) Research Programme (L2 NIC Award No. L2NICCFP1-2013-2). Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not reflect the views of the Singapore Ministry of National Development and National Research Foundation, Prime Minister's Office, Singapore.

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