The development of underground pedestrian systems in city centres under the guidance of walkable cities

Jianqiang Cui[1], Andrew Allan[1], and Dong Lin[2]

[1]Institute for Sustainable Systems and Technologies, University of South Australia, Adelaide, Australia

[2]CSUS, China

Email for correspondence: Jianqiangjean@yahoo.com.cn

Abstract

A most important and special element of urban environment is city centre which is normally viewed as an identity of a city because of concentrated buildings and intensive services. Thus it is extremely important to keep pedestrian spaces in city centres of metropolises integrated and continual, but hard to achieve especially where road resources on the ground are crowded by vehicles for the efficiency. As compensation of urban pedestrian systems on the street level, underground pedestrian systems and skywalk systems not only extend the realm of pedestrians, providing a safer and more convenient walking environment, but also save land resources for more compact and sustainable city construction.

This paper provides a first step to standardise the way we look at underground pedestrian systems in the context of walkable cities. It draws together research on walkable cities and underground pedestrian networks to illustrate how better integration of underground pedestrian networks with urban pedestrian systems can be achieved. It reviews the influencing factors of underground pedestrian systems to guide the planning of an integrated pedestrian network that incorporates underground pedestrian systems. The paper paves the way for the collection of more detailed primary data on the decisive effects of those influencing factors to reach a better understanding of how underground pedestrian systems are affected by pedestrian usage, spatial activity patterns, the transportation system and urban design.

1. Introduction

Although it has been identified that it is extremely important to keep pedestrian spaces integrated and continuous, this can be hard to achieve especially in city centres of metropolises where road resources on the ground are crowded by vehicles for the efficiency of intensive commerce and concentrated services (Huang & Lu 2007). Separating pedestrian and vehicle traffic, to shield pedestrians from inclement weather and add a new level of retailing to encourage downtown development, in many large cities throughout the world such as in Toronto, Tokyo, Sydney, New York, Shanghai and London, underground pedestrian systems were advanced through the construction of either subway systems or underground shopping streets, sometimes in combination. Underground pedestrian systems, functioned as a medium by linking transport, working and leisure places together in integrated spaces with a variety of functions to create an urban synergy.

Underground pedestrian systems are systematic underground pedestrian spaces that have multiple functions for transport, public and commercial usage - such as underground shopping streets, and subway stations with underground concourses. Such underground pedestrian systems are normally located in CBDs, subcentres and regional centres in metropolises and strongly influence city functions. Adopting a systems approach to analysing urban pedestrian space helps to conceptualise the relationship between underground pedestrian systems and other pedestrian spaces within the broader urban environment. Firstly, viewing the city as a complex system, an underground pedestrian system is a vital subsystem of public space systems, expanding space and movement below the surface pedestrian systems. Secondly, an underground pedestrian system uses walking as a mode of transport to link and aggregate activities such as retailing and mass transit within an underground setting. Thirdly, an underground pedestrian system has an important functional feature through the provision of underground public passageways functioning as a medium that integrates ground level spaces with underground spaces.

Research on the functions of underground pedestrian systems appears to be lacking and largely descriptive. Previous research on subways and underground shopping malls has referred to only some parts of the system (such as Huang 2007; Tong 1998; Liu 2009), but has never concentrated on an underground pedestrian system as an integral element of a city's pedestrian network. Research on planning and design is normally concerned with a special part of underground pedestrian systems, such as underground concourses and atriums from the perspective of architecture or the design of internal spaces (such as Liu 2006; Chen & Wu 2002). During the development of cities in North America, attention focused on pedestrian networks that featured grade separation design elements, while the particular characteristics of underground pedestrian spaces were not considered enough to warrant separate study (such as Byers 1998a; Byers 1998b; Maitland 1992). According to Zacharias and Xu (2007b), former research on underground systems was descriptive concentrating on how to build the system and its characteristics, but was almost never an assessment of practice. Moreover, although walking has been regarded as a simple, cheap, sustainable and healthy transport mode, the target of constructing a walkable city using walking as an alternative transport mode is still a hard policy objective to fulfil. Underground pedestrian systems could contribute better outcomes for walking environments once issues that arose from integrating underground pedestrian systems into urban pedestrian systems are addressed.

2. Integrating underground pedestrian systems

Problems of integrating underground pedestrian systems into urban pedestrian systems arise not only within underground pedestrian spaces, but also within the intermediary spaces connecting the street level to underground pedestrian spaces. Such problems include: the inherent shortcomings of being underground; and a lack of consistency in organisation, transition spaces, signage and other way-finding devices (Wang & Shu 2000).

A series of interesting surveys by Zacharias (2000, 2006) examined underground pedestrian systems from the perspective of pedestrians, which reflected pedestrian reactions and behaviours in such an environment revealing key issues associated with integrating underground pedestrian systems into an urban pedestrian system. In these studies, 43 visitors freely explored the underground system in Montreal while 25 participants explored a virtual reality presentation to see how they navigated through the space. He found that locally based information is vital to guide pedestrian behaviour in an underground environment. He utilised the walking enumeration method to analyse the results of the 74 links (public corridors) survey. He found that the central area of an underground system should be focused on because it is much more attractive for pedestrians and was where they aimed to gain information to locate their position. His research used comprehensive pedestrian counts together with a property use survey updated with 1996 and 2003 data sets and indicated that economic profits are related to the amount of pedestrian traffic in the corridors. Therefore attention should be paid to the number of pedestrians in the corridors in the future to keep the economic liveliness of a commercial space. He also put forward the proposition that a new public space is the most vital factor in trying to attract pedestrians. Improving environmental quality in an urban renewal program would also receive benefits (Zacharias & Xu 2007a). His research concentrated on the following aspects: orientation facilities (pedestrian organisation), vital nodes (central area), the relationship between pedestrians and the economy, public space (underground space usage) and benefits from improving the environment. Pedestrian organization was chosen as a critical factor to specify in underground systems.

Pedestrian flow inside underground pedestrian spaces could possibly be organized and channelled if the environment inside could provide an object orientated and accessible space. Orientation facilities improve pedestrians' ease and ability to navigate once they have entered and also clear and consistent directional signage provides a good way to help their orientation. Choi and Morita (2005) focused on how to improve the effectiveness and efficiency of information signs with regard to their location, height and placement, providing coordinated information about points and places, the view point from a pedestrian's walking behaviour and how they assist in creating connections between spaces. Shima's (2006) research concentrated on how to create a barrier-free information environment by guidance and information signs on the following aspects: balance between signs and advertisements; easy-to-find information board; information selection; easy-to-understand signs; continuity of signs; consistency of location names; providing more information in advance; use of an information centre updating information; measures to identify a location; consideration for those with weak eyesight; wheelchair users; and disaster prevention. Accessibility inside these spaces is also a very basic design component for organizing pedestrians. The passageways' length, width and height, the materials and colours, the lighting, sonic and air quality, the dimensions, the stairs and elevators are necessary to make up a pedestrian environment. Facilities for the elderly and the physically handicapped, emergency passages, fireproofing facilities and fire extinguishers are vital design elements too (Carmody & Sterling 1993; Golany & Ojima 1996).

Possibly, the realization of all these needs within the walking environment may not be sufficient to induce smooth walking traffic (Alfonzo 2005). For pedestrians who are familiar with an underground environment, their behaviour could be largely influenced by their experience, while for strangers - such as tourists - it mostly depends on what they could perceive from the system, not only with regard to form and functionality aspects but also with respect to the psychological aspects (Durmisevic & Sariyildiz 2001). applying this theory to an underground pedestrian environment, the survey design focused on how the perception of space affects pedestrian behaviour, and what kind of perceptions advance or obstruct pedestrian organisation, as well as what the interaction between pedestrians who are familiar with the environment inside and those who are not contributes to an understanding of pedestrian organization in underground pedestrian systems.

Underground pedestrian systems integrate with the urban environment through their entrance/s and exit/s which are their visual interface with the city at the street level. The surface and underground spaces are easily perceived as completely separated from one another. Jung, Kim and Park (2009) indicated that the entry and exit of underground pedestrian spaces are processes of transition between exterior and interior as well as above and below grade. The process may make people feel that there is a great difference, for example, often negatively, visually and psychologically in transitioning from the interior to the exterior, from light to dark, from open to confined, from familiar to unknown because of distinct shortcomings in the underground spaces. To reduce this difference, the quality of the transition space is extremely vital. The interface may present the only opportunity to establish a connection. It creates spatial abundance by including two sets of contradictory phenomena, with opposing characteristics – inside and outside – within a single space. They also proposed that although the intermediary space has a profound influence on the pedestrian's conception of logical space orientation, unfortunately, literature on research with regard to how an effective transition is created between underground and ground level spaces for underground pedestrian networks was lacking.

The above issues regarding accessing the walking environment for underground systems related to the ingress and egress of the systems as part of objects of the built environment of underground pedestrian systems. When referring to building walkable cities, research was conducted with a focus on underground pedestrian spaces but incorporating the interfaces of the underground pedestrian spaces at street level. The requirement of becoming a more walkable city offers future opportunities for the construction of underground pedestrian systems.

3. Walkable cities

Strategies for underground pedestrian systems have failed to establish a basis for creating and planning walkable cities. There is currently no identified standard way to measure underground pedestrian systems in the context of a walkable city. The approaches through which walkable cities could be addressed by underground pedestrian systems have not been identified. With Regard to the aim of planning for a walkable city, Southworth (2005) and Bell (2004) argue that a walkable city incorporates a dominant pedestrian usage in a city's transport system. For example, from Southworth's statement (2005, p. 246), 'encouraging people to choose walking over driving for a walkable city', and Bell's statement (2004, p. 5), 'in walkable cities, people choose to walk over other transport modal choices', highlight the importance of encouraging a dominant pedestrian usage in a city's transport system.

Even though no direct standard is given to measure a walkable city, Brown et al. (2007) suggests a combination of interests from different groups in the built environment can be used to promote walking. Those interests provide diverse understandings of walkable cities: city officials want a safe and popular environment - especially in central areas - to attract people with different destinations; Social equity advocates want an equal environment for different kinds of pedestrians such as the elderly, children, and disabled people; environmentalists want an environment with less car dependence and accordingly less roads, car parks, car emissions, noise and pollutants; and New Urbanists want an environment supporting a sense of community with diverse and pedestrian-friendly places and efficient resource usage (achieving through mixed uses, transit oriented transport, medium densities and grid streets networks). Although these interests focus on different aspects of walkability, they all underscore the built environment as a key element in promoting more walkable cities.

The built environment, according to Leyden (2003), is the way we design and build our communities and neighbourhoods. In another definition, it is a part of physical environment constructed by human activity (Saelens &Handy 2008). The functions of an attractive built environment promoting walking have been explored in a considerable body of research (such as Saelens & Handy 2008; Brown et al. 2007; Forsyth & Southworth 2008; Hoehner et al. 2006; Leyden 2003). Southworth (2005) identified six criteria of the built environment that can help to achieve walkable cities, namely: (1) connectivity; (2) linkage with other modes; (3) fine grained land use patterns; (4) safety; (5) quality of path; and (6) path context.

Southworth (2005) placed special emphasis on the finding that senior citizens prefer to walk in malls (an indoor environment) because of safety, comfort and sociability. Saelens and Handy (2008) reviewed prior research between 2002 and 2006 about environmental features associated with more walking to potential destinations and distilled six key aspects: (1) accessibility (distance to destinations); (2) mixed land use; (3) high density; (4) aesthetic qualities (attractiveness of the environment such as pedestrian infrastructure and connectivity of the network); (5) safety; and (6) walkability (general combination of all attributors).

Brown et al. (2007) divided previous research about environmental features that correlates walking into objective and subjective categories with a focus on small scale or large scale. In large scale studies, density and pedestrian accessibility to diverse destinations are exclusive correlations to be measured. But they also suggested that a new research trend is a focus on micro level design features. They summarized these micro-level design features in pedestrians' perceptions to include small-scale streets incorporating accessible or high-quality sidewalks or paths, good access to desired destinations, desirable destinations, pleasant pathways and a sense of safety. However, these objective perceptions have limited usefulness because the environmental features are often subjectively rated. When referring to actual physical environments, previous research showed density, diverse land use and destinations, and pedestrian-friendly designs are combined features of walkable places.

The relationship between the built environment and walkability (the ability for walking) is studied in different ways by different researchers. Studies tend to focus on three common issues: land use patterns; the transportation system; and urban design (Saelens &Handy 2008). To develop this way of thinking from street level down to the level of the underground pedestrian network, it is useful to think of land use patterns being the distribution of activities and the buildings within the spaces of the network above and underground; the transportation system being the physical infrastructure of roads, sidewalk and bike paths in the street level and walkways, subways, roads and car parks underground, as well as the service this system provides; and urban design being the arrangement and appearance of the physical elements within the spaces of the network above and below ground.

To effectively examine the built environment of underground pedestrian systems, the fields of planning, transportation planning, urban design, environmental planning, human behaviour and engineering are useful to draw upon. As a first step, the influencing factors of the urban environment of underground pedestrian systems needs to be considered before data collection and specific analysis of built environment can occur.

4. Influencing Factors of Underground Pedestrian Systems in Urban Environment

Underground pedestrian systems are not a universal phenomenon. It is not unusual to find that some cities have underground pedestrian systems while others do not, and existing underground pedestrian systems in different locations have different scales and physical designs. Many conditions have combined create a broad context within which underground pedestrian systems were forced to develop (Belanger 2007). As concluded in the above section, the built environment is the key to improve the walkability of a city. A clear understanding of the relationship between underground pedestrian systems and walkability can be reached if the importance of various factors of underground pedestrian systems in the urban environment can be addressed. Although the influence of the built environment is the most important issue to be targeted, the natural environment still has significant importance in the development of underground pedestrian systems.

The natural environment of underground pedestrian systems is determined by natural resources such as urban geology, topography, soil, air, surface water and biological system (Xie & Deng 1996). Carmody and Sterling (1993) discuss a series of advantages and disadvantages of utilizing underground spaces as potential factors that influences the decision to build underground. Climate, geology and topography relate to most of the benefits and drawbacks. Moreover, the three aspects also are mentioned as common motivations in constructing the systems in other research (such as Byers 1998b; Sakakura, Shimizu and Itabashi 2007; Tong 1998; Belanger 2007; Eady 1990).

The built environment of underground pedestrian systems includes the economic, cultural, social and built environments which are underpinned by the natural environment (Xie & Deng 1996). As mentioned before, pedestrian planners have attempted to improve the walkable environments by focusing on land use patterns, the transportation system and urban design.

Influencing factors of underground construction in the built environment such as economic performance, the status and scale of a city, land usage, defence requirements and technology have been considered in previous research (Li 1993). Other factors such as traffic congestion, subway construction, underground retail spaces and developing public transport were also considered (Byers 1998b; Sakakura, Shimizu and Itabashi 2007; Belanger 2007).

4.1. Weather

Belanger (2007) suggested that climate is the largest influence in the decision by a developer to build an indoor environment in North America cities such as Toronto, Montreal and Chicago. Indoor environments are likely where there are hot and humid summers and long cold winters with often severe conditions such as windy and wet streets. Tong (1998) stated that the development of underground streets in some cities in Japan to some extent related to their weather conditions. In Japan, northern areas have a cold winter with a long period of snowfall while the middle and southern areas of the country are humid and rainy. Tong also indicated that the construction of underground streets in Japan was a common consideration if a city has an average temperature below zero degrees Celsius in January and more than 500 mm snowfall. Sakakura, Shimizu and Itabashi (2007) proposed an approach that an underground pedestrian network worked together with 'snow' (a technical jargon term for air conditioning) for optimum use of an air conditioning system. Summarized in those statements, temperature, rainfall, snowfall, wind and humidity are significant aspects to be considered as possible justifications for developing indoor pedestrian systems despite there being a lack of detailed causal empirically based research evidence.

4.2. Geology and topography

Li (1993) regards geology as one of the influencing factors affecting underground space usage and accordingly, he explained that Italy's slow development on underground pedestrian spaces and structures was because of unfavourable geologic conditions while underground rock mass in Swedish and Swiss cities has been beneficial to facilitating underground urban centre developments. Geology affects the potential for underground construction, and the process of constructing an underground pedestrian network may compromise an area's geologic stability determined by its rock and soil content thereby providing a challenge for the planning, design and construction of underground structures (Carmody and Sterling 1993; He 2008; Qian & Zhuo 2002). When referring to the influence of topographical factors, Eady (1990) suggests that the choice of an underground pedestrian system in Montreal is partly because of that city's hilly environs. Golany and Ojima (1996) state that a sloping site is a superior topography for solving environmental problems such as providing access to natural light for indoor settings, which was well suited to Montreal's hilly location.

4.3. The scale of cities

For developed and developing countries, underground spaces are vital development choices for solving resources and environmental problems. Even for countries such as Canada and

America with their vast territories, the problems related to urban resources are still very severe because their populations concentrated in cities (Chen and Wang 2005). Land use pressures from the growth and urbanization of the world’s population can be released partly through placing facilities underground (Carmody and Sterling 1993). Li (1993) indicates that population, city size and thus population density lead to different results in underground space utilization as evidenced through a comparison between Japan (focused on quantity) and France (focused on quality). This research indicates a possible relationship between population, city size and underground pedestrian systems.

4.4. Economic level

Economics is a key element in deciding the potential of underground space utilization because an initial investment in an underground project can be 3-10 times the cost of equivalent development at ground level, at least in terms of area (Chen and Wang 2005). Per capita income is often used to measure the wealth of the population of a nation and could also be used at a regional level to determine the economic viability of an underground pedestrian system. As Cypher and Dietz (2004) states, it is essential to consider per capita income to compare development level of different countries. Similarly, the per capita income of a city can measure the economic performance and status of a region. Previous research demonstrates that there is an empirically based link between a city’s annual per capita income and its degree of underground space utilization. According to Chen and Wang (2005), it is estimated that when annual per capita income is between 200 and 500 USD, underground space utilization tends to occur, spurring on economic development; when annual per capita income is between 500 and 2000 USD, urban underground spaces can become relatively common place in central urban areas; and when the annual per capita income exceeds 2000 USD, urban underground space utilization can reach a high level with cities exhibiting extended and integrated underground pedestrian networks.

4.5. Subway systems

Commonly, underground pedestrian spaces combine with a commercial function as underground shopping streets, or combine with a public communication function as underground space nodes (such as underground concourse and atrium), or combine with a public transport function as an underground layer of passenger flow. Subways were regarded as the most vital contribution to underground pedestrian space utilization (Barker 1986; Belanger 2007). For grade-separated pedestrian systems, cities with established subway systems appeared to have underground pedestrian links already in evidence (Carmody and Sterling 1993). Tong (2009) indicated that when subway systems became the main transport mode of a city, there emerged a requirement of considerable spaces for underground transport transfer facilities. To achieve efficient usage of spaces and to satisfy the requirement of shopping co-located with subway transport, underground spaces around subway stations integrated commercial functions more effectively. With the increasing dependence on subway transport, spaces around subways have obvious economic benefits by virtue of the large volumes of passing pedestrian traffic accessing or leaving the subway. Surrounding spaces of commerce helped to integrate subways through the expansion of underground pedestrian walkways (Bazinet 2004; Liu 2009). Accordingly, the scale of the subway systems of a city is possibly correlated with the size of underground pedestrian systems. The number of lines, stations, passengers serviced and the total length of the subway normally indicate the scale of a subway system.

4.6. Intensity of retailing activities

Underground retail spaces also can be viewed as a catalyst for the construction of an underground pedestrian system. An initial motivation for constructing underground pedestrian systems was usually to provide additional commercial spaces. Potentially, underground pedestrian systems with retail spaces in a city centre, allows city centres to compete with car oriented suburban shopping malls that have weakened the commercial status of city centres, particularly cities without an underground pedestrian system (Byers 1998a). When connecting with subway stations, the additional spaces provided a chance to attract pedestrian flows, thus customers were offered convenience and retailers were offered profits, which contributed to the extension of underground pedestrian systems (Bazinet 2004). Hence, the area of an underground retail spaces, the number of shops and passengers serviced could possibly be determining factors indicating the likelihood of construction of underground pedestrian systems.

5. Conclusion

Underground pedestrian systems can be better integrated into the pedestrian network to create a more walkable city. The vital issues for integrating underground pedestrian systems into a city’s urban pedestrian network examined in this paper include the organization of underground pedestrian systems and how they relates to a city’s wider pedestrian network. The built environment was identified as a key factor in promoting more walkable cities and improvement towards ultimately developing an underground pedestrian system that can be implemented through land use patterns, the transportation system and urban design factors. The paper also identified the influencing factors from natural and built environments in the developments of underground pedestrian systems.

The next step of the research will focus on the decisive effects of those influencing factors from data collection for case studies and more detailed information regarding land use patterns, the transportation system and urban design to ultimately produce general principles for walkability in underground pedestrian systems in centralised urban settings.

References

Alfonzo, MA 2005, 'To Walk or Not to Walk? The Hierarchy of Walking Needs', *Environment and Behavior,* vol. 37, no. 6, pp. 808-836.

Barker, MB 1986, 'Toronto's Underground Pedestrian System', *Tunneling and Underground Space Technology,* vol. I, no. 2, pp. 145-151.

Bazinet, G 2004, 'Management of City Center Development and Underground Pedestrian System in Montreal', *Underground Space,* vol. 24, no. 4, pp. 548-550.

Belanger, P 2007, 'Underground Landscape: The Urbanism and Infrastructure of Toronto’s Downtown Pedestrian Network', *Tunneling and Underground Space Technology,* vol. 22, no. 3, pp. 272-292.

Bell, A 2004, 'Legible London: Developing a Single Walking Wayfinding System for London', paper presented at the Fifth International Conference on Walking in the 21st Century, Copenhagen, Jun. 9-11.

Brown, BB, Werner, CM, Amburgey, JW & Szalay, C 2007, 'Walkable Route Perceptions and Physical Features: Converging Evidence for En Route Walking Experiences', *Environment and Behavior,* vol. 39, no. 1, pp. 34-61.

Byers, J 1998a, 'The Privatization of Downtown Public Space: The Emerging Grade-Separated City in North America', *Journal of Planning Education and Research,* vol. 17, no. 3, pp. 189-205.

Byers, JP 1998b, 'Breaking the Ground Plane: The Evolution of Grade-Separated Cities in North America', Department of Geography, Doctor of Philosophy thesis, The University of Minnesota.

Carmody, J & Sterling, R 1993, *Underground Space Design*, Van Nostrand Reinhold Publishing Company, New York.

Chen, Z & Wang, Y 2005, *The Planning of City Underground Space*, Southeast University Press, Nanjing.

Chen, Z & Wu, T 2002, 'Investigation on Design of Atrium in Underground Construction', *Underground Space,* vol. 22, no. 4, pp. 347-350.

Choi, J-S & Morita, Y 2005, 'The Distribution of Signs and Pedestrians’ Walking Behaviors in Underground Space - A Case Study of the Underground Shopping Center in Taegon, Korea', *Journal of Physiological Anthropology and Applied Human Science,* vol. 24, no. 1, pp. 117-121.

Cypher, JM & Dietz, JL 2004, *The process of economic development*, Routledge, Abingdon.

Durmisevic, S & Sariyildiz, S 2001, 'A Systematic Quality Assessment of Underground Spaces - Public Transport Stations', *Cities,* vol. 18, no. 1, pp. 13-23.

Eady, RM 1990, 'The Down Town Pedestrian Environment: An Examination of Winnipeg's Weather-protected Walkway System from a User's Perspective', Department of City Planning, Master of City Planning thesis, University of Manitoba.

Forsyth, A & Southworth, M 2008, 'Guest Editorial: Cities Afoot - Pedestrians, Walkability and Urban Design', *Journal of Urban Design,* vol. 13, no. 1, pp. 1-3.

Golany, GS & Ojima, T 1996, *Geo-Space Urban Design*, John Wiley & Sons, Inc., New York.

He, S 2008, *Underground Engineering*, trans. J Cui, Tsinghua University Press & Beijing Jiaotong University Press, Beijing.

Huang, J 2007, 'Discussion of the Intensive Development of Public Space at Metro Stations', *Journal of Guangdong University of Technology,* vol. 24, no. 4, pp. 109-112.

Huang, J & Lu, J 2007, 'Research on Pedestrian Space System: Planning and Design', *Modern Urban Research,* vol. 22, no. 2, pp. 48-53.

Hoehner, CM, Ivy, A, Ramirez, LB, Meriwether, B & Brownson, RC 2006, 'How Reliably Do Community Members Audit the Neighborhood Environment for Its Support of Physical Activity? Implications for Participatory Research', *Journal of Publich Health Management Practice,* vol. 12, no. 3, pp. 270-77.

Jung, HS, Kim, YO & Park, HT 2009, 'Spatial Structure Analysis in Accordance with the Mode of Interconnection between Surface and Underground Pedestrian Networks', paper presented at the *the 7th International Space Syntax Symposium*, Stockholm, 8-11 June.

Leyden, KM 2003, 'Social Capital and the Built Environment: The Importance of Walkable Neighborhoods ', *American Journal of Public Health,* vol. 93, no. 9, pp. 1546-51.

Li, W 1993, 'Factors of Influence of Development and Utilization of Underground Space', trans. J Cui, *Underground Space*, vol. 13, no. 2, pp. 118-124.

Liu, J 2006, 'Discussion on Effect of Underground Theme Square on Underground Street', *Chinese Journal of Underground Space and Engineering,* vol. 2, no. z1, pp. 1181-1185.

Liu, J 2009, *Underground Streets Design and Theory in View Of Urban Three-dimensional Development*, trans. J Cui, Southeast University Press, Nanjing.

Maitland, B 1992, 'Hidden Cities - The Irresistible Rise of the North American Interior City', *Cities,* vol. 9, no. 3, pp. 162-169.

Qian, Q & Zhuo, Y 2002, *Underground City*, trans. J Cui, Tsinghua University Press & Jinan University Press, Beijing & Guangzhou.

Saelens, BE & Handy, SL 2008, 'Built Environment Correlates of Walking: A Review', *Medicine & Science in Sports & Exercise,* vol. 40, no. 7 Suppl, pp. 550-66.

Sakakura, Y, Shimizu, H & Itabashi, H 2007, 'Sapporo’s Urban Management and Roles of the Underground Path', paper presented at the 11 Associated Research Centers for Urban Underground Space Conference, Athens, Sept. 10-13.

Shima, T 2006, 'Installation of Information and Guidance Sighs in the Namba Terminal (underground shopping mall)', *Osaka Its Technology*, no. 48, pp. 1-6.

Southworth, M 2005, 'Designing the Walkable City', *Journal of Urban Planning and Development,* vol. 131, no. 4, pp. 246-257.

Tong, L 1998, *Underground Shopping Street Planning and Design*, China Architecture and Building Press, Beijing.

Wang, B & Shu, Y 2000, 'Analysis of Factors Affecting Urban Underground Space Environment', *Journal of Tongji University,* vol. 28, no. 6, pp. 656-660.

Xie, W & Deng, W 1996, *Urban Economics*, trans. J Cui, Tsinghua University Press, Beijing.

Zacharias, J 2006, 'Exploratory Spatial Behaviour in Real and Virtual Environments', *Landscape and Urban Planning* vol. 78, no. 1-2, pp. 1-13.

Zacharias, J 2000, 'Modeling Pedestrian Dynamics in Montreal's Underground City', *Journal of Transportation Engineering,* vol. 126, no. 5, pp. 405-412.

Zacharias, J & Xu, M 2007a, 'Pedestrian Dynamics, Layout and Economic Effects in Montreal's Underground City', *Urban Planning International,* vol. 22, no. 6, pp. 21-27.

Zacharias, J & Xu, M 2007b, 'The Underground System as Economic Generator for Montreal's Central City', *Urban Planning International,* vol. 22, no. 6, pp. 28-34.