Australasian Transport Research Forum 2011 Proceedings
28 - 30 September 2011, Adelaide, Australia
Publication website: http://www.patrec.org/atrf.aspx

Influencing Factors for Developing Underground Pedestrian Systems in Cities

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Abstract

Underground pedestrian systems (UPS) have been developed worldwide especially in the central areas of mega cities. They are integrated with subway systems, underground shopping streets and malls, and the basement of department stores in various forms and integrated with commerce, transport, retailing and public usage in urban functions. In cities with severe weather conditions such as Toronto and Montreal in Canada, UPS provided a weather-controlled walking environment. In dense urban settings such as Tokyo, Japan and Shanghai, China, UPS provides a comprehensive usage of urban space that is comparable to that which occurs at the street level.

The natural and built environments affect the utilization of UPS. Environmental factors are discussed to demonstrate how UPS have developed and functioned. Based on previous research, this paper has selected 19 cities as cases studies to explore the decisive factors of natural and built environments that have influenced UPS development specifically with regard to four aspects namely climate, subway construction, land usage and economic environment. The research revealed the extent of prevalence of these four aspects in cities and determined the differentiating factors of the natural and built environments that resulted in the establishment of UPS. SPSS was applied to test the differences between developing and advanced economies in relation to the prevalence of these factors.

1. Introduction

Strategic usage of urban spaces on walking from the perspectives of management and design considerations was based on natural and built circumstances, such as controlling time and changing the physical design of streets (regulations on restricting automobiles at certain areas at certain time periods and creating auto-free malls), and horizontal (street-widening, pedestrian district, pedestrian mall and transit ways) and vertical separation (skywalks and underground walkways) (Eady 1990, p. 10). Certain types of strategy can also be used for various considerations. These include viewing underground pedestrian systems (UPS) as a utilization of three-dimensional spaces, comprehensive underground space development integrated with the street level or as a type of grade separation systems. From a considerable number of cases, UPS have provided a weather-controlled walking environment, releasing pressure on the supply and demand conflicts of urban land and space resources, minimizing vehicle-pedestrian conflicts, facilitating links with underground mass transit systems, and integrating urban functions.

There is a long history of underground walkable spaces being used to accommodate urban functions. Medieval UPS in Cappadocia, Turkey were developed about the 7th or 8th century AD included 36 underground systems. Some underground walkways were 10 kilometres in length (Wand and Chen 2010, p. 40). However, those UPS were constructed for defence and shelter purposes, which is a distant design consideration in the majority of modern UPS. Modern UPS with multiple functions have been well established as an urban development phenomenon for many decades. During the 1930s, subway stations in Japan began to build underground walkways with shops (Tong 1998, p. 1); from the 1950s, cities in Canada and the United States constructed UPS or skywalk systems (City of St. Paul 1986); from the 1980s on, Chinese mega cities built some UPS in central areas and extended their scale gradually for walking and shopping purposes with the Reform and Opening Up policy in the economic system (Zheng 2003, p. 87; Jia 2008, p. 16). Besides Japan, North American countries and China, UPS have also developed in a considerable number of other cities around the world. Cui et al. (2010) selected 51 cities with UPS to conduct research, and noted that those systems were distributed across cities in North America, South America, Europe, Asia and Oceania. However, notwithstanding the apparently broad global distribution of UPS, most UPS were found to be concentrated in East Asia, Europe and North America. Past research on UPS has focused on UPS in these areas with regard to motivating factors, development mechanisms and their effects on their local urban environments (Maitland1992; Byers 1998b; Belanger 2007; Wang and Liang 2010).

It is easy to link some motivating factors with underground space development, such as in the central areas of Canada, some cites have uncomfortably dry and cold weather conditions; in the south-western areas of the United States, some cities have severely dry and hot weather conditions; in many of the metropolises of the United States and Japan, urban development has intensified conflicts between demand and supply of spaces, resulting in escalating land prices; in the cities of Japan and China, city expansion has had to be controlled to a manageable scale, as well as protecting farmland and to provide urban defence; the influence of planning policies also proved to be a major driver for implementing UPS especially in western countries. Additionally, in major cities with intense skyscraper development, deep building foundations necessitate basement levels that can be up to 10 to 15 levels deep. UPS can be well placed to take advantage of building basements of multiple levels. Moreover, it is mentioned that with a controlled environment, retailers can easily decorate and maintain their shops without worrying about security issues. And it is also believed to be essential to provide a pleasing walking environment to shoppers – safe from the threat of criminals, without the disturbance of vehicular traffic, in a weather-controlled indoor environment of high quality (Golany and Ojima 1996). In the research of North American UPS, weather, the separation of pedestrians and vehicles, the promotion of development, adding a new level of retail and adding more office space were supposed to be the original purposes of developing UPS in North American cities (Table 1). But it is worthy to note that besides UPS, some cities also chose skywalks as alternative walking systems such as in Calgary with their "+15 Skywalk" system and Sydney. The reasons for utilizing the above ground pedestrian systems in the case of Calgary are possibly due to the comparatively small city scale, lack of underground rail systems, and economical considerations, whereas for Sydney, the driving rationale were the temperate climate, the desire to capture enticing city space scenes and the requirement to open up a broad network of interconnected retailing levels above the street to complement retail levels below ground and at street level.

Nevertheless, the utilization, development and extension of UPS cannot be explained by a single reason, but by multiple motivating factors that have developed, interacted and intensified over time. Although for different cities, the effects of various influencing factors are dissimilar, there are some effects from some factors could be universal. And this universality could indicate UPS development potential. Actually, the research on such universality is inadequate because research has mostly focused on an individual case study or generated descriptive conclusions, such as by Li (1993), Belanger (2007)and Wang and Liang (2010) without an analysis of measurable quantitative data. What's more important, currently, some developing countries treated UPS as an effective approach to solve urban problems that have resulted from a rapid urbanization process. In the mega metropolises of China such as Shanghai, Nanjing and Guangzhou, the scale of underground utilization has increased rapidly within the past two decades. Compared with developed countries, urban environments and the effects of environmental factors in developing countries are different. Determining what influences those factors and what the obvious differences for UPS in an urban environment are in developing nations compared to advanced nations is essential to understanding the development of UPS and the urban settings in which they are optimal.

Table 1 Original Purposes of Developing UPS in North American Cities

City	Year of First Connection	Original Purpose
Edmonton, AB	1970	Weather
Montreal, QB	1962	Weather
Toronto, ON	1959	Weather
Chicago (Wang & Liang 2010)	1951	Weather
Dallas, TX	1965	Add a new level of retail
Houston, TX	1947	Separate pedestrians and vehicles

Source: City of St. Paul, Dept. of Planning and Economic Development

2. Methodology

To answer these questions, firstly, a database with UPS cases was established. Then influencing factors of the urban environment from previous research were considered and selected. Collecting data of selected influencing factors and analysing them through statistics and SPSS can determine a universality of the effects of the influencing factors, correlations and an understanding of diversity of the effects in developing and advanced cityscape environments.

2.1 Cases of Underground Pedestrian Systems

UPS has been implemented in significant and substantial cities. Cui et al. (2010, p. 5) identified 51 UPS from conference papers, journal articles, books and degree theses. This research selected 19 UPS in Canada, United States, China, Japan, Russia and Hong Kong (Hong Kong was considered separately from other Chinese cities since its urban environment is different from other Chinese cities due to its historical context and status as a separately administered political entity). Table 2 provides summary details of the 19 UPS selected.

2.2 Selection of Influencing Factors

UPS developed in urban environments and thus, the motivations of developing UPS can be considered from two aspects namely the natural and built environments. Previous research indicated that with regard to the natural environment, climate, geology, topography, soil and water factors were potential factors that strongly influenced the selection of an underground pedestrian network (Carmody and Sterling 1993; Tong 2005). With regard to the built environment, economic, cultural, social environment and construction capability factors significantly contributed to the decision favouring UPS development (Xie and Deng 1996; Li 1993).

Accurate selection of influencing factors that affect UPS development is a key objective for this research. A number of influencing factors that previous literatures referred to is the basis for the selection. Additionally, applying different approaches to classify those influencing factors could ensure the appropriate selection of influencing factors in this research.

One of the approaches that can be applied is the Advantages Deduction Method (ADM). The application of this method posits that the implementation of UPS would bring many benefits to the city, which has promoted the imitation and utilization of UPS by other cities (Byers 1998a). The advantages of developing UPS, such as safety from poor weather conditions, isolation from traffic impact, a secure commercial environment from criminal activity, the promotion of pedestrian activity, encouragement of subways usage, mitigation of conflicts between supply and demand of urban land and the integration of commercial, service and transportation functions are key considerations in this methodology.

However, a methodology that only focused on advantages would result in misjudgement because with respect to underground space utilization, the debate between supportive and opposite opinions is unresolved and runs the risk of neglecting significant contributing factors to understanding the development of UPS. Carmody and Sterling (1993, p. 26) and Golany and Ojima (1996) summarized supportive and opposite arguments, which mainly focused on land usage, social effects, economy, transportation, safety, environment, life quality and health. Integrating the advantages of UPS with given references (i.e. authors with divergent arguments), climate, subway construction, land usage and economic environment were confirmed to be the four influencing aspects of the research.

Table 2 Summarization of Underground Pedestrian Systems Selected

Country	City	Underground Pedestrian System
Canada	Edmonton, AB	“Pedway”, connecting buildings and LRT stations of the downtown core
	Montreal, QC	“RESO”, 32 km, covering more than 41 city blocks (Besner 2007, p. 1)
	Toronto, ON	“PATH”, 6 blocks wide, 10 blocks long, 27 km (Belanger 2007, p. 272)
	Vancouver, BC	Over 3 city blocks, connecting 2 shopping malls, 200 stores and three stations
	Winnipeg, MB	Connecting commercial office, office towers and downtown traffic
United States	Atlanta, GA	“Underground”, covering 6 city blocks
	Chicago, IL	“Pedway”, covering 40 city blocks (8km^2), connecting 50 buildings (Wang and Liang 2010, p. 96)
	Dallas, TX	“Dallas Pedestrian Network” (Zhu et al. 2007, p. 14), covering 36 city blocks by 15 bridges and 26 tunnels (Lassar 1988; Terranova 2009, p. 18)
	Houston, TX	4.5 km (Tong 2005; Zhu et al. 2007, p. 14)
	New York, NY	Locating at Rockefeller Centre in Manhattan, covering 10 city blocks (Tong 2005; Zhu et al. 2007, p. 14)
	Oklahoma City, OK	1.2 km, underground systems and skywalk systems covering 20 city blocks, connecting 30 buildings (Wang and Chen 2010, p. 42)
	Philadelphia, PA	Several underground concourses in Centre City connecting subway stations
Hong Kong	Hong Kong	Underground networks connecting buildings and shopping malls to Central Station (Yang et al. 2008)
Japan	Tokyo	6km, containing 141 shops, connecting 51 buildings (Guan and Yang 2001, p. 33)
China	Beijing	Locating at western area of Zhongguancun (Chen and Wang 2005, p. 24)
	Harbin	250,000 m^2, several underground shopping streets interconnected (Zhu et al. 2007, p. 20)
	Nanjing	Locating in Xinjiekou, connecting department stores, subway stations and shops
	Shanghai	People’s Square containing 10,000 m^2 underground commercial spaces, connecting underground parking and subways (Geng 2005, p. 39)
Russia	Moscow	“Perekhod”, Connecting commercial centers with kiosks, shops, buskers, pharmacies, often used as meeting places during winter times (Charlton 2010, p. 56)

Climate

Climate was one of the most critical aspects encouraging UPS utilization (Eady 1990, p. 30; Byers 1998a, p. 189; Belanger 2007, p. 279; Sakakura et al. 2007, p. 535). In cities with severe weather conditions, people are eager to use a pedestrian system that provides protection from bad weather. Because of UPS, people could reach their destination of work, business and shopping directly from the subway and railway stations without going outside (Wang and Liang 2010, p. 95). Although this link between severe weather conditions and UPS utilization appears likely, previous research revealed that cold weather cannot be concluded as a common motivation for underground pedestrian systems development worldwide (Cui et al. 2010, p. 9). The weather conditions of substantial cities that have built UPS cannot be categorized as the key motivating factor for implementation of a UPS. This research finding therefore paved the way for further research regarding the effects of the urban environment on UPS development. However, there are some limitations to this research. Consideration of less obvious findings of the motivating factors for UPS in cold climates and consideration of other weather related parameters may achieve more conclusive results. Cities with hot and humid summers, and/or cold winters, and/or windy conditions, and/or wet streets (Belanger, p. 279), and/or a long snow period, and/or rainy weather, and/or an average temperature below zero degrees Celsius (°C) in January (in the northern hemisphere) (Tong 1998, p. 28) are likely to develop UPS. This research will focus on the factors of snowfall, and temperature extremes as possible determining factors for the establishment of UPS.

Land Usage

Besides climate, UPS' function in reducing the conflicts between supply and demand of land and space resources is easy to appreciate. The relationship between population density and UPS construction can be explained from the following aspects: on one hand, the increasing number of automobiles and rising density of roads has eroded and divided pedestrian and public spaces (Robertson 1991, p. 301). New pedestrian spaces have had to be created to compensate for urban spaces, particularly in urban street settings that were previously the domain of pedestrians. On the other hand, increasing population density has contributed to the decline in life quality such as air and noise pollution, congestion and green space deficiency. Additionally in many cities in developed countries, interesting and convenient suburban shopping malls in conjunction with rapid low density suburbanization have competed with the city centre for commercial dominance. Developers and planners utilized UPS in city centres to increase their commercial competitiveness, providing pedestrian facilities with comfort and convenience and rebuilding urban image (Belanger 2007. p. 287). From this perspective, it would appear likely that there is a consequential link between the type of urban land use, its spatial dynamics (i.e. the extent of suburbanization with multi-nucleated centres and their strength relative to a city's commercial core) and the prevalence of an UPS.

Economic Environment

The apparent causality between the level of economic activity and UPS development also appears likely. The construction cost of an underground project is normally several times or even ten times that of an equivalent scale of project at street level. It can be concluded that it is impossible for underground space utilization at a considerable scale without a city having substantial economic wealth and/or capability to attract investment. Among economic indicators, per capita income is often used to compare the development level of different countries and could also be used at a regional level to determine the economic viability of a city (Cypher and Dietz 2004, p. 31). Previous research builds a quantitative link between a city's per capita income and underground space utilization. According to Chen and Wang (2005, p. 42), it is estimated that when the annual per capita income is between 200 and 500 USD, there is potential for underground space utilization to occur for the purposes of economic development; when the annual per capita income is between 500 and 2000 USD, urban underground spaces can be explored to a considerable extent; and when the annual per capita income exceeds 2000 USD, urban underground space utilization can reach a high level. The level of annual per capita income that previous research indicated is comparatively low compared to the annual per capita income in western countries where annual per capita income are closer to 20,000-40,000 USD. The reason for this difference is possibly that the research is based on the situation in China.

Subway Construction

Similarly, as with underground space utilization, subway construction has promoted UPS development. UPS can evacuate and collect pedestrian flow rapidly between subway stations and other transport modes, between neighbouring buildings and between underground streets and malls. The core purpose of subways is that they require the integration of various transport modes and space resources to create a “transport hinge” and movement exchange systems as a whole, which is also the function of an UPS. In this way, transport efficiency can be improved and urban space resources can be granted reasonable utilization (Huang 2007, p. 111). Subways and UPS are mutually self-reinforcing and have tended to developed in unison together.

3. Data Collection and Analysis

3.1 Cold and Hot Weather Conditions

While we need to set a standard to define the weather conditions of selected cities, several concepts need to first be established. There is the concept of Winter City where there is a long winter with severe weather conditions that severely disadvantages city life lived in the open at ground level. This concept can be used as a criterion of the degree of cold weather. The key judgment criterion for a Winter City is that there is a temperature mean value under 0 °C. However, from the literature, it appears that there can be uncertainty in determining the actual number of months with a mean temperature value under 0 °C. For example, Rogers and Hanson’s (1980, p. 21) definition is where average temperature in January is under 0

Table 3 Resources of the Data

Issues	Internet Resources
Weather Conditions	www.climate-charts.com
	www.weatherbase.com
	www.en.wikipedia.org
City Scale	Official website of the cities, states/ provinces, countries
	Official website of Census/ Statistics Department of the cities, states/ provinces, countries
	www.en.wikipedia.org
Economic Level	Official website of the cities, states/ provinces, countries
	Official website of Census/ Statistics Department of the cities, states/ provinces, countries
	www.calgaryeconomicdevelopment.com/sites/default/files/CED%20%20Calgary%20Wealth%20Fact%20Sheet%202010%20Edition%20%20Updated%20Nov.15,%202010.pdf
	www.economicdevelopmentwinnipeg.com/uploads/document_file/personal_disposable_income_per_capita_winnipeg_manitoba_canada.pdf
	www2.foi.se/rapp/foir2853.pdf
	www.toukei.metro.tokyo.jp/tnenkan/2009/tn09q3e014.htm
Subways	www.urbanrail.net
	www.subways.net
	www.en.wikipedia.org

Table 4 Data of Weather Conditions, City Scale, Economic Level and Subways of Cities Selected

Cities	Weather Conditions			City Scale				Economic Level	Subway Construction	
	No. of Month[1]	Annual Snowfall (cm/y)	Annual Average Temperature (°C)[2]	Population (Thousand)	Land Area (km²)	Density (people per km²)	Year	Annual Per Capita Income (2009, US$)	Urban rail Length (km)	Underground length (km)
Edmonton	5	124	15	782	684	1,143	2009	39,126	20	6
Montreal	4	210	20	1,621	365	4,439	2006	30,142	69	66
Toronto	4	124	20	2,503	630	3,972	2006	33,827	70	51
Vancouver	0	55	17	578	115	5,335	2006	31,845	49	1
Winnipeg	5	111	18	675	464	1,455	2009	31,942	N/A	N/A
Atlanta	0	5.1	26	541	339	1,596	2009	36,912	79	14
Chicago	3	110	22	2,851	588	4,849	2009	27,138	170	18
Dallas	0	8	29	1,300	886	1,467	2009	25,941	N/A	N/A
Houston	0	1	28	2,258	1,500	1,505	2009	25,563	N/A	N/A
New York	1	59	24	8,392	785	10,690	2009	30,885	337	223
Oklahoma City	0	23	27	560	1,570	357	2009	24,195	N/A	N/A
Philadelphia	1	59	24	1,547	350	4,420	2009	21,661	63	29
Hong Kong	0	0	29	7,034	1,104	6,371	2009	31,420	219	91
Tokyo	0	17	25	12,989	2,188	5,937	2009	48,597	329	329
Beijing	3	16[4]	25	13,300	1,368	9,722	2009	4,490	240	150
Harbin	5	63	21	4,747	7,086	670	2009	2,028	N/A	N/A
Nanjing	0	0[4]	27	5,460	4,723	1,156	2009	4,009	85	48
Shanghai	0	0[4]	27	11,346	2,649	4,283	2009	4,743	410	316
Moscow	5	274[4]	16	10,523	1,081	9,735	2009	17,760[3]	301	287

Notes: [1] No. of Months with mean temperature value under 0 °C a year;

[2] Average temperature of three months with the highest average temperature;

[3] Data of year 2010;

[4] Estimated data through assuming that the precipitation with weather temperature below 0 °C is snowfall.

Table 5 Satisfaction of the Hypotheses on Weather Conditions, City Scale, Economic Level and Subways

Cities	Weather Conditions		City Scale	Economic Level	Subway Construction	
	Winter City	Hot Summer Cities	Mega City	Good Per Capita Income	Subways	Well Developed Subways
Edmonton	1	0	0	1	1	0
Montreal	1	0	0	0	1	1
Toronto	1	0	0	0	1	1
Vancouver	1	0	0	0	1	0
Winnipeg	1	0	0	0	0	0
Atlanta	0	1	0	0	1	0
Chicago	1	0	0	0	1	0
Dallas	0	1	0	0	0	0
Houston	0	1	0	0	0	0
New York	1	0	1	0	1	1
Oklahoma City	1	1	0	0	0	0
Philadelphia	1	0	0	0	1	0
Hong Kong	0	1	0	1	1	1
Tokyo	0	0	1	1	1	1
Beijing	1	0	1	1	1	1
Harbin	1	0	0	0	0	0
Nanjing	0	1	0	1	1	1
Shanghai	0	1	1	1	1	1
Moscow	1	0	1	1	1	1

Note: 1 represents the city is satisfied the hypothesis; 0 represents the city is unsatisfied the hypothesis.

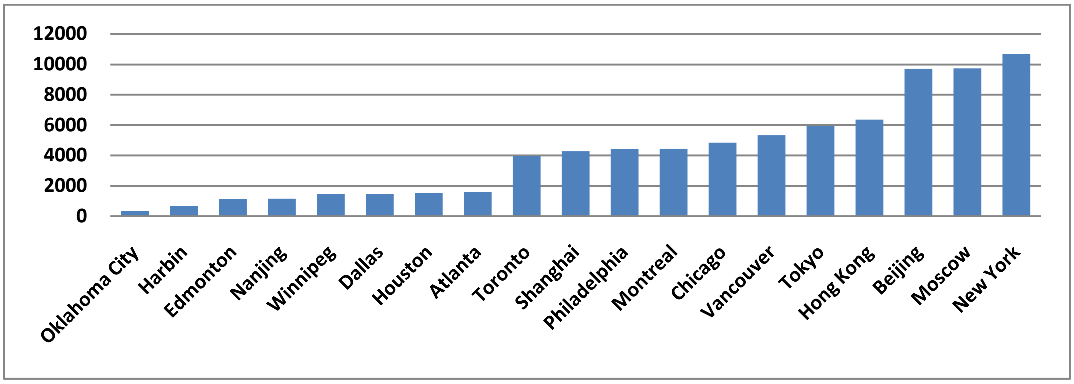
°C; Manty and Pressmen (1988) refer to at least two months' average maximum daytime temperature under 0 °C; and Liu's (1998, p. 3) definition is that there are three continuous months with average temperatures under 0 °C. More recently, at the 11th Mayors Conference 2004 (World Winter Cities Conference for Mayors) a Winter City was defined as those with 20 centimetres (cm) average snowfall per year or at least one month's temperature mean value under 0 °C (Len 2009, p. 4). According to this definition, data are collected on two aspects: the number of months with a mean temperature value under 0 °C per year and mean values of snowfall a year. With regard to a hot climate, similarly, there is no standard or acknowledged definition to judge whether or not a city experiences hot summers. The average temperature of three months with the highest average temperature was chosen as a criterion. Internet resources for data collection and the data of weather conditions are shown in Tables 3 and 4.

According to the latest definition for categorising a "Winter City", 12 (63%) of the 19 cities can be categorized as a "Winter City": this includes all Canadian cities, 57% of US cities and 50% of Chinese cities (Table 4). With regard to cities defined as having hot summers, 6 cities have an average maximum summer temperature over 26 °C while for 7 cities it is over 25 °C. To use the broader definitions of a "Winter City" and "Hot Summer" cities, with the exception of Tokyo, all of the remaining 18 cities described in Table 5 can either be classified as a Winter City with a cold winter or "Hot Summer". Tokyo and Oklahoma City are special cities. Tokyo belongs to neither the "Winter City" nor "Hot Summer" city classification while Oklahoma City can be categorized as both a "Winter City" and "Hot Summer" city. It can be concluded that almost all of the cities with UPS appear to be associated with climate as a driver of UPS implementation.

3.2 Urban Population, Urban Areas and Population Density

Urban population, urban areas and hence population density are indicators reflecting city scale. What these indicators may not show directly is the type of urban structure for the city's greater metropolitan area in terms of where it is positioned on the CBD centric-to-multi-nucleated centre continuum of urban structure city types. Data on the three aspects are collected in table 4. Regarding the city comparisons for urban population, 14 cities (74%) have a population of over 1 million: 40% of Canadian cities (Montreal with 1.6 million and Toronto with 2.5 million); 71% of American cities (New York City with 8 million and other four with 1 to 3 million); which contrasts starkly with all Asian cities, in particular, Beijing with a population of more than 13 million. With regard to urban areas, 10 North American cities are less than 1,000 km^2 in area and two cities (Houston and Oklahoma City) are around 1,500 km^2. However, the urban areas of Asian cities and Moscow are generally more than 1,000 km^2, although this reflects much large populations rather than sprawl as can be seen when comparing the population densities for these cities. Regarding population density, the figure varied from 357 to 10,690 people per km^2 (Figure 1). 11 cities exceed 2,000 people per km^2: 60% of Canadian cities, 43% of US cities, 50% of Chinese cities and three other cities.

Figure 1 Population Density of Selected Cities



To generalize the relationship between city scale and UPS, a standard of urban population scale needs to be clarified. The term “Mega City” is normally used to represent a city with considerable population scale. Various definitions are used to describe what is meant by a “Mega City”. As Sorensen and Okata (2011, p. 6) in drawing on the work of several researchers, suggested defining a “Mega City” as having a population scale that has varied from 4 million, to 8 million to ten million during past 30 years. But other research suggests that settling on a precise figure of population was not suitable to illuminate the concept of Mega City given that the populations of mega cities are continually growing and such giant cities are becoming more commonplace. According to Marzluff et al. (2008, p. 585), besides having a purely quantitative level of population as a defining standard, some research has suggested a population density with at least 2,000 people per km^2 should also be set as a standard. But the population scale that is normally applied in the literature is determined by the level of urban agglomeration rather than just the city itself, which may be a construct reflecting and political administrative construct. According to the United Nations (2004, p.78), New York, Tokyo, Beijing, Shanghai and Moscow are mega cities (Table 5).

3.3 Per Capita Income

From table 4, overall, it can be seen that Tokyo has the highest per capita income. Hong Kong, Canadian cities and American cities have similar per capita income of around 30 thousand USD per year in second place. It is followed by Moscow with less than 20 thousand USD. And Chinese cities have the lowest per capita income. Data of per capita income of 19 cities reflected the actual differences of economic levels of different countries and also the gap between developing and developed countries. But it cannot indicate the connection between per capita income and UPS development. Consideration of the national annual per capita income can be taken as a proxy indicator for a city’s annual per capita income (as is the case with many developed countries). Hence, comparison between national annual per capita income and the annual per capita income of the city possibly could indicate the economic capability of a city to undertake UPS development (Table 6).

Among the 19 cities examined, besides Hong Kong, the annual per capita incomes of 6 cities (32%) are higher than that of their nations: 1 Canadian city – Edmonton (but no American cities), 3 Chinese cities (Beijing, Nanjing and Shanghai), Tokyo and Moscow (Table 5). Surprisingly, all of the 7 American cities have lower per capita annual incomes when compared to their national level while 75% of Chinese cities have higher per capita income than that of their national level. The reason for this phenomenon is that in the US, wealthy people tend to live in suburbs because of the perception that they offer better living environments whilst in Asia, the situation is the opposite: wealthy people tend to live in the city for convenience and greater amenity. The high level of per capita income of Edmonton possibly relates to a local and recent mineral resources boom in shale oil mining.

Table 6 National Per Capita Income (2009, US$)

Country	Canada	USA	China	Japan	Russia
Per Capita Income	36,429	39,138	2,760[1]	39,993	10,522[2]

Notes: [1] China has comparatively low urbanization level. Country population’s income is much lower than that of in cities. To make the data more valuable, national per capita income of city population is used;
[2] Data of year 2010;
[3] The exchange rate of 2009 from USD to Chinese RMB is 1: 6.8310; from USD to CAD is 1: 1.1405; from USD to JPY is 1: 93.57; from USD to RUB is 1:30 (2010).

Sources: www.bcstats.gov.bc.ca/data/bus_stat/bcea/tab1.asp; www.census.gov; www.stats.gov.cn; www.stat.go.jp; www.emeraldinsight.com/authors/writing/calls.htm?id=3195.

3.4 Subways

Subways are generally associated with UPS developments, given that UPS usually provide the pedestrian ingress/egress to the subway stations. As shown on Table 4, nearly three quarters of the cities have an urban rail system: 80% of Canadian cities, 57% of US cities, 75% of Chinese cities, Hong Kong, Tokyo and Moscow. But among those cities that have urban rail systems, the underground component occupied various proportions of their respective urban rail systems: for some cities, urban rail systems are almost totally underground such as Tokyo while urban rail systems of some cities hardly have any underground components such as Vancouver. Montreal, Toronto, New York, Beijing, Nanjing, Shanghai, Hong Kong, Tokyo and Moscow have comparatively well developed subway systems. They make up 40% of Canadian cities, 14% of US cities, 75% of Chinese cities and other three cities (Hong Kong, Tokyo and Moscow). Generally, a lesser percentage of US cities tend to have urban rail systems and a much smaller percentage of underground railway systems when compared to Canadian and Chinese cities. The dichotomy evident between Canadian cities and their US counterparts is interesting and can be explained by the extreme winter climate in continental inland Canadian cities, whereas US cities have less extreme winters, are much more car dependent due to a long term concerted push by governments to encourage personal travel by car with investment in the car industry and a national freeway network, which consequently has been accompanied by poorly developed public transit.

When we put the data of the four influencing factors of the 19 cities together (see Table 5), we find that the decisive effect of the four influencing factors from high to low are climate with 95% of cities, subway systems with 74% of cities (well developed subways with 47% of cities), economic level with 37% of cities and city scale with 26% of cities. There are 3 cities that fulfilled all 4 influencing conditions – Beijing, Shanghai and Moscow; 7 cities that fulfilled three or more influencing conditions; and 5 cities that only fulfilled 1 influencing conditions - Winnipeg, Dallas, Houston, Oklahoma City and Harbin. Asian cities (including cities in China, Tokyo, Moscow and Hong Kong) tended to possess more influencing conditions before developing UPS when compared to cities in Canada and the United States. And American cities tend to be the most lacking with necessary conditions for UPS amongst the three nations.

3.5 Differences on the Influencing Factors in UPS Cities

The analysis from above sections revealed that with the exception of climate, which is a common influencing factor in 95% UPS cities, prevalence cannot be concluded for the other three influencing factors. Thus differences are expected in relation to well developed subways, economic level and city scale. UPS had developed in both advanced and developing countries. It is interesting to explore whether or not there is a statistically significant difference between the three influencing factors. According to the classification from the International Monetary Fund (2010), Canada, United States, Japan and Hong Kong are advanced economies while China and Russia are developing economies.

Data of the three aspects from table 5 was used through the application of SPSS to test whether or not the differences exist in the two categories. The outcomes of SPSS analysis are shown in Table 7. On the table of group statistics, it is clear that for mega cities, the mean for city of advanced economies is lower than that of city of developing economies. That is, UPS cities in developing economies have, on average, a higher city scale than those in advanced economies. Similar results are found for good per capita income. The mean for cities of advanced economies is lower than that of cities in developing economies. UPS cities in developing economies have, on average, a better economic level when compared to their national level than those in advanced economies. With regard to well developed subways, the mean for cities of advanced economies is lower than that of cities in developing economies. UPS cities in developing economies have, on average, better developed subway systems than those in advanced economies. On the table of Independent Sample Tests, the values under "Sig." are greater than 0.05. We can assume that the variances are approximately equal. The results of the Independent Sample T Test indicated that on the aspects of mega city and good per capita income, there are significant differences between UPS cities in advanced countries and developing countries. And on the aspect of well developed subways, the difference is less significant.

Table 7 Outcome of SPSS Independent Groups T-Test

Group Statistics

	City	N	Mean	Std. Deviation	Std. Error Mean
Mega City	1	14	.14	.363	.097
	0	5	.60	.548	.245
Good Per Capita Income	1	14	.21	.426	.114
	0	5	.80	.447	.200
Well Developed Subways	1	14	.36	.497	.133
	0	5	.80	.447	.200

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Mega City	Equal variances assumed	3.752	.070	-2.119	17	.049	-.457	.216	-.912	-.002
	Equal variances not assumed			-1.735	5.314	.140	-.457	.263	-1.123	.208
Good Per Capita Income	Equal variances assumed	.017	.899	-2.609	17	.018	-.586	.225	-1.059	-.112
	Equal variances not assumed			-2.545	6.791	.039	-.586	.230	-1.133	-.038
Well Developed Subways	Equal variances assumed	2.204	.156	-1.749	17	.098	-.443	.253	-.977	.091
	Equal variances not assumed			-1.844	7.842	.103	-.443	.240	-.999	.113

Cities with UPS in developing countries and advanced countries have statistically notable differences on the city scale, economic level and extent of subway. The phenomenon possibly can be explained by the urban background that UPS is rooted within. City development experiences different stages. The stage of urban development model suggested that there are four distinct stages of urban development: firstly, population concentration and centralisation; secondly, concentration continues with a relative decentralisation (faster growth of population in the suburban periphery than in the core); thirdly, population in the core has a absolute declines and people goes to the surrounding ring; and fourthly, urban regions as a whole lose population (Hall 1971; Hall et al. 1973). For developing countries, UPS developed for the purpose of solving problems of urbanization while in advanced economies it was for the purpose of suburbanization.

China, as a representative example of developing economies, is transitioning through a rapid urbanization process. For example, the proportion of residents of city and town in China increased from 29% to 45% during 1995-2007, a 1.3% annual rise. During the urbanization process, considerable labour from the countryside moved to cities. Urban population increased and urban areas sprawled. But the urban population density stabilized at a high level (Ying 2010). Meanwhile, in North American cities, the representative example for advanced economies, cities are transitioning through a suburbanization process. With job and housing decentralisation, people moved out from the city core and even from the urban regions for North American cities. Thus the urban population or its density is comparatively low.

The background of urban development stages that UPS is rooted in can also explain the development of subways to varied extent in cities of developing countries and advanced countries. For developing economics, a centralised urban spatial structure created a conflict between land supply and demand. Underground space development accommodating urban functions can release urban land shortage (Zhai 2004). In addition, private car usage is not dominant in urban transportation which currently relies on public transport such as buses and urban railways. Accordingly, as the representative for public transport utilizing underground spaces, subway systems received continuous advocation and promotion. In advanced economies, the dispersed urban spatial structure dissipated land shortages. The prevalence of private car transport disadvantaged investment in public transport, which inhabited subway developments, which are a comparatively high cost infrastructure in urban regions.

UPS cities in developing economics have achieved comparatively better economic performance when compared to their national level than those of the advanced economies. This possibly because in developing economies, the gap in city per capita income is greater than it is in advanced economies. In developing countries, cities with strong economic abilities can achieve nearly double the economic performance of their national level. A few metropolises with comparatively strong economic abilities were committed on shaping an urban image for modern metropolises partly by the construction of subway systems and UPS. In advanced economies, the gaps of city per capita income between cities are comparatively small. The decisive influence of economic level in developing UPS is less significant.

4. Conclusion

The paper presented the decisive influence of climate, subway construction, urban scale and economic level on the development of UPS worldwide from a quantitative perspective. The pioneering research regarding the influence of environmental factors on UPS development has helped to develop a better understanding of the key influencing factors for the prevalence of UPS amongst the world's major cities. Knowledge of these influencing factors can assist other cities without UPS determine the value to their city of investing in an UPS and what preconditions they require for a successful UPS.

The contribution of the research focused on the following aspects:

- Climate, subway construction, land usage and economic environment were confirmed to be the four important influencing aspects of the research, and their prevalence among the UPS cities from high to low is climate (with 95% of cities), subway systems (with 74% of cities, well developed subways with 47% of cities), economic level (with 37% of cities) and city scale (with 26% of cities);

- Asian cities are more likely to develop UPS with possessing more influencing conditions when compared to cities in Canada and the United States. The development of UPS in American cities tends to be least affected by the four influencing conditions amongst the three nations.
- SPSS statistics analysis helped to understand various decisive effects of these factors. The SPSS Independent Group T-Test indicated that statistically significant differences existed at an economic level, subways and for city scale in determining the existence of UPS in developing and advanced economies. The differences rooted on the different stages of urban development and thus the different urban spatial structure of developing and advanced economies. On the one hand, for developing economies, the urbanization process resulted in population concentration. High population densities in metropolises, land shortages, prevalence of public transport, and comparatively strong economic abilities in their nations are features interweaved in the urbanization process that have contributed to continuous subway and UPS development. On the other hand, for advanced economies, UPS were used to complement suburbanization and characteristics by phenomenon such as dispersed urban spatial structure, job and housing decentralisation, prevalence of private car usage and uniform income.

Developing countries developed UPS based on urban environments which are considerably different to cities in advanced countries. That is the principal reason why although UPS have developed in advanced economies for more than half a century, the trend that UPS extended in developing economies still requires further investigation. In addition, while the reality and practice of UPS projects appears to be beneficial, the assessment of their impact is much less adequate highlighting the necessity of further research of UPS development in developing economies. This research has provided a sound basis for further examination of the role of UPS in urban environments in developing economies.

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