



## Review article

## Access to urban transportation system for individuals with disabilities

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## ABSTRACT

Urbanization and aging population has become a significant issue in many global cities. It is necessary that the design of built environment to be supportive and provide adequate access to essential urban and social resources, e.g. employment, education, medical, social welfare and recreation etc., for all, including individuals with disabilities. Safe, efficient and accessible transportation is a key component of community integration. This study attempts to review the current practices and guidelines for accessible design of transportation, both access to and within transport facilities, based on the information from the United States, United Kingdom, and Hong Kong. Besides, the effects of accessible design of transportation on perceived level of service, accessibility, safety and travel behavior would be examined. Therefore, good practices of accessible design that could address the needs for all, especially the elderly and individuals with different types of disability including visual impairment, hearing difficulty and reduced mobility, could be recommended. Hence, quality of life of vulnerable group can be enhanced, and community integration will be achieved in the long run.

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## Contents

1.	Introduction . . . . .	67
2.	Accessible design for transportation . . . . .	67
2.1.	Access to transport infrastructure and facilities . . . . .	69
2.2.	Traffic control and management . . . . .	69
2.3.	Access within transport facilities . . . . .	70
2.4.	Transport vehicles . . . . .	70
2.5.	Summary . . . . .	70
3.	Influences on travelers' perception . . . . .	70
3.1.	Quality of life . . . . .	70
3.2.	Level of service . . . . .	70
3.3.	Accessibility . . . . .	71
3.4.	Safety . . . . .	71
4.	Influences on travel behavior . . . . .	72
4.1.	Activity pattern . . . . .	72
4.2.	Mode choice . . . . .	72
4.3.	Journey time . . . . .	72
4.4.	Transport planning . . . . .	72
5.	Discussion . . . . .	72
5.1.	Mobility disability . . . . .	73
5.2.	Visual and auditory impairment . . . . .	73
5.3.	Elderly . . . . .	73
6.	Conclusions . . . . .	73
	Acknowledgement . . . . .	73
	References . . . . .	73

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## 1. Introduction

Urbanization is a significant issue in modern society. Presently around half of the world's population are living in urban areas. The urban population has been increasing much more rapidly than the overall population, and it is expected that more than two-third of the world's population will be living in urban areas by 2050. Asia is expected to be one of the concentrations for this growth in urban population [1]. Rapid urbanization often accompanies industrial revolution, rapid economic growth, and more prominently, reduced poverty. Urbanization could have a positive impact on individual quality of life, attributed to increased opportunity of employment, economic activity, consumer products, services, recreation, and entertainment. However, the urban built environment and access to essential facilities and services, including transportation and medical and social welfare services, may not always be sympathetic to the needs of vulnerable groups, including the elderly and individuals with disabilities.

Many developed societies are facing the problem of an aging population. In the United Kingdom, the proportion of the population above 65 years of age will be doubled in the next 15 years, while those over 80 years of age will be trebled [2]. In the United States, the proportion of the population above 65 years of age will be doubled by 2060 [3]. In Hong Kong, the proportion of the elderly population (above 65 years of age) is expected to increase from 12% (in 2015) to 25% (in 2035) over 20 years because of the increasing average life expectancy and declining birth rate [4]. An aging population poses numerous challenges including increased dependency on medical, social and welfare services. Increased access to these essential urban services induces a heavy burden on the urban transportation system.

Further, the needs of individuals with disabilities should not be neglected. In the United Kingdom about 20% of the population is considered to be disabled or impaired in some form, in which two-third are above 60 years of age and almost half of the disabled or impaired population were recognized as having difficulties of going out. In the United States, 12.6% of the total population are considered individuals with disabilities, while 35.5% of the population who are over 65 years of age are considered individuals with disabilities [5]. In Hong Kong, the number of persons with disabilities was estimated to be 578,600 (8.1% of population) in 2013. The definition of disability is having one or more visual, hearing, speech and mobility impairments for more than 6 months. For instance, the number of persons with a visual impairment, hearing difficulty, speech difficulty and mobility impairment was 174,800 (2.4% of overall population), 155,200 (2.2%), 49,300 (0.7%) and 320,500 (4.5%) respectively [2,6].

Community integration is an important issue for individuals with disabilities. Community integration refers to the extent of involvement, engagement, and participation of an individual in the same manner as the typical citizen in the community. It is essential that the built environment be supportive and provide access to community resources, including housing, employment, transportation, and community services, for all individuals. Therefore, design, planning, policy, practices and procedures should comply to appropriate guidelines for the enhancement of community integration for individuals with disabilities [7,8]. Accessible transportation is one of the key components that supports the community integration of individual with disabilities, with individuals with increased access to transportation reporting greater quality of life and lower levels of social isolation. In the United Kingdom, a national survey revealed that the number of trips made by the elderly increased by 12–19% and the travel distance of the elderly increased by 40–45% respectively during the 15-year period between 1985 and 1998, while the increases for the overall population were only 3% for the number of trips and 27% for travel distance over the same period. Better access to transport was correlated to the increase in mobility and social participation, and therefore more positive perception of quality of life [9].

Therefore, it is essential to review the current guidelines and practices governing the design and planning of transport facilities that

could influence the travel behavior of individuals with disabilities. In this study, appropriate design of the outdoor environment and/or access to transport facilities (e.g. footpath, accessible route, ramp, curb and pedestrian crossing, etc.) and indoor environment and/or access within transport facilities (e.g. stair, escalator, movable walkway, lift, platform and transport vehicles, etc.) is identified. Further, the influence of accessible design of transportation on the perception and travel behavior of individuals with disabilities will be examined. The attributes concerned are quality of life, perceived level of service, accessibility, safety, activity pattern, and mode choice.

The overall purpose of this paper is to identify appropriate design of transport facilities and services that are accessible for all, including the elderly and individuals with disabilities; to enhance the awareness of accessibility needs in policy, legislation and procedures for strategic urban transport planning. Hence, community integration for all, both from the physical and physiological perspectives, will be improved. First, current practices and guidelines of accessible design for transport facilities in the United States, United Kingdom and Hong Kong will be reviewed in Section 2. Second, studies focused on the anticipated changes in perception and travel behavior of individual with disability in response to accessible transportation will be reviewed in Sections 3 and 4 respectively. Third, impacts on the design, construction, management and operation of transportation infrastructure and facilities for individual with different disabilities, including visual, auditory, and mobility impairment will be discussed in Section 5. Concluding remarks will be given in Section 6.

## 2. Accessible design for transportation

In the United States, accessibility design standards and guidelines for the built environment of transport facilities considering the need of individuals with disabilities, in accordance to the Americans with Disabilities Act (ADA) of 1990, was set out in 2002. The design specifications were based on ergonomic dimensions of both adult and children, and additional requirements of individuals with disabilities, such as wheelchair users. All newly constructed facilities and renovated parts of existing facilities should comply with these design specification [10]. In the United Kingdom, legislation on disability discrimination was introduced to require obligatory provision of access to buildings and facilities for individuals with disabilities in 1996. In response to this, the Department for Transport established a comprehensive guideline for the design of accessible transport facilities [11]. The requirements specified were applicable to the design and operation of the pedestrian environment, transport infrastructure, and public transport facilities. In Hong Kong, a design manual specifying the design requirements for building and facility access for individuals with disabilities, in accordance to the Disability Discrimination Ordinance 1995, were established in 2008 [12]. Again, the design manual was applicable to the design and construction of both new building and alternations or additions to existing building. Design standards and requirements for access to transport infrastructures, facilities, and vehicles as specified in the relevant guidelines of the United States, United Kingdom and Hong Kong are summarized in Table 1.

As illustrated in Table 1, accessible design guidelines for the United States specify the minimum required dimensions for numerous areas of buildings, including public access routes, ramps, doors and/or entrances, stairs, escalator, lifts, and requirements of transport facilities, including bus stops, railway platforms and railway stations [10]. The design guidelines of the United Kingdom, the capabilities and specific needs of individuals with different types of disabilities, including visual impairment and mobility impairment (i.e. person using white-tipped canes, person with assistance dog, and wheelchair user, etc.) were considered. These guidelines specified both minimum and desirable required dimensions for building infrastructures and facilities, including public access routes, ramps, entrances, stairs, escalators and lifts, traffic control facilities, including curbs, pedestrian crossings, footbridge and/

**Table 1**

Guidelines of accessible design for access to and access within transport facilities.

Category	Measure	United States [10]	United Kingdom [11]	Hong Kong [12]
Access to transport facilities	Access route/footpath	<ul style="list-style-type: none"> <li>› Minimum clear width of 915 mm (desirable width of 1525 mm)</li> <li>› Minimum passing space of 1525 mm × 1525 mm for every 61 m</li> <li>› Maximum change in level of 13 mm</li> <li>› Surface be firm and slip-resistance</li> </ul>	<ul style="list-style-type: none"> <li>› Minimum clear width of 1500 mm (desirable clear width of 2000 mm)</li> <li>› Minimum clear width of 1000 mm when there is obstacle with maximum length of 6 m</li> <li>› Minimum clear width of 3000 mm at bus stop and 3500 mm by shops</li> <li>› Maximum cross-slope gradient of 1:40</li> </ul>	<ul style="list-style-type: none"> <li>› Minimum clear width of 1050 mm (desirable clear width of 1500 mm)</li> <li>› Surface be firm and slip-resistance</li> <li>› Access be provided with tactile guide path for individuals with visual impairment</li> </ul>
Access to transport facilities	Ramp	<ul style="list-style-type: none"> <li>› Minimum clear width of 915 mm</li> <li>› Minimum clear distance of 1525 mm for landing of ramp</li> <li>› Maximum gradient of 1:12 (desirable gradient of 1:20)</li> <li>› Maximum rise of 760 mm for each flight</li> <li>› Minimum curb height of 50 mm above ramp level on both sides of ramp for protection</li> </ul>	<ul style="list-style-type: none"> <li>› Minimum clear width of 1200 mm (desirable width of 2000 mm)</li> <li>› Minimum clear landing space length of 1200 mm (desirable length of 1500 mm)</li> <li>› Maximum gradient of 1:12 (desirable gradient of 1:20)</li> <li>› Minimum curb height of 100 mm above ramp level on both sides of ramp for protection</li> </ul>	<ul style="list-style-type: none"> <li>› Minimum clear width of 1050 mm (desirable clear width of 1200 mm)</li> <li>› Minimum clear landing space of 1500 mm × 1500 mm both ends of ramp</li> <li>› Maximum gradient of 1:12 (desirable gradient of 1:20)</li> <li>› Minimum curb height of 100 mm or guardrail height of 200 mm above ramp level on both sides of ramp for protection</li> <li>› Railing or barrier be provided at the lower end of ramp leading down to vehicular traffic</li> <li>› Tactile warning strips be provided at both ends of ramp and landing</li> </ul>
Traffic control and management	Dropped curb/crossing	<ul style="list-style-type: none"> <li>› Minimum width of 915 mm</li> <li>› Maximum gradient of 1:10 for dropped curb with detectable warnings</li> <li>› Tactile warning surface be provided</li> </ul>	<ul style="list-style-type: none"> <li>› Minimum width of 1000 mm (desirable of 1200 mm)</li> <li>› Minimum clearance of 900 mm for level area beyond dropped curb</li> <li>› Maximum gradient of 1:12</li> <li>› Be provided at all controlled crossing and every 100 m</li> <li>› Tactile surface be provided for individual with visual impairment</li> </ul>	<ul style="list-style-type: none"> <li>› Minimum width of 1200 mm</li> <li>› Minimum clearance of 800 mm for level area beyond dropped curb</li> <li>› Maximum gradient of 1:10</li> <li>› Maximum level difference of 15 mm with vehicular areas</li> <li>› Minimum width of tactile warning strip of 600 mm</li> <li>› Luminous contrast of tactile warning strip for elderly and individual with visual impairment</li> </ul>
Traffic control and management	Footbridge/underpass		<ul style="list-style-type: none"> <li>› Minimum clear width of 4.8 m</li> <li>› Minimum clear headroom of 3 m</li> <li>› Handrails of 1000 mm high above walking surface be provided both sides</li> </ul>	
Within transport facilities	Door	<ul style="list-style-type: none"> <li>› Minimum clear width of 815 mm</li> <li>› Minimum spacing of two doors in series of 1220 mm</li> <li>› Automatic doors and power-assisted doors be complied with relevant standard</li> </ul>	<ul style="list-style-type: none"> <li>› Minimum clear width of 900 mm (desirable width of 1200 mm)</li> <li>› Minimum space of 1340 mm (desirable of 2000 mm) between two doors in series</li> <li>› Minimum clear space of 1500 mm be provided both sides of door</li> <li>› Automatic sliding door be desirable</li> </ul>	<ul style="list-style-type: none"> <li>› Minimum clear width of 800 mm</li> <li>› Minimum clear width of area adjacent to door handle of 330 mm</li> <li>› Provision for wheelchair users, individual carrying luggage, and individual with baby carriages</li> <li>› Automatic sliding door be desirable</li> </ul>
Within transport facilities	Stair	<ul style="list-style-type: none"> <li>› Minimum tread depth of 280 mm</li> <li>› Minimum clear width of 1219 mm between handrails</li> </ul>	<ul style="list-style-type: none"> <li>› Minimum tread depth of 250 mm (desirable tread depth of 300 mm)</li> <li>› Maximum tread height of 170 mm (desirable tread height of 150 mm); minimum tread height of 100 mm</li> <li>› Minimum clear width of 1000 mm between handrails (desirable clear width of 1200 mm)</li> <li>› Maximum of 12 steps in one flight; minimum of 3 steps in one flight</li> <li>› Tactile warning surfaces be provided at both ends of stair</li> <li>› Color contrast be provided for nosing</li> </ul>	<ul style="list-style-type: none"> <li>› Minimum tread depth of 225 mm (desirable tread depth of 300 mm)</li> <li>› Maximum tread height of 175 mm (desirable tread height of 150 mm)</li> <li>› Maximum of 16 steps in one flight with no landing (desirable of 12 steps)</li> <li>› Luminous contrast be provided for non-slip nosing and treads</li> </ul>
Within transport facilities	Escalator/moving walkway	<ul style="list-style-type: none"> <li>› Minimum clear width of 813 mm</li> <li>› Two contiguous level treads be provided</li> <li>› Sufficient luminous contrast for step edge</li> </ul>	<ul style="list-style-type: none"> <li>› Minimum width of 580 mm (1500 mm for moving walkway); maximum width of 1100 mm</li> <li>› Maximum step height of 210–240 mm</li> <li>› Minimum height clearance of 2300 mm</li> <li>› Maximum speed of 0.75 m/s (desirable speed of 0.5 m/s)</li> <li>› Maximum angle of inclination of 35° (1:20 for moving walkway)</li> <li>› Minimum level run-off of 6 m at each end of moving walkway</li> <li>› Clear emergency stop switch and audible warning be provided</li> </ul>	<ul style="list-style-type: none"> <li>› Maximum angle of inclination of 30°</li> <li>› Sufficient luminous contrast for step edge, handrail</li> <li>› Tactile warning strips be provided at each end of escalators</li> <li>› Clear signal or audio indicator for escalator and moving walkway</li> </ul>
Within transport	Lift	<ul style="list-style-type: none"> <li>› Minimum internal dimension of 1730 mm × 1291 mm</li> </ul>	<ul style="list-style-type: none"> <li>› Minimum internal dimension of 1250 mm × 1000 mm</li> </ul>	<ul style="list-style-type: none"> <li>› Minimum internal dimensions of 1200 mm × 1100 mm</li> </ul>

Table 1 (continued)

Category	Measure	United States [10]	United Kingdom [11]	Hong Kong [12]
facilities		<ul style="list-style-type: none"> <li>› Minimum clear entrance width of 915 mm</li> <li>› Visible and audible signal provided at lift entrance, with specific signals for up and down directions respectively</li> <li>› Visual and audible signal be provided</li> </ul>	<ul style="list-style-type: none"> <li>› Minimum clear entrance width of 900 mm</li> <li>› Minimum clear entrance height of 2100 mm</li> <li>› Height of handrail between 900 mm and 1000 mm</li> <li>› Visual and audible announcement be provided both in and outside</li> </ul>	<ul style="list-style-type: none"> <li>› Minimum clear entrance width of 850 mm</li> <li>› Wheelchair turning space of 1500 mm × 1500 mm be provided</li> <li>› Height of handrail between 850 mm and 950 mm</li> <li>› Audio signal be provided to alert door closing</li> <li>› Braille and tactile markings provided for lift control buttons</li> </ul>
Within transport facilities	Signage/information	<ul style="list-style-type: none"> <li>› Width-to-height ratio of letter between 3:5 and 1:1</li> <li>› Minimum character height of 75 mm</li> <li>› Height of sign above ground of 1525 mm</li> <li>› Assistive listening system be provided</li> </ul>	<ul style="list-style-type: none"> <li>› Width to height ratio between 3:5 and 1:1</li> <li>› Minimum character size: reading distance ratio of 1:27</li> <li>› Wall-mounted signs be centered at 1400 mm from the ground</li> <li>› Audible alarm system be operated of 15 dB over prevailing sound level</li> </ul>	<ul style="list-style-type: none"> <li>› Minimum size of 200 mm high</li> <li>› Minimum luminous contrast of 70%</li> <li>› Braille and tactile floor plan be provided for individual with visual impairment</li> <li>› Assistive listening system be provided for individual with hearing impairment</li> <li>› Sign be designed for individuals with intellectual, cognitive and sensory disabilities</li> </ul>
Transport vehicles	Bus	<ul style="list-style-type: none"> <li>› Bus stop platform of minimum clear length of 2438 mm; minimum clear width of 1525 mm</li> </ul>	<ul style="list-style-type: none"> <li>› Raised bus boarding area of width of 500–1500 mm (desirable width of 1800 mm); length of 3000 mm (desirable length of 9000 mm)</li> <li>› Raised curb height of 125–140 mm (desirable of 160 mm)</li> <li>› Maximum walking distance from all buildings of 400 m Bus stops in opposing directions on single carriageway be staggered with a minimum distance of 40 m</li> <li>› Use of low-floor wheelchair accessible vehicles</li> <li>› Maximum gradient from bus step (250 mm) to reference curb height (125 mm) of 1:8; minimum ramp length of 1000 mm</li> <li>› Minimum size of bus stop sign of 300 mm wide by 250 mm high</li> <li>› Minimum height of bus stop sign bottom of 2500 mm above ground</li> <li>› Timetable information located between 900 mm and 1800 mm in height</li> </ul>	
Transport vehicles	Rail	<ul style="list-style-type: none"> <li>› Difference in vehicle and platform vertical level be less than 16–76 mm for rail transit</li> <li>› Platform edge not protected by platform screens or guard rail be provided detectable warnings</li> </ul>	<ul style="list-style-type: none"> <li>› Minimum clear space of 2000 mm, excluding safety zone, for platform</li> <li>› White line of 100 mm wide for platform edge of off-street rail service for individuals with visual impairment</li> <li>› Tactile warning surface be provided for platform edge</li> <li>› Slip-resistant platform surface</li> <li>› Use of low-floor light rail transit vehicles with maximum required platform height of 350 mm</li> </ul>	

or underpass, and details of bus stops, bus terminals, bus vehicles, railway platforms and rail vehicles [11]. The design guidelines for Hong Kong also specified both minimum and desirable required dimensions for areas of buildings including access routes, ramps, curbs, entrances, stairs, escalators and lifts. In addition, special provisions for individual with visual impairment, hearing impairment, and mobility impairment were also specified [12].

### 2.1. Access to transport infrastructure and facilities

As illustrated in Table 1, for accessible routes, minimum and desirable clear width and passing space, surface requirement, and appropriate cross-slope were specified in all the guidelines reviewed. The desirable clear width ranged from 1525 mm to 2000 mm. The consideration was to allow the passing of two wheelchairs or at least that of one wheelchair and one walker. For accessible routes with slope and ramps,

minimum and desirable clear width, dimensions of landing at both end of the ramps, maximum gradient, maximum rise, and design of protections including curbs, barriers and guardrails were specified in all the guidelines. In general, the desirable gradient of ramp was 1:20. This consideration allows the safe and efficient movement of individuals with impaired mobility, including manual wheelchair users.

### 2.2. Traffic control and management

At mid-block pedestrian crossings, intersections, and access points to vehicles, flush access or dropped curb should be provided. As shown in Table 1, minimum clear width, clearance length of level area beyond, maximum level difference and maximum gradient of dropped curb were set out. Provision of luminous contrast and/or tactile surface for individual with visual impairment was also specified. In general, maximum gradient between 1:10 and 1:12 is recommended. In

addition, British guidelines also specified the design requirement for footbridge and underpass. For instance, minimum clear width, headroom, and height of handrail were specified.

### 2.3. Access within transport facilities

Within transport infrastructures and facilities, including public transport stations, terminals and interchanges, design requirements for doors or entrances, stairs, escalators or moving walkways, and lifts were specified. As shown in Table 1, minimum clear width and minimum spacing between series of doors were specified, in accordance to the requirement for smooth and safe maneuvering of those individuals using wheelchairs. In particular, automatic sliding doors and power-assisted doors are recommended. For steps and stairs, minimum tread depth, maximum tread height, and number of steps in one flight were specified with respect to the needs of individuals with walking difficulties. Also, visual contrast is specified in the Hong Kong and British guidelines to aid individuals with lower visual acuity. Similarly, minimum internal dimensions and clear entrance width for lift and lift car were specified, based on the smooth and safe maneuvering of individuals using wheelchairs. Additionally, visual and audible signals for door closing, upward, and downward movement of the lift car should be provided.

In addition, the provision of escalators and moving walkways is essential to improve the accessibility and efficiency of high movement volume over substantial lateral distances and changes in vertical level. As illustrated in Table 1, minimum clear width, height clearance, maximum step height, speed, and angle of inclination for escalators and moving walkways were specified. In particular, the desirable speed of escalators and moving walkways should be less than 0.5 m per second and desirable angle of inclination of escalator should be less than 30°, with respect for the comfort and safety of the elderly and individual with walking difficulties. Besides, clear visual and audio signals and/or warning should be provided at the ends of escalator and moving walkway.

For signage, minimum size and recommended width-to-height ratio of character, height of sign above ground, and visual contrast were specified. The recommended height of sign ranged from 1400 mm to 1525 mm. Besides, recommended sound level of audible alarm system and assistive listening system for individual with visual impairment and hearing difficulty were also specified.

### 2.4. Transport vehicles

As shown in Table 1, design standards for transport facilities including public transport stations, terminals and interchanges were detailed in British guidelines. For bus transport, recommended dimensions of raised bus boarding platform, curb height and gradient from curb height to bus step were specified. The use of low-floor wheelchair accessible vehicles, and provision of clear bus stop sign, and timetable information were recommended. For rail stations, minimum clear space on the platform, design of platform edge warning, provision of slip resistance platform surface, and platform height were specified. In general, the difference in level between rail vehicle and platform should be less than 76 mm, for safe and efficient access of all passengers. For on-street rail vehicles, use of low-floor transit vehicles and platform height of 350 mm were recommended.

### 2.5. Summary

In this section, the design requirements for access to transport facilities, access within transport facilities, and access to vehicles as specified in the US, UK and Hong Kong's guidelines, in accordance to the needs of individuals with visual, hearing and mobility impairments, were reviewed. In general, appropriate clearance width and gradient of footpath, accessible route, ramp and curb were specified in all the guidelines

reviewed. The guidelines consider the efficient and safe maneuver of individual with different types of impaired mobility, including individuals using white-tipped cane, rollators walking aid users, and wheelchairs. Guidelines for hazard protection using contrast, audible signal, tactile indicator, and surface texture, for both outdoor environment/access to transport facilities and indoor environment/access within transport facilities, were specified to assist the movement and navigation of individuals with visual impairments and hearing difficulty.

## 3. Influences on travelers' perception

In the previous section, guidelines for the accessible design of both access to and access within different transport facilities were reviewed. The needs and consideration for individual with different types of disability (i.e. visual, hearing, mobility impairment, etc.) were clearly set out. In this section, studies on the effectiveness of accessible design for the elderly and individuals with disabilities were reviewed. The attributes examined were perceived quality of life, level of service, accessibility and safety and operation efficiency. Key findings of the studies on the effect of accessible design, from the perspectives of quality of life, level of service, accessibility and safety perception are summarized in Table 2.

### 3.1. Quality of life

Banister and Bowling [9] attempted to examine the relationship between activity pattern, environmental and social attributes, and perceived quality of life of elderly people, using a perception survey. Results indicated that the perceived quality of life of the elderly was more positive when his/her frequency of activity engagement was higher than three per month and one had better access to transport, regardless of private and public transport. Banister and Bowling [9] also suggested that policy initiative for providing better transport facilities and services was one of the six main components that determine the perceived quality of life of the elderly.

### 3.2. Level of service

As better transport service has been shown to enhance quality of life, especially for elderly and individuals with disabilities, it is essential to identify the factors contributing to level of service of transport infrastructures and facilities. Wennberg et al. [13] attempted to evaluate the effect of improved outdoor walking environment on perceived mobility and level of service of elderly. Measures including removal of level difference, uneven surface, drainage grooves and high curbs; provision of adequate warning, lighting, balance support, signs and ramps; and installation of automatic door openers were considered. Unfortunately, no evidence was established for the enhancement of level of service, even though the mobility was improved after the anticipated changes in the walking environment. However, perceived level of service of public transport was found to be enhanced with the provision of integrated travel information systems and improved bus stop design [14,15,16]. For instance, perceived usefulness of integrated travel information systems was enhanced with the provision of both static and dynamic ease-of-access information of different transport modes, transport interchanges and parking facilities. It was particularly important to individuals with mobility impairments. Pre-trip journey planning scenarios, ease-of-access information to service facilities, and photographs illustrating the potential physical barriers were recognized as useful, especially for individuals with lower level of independence [14]. Perceived usefulness and level of service varied by traveler groups. A Norwegian study indicated that universal design was the most beneficial to individuals with impaired mobility including wheelchair users, and passengers carrying pram and heavy baggage. The essential universal design elements for individual with impaired mobility were barrier-free access to buses, elevated bus stop platforms, tactile markers with contrasting



**Table 2**  
Effects of accessible design on travelers' perception.

Attribute	Measure	Key finding	Vulnerable group concerned	References
Quality of life	Public transport	› Perceived quality of life increased with access to public transport	Elderly	[9]
Level of service	Access route	› No association between perceived level of service of elderly and improved walking environment	Elderly	[13]
Level of service	Travel information system	› Perceived usefulness of travel information system for individual with impaired mobility improved with provision of ease-of-access information for transport facility	Mobility impairment	[14]
Level of service	Bus service	› Perceived level of service for passenger with baggage improved with the use of universal design › Perceived level of service for individual with impaired mobility improved with the use of universal design › Perceived level of service for individual with disability increased with the presence of bus route and schedule information at bus stop › Perceived level of service increased with the presence of shelter at bus stop › Perceived level of service increased with the provision of seat at bus stop › Perceived level of service decreased with average journey time	Visual, hearing and mobility impairment	[15,16]
Accessibility	Access route	› Accessibility to public transport improved with the provision of level and slip-resistance footpath surface, bench, safe crossing, extended pedestrian green time, and protection from fast moving traffic › No association between accessibility to transport facilities of elderly and improved walking environment › Accessibility of wheelchair user decreased with cross-slope gradient	Elderly, mobility impairment, wheelchair user	[9,13,17]
Accessibility	Bus service	› Accessibility of wheelchair user increased with clear width of footpath › Low-floor access bus vehicle improve accessibility › Reduced curb height bus stop design improve accessibility › Accessibility of wheelchair user improved with the provision of firm, stable, slip-resistance loading/unloading platform	Elderly, visual, hearing and mobility impairment, wheelchair user	[18,19]
Accessibility	Rail service	› Accessibility of individual with impaired mobility increased with improved multi-modal interchange facilities, rail transit platform	Wheelchair user	[20]
Accessibility	Transport policy	› Accessibility of elderly enhanced with strategic planning, institutional cooperation, and political awareness	Elderly	[21]
Safety	Bus service	› Safety, durability, cost and efficiency of bus transport service improved with provision of plastic lumber portable loading/unloading bus platform for wheelchair user	Wheelchair user	[19]
Safety	Access route	› Perceived safety level enhanced with separation between footpath and traffic, lowered speed limit	Elderly	[22]

color for buses and platforms, gentle ramps, and small gaps between buses and platforms [15]. Moreover, a perception study also indicated that the perceived level of service of individuals with disabilities and impaired mobility (carrying large items, suitcase, shopping bags, and baby) was enhanced with the availability of bus route and schedule information at bus stop. On the other hand, the perceived level of service of regular users was enhanced with the provision of shelter, condition of waiting area, seat availability, and reduced journey time [16].

### 3.3. Accessibility

Accessibility may enhance activity participation and perceived quality of life, especially for individual with impaired mobility. Studies have been conducted to identify contributing factors to accessibility of transport infrastructures and facilities. For accessible routes, even and slip-resistance surface, safe pedestrian crossing, extended green time at pedestrian crossings, and protection from fast moving traffic were found to be correlated with the accessibility [9,13]. In particular, a capability model has been developed to evaluate the accessibility of manual wheelchairs. Results indicated that presence of cross-slope with gradients greater than 2.5% could impact accessibility, especially for long distance journeys [17]. For public transit service, design of transit stops and/or platforms and transit vehicles were related to perceived accessibility. Results of perception surveys for bus services indicated that accessibility was enhanced with increased bus stop density, use of low-floor access buses, firm and slip-resistance bus platforms, and reduced curb height at bus stops, especially for wheelchair users [18,19]. On the other hand, a spatio-temporal analysis of public transit network travel behavior indicated that accessibility was enhanced by improved design of multi-modal interchanges. For instance, raised rail transit platform to align with rail transit vehicles, and provision of street-to-

platform and platform-to-platform step-free accesses at major interchanges would be essential [20]. More importantly, it was essential that accessibility planning be incorporated into strategic urban planning. The essential components were disability policies, an accessibility advisor, cooperation with advocacy organizations, and awareness of government directives [21].

### 3.4. Safety

Safety performance and cost effectiveness of universal access design of transport facilities are also important. To support frequent bus route changes and improve operation flexibility, a portable bus loading/unloading platform was examined. Results of the evaluation indicated that operational efficiency and safety of bus transit services could be enhanced by the introduction of a plastic lumber platform for wheelchair users, considering the structural performance, durability and life cycle cost. Moreover, the cost-effectiveness of bus service was enhanced [19]. On the other hand, an improved walking environment could enhance the perceived safety level for elderly and individual with disabilities. Clear separation between footpath and cycle path, reduced speed limit, and improved pavement surface were found essential for individuals who were dependent on walking and using mobility devices [22].

To conclude, perceived accessibility and safety, both access to and use of public transport, was found enhanced after the introduction of accessible designs including raised bus loading/unloading platforms, reduction of curb height, and removal of level differences, especially for individuals using wheelchairs and individuals with cumbersome baggage. Geospatial information of ease-of-access transport facilities was found useful for pre-trip planning. Though no association could be established for the relationship between the enhancement of the walking environment, mobility and perceived accessibility, perceived quality

of life could be enhanced with the improvement of access to essential service and increases in activity engagement.

#### 4. Influences on travel behavior

Changes in perceived accessibility, safety and level of transport service may affect travel behavior. Influences of accessible transportation on travel time, frequency of travel, route choice and mode choice should be evaluated. Key findings of studies on the travel behavior of individuals with disabilities are summarized in Table 3.

##### 4.1. Activity pattern

Improved accessibility to transport facilities may enhance the activity participation and thus perceived quality of life, especially for the elderly and individuals with disabilities. Results of elderly travel surveys indicated that improved access to transport increased engagement in social activities among the elderly, regardless of presence of long standing illness, mobility impairment and transport mode. Improvement of public transport service, walking environment, and perceived security and safety were influential to the association between activity participation and accessibility [9]. Factors interacting with the association were demographic, perceived health condition, independence on walking, household attributes, and presence of traffic and environmental barriers [22].

##### 4.2. Mode choice

Mode choice may be affected by perceived level of service. Use of public transport service may be enhanced with improved accessibility. A mode choice survey in London indicated that elderly and individuals with disability were found more likely to use bus service, when the bus vehicles (low-floor access buses) and bus stop designs (reduced curb height) were improved [18]. A passenger survey in six Norwegian cities indicated that number of public transport trips increased by 2.5% after the introduction of universal design. The changes were remarkable for wheelchair users, and individuals with visual impairment and hearing difficulty [15].

##### 4.3. Journey time

Other than the perceived level of service and accessibility, journey time may also influence mode choice. Prior research indicates that walking time was significantly reduced, especially for the elderly and individuals with impaired mobility, after the improvement of the walking

environment and accessible route. The attributes were level difference, surface conditions, presence of drainage grooves, curb height, and balance support [13]. From the network perspective, average overall journey time of individual with impaired mobility can be 80% higher than that of individuals without constraint. To effectively reduce the journey times of the elderly and individuals with impaired mobility using public transit, high-demand rail transit stations and multi-modal interchanges should be given priority for accessibility upgrades [20].

##### 4.4. Transport planning

Pre-trip planning could improve the travel experience of individual with impaired mobility. An integrated framework for geospatial information of transport facilities (taxi, tram, bus and train, etc.) and essential services (clinics, cafes and banks, etc.) in a graphical user interface was found useful and essential. For example, network-wide ease-of-access ratings of these transport and service facilities were relevant to the need of individuals with limited mobility [14]. From the implementation and legislative perspectives, awareness of government directives and institutional cooperation in strategic urban planning is essential for improving the walking environment, and accessibility of transport facilities and services [21].

To conclude, the journey time of individual with disability may be reduced substantially with the improvement of the accessible design of public transport vehicles, facilities, terminals and interchanges. Public transport use was found to increase after the implementation of accessible design, especially for individuals with visual, audial and mobility impairment. In addition, the activity engagement of the elderly can be increased with improved access to transport. Ease-of-access information for pre-trip planning was found useful in enhancing the travel experience.

#### 5. Discussion

A review of accessible design guidelines for transport facilities in United States, United Kingdom, and Hong Kong was conducted. Studies on perception and attitude of individuals with disabilities towards accessible design, and their influences on travel behavior were examined. It appears that the standards and guidelines of accessible design cover many components of both access to and access within transport facilities and services, for various modes including pedestrian, bus, and rail public transport. The guidelines considered the needs of vulnerable groups including the elderly, passengers with children and/or luggage, and travelers with disabilities. This section summarizes the needs and

**Table 3**  
Effects on travel behavior.

Attribute	Measure	Key finding	Vulnerable group concerned	References
Activity pattern	Transport accessibility	› Number of social activities increased with accessibility to public transport	Elderly	[9]
Activity pattern	Access route	› No association between mobility impairment and long standing illness		
Activity pattern		› Activity engagement of elderly increased with improved footpath, pavement surface, dropped curb, and lowered speed limit	Elderly	[22]
Mode choice	Bus service	› Frequency of walking trip increased with improved footpath and separated traffic		
Mode choice		› Bus use of elderly and individual with impaired mobility increased with bus stop density	Elderly, visual, hearing and mobility impairment, wheelchair user	[15,18]
Mode choice		› Bus passenger trip increased by 2.5% with the use of universal design		
Journey time	Access route	› Walking time of elderly reduced with level footpath, even surface, reduced curb	Elderly, mobility impairment	[13]
Journey time	Rail service	› Journey time for individual with impaired mobility decreased with improved rail transit interchange and multimodal interchange facilities	Wheelchair user	[20]
Transport planning	Travel information system	› Pre-trip planning improved for individuals with lower level of independence and activity engagement	Mobility impairment	[14]
Transport planning		› Ease-of-access information to transport facilities improved pre-trip planning for individuals with impaired mobility		
Transport planning	Transport policy	› Accessibility planning for elderly be prevalence in nowadays strategic urban transport planning	Elderly	[21]

attributes that determine the accessibility and satisfaction of individuals with different types of disabilities.

### 5.1. Mobility disability

In general, studies suggest that individual with impaired mobility, including pedestrians with walking aids and both electric and manual wheelchair users, found that barrier-free design of public transport were essential. Elevated platforms for loading and unloading of buses, removal of level difference at curb side, and reduction of gap size between platforms and bus/rail transit vehicles improve accessibility. In addition, reduction of level difference and gradient of ramps, cross-slope design, and provision of sufficient clear space at the landing of ramps and platforms may reduce difficulties in maneuvering for wheelchair users, especially manual wheelchair users. In addition, the journey time of wheelchair users may be reduced substantially if accessible design is implemented at high-demand transit stations and multi-modal interchanges. Moreover, geospatial information regarding accessible facilities for pre-trip planning was perceived as useful by individuals with impaired mobility [14,15].

### 5.2. Visual and auditory impairment

For individuals with visual and auditory impairment, route guidance with contrasting color tactile markers for accessible routes to transport facilities and within transport facilities, especially clear indication of position of bus stop, platform, entrance and vehicle, were found to be useful and effective in improving accessibility and perceived level of services. Audio information for the arrival of public transport vehicles could also improve the perceived level of service of public transport. In addition, clear and large signage, and timetables in large print that are legible to individuals with impaired vision are necessary [15,16].

### 5.3. Elderly

Numerous studies examined the accessibility, travel behavior, activity pattern, and their influences on perceived quality of life of the elderly. In general, improved access to transport may reduce the level of dependence while increasing activity engagement, and thus enhance the perceived quality of life of the elderly [9,22]. For example, a good pedestrian environment and high level of transport service were found essential to the elderly. Perceived environment, safety and security also affect trip characteristics with respect to trip frequency, trip time and transport mode, of the elderly. Maintenance and management of the footpath, accessible route, bus stop and the surrounding environment are essential [13,15].

## 6. Conclusions

Accessible transport is a key factor in access to essential urban resources and services, including housing, employment, social welfare, and recreation. It is importance to be inclusive of the needs of individuals with disabilities in the design of the built environment, urban facilities and services, to enhance the quality of life for all, and thus support community integration. This study reviewed current practices and guidelines for accessible transport design in the United States, United Kingdom, and Hong Kong, of (i) access to transport facilities, and (ii) access within transport facilities. The design of components including accessible routes, ramps, curbs, entrances, stairs, escalators, lifts, platforms and public transport vehicles should take into account the safe and efficient travel of individuals with different disabilities: i.e. visual impairment, hearing difficulty and reduced mobility. The influence of accessible design on travel behavior was also evaluated. It was revealed that perceived safety and level of service of individual with impaired mobility is remarkably enhanced after the introduction of accessible design of transport stations/bus stops. The walking environment was also

found to affect the level of satisfaction and perceived safety and security, especially for individual with impaired mobility and the elderly. In addition, public transport journey time of individuals with disabilities could be reduced, and travel and activity participation could be enhanced. It was suggested that accessible design should be implemented from the perspective of an integrated network approach, and priority should be given to passenger concentration points in the multi-modal transport system. Given advances in information technology, it is essential to enhance the availability of geospatial information of accessible facilities for pre-trip planning and real time navigation, to improve travel time reliability. Awareness of directives in strategic urban and transport planning should also be enhanced to achieve the sustainable development of an accessible transport system [21].

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