Design Guidelines of Public Transportation for Older Adults in Urban Areas

by

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Abstract

Population aging is a trend all over the world. It results in the increasing number of older adults in the whole population in a country. This is especially notable in urban areas; the elderly seek good life quality, social benefits and medical care there. Population aging will influence urban areas in the world considerably, as the demographic of older adults become the largest group of the society.

Due to the changes in physical abilities, such as recessions of muscle and sense organs, older adults feel difficulty in taking part in social activities; this may be a factor that contributes to the number of older adults suffering from loneliness. It becomes a vicious circle in that changes in physical abilities disable them to join in social activities, and lack of communication exacerbates loneliness. In order to break the circle, it is necessary to help older adults engage in social activities and communications. Public transportation may become a link to connect seniors to various social engagements; improved public transportation interior facilities and arrangements meet both physical and psychological mobility needs of older adults, may help build an active aging society and enable older adults to enjoy their city lives more fully.

In this thesis, a logical deduction would be firstly demonstrated to emphasize the influence of public transportation on older adults' needs of social engagement and wellbeing. Then based on several important theories, concepts and case studies, design guidelines of public transportation interior facilities would be created. Finally a new design of public transportation interior would be performed by applying guidelines, compared to the existing design.

Acknowledgments

I would like to begin by giving my thanks to my parents. I could never think of continuing my further study, and complete my master's courses in a distant country, without the selfless dedication and patient instruction from them. It has been my mother's determination and my father's sacrifices that have allowed me to have the opportunity to reach this academic milestone.

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List of Abbreviations

ADA	Americans with Disabilities Act
BIFMA	Business + Institutional Furniture Manufacturers Association
CDC	Centers for Disease Control and Prevention
CHD	The Center for Health Design
CUD	The Center for Universal Design
DOT	U.S. Department of Transportation
EBD	Evidence-Based Design
MTA	Metropolitan Transportation Authority (New York City)
SFMTA	San Francisco Municipal Transportation Agency
UD	Universal Design
UN	United Nations
WHO	World Health Organization

Chapter 1: Introduction

1.1 Background and Problem Statement

The world is experiencing population aging (United Nations, 2013). Most developed countries accept that people who are 65 years or over are defined as older adults (World Health Organization, 2015). In the US for example, in 2012, the population of 65 years old and over reached 43 million, which composed 13.7% of the whole population in the US, and the percentage is predicted to reach 16.7% in 2020 (Ortman, Velkoff & Hogan, 2014). Older adults aged 65 or older may suffer from chronic diseases such as arthritis, hypertension, heart disease, and diabetes; physical and cognitive ability, body physical function, and even psychological problems such as loneliness (Queen et al., 2014; Turcotte & Schellenberg, 2006).

Older adults' physical and mental health strongly influences their daily lives, such as their mobility and social engagement (Turcotte & Schellenberg, 2006); meanwhile, Rowe and Kahn (1997) argued that social engagement and mobility are important factors that influence older adults' health and successful aging. Thus, there is a strong relationship between older adults' health and social engagement, which is based on Dumbaugh's (2008) opinion, who stated that health conditions limit old adults' social engagement, and lack of social engagement may deteriorate their health condition. Mobility becomes a key determinant to improve social relationships to help older adults engage in social activities.

In an urban area environment, there are some factors that discourage older adults' mobility and make it hard to get out of their home. First, their body function declines, strongly influencing their mobility, which are mentioned above. Second, Börjesson, Hamilton, Näsman and Papaix (2015) argued that urban areas all over the world are suffering from congestion. Thus, low mobility efficiency causes older adults to feel it is difficult to get to their destinations. Third, older passengers feel lack of safety and inconvenience when they take public transportation, due to some factors such as unskilled drivers and the lack of related assistive facilities (Dumbaugh, 2008). Fourth, Samet (2007) suggested that "traffic may be a significant contributor to the adverse effects of air pollution on public health" (p. 1021). In such complicated urban environments, there are many potential problems that prevent older adults from getting access to social activities, and these problems may even lead to chain reactions and result in related social problems.

Therefore, mobility in big cities influences older adults' connections to our society significantly. Government and designers should develop systematic design approaches to meet the needs of older adults, benefit the mobility of this demographic group, and further enable them to engage with social activities, letting them enjoy their city lives.

1.2 Need for Study

Population aging is becoming a global trend that cannot be ignored. The demographic group of older adults has a significant interrelationship in our societies, and has an increasing

influence on the development of our world. With such a background, this study focuses on the mobility of older adults in urban areas, and tries to synthesize some design guidelines to ease the social activities of older adults. The need of study is demonstrated from several aspects in a logical way.

First, the basic studies of the physical and psychological conditions of older adults are needed, because they are the prerequisites to learn more about the mobility needs of this demographic. The understanding of aging knowledge, such as the decline of physical body functions and loneliness, may help designers to set up initial goals and plan the mobility methods for older adults.

Second, the physical and psychological needs of older adults should be studied and understood, especially for mobility needs. Such needs come from the consideration of older adults' body and mental situations, and also from the inconvenience of their social activities during daily lives.

Third, this study focuses on the mobility needs of older adults in urban areas, because designers and city planners need to understand such needs. Based on the mobility needs from older adults, designers could find the weakness and inconvenience about the transportation system and related facilities; they could pay more attention to such problems and seek ways to improve and solve these problems to meet the needs of older people.

Fourth, designers and city planners should refer to existing transportation design theories and guidelines, taking older adults and even more demographic groups of people into

considerations, and then try to synthesize and improve the existing theories and guidelines, finally forming new guidelines for the designing of transportation and related facilities. The guidelines should be universal to meet not only the needs from young and older adults, but also more demographic groups, such as disabled people, children, etc.

All the needs of study concern the mobility of older adults, to try to help them engage with social activities and so an active aging society can be built.

1.3 Objectives of Study

1. To research the background of aging society and understand its general problems.

2. To study the physical and psychological situations of older adults in urban areas.

3. To understand the body functions' decline and loneliness among older adults.

4. To draw conclusions regarding some main aspects of social factors that influences the lives of senior citizens.

5. To study the interrelationships among these social factors and how these factors are essential aspects that should be of concern.

6. To study the general social needs of older adults in urban areas.

7. To research how social factors affect the social needs of senior citizens

8. To prove the importance of researching transportation for the mobility of older adults in urban areas.

9. To organize ideas and solutions to transportation improvements, and then generate

applicable guidelines for the mobility of older adults in urban areas.

10. To apply guidelines to more general mobility methods and diverse groups of people.

1.4 Definition of Terms

Biophilia: Biophilia is the theory that humans have an innate relationship with nature. Such connection has been passed along throughout human evolution (Wilson, 1986).

Ergonomics: Ergonomics is a multidisciplinary activity that assembles information on people's capacities and applies that information in designing jobs, products, workplaces, and equipment (Eastman Kodak Company, 2004).

Evidence-Based Design (EBD): Evidence-Based Design is defined as the process of basing decisions about the built environment on credible research to achieve the best possible outcomes (The Center for Health Design, CHD, 2016).

Older adults: Older adults are defined as people 65 years old or over in many developed countries (WHO, 2015).

Preventive Healthcare: Preventive healthcare "encompasses both the care of individual patients, and public health practice, and as is evident in the name, focuses on the prevention of disease rather than treatment, per se" (Katz & Ali, 2009, p. 3).

Population aging: Population aging is an age structure tendency that the age of a country or region rises due to rising life expectancy and/or declining fertility rates. Usually it could be measured by the proportion of the population 65+ years old and the median age of the population

(Sanderson & Scherbov, 2015).

Social engagement: Social engagement is considered as an interpersonal interaction outside the home, such as social community activities, which indicates life satisfaction, especially among older adults (Herero & Extremera, 2010; Levasseur et al., 2011; Maier & Klumb, 2005).

Transgenerational Design / Universal Design (UD): Transgenerational Design is defined as the practice of design products or environment that meet the needs of aging population, meanwhile rejecting the discriminatory and stigmatizing, specialized products or devices targeted directly at older adults, because transgenerational design could also be applied to other age groups of people (Newbill, 2007; Pirkl, 1994, p. 228).

Urban areas: Urban area is defined as area of 50,000 or more people (United States Census Bureau, 2015).

1.5 Assumption

This thesis focuses on the mobility of older adults in urban areas, and I believe this research orientation meets the needs of older adults, lets them enjoy their city lives and furthermore, benefits our society. The expected outcomes are based on several assumptions.

Assumption 1: This focus maximizes the benefit to our society when concerning the major demographic group of our society.

Many countries experience population aging. As stated in the problem statement, it is expected that older adults will reach 16.7% of the whole population in the US, and it is the biggest demographic group in the society. Considering from common sense that paying more attention to the major demographic group will benefit the whole population remarkably, it also should be assumed that helping older adults and trying to meet their social needs will improve their health conditions, let them feel more independence from others and feel ease in engaging in social activities. Thus, it will further benefit the development of the society in that it helps relieve the pressure on medical care and younger generations; also care measures of older adults will give the young generation confidence to work and live, which ensures the sustainability and prosperity of the urban areas.

Assumption 2: Social engagement improves older adults' living quality in urban areas.

Due to the declines in body functions, older adults gradually feel it is difficult to do things alone, especially engaging in social activities. Due to lack of communication and care from our society, they feel loneliness at home; sometimes they may even suffer from mental problems. Thinking of this conversely, it is assumed that active social engagements among older adults help them get rid of loneliness, release mental pressure, improve physical body exercises, further enabling them to live happier lives in urban areas.

Assumption 3: Mobility improvement helps social engagement.

As assumed that old adults feel difficulty in going out and enjoying social activities because they find it hard to move because of body function declines. It is easy to further assume that improved mobility methods and related facilities may let them feel ease to move by themselves, and then comfort them to engage in social activities, and finally help them enjoy their urban lives.

The assumptions form a logical way to infer that mobility of older adults in urban areas is an important factor that is associated with social benefits, convenience and happiness among this demographic group. These assumptions need more theoretical support.

Assumption 4: There is enough financial and technological support to make improvements on public transportation.

The improvement of public transportation is, however, not only a design issue, but should be supported by the local government as well as cooperation with different technology. Thus, our design improvements and guidelines are based on the assumptions that full support from budget and technology could be obtained.

1.6 Scope and Limits

Scope

The topic of this study focuses on the improvement of mobility or transportation to help connect older adults to social engagements and environment in urban areas, with the background

of global population aging.

First, this study mainly concerns age-related physical declines in ability. Older adults suffer from the recession of body functions and physiological changes, such as muscles, visional and auditory senses. Also, many of them suffer from chronic diseases, such as hypertension, diabetes and so on. They may feel it inconvenient and difficult to walk in a crowded city environment, poorly designed interior space, or a public transportation system.

Second, the research will pay attention to the social engagements. As mentioned before, social engagements play an important role in that they benefit older adults' lives, and this point will also be supported in the following chapter.

Third, this study should focus on older adults' mobility in urban area environment. The mobility in urban area environment refers to transportation activities elderly people may encounter, especially public transportation system. Mobility activities connect seniors to various social engagements, in this case by using public transportation to their destinations without barriers.

Limits

This study has its limits. First, the research focuses on the improvements of transportation in urban areas, which means this study considers less other regional areas, such as suburban or countryside locations. Urban areas usually have common social environments with a large population and better social systems, while there are big differences between urban and other

parts of the nation: population and development situations of local economy and natural environments vary a lot. In this circumstance, this study may not properly be applied to these places.

Second, the demographic group of older adults in urban areas are large in number; however, in this research, it is impossible to investigate such a big population. Therefore, the proper solution is to collect data and statistics from books, related materials, journals and so on. Most of the research is based on latest data. So, the result may be affected by the opinions and comments from others. Also, the research is limited to urban areas, so there may be some differences in thoughts between urban and rural citizens, which could also affect the results of this study.

Third, there are many factors that could affect the mobility of senior citizens, abilities and physiological changes, and diseases are common factors. However, psychological need is also another important factor that could influence the mobility of older adults. Senior citizens need social belongingness and respect from our society to be enable to accept the services offered by our society. However, psychology of older adults is a broad topic that it is difficult to discuss in detail in the thesis, and this part may not be paid a lot of attention to. Also, factors such as geographic limitations, weather conditions, and economic levels may also affect the mobility of senior citizens.

1.7 Procedures and Methodology

Procedure 1: Identify the interest of the subject matter.

Methodology: Population aging is a global trend that should be paid more attention to. Based on this interest, books and materials about population aging and older adults' needs of transportation in urban areas are studied, and some existing methods and solutions dealing with current situations are collected. Then these materials are gathered to start this thesis.

Procedure 2: Study the needs of older adults in urban areas.

Social engagements keep older adults in good physical and psychological health, maintaining a sustainable and active environment for the living of senior citizens and the whole population in the city.

Methodology:

- List types of social engagements.
- Study why these social activities attract older adults.
- How these engagements meet the needs of older adults.
- How to improve social engagements and help older adults to enjoy city living.

Procedure 3: Study the body changes of older adults.

The study of body changes of older adults is the key to help improve the living and mobility of senior citizens in urban areas. In this procedure, latest papers and articles are studied to help have a general knowledge of body function recessions of elderly people. Also, some

professors who have professional knowledge about this field of study were consulted to have a further understanding of the conditions of older adults. Then, according to the focus of this study, more attention should be paid to the body functions which relate to mobility and transportation parts, such as visual and hearing senses, muscles and so on. Furthermore, references, information and data were collected to support the topic of research.

Methodology:

- Study the abilities and body changes of older adults.
- Conduct extensive literature reviews.
- Consult professors for professional ideas and information.
- Narrow down the research to meet the topic of this study.
- Collect data and information for supporting topic of study.

Procedure 4: The improvement of mobility and transportation.

Mobility and transportation, considered as the connection between senior citizens and social engagements, play important roles in daily lives in big cities.

Methodology:

- List all the possible mobility and public transportation methods older adults may use.
- Analyze the advantages and disadvantages of each travel methods.
- Consider feasible improvements of these methods to meet the requirements of older adults.

- Determine how transportation play a role to connect older adults to social engagements.
- Analyze how these travel methods interrelate and collaborate with each other to improve the quality of older adults' mobility.

Procedure 5: Synthesize gathered information to form guidelines for the mobility of older adults in big cities with the background of population aging.

In this procedure, solutions should be found to form guidelines for the mobility of older adults. Based on concluded information and statistics, there are some unique ideas of how to deal with problems in aging society.

Methodology:

- Arrange the information and data; find the problems and obstacles of the old during transportation.
- Develop general guidelines for the improvement of older adults' mobility in big cities.
- Apply the guidelines to specific big city environment to solve specific problems.
- Extend these solutions into other potential uses, to see whether these solutions could solve other similar kinds of problems.

1.8 Anticipated Outcome

This study focuses on the mobility of older adults in urban areas with the background of

population aging; this work also aims at connecting older adults to various social engagements, helping them keep good health and enabling them to enjoy their lives. By researching the topic, there are some anticipated outcomes:

First, this study identifies several physical and psychological problems regarding current situations of senior citizens. By reading related books and materials and consulting professors in specific field of studies, conclusions and recommendations may be considered as outcomes that could be referred to and applied in other studies concerning older adults' issues.

Second, the research into the needs of senior citizens in urban areas finds that social engagements play an important role in the lives of elderly people. Social engagements help older adults get in touch with social activities, letting them feel they are an important part of society. Research shows that social engagement benefits the physical and psychological needs, helps older adults physically move and use the body as well as letting them get rid of loneliness, improve their health and maintain social networks. Thus, the outcome concludes that social engagement is a key factor that comes from older adults' needs and influences their daily lives.

Third, the topic of this thesis focuses on the mobility and transportation improvements in an aging society. Transportation may be considered the link between older adults and social activities. Therefore, it is crucial to reconsider the arrangements, management and construction of the system. The anticipated outcome will be applied to a specific transportation environment, a city metro system, to illustrate how public transportation eases the mobility of such a demographic group of people, enabling them to get connected with society.

Fourth, some guidelines based on the research and study in this thesis may be applicable in other forms of transportation or even to other areas. Thus, these guidelines can help specific cities build convenient transportation systems, and furthermore enable local older adults to enjoy social activities and living in the city. Also, the outcomes may be referred to by other studies, in order to help improve the transportation or mobility in other regions.

Chapter 2: Literature Review

2.1 Overview

Previous background research highlighted the significance of the role of social engagement among older adults in urban areas. Due to physical ability decline in their bodies and their psychological needs, mobility becomes one of the most important factors to influence their social engagement. Further redesign considerations are needed to improve the satisfaction in mobility within urban areas, especially focusing on public transportation. In the literature review, the causal effects of these variables toward older adults' satisfaction in living in urban areas will be clarified and the mediating variable of social engagement among the relationships will be further studied. Finally, some hypotheses will be proposed based on the findings from literature review.

2.2 Population Aging and Social Planning

Population aging is a phenomenon all over the world, and it gradually puts much pressure on our society. Chand and Tung (2014) supported this opinion by arguing that, with the process of population aging, a large proportion of its gross domestic product (GDP) has to be spent to deal with the age structure change. To clarify further, a great portion of a country's budget should be spent in the form of pensions and medical care for older adults, which is at the cost of

potential investments in other areas, such as education and infrastructure. Thus, the society and local government should have plans to deal with such problems (O'Brien, 2014). The data and guides from WHO (2007) suggested that ensuring enabling and supportive environments is a key global priority in planning for population aging. Based on an Australian case, O'Brien (2014) explained further that providing an adequate standard, age-friendly infrastructure is the greatest challenge from population aging. In conclusion, in order to deal with population aging, society as a whole and local government should come up with feasible plans to set up standards and support age-friendly infrastructure.

Hypothesis 1: Age-friendly infrastructure helps improve the living quality of older adults and relieves the social pressure from population aging.

2.3 Older Adults in Urban Areas

The proportion of people over 65 years of age is higher in rural areas than in urban areas in the US, because of the traditional view that urban areas are crowded and noisy (Baernholdt, 2012). However, there is a trend of millions of older adults moving back to urban areas, as urban areas could provide various public services, infrastructures and social activities, such as medical care, public transportation, community activities etc. (Kochera, Straight & Guterbock, 2005; Yoder, 2013).

In addition to the external factors above, there are several internal factors that also strongly influence living quality of older adults. First, daily activities require muscle strength and

power. However, both may decline in function due to age-related changes in the neuromuscular system among older adults (Skelton et al., 1994). That means, even though some activities such as holding, lifting and climbing upstairs, are normal and easy to young generations, they become difficult for many older adults. Second, Pichora-Fuller (2015) argued that "over the adult life span, there are gradual and age-related losses in cognitive processing" (p. 108), such as the basic cognition declines in seeing, hearing. Also, Rowe and Kahn (1997) suggested that cognition declines in learning and short-term memory among older adults should also be paid more attention to. Thus, declines in cognition among older adults also make them feel difficulty in participating in normal daily activities. Third, with the physical ability changes, some of the body function declines may become diseases. According to Alzheimer's and Aging Research Center (2011), older adults may suffer from diseases like cardiovascular disease, Alzheimer, diabetes, obesity etc. Kalache and Kickbusch (1997) explained the age-related physical function capacity decline via Figure 1, and demonstrates that even through there is only a small difference in body

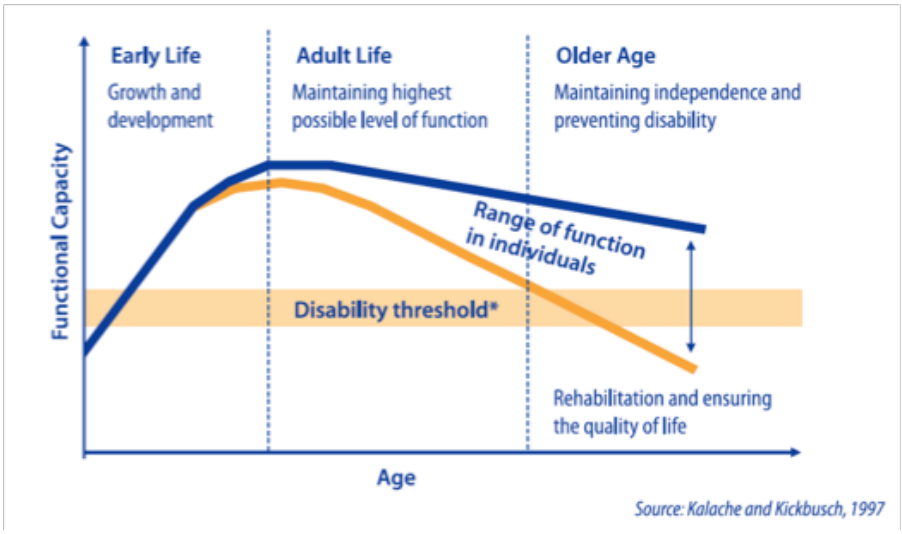

Figure 1: Functional Capacity over the Life Course (Kalache & Kickbusch, 1997)

functions among people in early life and adult life, due to series of complicated factors, the differences of body functions declines vary significantly. This is called range of function in individuals. It can be seen that the function abilities of some people even drop below the disability threshold, which means a considerable number of older adults may suffer from disabilities. Thus, it is important to maintain good health conditions and prevent diseases and disabilities in older age to ensure active aging.

So again, what are the "series of complicated factors" concerning the function capacity decline among older adults? Rowe and Kahn (1997) introduced the "Successful Aging" theory, and the conceptual model is shown in Figure 2. They stated that: "We define successful aging as including three main components: low probability of disease and disease-related disability, high cognitive and physical functional capacity, and active engagement with life" (p. 433). One factor is not enough to build a successful aging, but all three components make the contribution

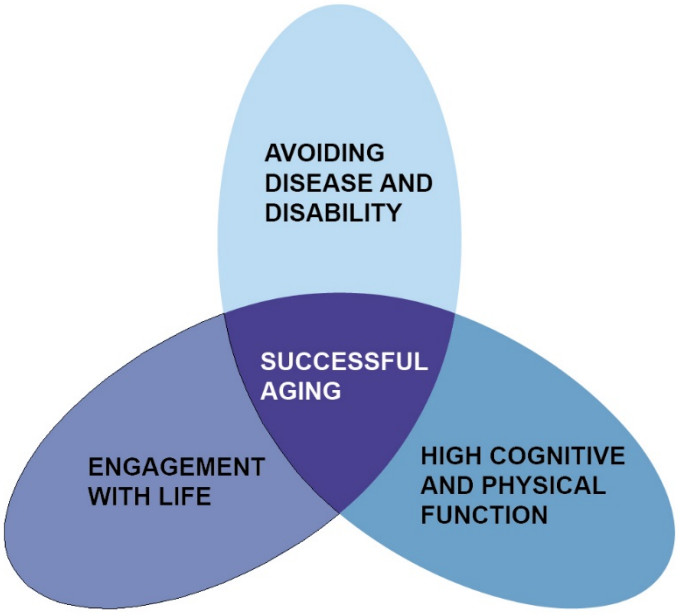

Figure 2: Successful Aging Theory (Rowe & Kahn, 1997)

together. This theory generally defines the factors that influence older adults' lives from a big picture, which gives us a holistic idea to deal with aging issues. However, in the thesis, further studies are needed to find specific factors that influence older adults in urban areas.

Therefore, physical ability declines, cognition recessions and age-related diseases are three factors that influence the living satisfaction and quality of older adults in urban areas. By conversely thinking of this conclusion and rephrasing it in a positive way, it could be concluded that:

Hypothesis 2: Low probability of age-related disease, high cognitive and physical functional capacity enable the living satisfaction and quality of older adults in urban areas.

2.4 Needs of Older adults in Urban Areas

In the previous section, the conclusion has been made that keeping good health helps older adults live better urban lives. However, further studies are needed to understand how older adults could keep their health, and what their actual needs are.

Kumari (2015) stated that, due to the global changes in social, economic and demographic factors, the relationship between older adults and our society has been undermined, and isolation keeps them from communicating with our society and loneliness negatively influence the quality of their lives. Furthermore, Queen et al. (2014) argued that loneliness is a kind of psychological feeling, under long term effects of which, older adults may suffer from health problems. It is true that preventing and alleviating social isolation and loneliness among

older people is an important issue all around the world (Cattan et al., 2005). Thus, loneliness among older adults is a big issue; it leads to negative influences of older adults' living quality and may even deteriorate their health conditions. Beyond the basic needs of medical care, public services, etc. from our society, it is clear that loneliness is a key to the quality of lives in urban areas, and preventing loneliness, or encouraging social engagement, is one of the most important needs among older adults.

Social participation is defined as "the involvement of the person in activities that provide interactions with others in the community, and is a key element of successful and healthy aging" (Levasseur et al., 2015). Social engagement could also be predicted to be a positive influence on living satisfaction among older adults. The satisfaction was categorized into two aspects: physical benefits and psychological needs. First, the study from Barnes et al. (2004) found that social engagement and support benefit cognition functions of older adults. A later study by Krueger et al. (2009) also confirmed that older adults who regularly join in social activities suffer less from cognition decline, because physical exercises enhance the bodies of older adults and keep them healthy. It could be inferred that older adults could get the physical benefit of delaying cognition decline when they enjoy social engagement regularly, and the physical benefits lead them to feel ease and satisfaction in living in urban environments. Second, Cacioppo, Hawkley and Thisted (2010) indicated that loneliness has been confirmed to be related to depression symptoms and may further lead to health problems, and this is especially true for older adults. Social engagement shows an important role to relieve loneliness among older adults (Shankar et

al., 2011).

Also, as mentioned before, the “Successful Aging” theory, or engagement with life, our communities, and society, is one of the most important factors to influence the living quality of older adults in urban areas. Based on the statements above, it could be concluded that:

Hypothesis 3: Physical and psychological needs of older adults influence their health conditions.

Hypothesis 4: Social engagement meets the physical and psychological needs of older adults.

2.5 Mobility

As assumed in the former section, social engagement meets the physical and psychological needs of older adults, but how could older adults to be connected to diverse social activities? Older adults should move from their dwellings to social activity locations. In other words, they could get to social activities via multiple mobility formats.

Mobility is a basic ability of individuals to meet the challenges of everyday life, such as walking for leisure, completing daily tasks, engaging in activities associated with work and socializing, and using various forms of transportation (Satariano et al., 2012). Anderson et al. (2014) hold the opinions that mobility plays a vital role in supporting a successful aging society, and public health could benefit from a unified form of all kinds of mobility among older adults in dwelling communities and urban areas. It is crucial to maintain mobility for active aging,

because it allows older adults to sustain dynamic and independent urban lives (World Health Organization, 2007). However, mobility limitations often result in a chain effect of deterioration in the consequences of the health and well-being of older adults (Prohaska et al., 2011; Ragland, Satariano, & MacLeod, 2005; Satariano et al., 2012). The statements above clarify an important cause and effect relationship that the ease of mobility and transportation methods has a positive influence on older adults' health conditions. To be more specific, on one hand, mobility and transportation physically offer older adults more opportunities to access to social activities, exercise their bodies and keep them health; on the other hand, mobility and transportation psychologically enable older adults to get rid of loneliness through social engagements, keeping them in good moods and healthy psychological conditions. Social engagement is a mediator variable in this relationship. Thus, it could concluded that:

Hypothesis 5: Mobility positively influences the physical and psychological needs of urban older adults, and keeps them in good health condition.

2.6 Public Transportation

People usually have multiple ways to commute in urban areas, such as walking, driving, public transportation, taxi, private transportation through others, etc. They could use one or some of the combinations of these methods to get to their destinations. According to the study and survey from Dahan-Oliel et al. (2010), for community and urban dwelling older adults, driving, walking and public transportation are the top three commute methods usually selected.

Driving is the most convenient way to commute to the destination directly, and this is especially true for some western developed countries, such as the US and Canada (Hendrickson & Mann, 2005). However, nowadays in urban areas, driving is becoming more and more difficult. Traffic congestion during rush hours makes people wait for long times, people feel inconvenient in such conditions, and even the local governments have to take actions to limit private driving and encourage public transportation (U.S. Department of Transportation, 2015).

Walking is a good way to get to the destinations, and this especially benefits older adults, because despite the traffic, older adults could walk to everywhere by themselves; also walking is considered as a way for fitness, which benefits their health by slowing down physical function decline and reducing the chances of disease and disabilities (World Health Organization, 2002). However, walking is limited in that even healthy older adults can only walk within a short range of distance, which means they have to use other ways of transportation to get to remoter destinations, and such methods should be located within older adults' convenient walk range (Wardman et al., 2014). Thus, walking is a good mobility choice but has to cooperate with other travel methods, like public transportation (bus, metro etc.) to enable older adults to engage in social activities.

Public transportation plays such an important role in the mobility of older adults in urban areas. First, public transportation could reach almost everywhere in the urban areas, so older adults could join in social activities wherever they want, as Trompet et al. (2013) mentioned, through "Availability" in the criteria for accessing public transportation. Also, certain kinds of

public transportation, like a metro system, enables older adults to avoid heavy traffic on roads, which makes mobility safer as well as saving time (i.e. Criteria “Security” and “Time”, Trompet et al., 2013). Second, the emission of greenhouse gases results in serious global environment issues, and transportation tools are one of the most important contributors as they consume large amount of fossil fuels (Sookun, Boojhawon and Rughooputh, 2014). In order to build a sustainable and environmentally-friendly urban areas, many urban governments financially support and encourage people to use public transportation instead of private cars to optimize and control the emission of carbon dioxide (Kyte, 2011). Moreover, clean energy like electric power is widely used in public transportation such as metro system, and also hybrid energy in buses helps improve urban environments (Millo, Rolando, Fuso and Zhao, 2015). Third, epidemiological and toxicological studies worldwide have suggested that exposure to traffic-related air pollution strongly influences various respiratory and cardiovascular diseases (Hoek et al., 2013; Raaschou et al., 2012). With the promotion of public transportation in urban areas, less pollution will be generated, which benefits the health of older adults as well as other urban residents.

Thus, several opinions support that public transportation is a better mobility method for older adults in urban areas, and it can be concluded that:

Hypothesis 6: Public transportation positively influences involvement in social engagements among older adults in urban areas.

According to H4, H5 and H6, it can be deduced that social engagement plays the role as a mediator to link the influence between public transportation and older adults' needs. Thus, Hypothesis 7 is proposed:

Hypothesis 7: Social engagement positively mediates the relationship between mobility and needs of older adults in urban areas.

2.7 Theoretical Framework

In the literature review, several related studies and theories are studied, and seven hypotheses are concluded concerning the relationships among older adults' needs, social engagements, mobility and transportation, and older adults' living quality in urban areas. The theoretical framework is demonstrated in Figure 3.

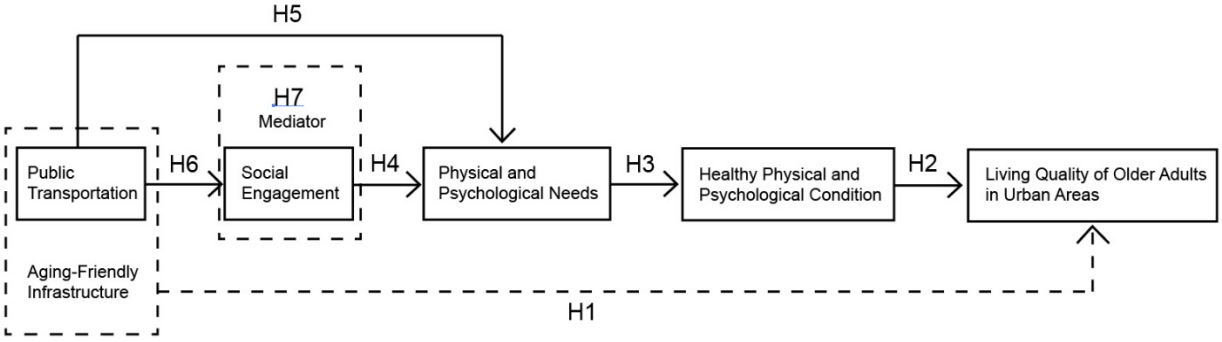

Figure 3: Theoretical Framework

The theoretical framework is deduced from the hypotheses concluded from the literature review, and arranged in a logical way to demonstrate their relationship. Public transportation systems, as an aging friendly infrastructure, benefit the living quality of older adults in urban areas indirectly through several factors. First, public transportation in urban areas enables older

adults to get to diverse social activities, which improves their social engagement; second, social engagement has been proven to meet the physical and psychological needs of older adults. To be more specific, social engagement exercises their physical abilities as well as helping them get rid of loneliness, third, improve their health conditions and finally, positively influence their living quality in urban areas.

2.8 Related Theories and Principles

Third place

Oldenburg (1999) proposed the concept of “third place”; the author conceived a public space which could provide social engagements among older adults, instead of home and workplace. While the key word, social engagement, is a universal human need, it is of particular interest in the context of older adults as they lived in urban areas where they have diverse ways to join in social activities. Older adults retire from their work and they spend most of their time at home. Objective realities, like retirement, physical body function decline or poorly-designed public space make it difficult for them to join social activities. Oldenburg (1999) gave an idea that a new public space could be created or an existing public space could be redesigned as a “third place”, to help older adults improve social activities. Public transportation is such a major public space other than home and work place that older adults could enjoy social contacts, like communication, there. Thus, in this study, public transportation would be considered as a third place to help especially older adults to get in touch with our society.

Universal design (UD)

As discussed before, older adults suffer from decline in body physical functions. Nelson and Stolterman (2003) argued that consumers tend to ignore products or services which are of inaccessibility, bad usability, or no satisfaction in the interaction with them, and such number of people is increasing. When referring to older adults, when they think the public transportation system is not convenient, or even difficult to use, they would rather walk or stay at home. Current transportation interior and facility design may not assist and help older adults feel ease in such public environment, because they may need special equipment in a public transportation environment.

Concerning the special needs from older adults, the question becomes that, is it possible to design public transportation especially for older adults? Before answering the question, a term should be introduced, called “Transgenerational Design”. Transgenerational design is a kind of universal design, and it is defined as the practice of design products or environment that meet the needs of aging population, meanwhile rejecting the discriminatory and stigmatizing, specialized products or devices targeted directly at older, because transgenerational design could also be applied to other age groups of people (Newbill, 2007; Pirkl, 1994, p. 228). From the definition, it is understandable that older adults do not want to be treated differently, even though they are aging and feel it difficult to join in some social activities, but they are willing to be respected and accepted as a part of our society. They prefer to stay with different age groups of people. Also,

Essex (2002) argued that intergenerational interaction is beneficial to both elder parents and children, and aids in developing strong affective ties with different generations. It can be inferred from this point that it is also beneficial when older adults could have interaction, communication, and activities with different age groups of people, because such intergenerational interaction will promote strong social relationships between older adults and our society. In such circumstance, universal design is necessary to consider in public transportation environment. As Luscombe (2003) said, “we are trying to make sure no one group is excessively penalized by design” (p. 1). Universal design is a better option in designing public spaces for older adults; examples include such as wider folding seats that could enable people with obesity to sit comfortably.

Again, from the perspective of investors and city planners, such as the governments, they usually consider it costly when applying universal design, because it takes much time and money to implement such project in public infrastructure, including public transportation. However, Björk (2009) holds a different view and states that “many become losers when the Universal Design perspective is neglected” (p. 1). He considered the return of investment (ROI) will offset the cost in design and manufacture, creating profit and benefiting more people in the foreseeable future. In agreement with this idea, universal design concepts will be applied in this study and design considerations to help make older adults feel more convenient in public transportation.

The Center for Universal Design at North Carolina State University (NCSU) has developed seven principles aimed at helping designers to evaluate existing designs, giving suggestions for the design process, and imbuing designers to use universal design to benefit more

demographic groups, especially older adults (Story, Mueller & Mace, 2001). The seven principles are:

- Principle 1: Equitable Use
- Principle 2: Flexibility in Use
- Principle 3: Simple and Intuitive Use
- Principle 4: Perceptible Information
- Principle 5: Tolerance for Error
- Principle 6: Low Physical Effort
- Principle 7: Size and Space for Approach

In the guideline development chapter, the seven principles will be discussed and analyzed to help us understand the benefit of universal design, and further help develop the guidelines for public transportation facilities.

Evidence-Based Design

Evidence-Based Design (EBD) is defined as the process of basing decisions about the built environment on credible research to achieve the best possible outcomes (The Center for Health Design, CHD, 2016). EBD is a concept that originally comes from the healthcare field, aimed at designing and building spaces for healthcare to help improve work efficiency, safety and convenience among staff and patients, and reducing healthcare related errors, etc. EBD is widely used in healthcare layout design, facilities arrangement, illumination, etc. It gives us

strong evidence from credible research and can help environment planners to decide the layout of facility designs. Here is a very typical EBD design example to show how EBD helps make design decisions and benefits patients and caregivers.

The same-handed rooms are patient rooms that use the same identical configuration; thus the navigation of such room will be instinctive for staff (Stichler & McCullough, 2012). Compared to mirror image rooms, which are rooms that use the mirrored configuration, the same handed rooms require a higher budget because they require separated system facilities. However, many studies indicate that the same handed room improves the performance of staff. Reiling (2006) argued that the same handed room makes the standardized configuration with the headwall always the same direction, will help caregivers reduce the time consumption when orientating and locating themselves in such rooms, and improve their work efficiency as well as reducing errors. Also, a study from Stichler and McCullough (2012) reported that same handed rooms make caregivers feel less stressed, and they finish their work in a shorter time.

It is possible that the healthcare related design concept and methods could be applied into public transportation, and help the layout and facility design to cater to the needs for older adults. There are two important principles from EBD that could be applied.

First, standardized configuration. Standardized configuration enables the transportation interior design use the same or similar layout and facility design, to help passengers navigate themselves in public transportation environment, intuitively enabling them to use facilities in the public transportation system, letting passengers feel at ease and convenient in such environment.

Second, sustainability. Sustainability is the philosophy to collaborate the physical space design with the principles of economic, social and ecological sustainability (Harris, et al., 2008). While it is an important application of the evidence-based design, sustainability considers the benefit of EBD from a long-term perspective, even though it is costly at the beginning of the construction and implementation phases. Such principle will also be discussed in the next chapter.

Preventive Healthcare

The preventive healthcare "encompasses both the care of individual patients, and public health practice, and as is evident in the name, focuses on the prevention of disease rather than treatment, per se" (Katz & Ali, 2009, p. 3). They also mentioned that health promotion is one of preventive healthcare methods, which helps prevent several diseases and enhances a positive feeling of health, by providing nonmedical interventions, such as changes in lifestyle and environment. Health promotion requires society, local government, and public institutes to improve social structure, public facilities etc. to enable more people to join in them. This is especially true for older adults, because several kinds of aging-related diseases and physical decline appear among older adults, so they are seeking ways to prevent such diseases or delay the body functions decline.

Sin et al. (2015) pointed out that prevention in primary care is better than cure among older adults, and it requires the collaborative efforts of multiple health care disciplines to help

maintain health and functional independence among older adults. In other words, our society and public healthcare should help older adults to prevent certain aging related diseases and body function decline before they suffer from such conditions. As discussed before in the theoretical framework, the feature of social engagement provided by public transportation services to older adults meets their physical needs and enables them to take part in social activities. Social activities make them feel happy as well as helping them exercise, improving their body fitness and reducing the chance to suffer from certain age related diseases. Thus, social engagement provided via public transportation is an important essence of preventive healthcare that benefits the health among older adults.

One form of preventive healthcare, from psychological perspective, is called biophilia. People like nature and prefer natural items and features in an interior environment. Why? Heerwagen (2001) argued that it is necessary to understand the word “biophilia”, which connects nature to people and covers a range of benefits relating to physical, psychological well-beings and human development and social behavior. And what is biophilia? Biophilia is the theory that humans have an innate relationship with nature. Such connection has been passed along throughout human evolution (Wilson, 1986). Kellert (2005) concluded that there are three types of contact we have with nature: direct, indirect and symbolic. In public transportation’s interior environment, it seems difficult to set plants directly in the limited environment, but still indirect and symbolic ways could be used. In an indirect way, for example near the bus stops or stations, a flower nursery can be planted along the side of the bus stop, so people in the bus could see the

plants and feel the vitality of our nature indirectly through the windows. Even in a metro station underground, such small sized flower nurseries could be set there to break the monotonous environment. The symbolic way, also known as organic design, involves the use of shapes and forms that reflect natural elements (Kellert, 2005). It can be cooperated with vernacular design, which concerns local history, culture and background when designing spaces. Thus, in a symbolic way, some design could be used from natural elements, such as culture-related plants to decorate the public transportation systems, and let people feel ease and have good moods in such environment.

Another form of preventive healthcare, from physical perspective, is called ergonomics (or human factors). Stanton (1998) stated that due to physiological and psychological capacities and limitations, human factors and ergonomics consider the interaction and adjustment between products and people. Also, Bridger (2009) defined ergonomics as “the study of the interaction between people and machines and factors that affect the interaction” (p. 1). Initially, the term was used to describe interaction in work environment to help reduce the chance of long-term fatigue and job-related stress. An example is that an ergonomic office chair fits the back shape of human beings and could change the angle to adjust to certain people. This allows them to feel convenient as well as reducing job-related stress and improving work efficiency. In addition, ergonomics can also help avoid accidents, injuries, errors, user difficulty, low morale, etc. (Nussbaumer, 2014). Such concept could also be applied in public transportation facilities. For instance, older adults may often interact with chairs in public transportation. Thus, well-designed

chairs in buses could let them feel convenience, reduce the chance of injuries, accidents, and on a long-term basis, relieve the stress, which may cause some physical diseases among older adults.

In order to improve the interaction between human and product, concerning the safety, work efficiency, accessibility, reducing fatigue or work related disease, Americans with Disabilities Act (ADA), which was founded in 1990, set its first standards for accessible design in 1991, and revised the standards in 2010. Thus, it is the so called 2010 ADA Standards for Accessible Design. Also, in cooperation with Department of Transportation (DOT), in 2006, ADA and DOT revised the ADA standards especially for transportation facilities. This is called the Americans with Disabilities Act (ADA) Standards for Transportation Facilities (United States Access Board, May 2016). Such procedures set standards for preventive healthcare, so that it is easy for preventive healthcare to be implemented in related design areas. Also, ADA standards follow Universal Design (UD) principles: 1) equitable use, facilities in transportation systems should meet the requirements for as many people as possible, so that disabled people and older adults could enjoy public transportation services; 2) flexibility in use, because of limited spaces in public transportation, certain spaces could be used and switched in different purposes, like for wheelchair, people with obesity and so on; 3) size and space for approach, the size of the door and the space should be standardized, so that size and space could meet the requirements of accessibility, for example, people with wheelchair and other passengers could get into the door easily and conveniently.

2.9 Summary and Guidelines Concept Framework

Based on the logical inferences in the literature review, it could be concluded that the improvements in the public transportation meet both psychological and physical requirements of older adults, enabling them to engage in social activities and feel at ease in accessing to various public transportation services.

In the next phase, several theories and concepts were introduced to help build and develop our design guidelines for public transportation interior facilities. The theories and concepts are mainly summarized into four aspects: 1) Third place, 2) Universal design (UD), 3) Evidence-based design (EBD), and 4) Preventive healthcare. The guideline concept framework chart is shown in Table 1.

Third place theory focuses on how to build public transportation environment to be a place where older adults could engage in social contact, feeling at ease to enjoy public services without any restrictions. The guidelines for this part will come up with several suggestions to help improve social engagement among older adults.

	Theories / Concepts	Guidelines	Desired Outcomes
Public Transportation	Third Place	Social Engagement Accessibility	Provide a environment for interactions and accessibility
	Universal Design (UD)	7 Principles	Meet needs of older adults and other demographic groups
	Evidence-Based Design (EBD)	Standardization Sustainability	Improve safety, efficiency etc. For long term benefits
	Preventive Healthcare	Psychological Physical	Prevent loneliness Delay physical abilitiy decline

Table 1: Guideline Concept Framework

Universal design (UD) meets the needs of older adults as well as other demographic groups, assisting older adults to engage in public transportation services as other people do, despite any limitations. UD design considerations benefit older adults by enabling them to interact with our society and maintain their daily activities and mobility needs. Also, UD meets the needs of other groups of people, like disabled people or people with obesity, and could be adjusted to people with diverse anthropometries. The guidelines follow the seven principles from UD, and will be revised especially for public transportation.

Evidence-based design (EBD) helps improve the safety, operation efficiency, etc. in public transportation environments. In this environment, EBD will focus on forming standardization based on credible research, promoting sustainability so that design can provide long-term benefits.

Preventive healthcare provides guidelines to prevent psychological and physical health issues in public transportation environment. On one hand, in line with “Third Place” theory,

preventive healthcare improves social engagement to prevent loneliness and other mental health issues; on the other hand, following the ADA standards and ergonomics principles reduce stress and increase convenience accessibility during older adults' time in public transportation.

In the next chapter, some design cases will be studied to help develop detailed guidelines for each aspect. Guidelines will be examined and applied later to a specific public transportation occasion and environment to show how the guidelines will help improve daily activities and living quality of older adults in urban areas.

Chapter 3: Case Study and Guideline Development

3.1 Overview

In Chapter 2, following a logical deduction, it is concluded that enhanced facilities and services in public transportation help older adults engage in social activities, provide a method for them to keep healthy, and further improve their living quality and urban life. Then, a general guideline framework based on several theories and concepts was generated to form standard guidelines of public transportation, especially for older adults in urban areas. In this chapter, several cases will be studied to validate the theories and concepts from the literature review phase to give us better solutions than normal designs, help find pros and cons in current public transportation facilities and services, and inspire us to come up with feasible solutions for the increased mobility of older adults. The general guideline concept framework will be enriched with detailed items, and finally form the standard public transportation guidelines for older adults, which could be applied to similar transportation environments and even wider ranges of transportation situations and formats.

3.2 Case Study

3.2.1 Third place: Social Engagement

The term “third place” originated from Ray Oldenburg’s (1999) book *The Great Good*

Place. He illustrated some places that could be considered a Third Place, such as cafés, coffee shops, community centers, stores etc. In Chapter 2 of the book, Oldenburg summarized eight characteristics of Third Places (pp. 20 - 42):

1) On neutral ground: People are free to join or leave the place.
2) The third place is a leveler: People can enjoy the place, no matter what their social status are, whether they are rich or poor, etc.
3) Conversation is the main activity: People can engage in social activities freely and delightedly, and communication is the most important, but not the only, activity.
4) Accessibility and accommodation: Assistive facilities help older adults physically freely enjoy social activities.
5) The regulars: Friends come to the place regularly, and help set the mood and characteristics of the area.
6) A low profile: Third places are good places, but it does not mean the place should be well-decorated. Instead simplicity and affinity are the key words of the tone.
7) The mood is playful: Third places are places where joyfulness and relaxation are aimed for, so people will have no stress and tiredness here.
8) A home away from home: People feel belongingness, respect, and that they are just like the owner of the place.

Applying these characters to public transportation interior environment, the list will be checked step by step. Public transportation is a neutral place where people from different races,

social status, and different age groups could gather. People regularly take public transportation and they can talk with each other freely. However, in order to make public transportation environment a third place, some improvements should be implemented based on current situations. The improvements should be 1) how to improve communication in public transportation environment; 2) the accessibility should be considered to meet more groups of people; and 3) how to make the environment simple but playful.

Case 1: face-to-face seats

Usually in most public transportation, the seats are arranged to face the same direction. Simply because the passengers are strangers, it is embarrassing to sit face to face and have eye contact. Such seat arrangement limits the opportunity for some people who are willing to communicate with friends or others, especially if you have several friends taking the transportation at the same time. Some long-distance trains or dining carriages have face-to-face seats, usually with a small table, so people could enjoy talking and food, enjoy the time and feel how the time flies. For example, in the standard carriage of the Vienna to Prague train (EuroCity, Figure 4), there are two kinds

Figure 4: Face-to-Face Seats in EuroCity Train

of seat settings. One is the regular seats that face the same direction, and the other one is the face-to-face one with a small table between the seats. These two kinds of seats are evenly arranged in the carriage space. The consideration of arranging face-to-face seats is to improve the communication in the long trip so people would not feel bored. Train carriages have certain designed occupancies, while public transportation in urban areas are intended to carry as many passengers as possible, so the train's interior is different from urban public transportation. Even so, such face-to-face seats could be applied to public transportation interior space, because such a feature shares the concept of "third place", and offers opportunities for communication among passengers, especially for older adults.

However, a question arises from this arrangement. Because of such beneficial seat arrangement, should all the space be arranged with such face-to-face seats? The arrangement is questionable. Because the main purpose of public transportation in urban areas is to carry as many passengers as possible to their own destinations, such feature may occupy much space and reduce standing spaces for passengers; also, not all the passengers want to have face-to-face communication during their taking of the transportation, but they want privacy. Thus, the combination of both face-to-face and one direction seats should be arranged, but the number units of face-to-face seats in each bus or metro carriage should be limited according to the specific situation, typically 1 to 2 units. Such arrangement also follows the universal design principles and it will be discussed in the UD section later. Also, due to the arrangement of the face-to-face seats, the initial capacity of the metro car is reduced. In this circumstance, the metro

management agent could either add a car to a metro, or increase the frequency of the metro system in a day. Only design is considered as a designer, however; the design should also cooperate with other field of studies, like management, technology, etc. And sometimes in realty, a design cannot be realized due to limitations from other aspects. This concern will be discussed in the limitation and future study in Chapter 5.

Case 2: accessibility

With the population aging and the rising concerns about disability, more and more public transportation offers accessible environments, like wheelchair space and other assistive facilities that enable wheelchairs to enter the carriage, such as ramps and wheelchair lifts. The installations of accessible and handicapped equipment aim at expanding the public transportation service to a wider range of population. One of the most benefited demographic group is the older adult, because quite a percentage of older adults suffer from body function decline and even disabilities, so they need extra assistance. However, the space in urban public transportation is “valuable” (sustainability). The case studies for accessibility will follow the sequence of how older adults get into the public transportation space, especially with wheelchairs: 1) how to enter the public transportation space, 2) how to target the accessible facilities, and 3) how to use the accessible facilities.

The first example shows how wheelchairs enter a public transportation tool. It is not a big problem, for example, for a wheelchair to enter a metro carriage, but it is when entering a bus or a van, because the door of a bus or van is higher than the ground. Figure 5 (San Francisco Municipal Transportation Agency, SFMAT, 2012) shows two kinds of Muni buses in San Francisco. It shows two ways for the wheelchair to enter the space. The first one is the ramp. The ramp could either manually be placed between the door and the ground, or could be a mechanical structure under the door of a bus. The second one is the wheelchair lift. Such a lift is used when the main door of the vehicle is not suitable for a wheelchair to enter, or the vehicle is relatively small. In this case, the lift is usually installed on the back door. In order to use the lift, a lift machine structure should be equipped, and such a structure may occupy some space. The wheelchair lift is usually used in private and small community transportation vehicles, while the lift is not the best solution for mass public transportation, because the lift takes time and space. However, it is good option to renovate and

Figure 5: Two Ways of Accessible Facilities for Wheelchair: Ramp (upper) and Lift (bottom)

equip old transportation tools which did not have accessible equipment before. Which methods to choose depends on the situation, and both accessible tools benefit older adults or other groups of people with wheelchairs.

The second example is the wheelchair space design. Figure 6 (Spsmiler, 2010) shows the interior of an S8 Stock train (London Underground) with folding seats and space for 'personal wheeled transports' such as wheelchairs and children in a pushchair. The wheelchair space is easy to target, as there is a handicap sign on the glass board; also for this carriage interior design, the wheelchair space occupies most of the right side space. Other metro carriages follow the same arrangement, so it is convenient to find and use the space. The next step is how to use the space. The folding seats give us an intuitive idea that such space is for multiple uses, at least two kinds. When there is no wheelchair, passengers could pull the seats down and use them as priority seats, because the folding seats are close to the door and ease the mobility especially of older adults. When someone with a wheelchair needs to use the space, passengers can push the seats up, or the seats could scroll up automatically. Then the wheelchair could be placed and fixed next to the board; then at last the companion could pull down and use the far side of the folding seat.

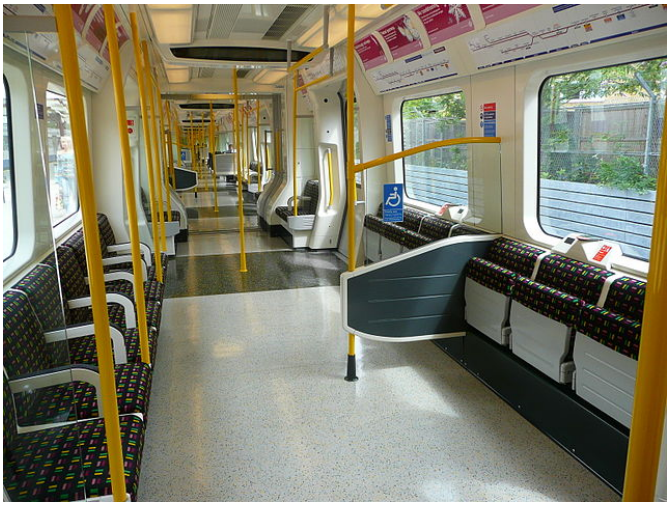

Figure 6: Interior of an S8 Stock Train, London Underground (Spsmiler, 2010)

ADA Standards for “Third Place”

The application of the concept of “third place” to public transportation should also consider ADA (2010) standards to be able to meet the requirements of people who need accessibility.

ADA 221 discusses assembly areas, which provides wheelchair spaces, companion seats, and designated aisle seats complying with 221 and 802 (ADA, 2006, p. 46). Also in Table 221.2.1.1 (p. 46), ADA provided the number of wheelchair spaces required in certain number of seats: 4 to 25 seats require 1 wheelchair space, 26 to 50 seats require 2 wheelchair space, 51 to 150 seats require 4 wheelchair space etc. Usually in urban public transportation, the seats in each car are less than 50, thus the wheelchair spaces are usually less than 2, but sometimes may range from 1 to 4 depending on the specific urban situations (e.g., relatively high percentage of older adults).

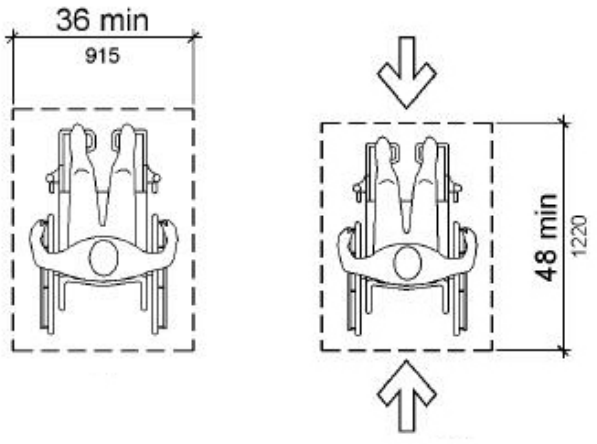

Figure 7: Wheelchair Space Minimum Dimension, ADA 802.1.2 & 802.1.3

ADA 802 (2010) set standards for the wheelchair spaces and companion seats. Figure 7 shows the minimum dimension requirement for wheelchair spaces. ADA 802.3 explained how the companion seats should be placed: “The shoulder alignment point of

the wheelchair space shall be measured 36 inches (915 mm) from the front of the wheelchair space. The floor surface of the companion seat shall be at the same elevation as the floor surface of the wheelchair space" (ADA, 2006, p. 177). Also, in Figure 6, the S8 stock of London Underground gives a good example of a companion seat. There are three foldable seats in wheelchair spaces. The wheelchair occupies a two-seat space, and the remaining foldable seat could be used as a companion seat.

Third Place – Conclusion and Guidelines

The core of the "Third Place" is to help older adults engage in social communication and activities in public transportation environments. There are two key aspects of the concept. One, from the psychological aspect, is the social engagement; the other one, from the physical aspect, is the accessibility. Social engagement benefits older adults and could improve their living quality. Thus, eye contact, a smile, or a warm talk with friends could let them feel happy about their environment and living quality. The opportunity offered by the public transportation, like face-to-face seats, enables them to engage in social communication, and lets them feel satisfied with public transportation services. Accessibility considers the physical body conditions of older adults; some of them need assistive or handicapped tools, and wheelchair is the most commonly seen tool. The ability to enable the setting of a wheelchair is one of the most important key factors to demonstrate the accessibility of the public transportation and show the quality of the services. Related urban public transportation facilities should be equipped and should also follow

the same standards. The design of accessibility should follow ADA standards to be able to work universally on other kind of public transportation tools.

3.2.2 Universal Design (UD)

The guidelines aim at improving the experience of older adults when they take any public transportation, but why should universal design be considered here? Older adults are not the only passengers in public transportation; there are other demographic groups of people as well. Even though older adults may have more special needs when taking public transportation, the universal needs cannot be compromised only to cater to the older adults. Thus, our idea is simple: meet the universal needs first, and then consider the special needs from older adults. In such circumstances, the facilities in public transportation could not only be used by young people, but also meet the needs of older adults. This is our goal of introducing UD here.

The Center for Universal Design in North Carolina State University has focused on UD for decades, and they proposed “The 7 Principles of Universal Design” as well as their guidelines (1997). Figure 8 shows the seven principles, and more detailed guidelines are listed in their official website. Each will be discussed to see how to apply them in public transportation.

Figure 8: The 7 Principles of Universal Design (The Center for Universal Design, NCSU, 1997)

Principle 1: Equitable Use

The design is useful and marketable to people with diverse abilities. The illustration given by CUD takes the power door as an example, the door is tall and wide enough that different people, with or without wheelchairs, could get in and out conveniently. Designers should not only consider the equity in physical use, but also think of psychological needs that no one wants to be treated differently, especially for older adults in a public transportation environment. The consideration of public transportation for older adults is in line with Principle 1; it reveals the phenomenon that public transportation is not really aging-friendly, so still has the space to improve to meet the needs of older adults. Thus, in order to make sure public transportation is of equitable use for different demographics, designers must consider the needs of older adults.

Guidelines

1.1 Make the facilities' design and arrangement appealing to all passengers, and provide the same ways of use without difficulty for all.

1.2 Show equal respect and understanding for all passengers.

Case 3 Equitable use: Overhead Comfortable Grip Height

The criteria of equable use for this specific case are set as: the overhead grip/handles should enable that most people are safe and feel comfortable; meanwhile enable females in 5th percentile height to reach the lower grip, so female around the 5th percentile of height can use

the grip for limited time and wait until the next available seat.

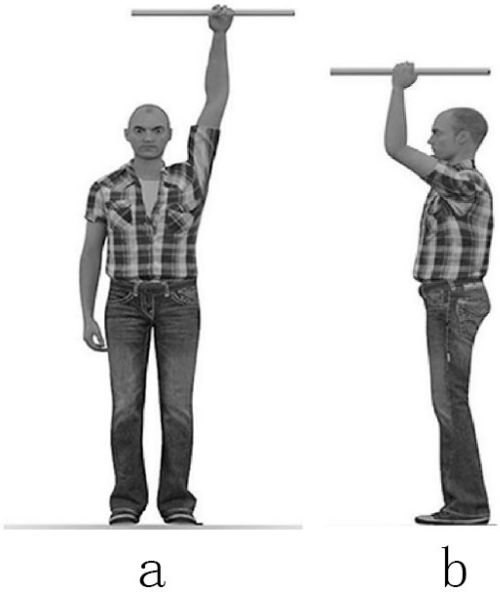

Figure 9: Overhead grip reach (a) and overhead comfortable grip height (b), Soares and Rebelo, 2016, Figure 25.2 and 25.3

First of all, there are two terms needing to be clarified: overhead grip reach and overhead comfortable grip height (see Figure 9). Soares and Rebelo (2016) pointed out that many of the anthropometric dimensions are related to some maximum distance. However, Soares and Rebelo (2016) indicated that maximum reach is not a comfortable gesture, especially in public transportation interior environment. Many standards, like ADA standards and CDC anthropometry data only provide extreme values (minimum or maximum values), but not comfortable ones when people interact with tools or facilities.

Soares and Rebelo (2016) launched quantitative research to study the overhead comfortable grip height. Based on the results, they concluded that overhead comfortable grip height has a strong relationship with body height, and they summarized the results using regression equations for both females and males. For females, the equation is $y = 0.962x + 16.7$ (y is overhead comfortable grip height, x is body height, measurement unit is centimeter). For males, the equation is $y = 0.784x + 47.52$.

Based on the anthropometric estimates for “elderly people” data from Pheasant (Body Space, Table 10.6, p. 183, 1996), and equations from Soares and Rebelo, (2016), Figure 10 demonstrates the grip heights of older adults of different genders, height percentiles and conditions.

According to Pheasant (Anthropometric estimates for ‘elderly people’, Table 10.6, p. 183, 1996) and equations from Soares and Rebelo, (2016), the overhead grip reach of 5th percentile older female is 1665 mm (1640 mm + 25 mm shoe height). The overhead comfortable grip height of 95th percentile older female is 1759 mm (0.962 x [163+2.5] + 16.7 = 175.9 cm). Again, the overhead comfortable grip height of 5th percentile older male is 1683 mm (0.784 x [151.5 + 2.5] + 47.52 = 168.3 cm), and the overhead grip reach of 5th percentile older male is 1795 mm (1770 mm + 25 mm shoe height). The overhead comfortable grip height of 95th percentile older male is 1879 mm (0.784 x [176.5 + 2.5] + 47.52 = 187.9 cm).

As shown in Figure 10, according to the set criteria, 5th percentile older female must reach the lower grip. Thus, the lower grip height should be the 5th percentile older female reach, which is 1665 mm. 5th percentile older male comfortable grip height is 1683 mm, which is close to 5th percentile older female reach height. Further, 95th percentile older female standing comfortable grip height is 1759 mm, which is close to 5th percentile older male standing grip reach. Thus, if the 95th percentile older female standing comfortable grip height is set as upper grip height, 95th percentile older male standing comfortable grip height as overhead pole height, and three different heights of grips could enable most of older adults to use them. Because lower

and upper grips cover the reach or comfortable grip heights from 5th percentile older female to 95th percentile older female in heights, upper grips and overhead poles cover the reach or comfortable grip heights from 5th percentile older male to 95th percentile older male in height. In addition, even 5th percentile older male in height could use lower grip height comfortably, because 5th percentile older male comfortable grip height is close to lower grip height.

In conclusion, lower grip height is the 5th percentile older female standing reach, upper grip height is 95th percentile older female standing comfortable grip height, and overhead pole height is the 95th percentile older male standing comfortable grip height. In this circumstance, most older adults could use these grips. However, in practice, the lower grip should be a little bit lower than data to ensure 5th female older adults in height could reach, and the values of these heights could be rounded and set in 5 mm increment. Thus, the lower grip height is 1660 mm, the upper grip height is 1760 mm, and overhead pole height is 1880 mm.

Normally, there are only two different heights of grips. One is the grips, the other is the overhead poles. In this situation, only upper grip height and overhead pole height are used. However, in order to enable public transportation to be older passenger friendly, three heights of grips are needed for some part of the public transportation, and the application of this criteria will be demonstrated in the following chapter.

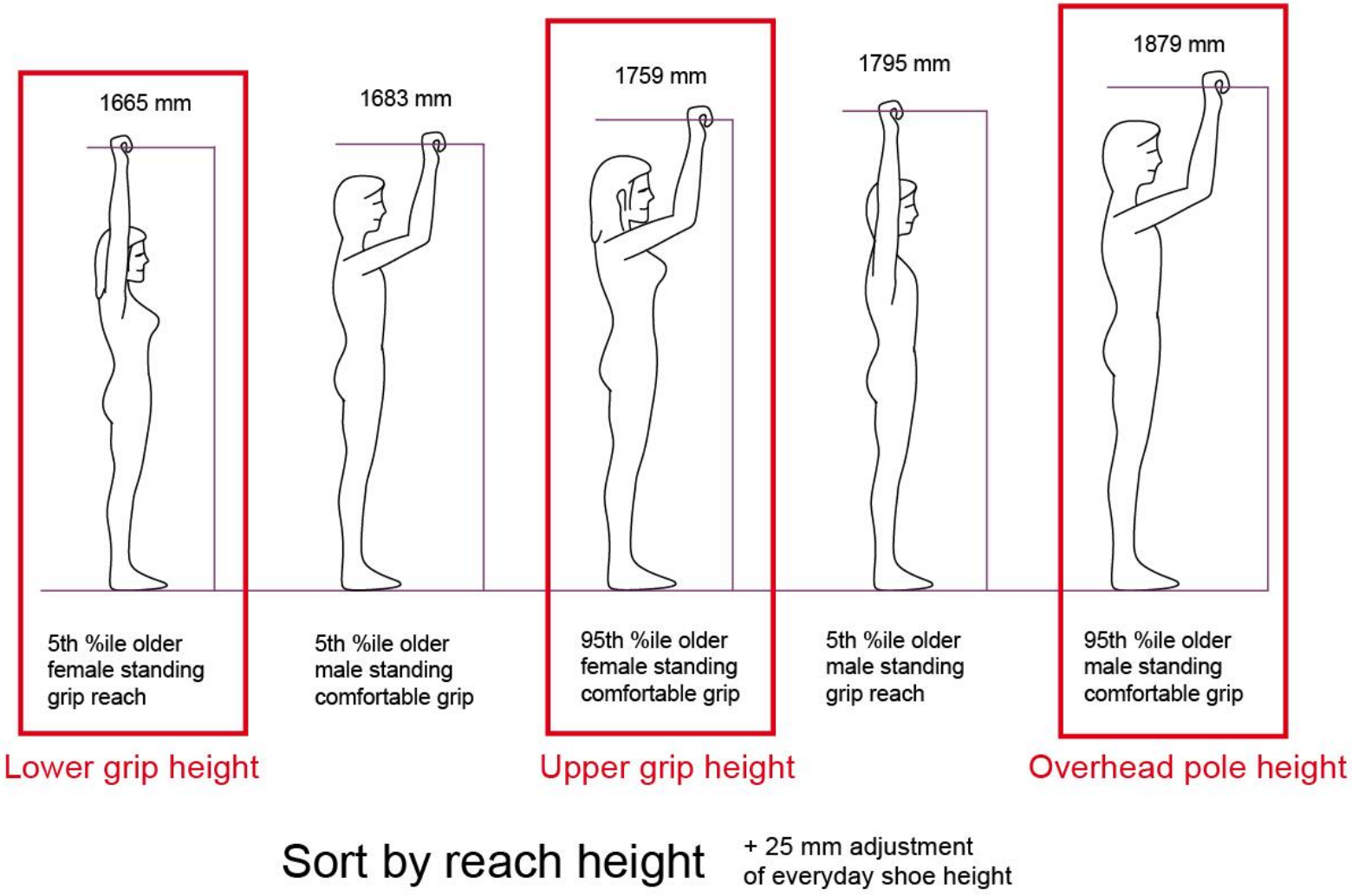

Figure 10: The Grip Heights of Older Adults in Different Genders, Height Percentiles and Conditions

There was little that research studied the overhead comfortable grip height, specifically focused on older adults. Thus, even though Soares and Rebelo's (2016) research was based on limited number of samples, it still could be considered a valuable reference, and it is also possible to apply their research outcome to enlighten future research, enriching this field of study.

Principle 2: Flexibility in Use

The design accommodates a wide range of individual preferences and abilities. CUD (1997) gave the example of "Scissors designed for right- or left-handed users." Such kind of scissors provide more options for people to use, which means people could use the tool, in the case of scissors, or facilities, in the case of public transportation, the way they feel is convenient or meets their physical and even psychological needs. A related concept in Evidence-Based Design is called "universal room," in which the space and facilities in the room are flexible in use so that it could meet different medical requirements. For example, it could change from an emergency room to an ICU room by changing the locations of the beds, facilities, and equipping with certain medical facilities which were already stored in the room for the purpose of flexible change. How to apply this principle to public transportation? Similar to the universal room concept, certain space in public transportation could be changed from seats to wheelchair space. This is simple because the passenger could just push the foldable seats up. Such design has been used in buses and metro systems in some urban areas, but improvements are needed to make the

space more flexible to more people with different body sizes, weights, or heights.

Guidelines

2.1 Provide multiple methods of use.

2.2 Cater to different conditions.

2.3 Adapt to passengers with different anthropometry.

Principle 3: Simple and Intuitive Use

Use of the design should be easy to understand, regardless of the user's experience, knowledge, language skills, or current concentration level. CUD gives an example of an instruction manual with drawings and no text. It is easier for people to understand instruction drawings, because texts need some time for people to interpret. Sometimes people may misunderstand and fail to use the facilities if the texts are not expressed clearly. Some simple and intuitive gestures and movements should be used, like pushing a button, pushing a door, or pulling a cable. A good example in public transportation is in many big cities, for example in Washington, D.C., where a bus stops usually upon a request. One simple way is to set buttons in the banisters. However, it is not convenient for passengers who are seated; thus, another simple way is to pull a request line mounted along the side of the bus. The request line is linked to a button. Once the line is pulled, the button is pulled to receive the request. Both the buttons in the banisters and the request line along the side of the bus could give you a voice says “stop requested.” The stop request is shown in the LED screen, to give feedback. But such a stop

request system should have simple, understandable and eye-catching instruction, to instruct people who are not familiar with it, like travelers from out of town.

Another example is foldable seats. Such foldable seats are widely used in big classrooms, theaters, and almost all people know how to push it down. The foldable seat design is simple and intuitive for many people; thus, the foldable seats are designed for wheelchair spaces. When there is no wheelchair, passengers could push down the foldable seat to sit; when there is a wheelchair, passenger could push the seat back to leave space for the wheelchair. It is simple enough that there is no need to have instructions here. (See Figure 6 Underground S stock)

Guidelines

3.1 Avoid complexity, keeping design simple and intuitive for most people.

3.2 Keep instructions and texts simple, clear and understandable.

3.3 Give feedback if possible when passenger does the motion correctly.

Principle 4: Perceptible Information

The design communicates necessary information effectively to the user, regardless of ambient conditions or the user's sensory abilities. CUD gives the example of redundant cueing in airports, train stations, and subway cars. Such an example indicates that the principle is very important in public transportation environment. Usually, there are two aspects of information that a passenger needs to know in public transportation. First one is how they can find their way to the right stops, stations or terminals, or wayfinding issues; second one is how they know they

have arrived at their destinations, or arrival notification. This study focuses on the facilities in the interior environment of public transportation; thus, the arrival notification aspect will be mainly focused on.

Usually in a bus, such as the Muni bus in San Francisco as an example, when approaching a station, a passenger will hear the voice inform of the name of the station. Also, a passenger can see the name of the stop in a small LED screen on the ceiling of the bus. Once confirming that the passenger wants to disembark at the next stop, a passenger can request a stop simply by pulling the stop request line along the windows or pushing the stop button in the nearby banisters, and the stop request will be shown in the screen and give the driver feedback to stop. Such ways of arrival notification and stop request can also be applied in many other urban areas in the US; however, there are some problems for the perception of the information.

First, the voice is clear for most passengers; however, it may not be clear enough for some older adults with hearing declines. Thus, the alternative way is the screen on the ceiling of the bus, but the only screen is located in the front of the bus. If the screen is small, older adults still may not see the name clearly (ADA font rules). Second, still taking the Muni bus in San Francisco for example, the stops are named after the two nearby crossing roads, like “Clay St & Montgomery St”, which means the stop is near the crossing of the Clay St and Montgomery St. It is easy to understand, and it is easy to locate by looking at a map, but this can still be difficult for people to remember. Because both the two streets are very long, it is hard to locate them if unfamiliar with the streets in the area. The fact is, people usually remember the landmarks

instead of the exact name of the streets. Again taking the “Clay St & Montgomery St” for example, when seeing the name of the stop, even if a native here, it may take a while to think of where it is. However, if the stop name is changed to “Transamerica Pyramid”, almost everyone knows the location. Because it is a landmark building in San Francisco, it is easy for passengers to remember the stop, especially older adults. Also, it is easier for travelers from outside the area to find the stop. Third, the “stop request” system improves the bus travelling efficiency, saving time and energy by passing a stop when there is no one get on or off the bus. Thus, the stop request system is very important to such operation mode. A simple and clear visible instruction is necessary to show passengers how to use the stop request system, especially for people who are not familiar with the bus operation mode, because it is easy for the passenger to pass their destination. In such circumstance, a simple instruction is needed, like illustration pictures or simple words.

Guidelines

4.1 Use multiple ways to deliver essential messages.

4.2 Simplify and improve the way of expressing information and instruction.

4.3 Follow ADA instructions to enable older adults and people with special needs to perceive the information easily.

Principle 5: Tolerance for Error

The design should minimize hazards and adverse consequences of accidental or

unintended actions. This means that everyone could make a mistake, but the facility's design should consider this and develop solutions to avoid negative and dangerous situations, as well as providing more chances for people to use the facilities correctly. The principle gives two examples: one is the "undo" feature in computer software, the other one is the double-cut car key. For the second, both sides of the key work in the keyhole whichever direction the key is inserted. Such a principle considers the safety of use of the tools and facilities. Sometimes during rush hour, there are many passengers in the metro stations. People are crowded in the metro carriage, so some people near the door may leave their backpacks or heels outside the door of the carriage. When the door is closing and touches whatever crossing the door, it will open again. The process repeats until the door is clear. This operation is also widely used in elevators. Such a feature allows passengers to make mistakes if they do not notice their backpacks or bodies are outside the door. Thus, when the door retreats, passengers will notice and move in a little bit. The design is a good example to keep passengers safe and give them more chances to take proper actions in public transportation environments.

Following this principle, public transportation has some poor designs that need to be improved. We may have the experience that the spring in the spindle of foldable seats is very rigid and strong, so it takes some effort to push the seats down. Also, when leaving the seat, the seat will automatically roll up quickly without any buffering, so it may cause a loud sound, or sometimes it may hit someone. Such a design is not user-friendly to older adults, because they may not have enough strength to push down the foldable seats. Also, they risk being hit and

injured when using the seats. Thus, in order to avoid the risks, the seats should also have buffering systems to lower the speed and strength of the seats. For example, when passengers push down the seat with a small effort, the seat can automatically and slowly roll down. Again, when passengers leave the seat, the seat can automatically and slowly roll up.

Guidelines

5.1 Provide features and elements to warn and prevent hazards and errors.

5.2 Provide fail-safe features.

Principle 6: Low Physical Effort

The design should be used efficiently and comfortably and with a minimum of fatigue. This principle concerns ergonomics, which is a kind of preventive care design and will be discussed in the following section. Briefly, ergonomics is concerned with the interactions between human and tools, trying to help people do the same things with less effort, and avoid fatigue and some chronic diseases like carpal tunnel. Lever or loop handles on doors and faucets are examples provided in the principle. Traditionally, the handles in the door are ball shaped, which people need to hold tightly to avoid losing their grip when rotating the ball handles. The new design uses a lever that is easy for people to use by simply pushing it down; a similar design is applied to faucets. Then how can the principles be applied to public transportation environment? One example is the ramp for the wheelchair. In many big cities in the US, the bus has a mechanical structure near the front door that could stretch out as a ramp for the wheelchair

to enter the bus. Such facility lowers physical effort so that people do not need to lift the wheelchair. Instead, people in wheelchairs could push it into the bus by themselves. Other examples, like the stop request lines along the bus, are easy for people to reach instead of finding the buttons in the banisters; also, the ergonomic seats in public transportation could let passengers feel comfortable, and avoid or delay some chronic diseases, especially for older adults. The ergonomic chair will be discussed in the next section.

Guideline 6

6.1 Lower effort and repetition.

6.2 Allow passengers to maintain a neutral body position and minimize sustained physical effort.

6.3 Use reasonable design by considering ergonomic principles and ADA standards.

Principle 7: Size and Space for Approach and Use

Appropriate size and space is provided for approach, reach, manipulation, and use regardless of user's body size, posture, or mobility. This principle mainly considers two kinds of spaces; the first one is the space for people to pass, and the other one is the space for people to operate facilities. In order to meets the space needs of more people, the space should be designed with consideration of some special or extreme conditions. For example, for “Wide gates at subway stations that accommodate all users”, in the picture (Figure 8), it could be seen that at the checking gates of a metro station, there is one especially for people with wheelchairs. The width

is larger than normal gates; this example shows the space for approach. Also, there is another example that shows the space for use. As mentioned in Principle 2: Flexibility in Use, the space for wheelchair in public transportation, considers the space for special use so that people with wheelchairs could use the space. Also, if there is no one using the wheelchair space, a foldable seat could be pulled down, and the seat could also be used for other needs, like for passengers with relatively big body sizes. The seat could be wider and afford more space. Some more details should also be considered when people pass or use the space in different situations, like when standing or seated. The facilities or operation interface should think of these interactions so people can use space conveniently.

Guidelines 7

7.1 Provide adequate spaces for passengers to pass and use.

7.2 Consider extreme conditions for space planning.

7.3 Consider the interaction between passengers and the facilities with different situations, like people standing, seated etc.

ADA Standards for Universal Design

In addition to Universal Design considerations, designers must take ADA standards into account. This section discusses ADA standards as they apply to each UD principle.

For Principle 1: Equitable Use, public transportation facilities should provide enough space for people to pass and use. For example, passengers should push the stop request button in

the banisters or pull the request line to request the bus to stop for disembarking. However, it can be difficult for people with wheelchair to do these. Thus, similar buttons should be designed in the wheelchair spaces, and also they should be easy for such passengers to reach. Thus, ADA 308 reach range is concerned with this issue. Figure 11 (ADA, 2006, pp. 83 - 84) shows the measurement requirement for people with a wheelchair to reach the side of the wall. These

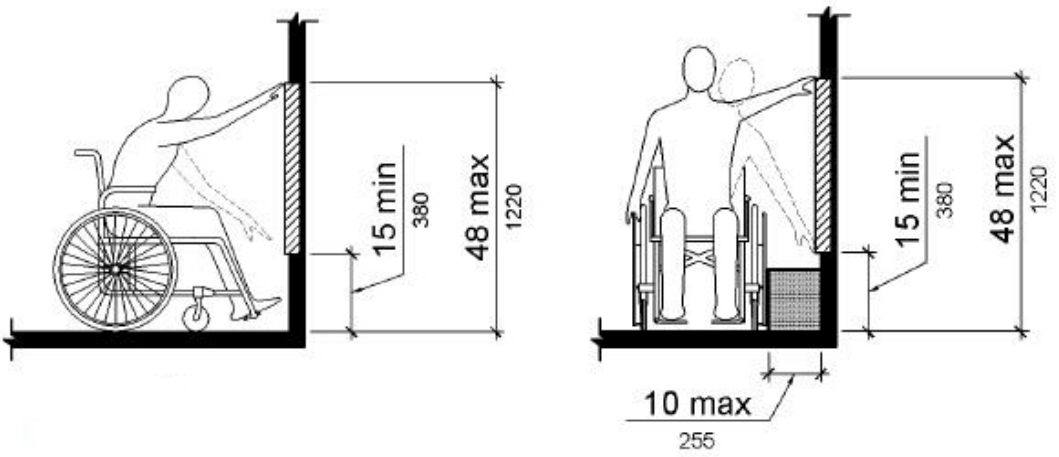

Figure 11: ADA 308, Forward and Side Reach with Wheelchair

standards help planners to design buttons and other tools in proper locations, in combination with the consideration of equitable use. Thus, even people with wheelchairs could request a stop without any help.

For Principle 4: Perceptible Information, the information on the wall or in the screen should be seen without any difficulty. ADA also has sign standards for the font size and graphics according to the distances of the passengers. According to ADA 703, a letter should have a height ranging from 5/8-2 inches, and above finished floor 48-60 inches (ADA, 2006, pp. 158-160). Also, Table 2 shows visual character height based on the viewing distance (ADA 703.5.5, 2010, p. 162).

Table 703.5.5 Visual Character Height

Height to Finish Floor or Ground From Baseline of Character	Horizontal Viewing Distance	Minimum Character Height
40 inches (1015 mm) to less than or equal to 70 inches (1780 mm)	less than 72 inches (1830 mm)	5/8 inch (16 mm)
	72 inches (1830 mm) and greater	5/8 inch (16 mm), plus 1/8 inch (3.2 mm) per foot (305 mm) of viewing distance above 72 inches (1830 mm)
Greater than 70 inches (1780 mm) to less than or equal to 120 inches (3050 mm)	less than 180 inches (4570 mm)	2 inches (51 mm)
	180 inches (4570 mm) and greater	2 inches (51 mm), plus 1/8 inch (3.2 mm) per foot (305 mm) of viewing distance above 180 inches (4570 mm)
greater than 120 inches (3050 mm)	less than 21 feet (6400 mm)	3 inches (75 mm)
	21 feet (6400 mm) and greater	3 inches (75 mm), plus 1/8 inch (3.2 mm) per foot (305 mm) of viewing distance above 21 feet (6400 mm)

Table 2: ADA 703.5.5, Visual Character Height

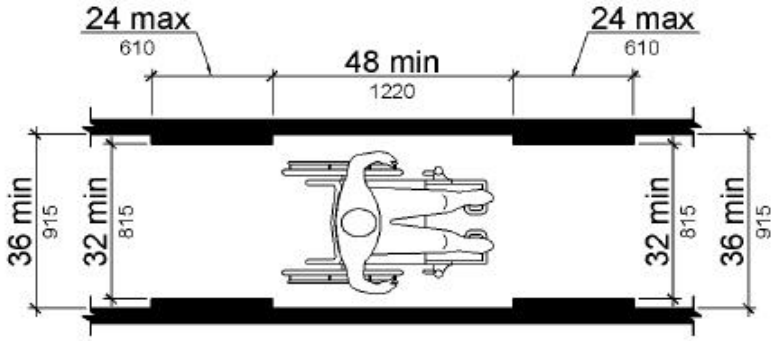

Figure 12: ADA 403.5.1, Clear Width of an Accessible Route

For Principle 7: Size and Space for Approach and Use, ADA 403.5 (Figure 12, ADA, 2006, p. 87), sets the standards for clear width of an accessible route. By following the design, all passengers, even with a wheelchair, could pass through the space easily.

ADA 404, Doors, Doorways, and Gates, sets the standards of doors for accessibility of public transportation. There are typically three kinds of door or gates, and Figure 13 (ADA 404.2.3, ADA, 2006, p. 88) shows the clean width of doorways. As certain doors have their own maneuvering clearances, designers should plan doorways of public transportation based on specific ADA doorway standards.

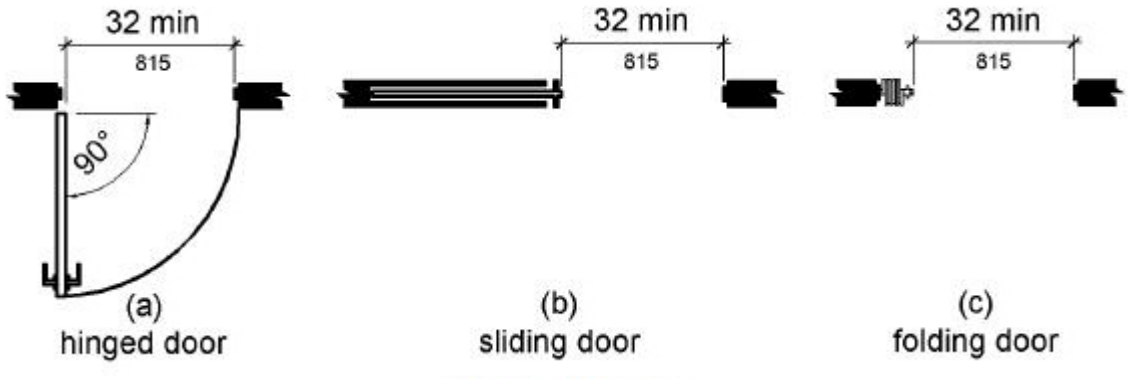

Figure 13: ADA 404.2.3, Clear Width of Doorways

3.2.3 Evidence-Based Design (EBD)

The term “Evidence-Based Design” was initially used in a healthcare environment, and was defined as the process of basing decisions about the built environment on credible research to achieve the best possible outcomes (The Center for Health Design, CHD, 2016). The goal of EBD is to enhance safety, improve work efficiency and reduce error and mistakes in a healthcare environment. It is possible to apply these ideas into public transportation systems. There are two important principles from EBD that should be included in the guidelines: 1) standardization and 2) sustainability. The two principles will be demonstrated and explained in case studies.

Case 4 standardization: Same-handed room

Same-handed room is a healthcare interior design issue that is well-researched. Even though the advantages of the same-handed room are debated, more and more studies show that such design could enhance safety, improve the work efficiency of staff, and reduce errors.

So what is a same-handed room? Stichler and McCulllough (2012) explained that “Same-handed rooms are private rooms that have an identical configuration so navigation of each room is instinctive for staff” (p. 125). Figure 14 (Stichler & McCulllough, 2012, p. 126) shows an example of same-handed rooms; the two patient rooms share the same layout design. Compared to mirrored patient room, same-handed rooms have some advantages. First, the patient rooms share the same layout design, so the location of equipment, medical supply, lightening switches are exactly the same. Therefore, caregivers could navigate the room, identify medical equipment and find certain medical supplies in the cabinet in a shorter time. Because the layouts are exactly the same, once the caregivers remember or are familiar with one patient room, they will be familiar with all the patient rooms, which saves much time for the training of the caregivers and staff, and improves their work efficiency when taking care of the patients. Second, such a layout design reduces medical errors. The staff are trained in the exact same patient room, so it is unlikely for them to put equipment or medical supply in a wrong place. Also, it is easy for them to find and locate items without errors. Third, same-handed room could reduce the noises penetrating from nearby rooms.

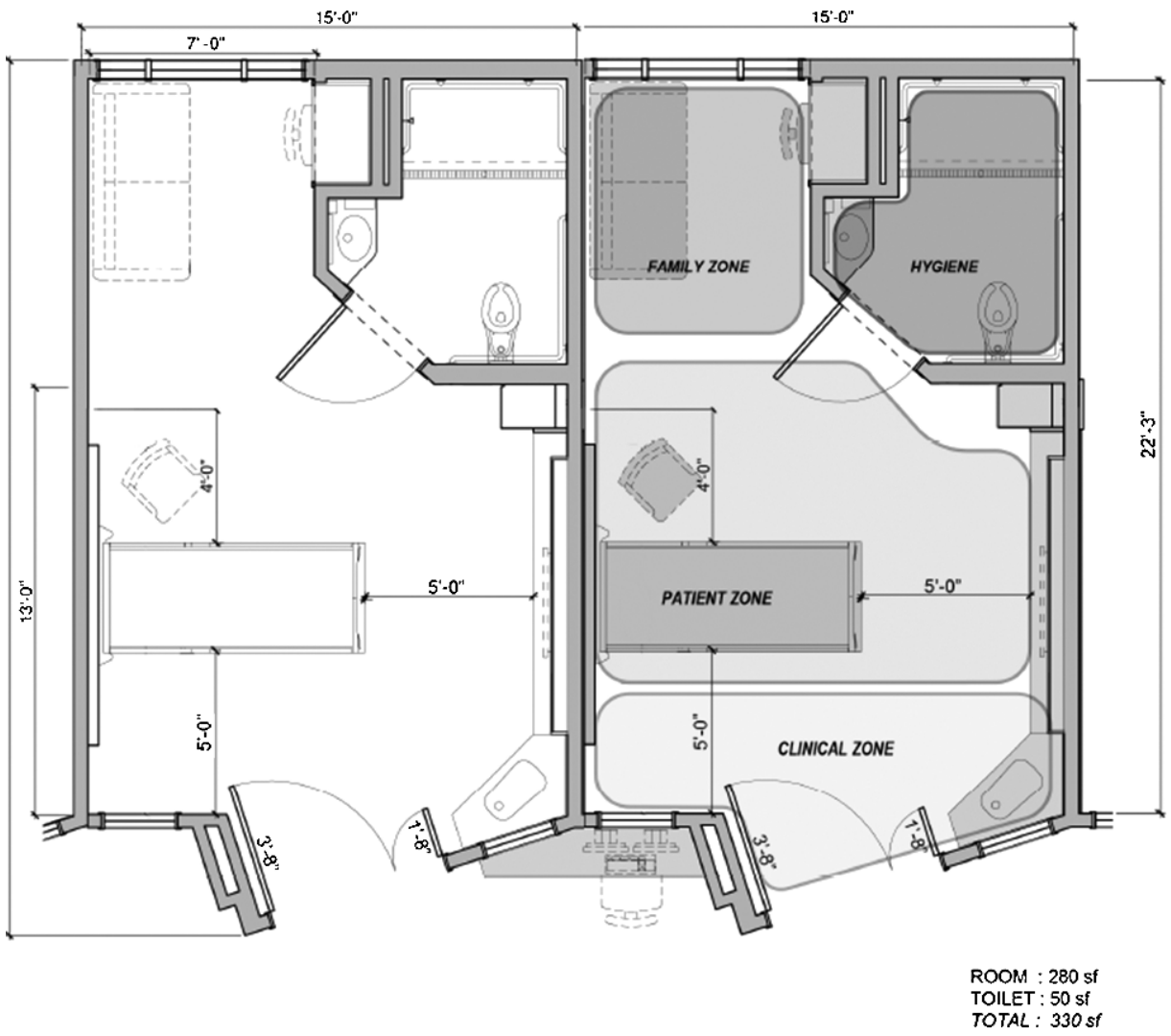

Figure 14: Same-Handed Room Design (Stichler & McCulllough, 2012, p. 126)

Same-handed rooms are an example of standardization. “Same-handed rooms feature an identical, repeated layout. This type of layout means the patient bed, technology, caregiver space, family space, washroom, and handwashing sink are in the same location in every patient room” (Atkinson, Hohenstein & McCu, 2011, p. 2). It is just like a standard car component that could be used in several car types, saving time and budget to design a specific one. Thus, how do designers apply the same-handed room design in public transportation interior arrangement? And

how do designers standardize public transportation?

Here is a feasible application for the wheelchair space in public transportation. For example, in all the metro cars, the wheelchair space was designed next to the right side of the door. In such circumstance, people with wheelchair will find the wheelchair space without any problem. When the door opens, the passenger simply goes inside and turn right, and the wheelchair space will be right there. Such arrangement not only benefits people with wheelchairs, but also improves the efficiency when people board the carriage and saves time. Other interior equipment could also be standardized and used in the same way. Once passengers become familiar with one type of public transportation, they will also be able to get used to similar equipment in other type of public transportation. This is especially true for older adults, many of whom suffer from memory decline. It is easier for them to remember how to use standard equipment or uniformly-designed spaces.

Standardization of urban public transportation space and equipment could enhance safety, improve operation efficiency, and benefit passengers.

Case 4 Sustainability: Universal Room

The universal room concept is initially from healthcare room design arrangement. The original term is “acuity adaptable room.” Brown and Gallant (2006) explained that “The Acuity Adaptable concept has evolved as a means of maintaining the patient in the same patient room or nursing unit from admission until discharge, regardless of the patient’s level of acuity. The

required level of care is brought to the patient instead of having the patient endure multiple transfers" (p. 327).

And further, Brown and Gallant (2006) compared universal room design with the acuity adaptable room, and stated that "The Universal Room began to evolve as the concept of a flexible patient room design that could accommodate a variety of patient types and an increasingly higher acuity mix of patients over its extended life" (p. 328).

By summarizing the statements above, such statement and conclusion could be briefly making that the acuity adaptable room was aimed at adjusting to patients with different acuity levels, and with the increasing needs of patient rooms for extended purposes, the universal room concept was generated to be more flexible to patients, as well as reducing the budget. In conclusion, there are two significant advantages of the universal room. First, it is flexible and could be used by patients with different acuity levels and in even more situations. This point is in line with Principle 2: flexibility in use from universal design (UD). Second, this room type is sustainable and budget-saving, because only a single room could meet the requirements of most patients. Therefore, healthcare centers or hospitals do not need to build different rooms for specific purposes, which saves space and budget.

How to apply this universal room concept in a public transportation environment? As discussed before in case 2 accessibility, there is a wheelchair space especially for people with wheelchairs, so how about when there is no wheelchair? How to get full use of space as public transportation in urban areas are usually busy and full of passengers? Following the universal

room concept, such wheelchair space could be transformed to a universal space. In public transportation interior, the universal space is defined as the small area that is equipped with folding seats and could be used as wheelchair space or seats. When there is no wheelchair, people could use the folding seats, just like in the London underground carriage (Figure 6), or standing space when in rush hours. However, this solution is still not enough to meet the criteria of flexibility, because the folding seats should also cater to people with different anthropometries. For example, if the seat should meet the requirement of people with obesity, the standard width may not fit for such group of people. Thus, the seat in a universal space should be wider and stronger to fit the heavier people. In addition, the height of the seat should be adjustable to cater to passengers with different height. Such universal space in public transportation could also be used by pregnant women, passengers with children, and older adults. The most important thing is, if such universal space follows the concept of sustainability, it could meet the needs of various passengers, while saving space and budget. Even though such design may cost a little bit more in the design and installment phases, it will pay back and benefit more people, especially for older adults in the long-term future.

Evidence-Based Design – Conclusion and Guidelines

Evidence-Based Design (EBD) is a term from the healthcare field, with some important concepts that could be used to improve the public transportation environment to meet the needs of older adults. There are two important concepts discussed, standardization and sustainability.

Standardization aims at forming uniform rules of the facility's design and arrangements, so that not only it is easy to manage and maintain the facilities for the public transportation operators, but also it is easy for passengers to locate and use certain facilities, because they have the same standards and utilize similar instructions. This design process improves safety and efficiency when taking the public transportation. Sustainability is in line with universal design rules that aim at meeting multiple needs within the same space. The idea maximizes and optimizes the use of limited space in public transportation, and enables people with special needs, including older adults, to access public transportation.

3.2.4 Preventive Healthcare

Preventive healthcare "encompasses both the care of individual patients, and public health practice, and as is evident in the name, focuses on the prevention of disease rather than treatment, per se" (Katz & Ali, 2009, p. 3). Diseases could come from two aspects, psychological, which could cause mental problems, like loneliness; and physical, which could cause fatigue, stress and even long term or chronic body diseases, like back injury and body function declines. In order to prevent certain age-related diseases and delay body function declines among older adults, and other groups of people, preventive healthcare measures should be implemented in public transportation services.

As disease is considered from two aspects, preventive healthcare should also consider those characteristics. First, interior design and facility arrangement should prevent older adults

from developing mental issues, such as loneliness, and the solution would be improving their social engagement among them. Such idea is also in line with the “third place” concept. Thus, in order to prevent psychologically related health issues among older adults, the designers should consider ways to improve social engagements, such as communication and eye-to-eye contact. The example would be the same as the “third place” example - the face-to-face seats.

Considering the psychologically related disease prevention, solutions can be also found from another aspect, - “biophilia”. As discussed in chapter 2, the word “biophilia” connects to nature and covers a range of benefits relating to physical and psychological well-beings, human development and social behavior. Being closing to nature relaxes people and keeps an active mood. Kellert (2005) concluded that there are three types of contact with nature: direct, indirect and symbolic. In a public transportation environment, it is not likely to plant grass land and trees there, but however this could be done in an indirect way, like arranging green land near bus or metro stations, and for the bus or metro carriage, big windows to enable people to see nature easily. Also a symbolic way, also known as organic design, involves the use of shapes and forms that reflect natural elements (Kellert, 2005). Some organic colors, like green or brown, or shapes, like flower or leaf symbol patterns, could be designed and used to decorate the interior of public transportation, to make passenger feel they are close to nature and happy.

Second, physically related health issues, can be prevented by introducing the term “ergonomics.” Bridger (2009) defined ergonomics as “the study of the interaction between people and machines and factors that affect the interaction” (p. 1). The term “ergonomics”

initially considered the improvement of work environment by trying to reduce work error, relieve stress and prevent chronic working-related diseases and disorders. The common ergonomics application is the ergonomic office chair.

Case 5 Ergonomics: Office Chair

Ergonomic office chairs are now widely used in the places where people work and maintain a sedentary posture for a long time, such as in an office. Traditionally, common chairs use a flat seat surface and straight back, but when people sit there for long, they will feel sour or hurt in the back; people will eventually suffer from chronic diseases and disorders which could have an influence on their daily lives. Also, a uniform seat, which cannot be adjusted, is not that user-friendly, because it cannot fit the people with different body sizes and heights.

Figure 15: Measurements from BIFMA Guidelines Used for Ergonomic Chairs. See Table 3 for values. (Allsteel Sum™ task chair pictured)

Thus, in such circumstance, designers pay more attention to designing an ergonomic office chair that reduces stress and improves convenience, and potentially prevents certain sedentary related body function disorders. Figure 15 (Allsteel, 2006, p. 24) shows an ergonomic

chair design based on BIFMA standards. BIFMA stands for Business + Institutional Furniture Manufacturers Association, and is “the not-for-profit trade association for business and institutional furniture manufacturers” (Business + Institutional Furniture Manufacturers Association, BIFMA, 2016). BIFMA does research on the safety, ergonomic, and sustainability of furniture as well as other products; tries to provide healthy, comfortable, and productive workspaces; and forms design standards by synthesizing research with engineering and materials considerations (BIFMA, 2016). There are two significant features of this kind of chair: 1) The ergonomic backrest design, which follows the shape of human spine;

		Specifications		
		Measurement	BIFMA Guideline	Allsteel Sum Chair
Seat Height	A	Popliteal height + Shoe allowance	15.0″ – 19.9″	15.0″ – 22.25″
Seat Depth	B	Buttock-popliteal length – Clearance allowance	No deeper than 16.9″ (fixed) 16.9″ included (adjustable)	15.0″ – 18.0″
Seat Width	C	Hip breadth, sitting + Clothing allowance	No less than 18″	18.0″
Backrest Height	D	None	At least 12.2″	24.0″
Backrest Width	E	Waist breadth	14.2″	16.0″
Backrest Lumbar	F	None	Most prominent point 5.9″ – 9.8″ from seat pan, in and out 1	Infinite through ht. of back (AutoFit™ technology)
Armrest Height	G	Elbow rest height	6.9″ – 10.8″ 7.9″ – 9.8″	7.0″ – 11.0″
Armrest Length	H	None	None	10.5″
Distance Between Armrests	I	Hip breadth, sitting + Clothing allowance	18″ (fixed) 18″ included (adjustable)	16.5″ – 19.0″

Table 3: Specific BIFMA Chair Design Guideline Measurements (See Figure 15 for visualization. All measurements are in inches).

and 2) the seat height adjustments. The ergonomic backrest design fits the shape of human spine, in order to minimize the stress on human's back, so people feel more relaxed when using such kind of design. The design should follow BIFMA ergonomic chair design standards: the backrest lumbar should range from 5.9 inches to 9.8 inches from seat pan to the most prominent point (see Table 3). Allsteel Inc. introduced AutoFit technology, which uses air displacement to find exactly where each back needs the most support, and then provides a customized fit (Allsteel, 2012, p. 6). According to Pheasant (1996), the optimal angle of the back will commonly be between 100° and 110°; and for most purposes, 5° to 10° of seat angle or 'tilt' is a suitable compromise. Also,

the height of the chair is adjustable, which means people with different heights can use this chair and adjust it to the most comfortable height. The advantages of using ergonomic chairs are reducing stress and catering to people with different body sizes.

However, why it is also important to use ergonomic design in urban public transportation, and how could it be made to fit people with special needs, especially older adults? As mentioned in Chapter 2, older adults suffer from physical function decline and it is easy for them to develop an injury and some chronic physical diseases. Normal chair and interior facilities in urban public transportation aim at saving budget by using less material and ergonomics were not considered in their construction. Young people may get used to the facilities without ergonomic considerations, but they do not meet the needs of older adults. An older adult who takes a bus every day, and uses the seat without ergonomic considerations, may feel stress and discomfort, and there would be an increasing risk for him/her to suffer from some chronic physical diseases. Thus, with the population aging and more and more older adults with needs of mobility, ergonomics are necessary to be considered in urban public transportation as a part of preventive healthcare. How to implement ergonomics considerations in a public transportation environment? Firstly, all the seats in public transportation should follow the ergonomics design and ADA standards, to reduce stress and improve convenience when passengers use public transportations, thereby increasing their willingness to take public transportation. Secondly, in order to be in line with UD, ergonomic seats should also consider special needs, like people with obesity, which is commonly seen in the US. The seat should not only have the ergonomic back design, but also the height

should be adjustable, and the width should be wider to fit the special needs of certain people. Such special ergonomic seats could be designed together with wheelchairs. Such space could either be used as a wheelchair space or a foldable and adjustable seat for people with special needs.

In this guideline, the features of the ergonomic chair and public transportation seats or benches could be combined; thus, the ergonomic chair also needs to consider both ADA and BIFMA standards. According to ADA 903 benches, Figure 16 shows the standards of bench back

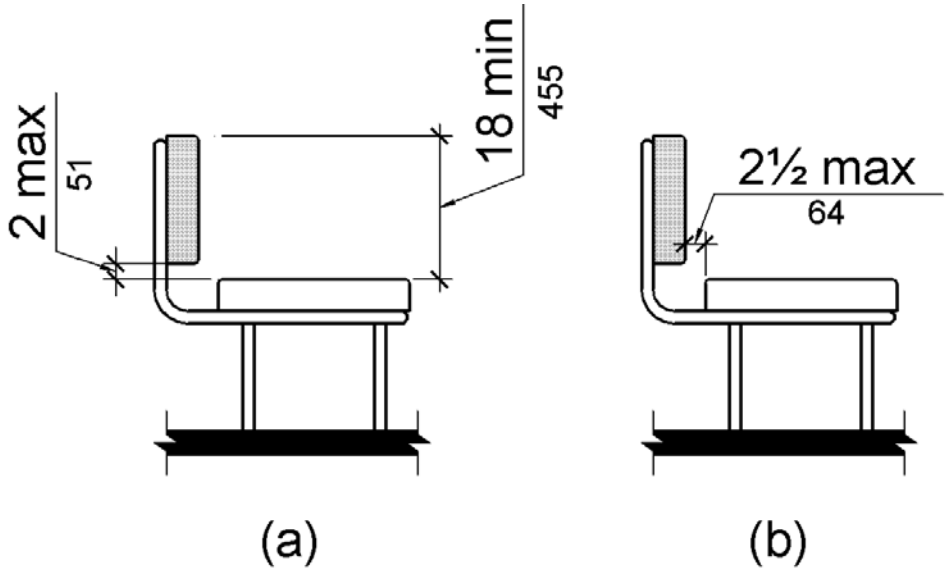

Figure 16: ADA 903, Bench Back Support

support.

The combined standards for seats and benches are explained below:

The foldable seat in universal space should follow BIFMA standards in that the backrest lumbar design should be in BIFMA standard range (the most prominent point 5.9 to 9.8 inches from seat pan, see Table 3-F). The adjustable seat height should be in BIFMA standard range (15

to 19.9 inches, see Table 3-A). The backrest height should be no less than 18 inches (same standards in both BIFMA and ADA 903, see Table 3-C and Figure 15). The optimal angle of the back will commonly be between 100° and 110°; and for most purposes, 5° to 10° of seat angle or 'tilt' is a suitable compromise. In addition, ADA has extra standards of the gap between seat pan and backrest (if applicable, see Figure 16).

Seats or benches (other than foldable seats) in public transportation are a fixed height of 15 inches. Other parts of the seats and benches design are the same standards as foldable seats.

Case 6 Biophilia

As mentioned before, people have a desire to get close to nature, and they will feel ease and relaxed when surrounded by nature or nature features. As discussed earlier, Kellert (2005) concluded that there are three types of contact we have with nature: direct, indirect and symbolic. When considering public transportation environments, it is less likely that any living plants could be planted or arranged in such environment. Thus, indirect and symbolic ways are more feasible to introduce biophilia into public transportation environment.

In Kopec's (2006) *Environmental Psychology for Design*, in the healthcare environment chapter, the author used a healing garden as an example, and stated that "the healing garden's design enables patients to walk through and among greenery. The layout also allows patients to have a view of the garden from their rooms, important for those who are unable to move through the garden itself" (p. 225). The case from healthcare environment inspires us in that even though

passengers in a public transportation tool cannot go through nature and greenery, the public transportation could provide some ways to help passengers feel like they are in nature.

First, the design should allow passengers to have a broad view of outside environment, which includes the green plants and gardens outside the transportation mode along the road of travel. Because big cities focus on creating green spaces now, including big windows on modern buses enables passengers to have a good view of the nature. Even in metro system underground, a flower nursery could be placed on the station platform, so passengers in the metro could see the plants when the carriage enters the stations. This indirect way of bringing nature into public transportation environments would allow passengers, including older adults, to feel relaxed when taking public transportation.

Second, as mentioned before, biophilia introduced a symbolic way, also known as organic design, that involves the use of shapes and forms that reflect natural elements (Kellert, 2005). Specifically, on a bus, it is easy to use indirect ways of biophilia so that passengers could see the outside nature environment through big windows; however, this is limited in metro situation because the carriages go through black tunnels most of the time. Thus in such circumstances, the symbolic way is another good option to improve biophilia in public transportation system. Any form of pictures, shapes, patterns, and materials that contain natural elements could be designed

for decoration in the metro carriages. For example, Figure 17 (Taro, 2013) is the interior of an Asahikawa Zoo Train from Hokkaido railway, Japan. The train carriage shows the animal elements, which is part of the nature, that could give passengers the feeling of vitality and nature. The kind of decoration in public transportation not only breaks boredom and tedium in the transportation environment, but also this kind of theme could be linked with the theme of the destination, like in the example, where the animal elements reflect the relationship with the theme of the destination – city zoo. Alternative to the specific figures of certain plants or animals, the symbolism could be more abstract, such as a pattern of flower shapes, sketch lines of trees, or the combination of nature colors etc.

Figure 17: Interior of an Asahikawa Zoo Train (Taro, 2013)

The biophilia concept in public transportation is the less expensive but more effective way to help improve the experience of public transportation in urban areas, especially benefiting older adults with the context of global population aging. Through this way, the public transportation could create an environment that enables older adults to feel relaxed and at ease when taking the transportation, relieving their stress, and building their confidence and willingness of taking public transportation. Local governments have several ways to generate

creative ideas of interior decoration of natural elements. For example, they could host a design competition that rewards excellent designs, which could generate plenty of creative ideas to implement biophilia in our public transportation. Thus, the biophilia concept is easy and less costly to be considered to improve the experience among urban citizens when they take urban public transportation.

Little research has focused on the way nature elements in the public transportation may play an important role to attract older adults as passengers, and limited formats of biophilia were used in studies; however, the idea will be enriched in the future to make more and more older adults enjoy the public transportation and the urban lives.

Preventive Healthcare - Conclusion and Guidelines

Preventive care, from the perceptive of public transportation, on one hand, from the physical aspect, ergonomics aims at preventing older adults and others from getting injured, delaying any chronic age-related diseases, and improving the interior facilities to meet the physical needs of older adults. On the other hand, from the psychological aspect, older adults may feel stressed and nervous about taking public transportation, because such environments are usually crowded and boring, and sometimes not aging-friendly. In order to change older adults' opinions so they may feel at ease to enjoy public transportation environment, the biophilia concept was introduced. Natural elements are related to the nature tendency of human beings to get close to nature, and are proven to benefit people, helping them feel relaxed and in a good

mood. Thus, either indirect or symbolic use of biophilia could be used to decorate the interior of public transportation, and enable passengers, including older adults, to feel they are close to nature while feeling public transportation is convenient and enjoyable.

3.2.5 Summary of Case Studies

This chapter aims at forming guidelines from several case studies, and these cases are based on the theories and design principles in the guideline concept framework. From case studies, it is better for designers to understand the meanings of the design theories and principles, how these theories and principles could be synthesized to form the guidelines, and what modifications should be made to enable the design theories and principles to be applied in public transportation interior environment.

3.3 Interrelationships of Guideline Theories

The design theory framework of public transportation for older adults in urban areas are summarized below. There are four aspects based on four theories and concepts. The detailed guidelines are discussed in several case studies and are summarized and revised to cater to public transportation environment. Some of the guidelines listed in certain aspect do not mean the guidelines only belong to this theory or concept; in fact, many guidelines could also be explained by other theories. Thus, the theories and guidelines are not independent, but they are interrelated with each other to benefit older adults and others in the public transportation environment. The

detailed guidelines will be created and synthesized later, based on the theory framework, ADA standards and priority of the items in the guidelines. Also, Figure 18 shows the guidelines and relationships among them.

One. Third Place

1.1 Improve social engagement and provide opportunities for older adults to engage in communication and social activities.

Format: face-to-face seats, big windows in public transportation.

1.2 Improve accessibility, enabling more people, especially older adults to access to public transportation without difficulty.

Format: universal space for multiple uses (wheelchair space, adjustable foldable seats), wheelchair lift, doorway extension.

Two. Universal Design (revised 7 principles for public transportation)

2.1 Equitable Use

2.1.1 Make the facilities design and arrangement appealing to all passengers, and provide the same ways of use for all without difficulty.

2.1.2 Show equal respect and understanding for all passengers.

Format: extended doorways for wheelchair, universal space meets the needs of different passengers.

2.2 Flexibility in Use

2.2.1 Provide multiple methods of use.

2.2.2 Cater to different conditions.

2.2.3 Adapt to passengers with different anthropometry.

Format: universal space for multiple uses (wheelchair space, foldable seats), adjustable foldable seats.

2.3 Simple and Intuitive Use

2.3.1 Avoid complexity, keep design simple and intuitive for most people.

2.3.2 Keep instructions and texts simple, clear and understandable.

2.3.3 Give feedback if possible when passengers are operating facilities correctly.

Format: push buttons, pull stop request lines in a bus, foldable seats

2.4 Perceptible Information

2.4.1 Use multiple ways to deliver essential messages.

2.4.2 Simplify and improve the way of expressing information and instruction.

2.4.3 Follow ADA instructions to enable older adults and people with special needs to perceive the information easily.

Format: arrival notification (sign design, voice notification), improve stop names for easy

understanding.

2.5 Tolerance for Error

2.5.1 Provide features and elements to warn of and prevent hazards and errors.

2.5.2 Provide fail-safe features.

Format: metro door opens when items in the doorway, buffering structure in foldable seats.

2.6 Low Physical Effort

2.6.1 Lower effort and repetition.

2.6.2 Allow passengers to maintain neutral body position and minimize sustained physical effort.

2.6.3 Use reasonable design by considering ergonomic principles and ADA standards.

Format: ergonomic considerations, ramps, stop request lines in buses.

2.7 Low Physical Effort

2.7.1 Provide adequate spaces for passengers to pass and use.

2.7.2 Consider extreme conditions for space planning.

2.7.3 Consider the interaction between passengers and the facilities for people in different situations, like standing, seated, etc.

Three. Size and Space for Approach and Use

3.1 Standardization aims at forming uniform rules of the facility's design and arrangements.

Format: same-handed room.

3.2 Sustainability is in line with universal design rules that are aimed at meeting multiple needs within the same space.

Format: universal room for multiple uses and saving space.

Four. Preventive Healthcare

4.1 Use ergonomics considerations to prevent older adults and other age groups of passengers from getting injured, delay any chronic age-related diseases, and improve the interior facilities to meet the physical needs of older adults.

Format: ergonomic chairs, handles, ADA standards

4.2 Use biophilia theory to enable natural elements to get close to passengers, benefitting passengers, helping them feel relaxed and keeping a good mood.

Format: indirect way (big windows in public transportation), symbolic way (nature related patterns, illustrations, pictures, etc.).

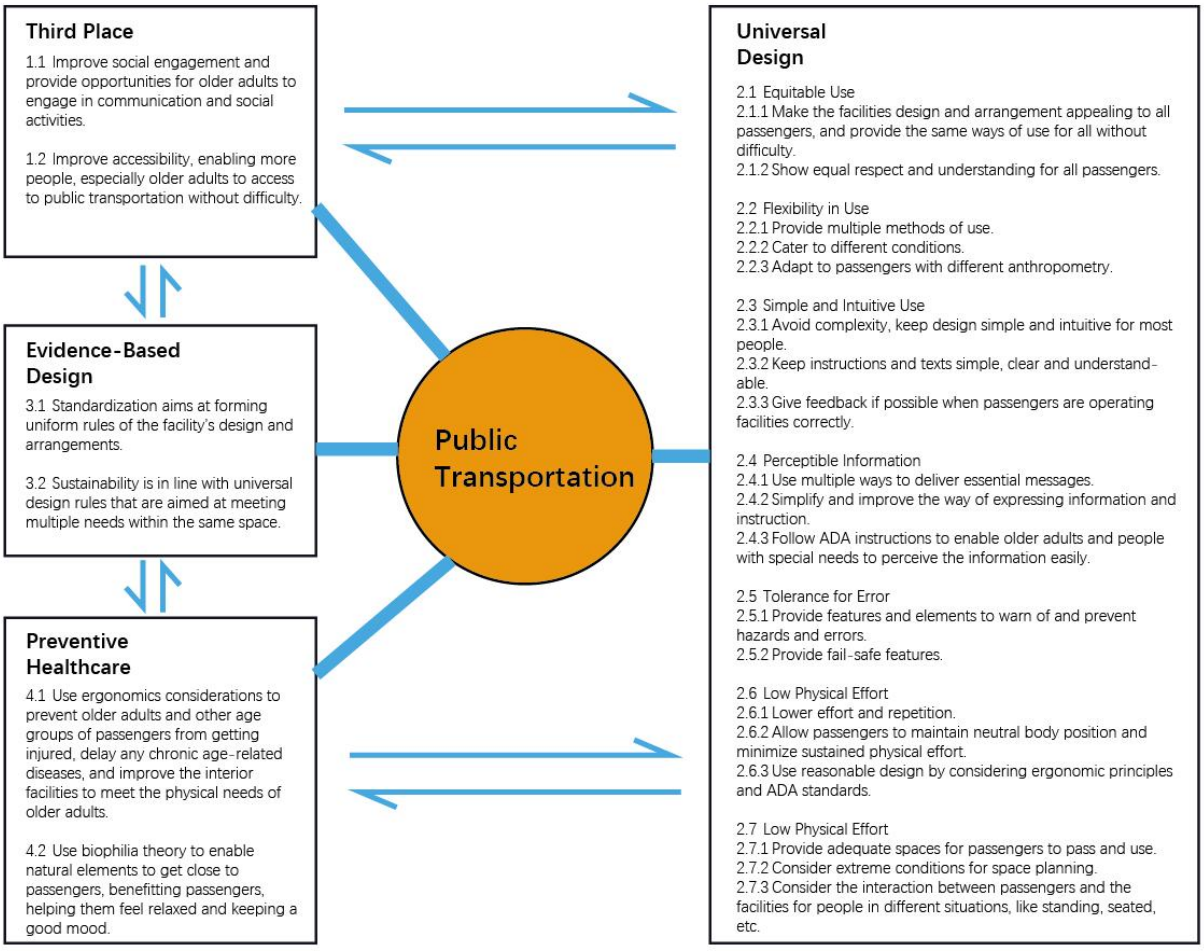

Figure 18: Interrelationships of Guideline Theories

3.4 List of Design Guidelines

This phase aims at forming a guideline list, based on the theory framework, ADA standards and priority of the items in the guidelines. The guidelines try to synthesize the interrelationships among these theories and principles, as well as following ADA standards to meet the physical needs of older adults. Also, the priority of the items in the guideline list is very important because in certain contexts, some guidelines may conflict with each other. Thus, in such circumstances, in order to prevent older adults' needs from being compromised, some

guidelines should be emphasized and some should be weakened or even dismissed. For example, the nature-related patterns make passengers feel at ease; however, some important signs on the wall cannot be seen clearly if the patterns use dark colors, or has less color contrast with the signs. In this situation, the perception of information is prior to biophilia. Thus, the nature-related patterns should either be lightened or even dismissed.

The guidelines consider three aspects to form the priority: 1) safety, 2) physical convenience, and 3) psychological joyfulness. Safety is always the first and most important issue for older adults in public transportation environment. Physical convenience is the purpose of redesigning and rearranging the space, because such purpose is the premise that it enables older adults to take public transportation without any barrier, like the wheelchair spaces in a public transportation environment. Last, psychological joyfulness is the main purpose of this study, and it is the key to improve travel and living quality of older adults in urban areas. Also, modern design and technology highly ensures the safety and physical convenience; thus, the goal is to implement as many guidelines possible to improve psychological joyfulness among older adults as well as other passengers.

List of Design Guidelines:

One. Safety

1.1 Tolerance for Error: Provide fail-safe features to warn of and prevent hazards and errors. (UD 2.5, Tolerance for Error)

1.1.1 The door must detect items in the doorway. The door must have warning tone and flash light when it is closing. The door must open when it detects items across the doorway during the closing process.

1.1.2 Emergency buttons should be placed where passengers can easily access controls. The emergency buttons could be located in vertical poles, in both sides of the doors, and near the foldable seat, which should be within reach range. Emergency buttons enable the interactions between passengers and public transportation, to stop the operation of the public transportation, and keep passengers safe when any emergency happens.

1.1.3 Foldable, rotatable, adjustable facilities must have buffering structures systems to avoid hurting passengers.

1.1.3.1 The foldable seat must have buffer when automatically scrolling up to avoid hurting passengers.

1.1.3.2 The door of the first aid box must have buffer when closing automatically.

Two. Physical Convenience

2.1 Improve accessibility, enabling more people, especially older adults to access to public transportation without difficulty. (Third Place 1.2)

2.1.1 Public transportation environment should have at least one universal space. In public transportation interiors, the universal space is defined as the small area that is equipped with folding seats that could be used as wheelchair space, or seats when there is no wheelchair, or

standing space when in rush hours. Universal space must comply to ADA 221 and 802: the minimum space for wheelchair is 36 inches by 48 inches.

2.2 Equitable Use. (UD 2.1, Equitable Use)

2.2.1 The grips or ring handles in the ceiling should offer different heights (2 to 3) or height adjustable, to enable 5th percentile older female in height to reach the lower one, as well as enabling most older adults to use these grips. The lower grip height should be 1665 mm (65.5 inches, 5th percentile older female standing reach height, Pheasant, 1996) and the upper height should be 1759 mm (69.3 inches, 95th percentile older female overhead comfortable grip height, Pheasant, 1996; Soares and Rebelo, 2016). And the overhead pole height is 1879 mm (74 inches, 95th percentile older male overhead comfortable grip height, Pheasant, 1996; Soares and Rebelo, 2016). See case 3 for detailed information. In practice, the lower grips should be a little lower to ensure 5th percentile female in height could reach them. Also, height values should be rounded and set in 5 mm increments. Thus, the lower grip height is 1660 mm, the upper grip height is 1760 mm, and overhead pole height is 1880 mm.

2.2.2 The doorway must enable wheelchairs to enter. It must comply with ADA 802. Thus, the minimum width of the door is 36 inches. In large sized public transportation, like metro, ferry etc., the door should enable two wheelchairs to enter and exit at the same time, the minimum width of the door is 72 inches, which is the double width of ADA standard 802; thus, it could allow two wheelchairs to enter and exit the door easily.

2.2.3 In line with 2.1.1, universal space should be a wheelchair space when there is a wheelchair; when there is no wheelchair, this space should be used for other passengers to sit or standing. Thus, a universal space should have a wheelchair space (ADA 802) and a foldable seat.

2.3 Flexibility in Use (UD 2.2, Flexibility in Use). Facilities in universal space should provide multiple methods of use, cater to different conditions, and adapt to passengers with different anthropometry.

2.3.1 In line with 2.1.1 and 2.2.3, the universal space should provide flexibility in use; it could either be used as a wheelchair space, seats or standing space. Such space should have a foldable seat. The minimum width of the foldable seat is 18 inches. It should be height adjustable, and the seat height should be in the range from 15.0 inches to 19.9 inches (BIFMA ergonomic chair standards, Allsteel, 2006). The backrest lumbar should range from 5.9 inches to 9.8 inches from seat pan to the most prominent point (see Table 3). The angle of the back should be between 100° and 110°, seat angle or ‘tilt’ should be between 5° and 10° (Pheasant, 1996).

2.4 Simple and Intuitive Use (UD 2.3, Simple and Intuitive Use). The design should be simple, have proper texts or instructions, and give different intuitive sound, light, or signal feedback both when passengers are operating facilities correctly and incorrectly.

2.4.1 The facilities on the wall should be 15 inches (min) to 48 inches (max) from the floor to enable people in wheelchairs to reach the facilities (ADA 308, wheelchair reach range).

2.4.2 In line with 1.1.2, there should be emergency buttons where passengers can easily access controls. The emergency buttons could be located in vertical poles, in both sides of the doors, and near the foldable seat, which should be within reach range (ADA 308, wheelchair reach range). Also, there should be stop request buttons and lines in a bus or similar interiors, by which such public transportation stops by request, so passenger could have some information exchanges with the public transportation system or the drivers.

2.4.3 Provide text or figure instructions to facilities. There should be signs and figure instructions for the wheelchair spaces, and first aid box. The text should be brief and font size must comply with ADA 703.5.5 standards for font size in public transportation (See Table 2). The figure instructions should be simple, easy and intuitive to understand.

2.4.4 There should be feedback when passengers use facilities. Sound and light signals are needed when passengers push buttons, pull stop request lines, and use the foldable seats.

2.5 Perceptible Information (UD 2.4: Perceptible Information)

2.5.1 Arrival notifications should provide multiple ways to deliver essential message (sign design, voice notification, digital information board etc.).

2.5.2 Improve station names for easy understanding; use names of famous sites or landmarks, instead of names of crossings.

2.6 Low Physical Effort (UD 2.6 Low Physical Effort)

2.6.1 If the doorway of the public transportation is higher than the floor, there should be either a ramp or a lift equipped near the door to help wheelchairs to enter.

2.6.2 The bench must follow ergonomic chair design (same standards as foldable seats except height adjustment, see section 2.3.1) to enable passengers to feel comfortable. The backrest lumbar should range from 5.9 inches to 9.8 inches from the seat pan to the most prominent point (Allsteel, 2006; see Table 3). The angle of the back should be between 100° and 110°, and the seat angle or 'tilt' should be between 5° and 10° (Pheasant, 1996). The bench design must also comply to ADA 903 bench back support standards. The height of the back support should be 18 inches minimum; the gap between back and seat pan should be 2 inches (maximum) in height and 2.5 inches (maximum) in width, if gap measurements are applicable.

2.6.3 in line with 2.2.1, the ring handles on the ceiling should offer at least two height options, or be height adjustable to allow more passengers to keep their body in neutral posture.

2.7 Size and Space for Approach and Use (UD 2.7, Size and Space for Approach and Use)

2.7.1 In line with 2.2.2, the doorway should enable wheelchairs to enter, and must comply to ADA 403, 404 and 802, for which the minimum width is 36 inches. In large sized public transportation, the minimum width of the door should be 72 inches.

2.8 Standardization (EBD 3.1). All the configurations and arrangements of the facilities should be uniform and standardized.

2.8.1 The wheelchair space should be located in the same place in same and similar public transportation interior. For example, in a metro interior design, all the wheelchair spaces should be located to the right side of the doorway. This guideline should also be applied to the first aid box, emergency buttons, stop request lines, etc., to allow passengers to be familiar with locations of the facilities in different public transportation systems quickly.

2.9 Sustainability (EBD 3.2). Sustainability is in line with universal design rules that are aimed at meeting multiple needs within the same space.

2.9.1 In line with 2.1.1, 2.2.3, and 2.3.1, there should be universal space in public transportation interiors.

2.10 Ergonomics considerations (Preventive Healthcare 4.1).

2.10.1 In line with 2.6.2 and 2.6.3, the bench and the foldable seats should follow ergonomic chair design (Allsteel, 2006; ADA 2016 and Pheasant, 1996).

2.10.2 In line with 2.2.1, the ring handles on the ceiling should be set at least two heights (lower height should be 67.4 inches; upper height should be 72.9 inches, see 2.2.1 for details), or height adjustable to allow more passengers to keep their body in comfortable postures.

Three. Psychological Joyfulness

3.1 Biophilia (Preventive Healthcare 4.2). Use biophilia theory to enable natural elements to get close to passengers, benefitting passengers, helping them feel relaxed and keeping a good mood.

3.1.1 Indirect way: in the premise of safety and structurally feasible, enlarge the windows of the public transportation, to allow passengers to see as much natural scenery as possible.

3.1.2 Symbolic way: could use nature related patterns, illustrations, pictures etc. to decorate the interior of the public transportation.

The guidelines are listed from Figure 19 to Figure 26.

Design Guidelines of Public Transportation for Older Adults in Urban Areas

One. Safety

1.1 Tolerance for Error: Provide fail-safe features to warn of and prevent hazards and errors. (UD 2.5, Tolerance for Error)

1.1.1 The door must detect items in the doorway. The door must have warning tone and flash lights when it is closing. The door must open when it detects items across the doorway during the closing process.

1.1.2 Emergency buttons should be placed where passengers can easily access controls. The emergency buttons could be located in vertical poles, in both sides of the doors, and near the foldable seat, which should be within reach range. Emergency buttons enable the interactions between passengers and public transportation, to stop the operation of the public transportation, and keep passengers safe when any emergency happens.

1.1.3 Foldable, rotatable, adjustable facilities must have buffering structures systems to avoid hurting passengers.

1.1.3.1 The foldable seat must have buffer when automatically scrolling up, to avoid hurting passengers.
1.1.3.2 The door of the first aid box must have buffer when closing automatically.

Two. Physical Convenience

2.1 Improve accessibility, enabling more people, especially older adults to access to public transportation without difficulty. (Third Place 1.2)

2.1.1 Public transportation environment should have at least one universal space. In public transportation interiors, the universal space could be defined as the small area that is equipped with folding seats that could be used as wheelchair space, or seats when there is no wheelchair, or standing space when in rush hours. Universal space must comply to ADA 221 and 802: the minimum space for wheelchair is 36 inches by 48 inches (see Figure 2.1.1).

Figure 19: Design Guidelines Page 1

Design Guidelines of Public Transportation for Older Adults in Urban Areas

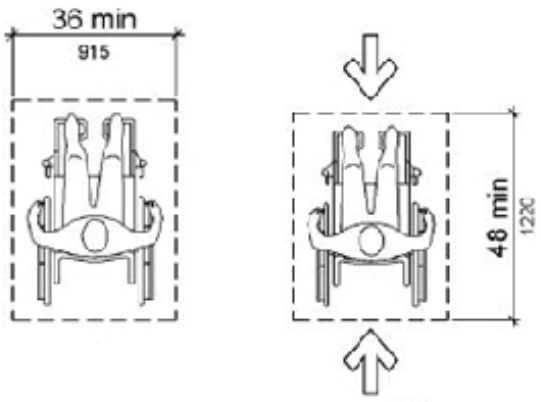

Figure 2.1.1: ADA 802, Wheelchair Space Minimum Dimension

Figure 2.2.1.1: Overhead grip reach (a) and overhead comfortable grip height (b)

2.2 Equitable Use. (UD 2.1, Equitable Use)

2.2.1 The grips or ring handles in the ceiling should offer different heights (2 to 3) or height adjustable,to enable 5th percentile older female in height can reach the lower one, as well as enabling most older adults to use these grips. Figure 2.2.1.1 demonstrates overhead grip reach (a) and overhead comfortable grip height (b).

Figure 2.2.1.2 shows the grip consitions of older adults in different gender and different height percentiles, and was sorted by grip heights from low to high. The lower grip height should be 1665 mm (65.5 inches, 5th percentile older female standing reach height) and the upper height should be 1759 mm (69.3 inches, 95th percentile older female overhead comfortable grip height). And the overhead pole height is 1879 mm (74 inches, 95th percentile older male overhead comfortable grip height). See case 3 for detailed information. In practice, the lower grips should be a little lower to ensure 5th percentile female in height could reach them. Also, height values should be rounded and set in 5 mm increments. Thus, the lower grip height is 1660 mm, the upper grip height is 1760 mm, and overhead pole height is 1880 mm.

Figure 20: Design Guidelines Page 2

Design Guidelines of Public Transportation for Older Adults in Urban Areas

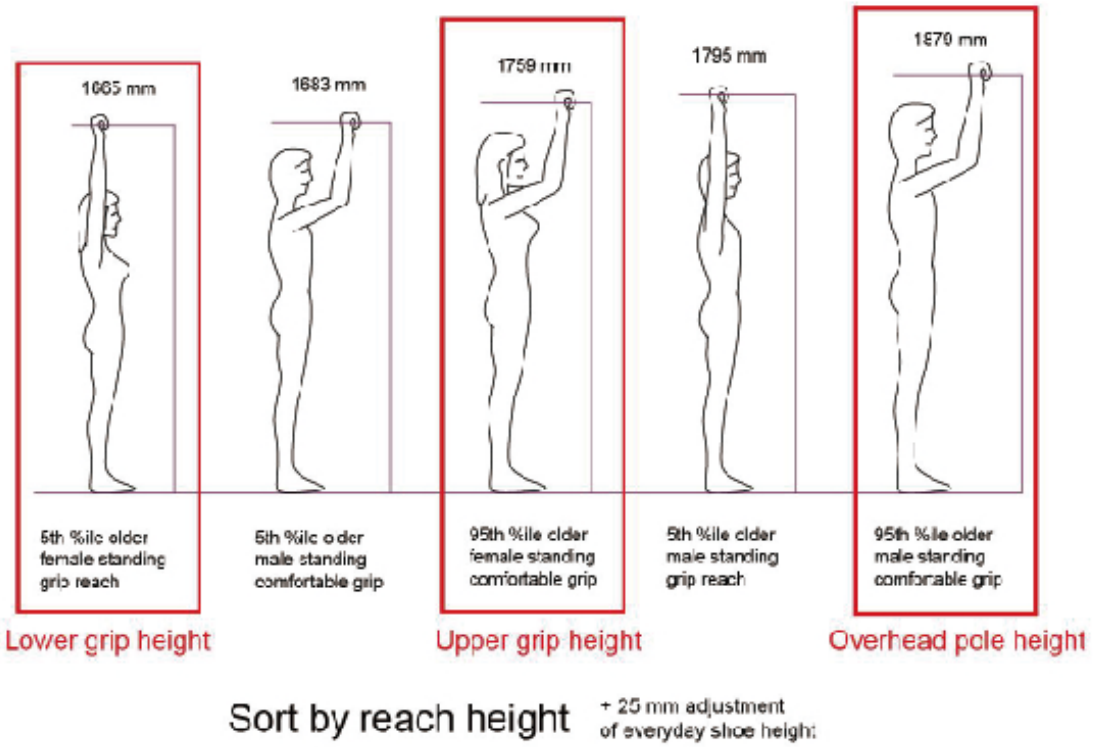

Figure 2.2.1.2: Standing Grip of Older Adults in Different gender, percentiles and conditions, sort by grip heights from low to high (+25 mm shoe height adjustment)

2.2.2 the doorway must enable wheelchairs to enter. It must comply to ADA 802. Thus, the minimum width of the door is 36 inches. In large sized public transportation, like metro, ferry etc., the door should enable two wheelchairs to enter and exit at the same time, the minimum width of the door is 72 inches, which is the double width of ADA standard 802; thus, it could allow two wheelchairs to enter and exit the door easily.

2.2.3 in line with 2.1.1, universal space should be a wheelchair space when there is a wheelchair; when there is no wheelchair, this space should be used for other passengers to sit or standing. Thus, a universal space should have a wheelchair space (ADA 802) and a foldable seat.

Figure 21: Design Guidelines Page 3

Design Guidelines of Public Transportation for Older Adults in Urban Areas

2.3 Flexibility in Use (UD 2.2, Flexibility in Use). Facilities in universal space should provide multiple methods of use, cater to different conditions, and adapt to passengers with different anthropometry.

2.3.1 In line with 2.1.1 and 2.2.3, the universal space should provide flexibility in use; it could either be used as a wheelchair space, seats or standing space. Such space should have a foldable seat. The minimum width of the foldable seat is 18 inches. It should be height adjustable, and the seat height should be in the range from 15.0 inches to 19.9 inches. the backrest lumbar should range from 5.9 inches to 9.8 inches from seat pan to the most prominent point. The angle of the back should be between 100° and 110°, seat angle or 'tilt' should be between 5° and 10°. See figure 2.3.1 for detailed information.

		Specifications	
		Measurement	Guidelines
Seat Height	A	Popliteal Height + Shoe allowance	15.0" - 19.9"
Seat Depth	B	Buttock-popliteal Length - Clearace allowance	No deeper than 16.9" (fixed) 16.9" included (adjustable)
Seat Width	C	Hip breadth, sitting + Clothing allowance	No less than 18"
Backrest Height	D	None	At least 12.2"
Backrest Width	E	Waist breadth	14.2"
Backrest Lumbar	F	None	Most prominent point 5.9" - 9.8" from seat pan, in and out 1
Backrest Angle	G	Angle between backrest and horizontal line	100° to 110°
Seat pan Angle	H	Angle between seat pan and horizontal line	5° to 10°
Gap Height	J	None	2" max (if applicable)
Gap Width	K	None	2.5" max (if applicable)

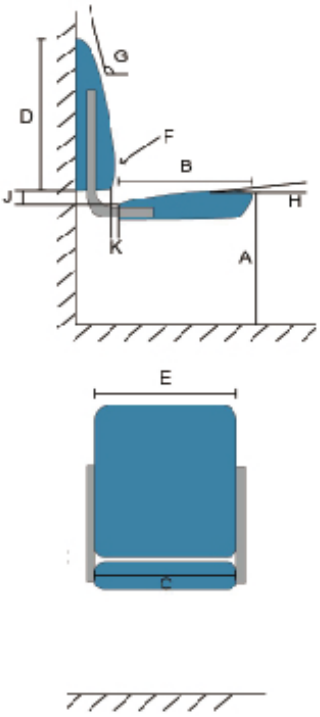

Figure 2.3.1: Foldable seat and bench standards

Figure 22: Design Guidelines Page 4

Design Guidelines of Public Transportation for Older Adults in Urban Areas

2.4 Simple and Intuitive Use (UD 2.3, Simple and Intuitive Use). The design should be simple, have proper texts or instructions, and give different intuitive sound, light, or signal feedback both when passengers are operating facilities correctly and incorrectly.

2.4.1 The facilities on the wall should be 15 inches (min) to 48 inches (max) from the floor to enable people in wheelchairs to reach the facilities (ADA 308, wheelchair reach range).

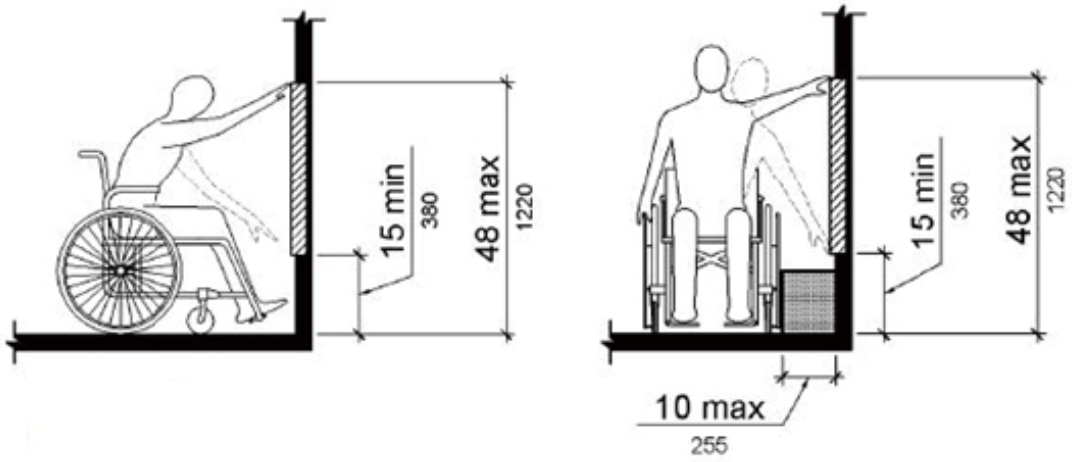

Figure 2.4.1: Forward and Side Reach with Wheelchair

2.4.2 In line with 1.1.2, there should be emergency buttons where passengers can easily access controls. The emergency buttons could be located in vertical poles, in both sides of the doors, and near the foldable seat, which should be within reach range (ADA 308, wheelchair reach range). Also, there should be stop request buttons and lines in a bus or similar interiors, by which such public transportation stops by request so passenger could have some information exchanges with the public transportation system or the drivers.

2.4.3 Provide text or figure instructions to facilities. There should be signs and figure instructions for the wheelchair spaces, and first aid box. The text should be brief and font size must comply to ADA 703.5.5 standards for font size in public transportation (See Table 2.4.3). the figure instructions should be simple, easy and intuitive to understand.

Figure 23: Design Guidelines Page 5

Design Guidelines of Public Transportation for Older Adults in Urban Areas

Height to Finish Floor or Ground From Baseline of Character	Horizontal Viewing Distance	Minimum Character Height
40 inches (1015 mm) to less than or equal to 70 inches (1780 mm)	less than 72 inches (1830 mm)	5/8 inch (16 mm)
	72 inches (1830 mm) and greater	5/8 inch (16 mm), plus 1/8 inch (3.2 mm) per foot (305 mm) of viewing distance above 72 inches (1830 mm)
Greater than 70 inches (1780 mm) to less than or equal to 120 inches (3050 mm)	less than 180 inches (4570 mm)	2 inches (51 mm)
	180 inches (4570 mm) and greater	2 inches (51 mm), plus 1/8 inch (3.2 mm) per foot (305 mm) of viewing distance above 180 inches (4570 mm)
greater than 120 inches (3050 mm)	less than 21 feet (6400 mm)	3 inches (75 mm)
	21 feet (6400 mm) and greater	3 inches (75 mm), plus 1/8 inch (3.2 mm) per foot (305 mm) of viewing distance above 21 feet (6400 mm)

Table 2.4.3: Visual Character Height

2.4.4 there should be feedback when passengers use facilities. Sound and light signals are needed when passengers push buttons, pull stop request lines, and use the foldable seats..

2.5 Perceptible Information (UD 2.4: Perceptible Information)

2.5.1 Arrival notifications should provide multiple ways to deliver essential message (sign design, voice notification, digital information board etc.).

2.5.2 Improve station names for easy understanding; use names of famous sites or landmarks as possible, instead of names of crossings.

Figure 24: Design Guidelines Page 6

Design Guidelines of Public Transportation for Older Adults in Urban Areas

2.6 Low Physical Effort (UD 2.6 Low Physical Effort)

2.6.1 If the doorway of the public transportation is higher than the floor, there should be either a ramp or a lift equipped near the door to help wheelchairs to enter.

2.6.2 The bench must follow ergonomic chair design (same standards as foldable seats except height adjustment, see section 2.3.1) to enable passengers to feel comfortable.

2.6.3 in line with 2.2.1, the ring handles on the ceiling should offer at least two height options, or be height adjustable to allow more passengers to keep their body in neutral posture.

2.7 Size and Space for Approach and Use (UD 2.7, Size and Space for Approach and Use)

2.7.1 In line with 2.2.2, the doorway should enable wheelchairs to enter, and must comply to ADA 403, 404 and 802, for which the minimum width is 36 inches. In large sized public transportation, the minimum width of the door should be 72 inches. See Figure 2.1.1.

2.8 Standardization (EBD 3.1). All the configurations and arrangements of the facilities should be uniformed and standardized.

2.8.1 The wheelchair space should be located in the same place in same and similar public transportation interior. For example, in a metro interior design, all the wheelchair spaces should be located to the right side of the doorway. This guideline should also be applied to the first aid box, emergency buttons, stop request lines etc., to allow passengers to be familiar with locations of the facilities in different public transportation systems quickly.

2.9Sustainability (EBD 3.2). Sustainability is in line with universal design rules that are aimed at meeting multiple needs within the same space.

2.9.1 In line with 2.1.1, 2.2.3, and 2.3.1, there should be universal space in public transportation interiors.

Figure 25: Design Guidelines Page 7

Design Guidelines of Public Transportation for Older Adults in Urban Areas

2.10 Ergonomics considerations (Preventive Healthcare 4.1).

2.10.1 In line with 2.6.2 and 2.6.3, the bench and the foldable seats should follow ergonomic chair design. See Figure 2.3.1.

2.10.2 In line with 2.2.1, the ring handles on the ceiling should be set at least two heights (lower height should be 67.4 inches; upper height should be 72.9 inches, see Section 2.2.1 for details), or height adjustable to allow more passengers to keep their body in comfortable postures.

Three. Psychological Joyfulness

3.1 Biophilia (Preventive Healthcare 4.2). Use biophilia theory to enable natural elements to get close to passengers, benefitting passengers, helping them feel relaxed and keeping a good mood.

3.1.1 Indirect way: in the premise of safety and structurally feasible, enlarge the windows of the public transportation, to allow passengers to see as much natural scenery as possible.

3.1.2 Symbolic way: could use nature related patterns, illustrations, pictures etc. to decorate the interior of the public transportation.

Figure 26: Design Guidelines Page 8

Chapter 4: Guideline Application and Design Improvement

4.1 Overview

In Chapter 3, guidelines are developed and revised, based on four important theories and concepts, to try to improve the experience of taking public transportation for older adults as well as more passengers. In this chapter, the guidelines will be applied to examine a specific public transportation environment, which is the New York City Subway. Both advantages and disadvantages will be discussed based on the guidelines, and a new interior facility and arrangement will be developed, according to the analysis in former chapters.

4.2 Introduction of New York City Subways

“The Metropolitan Transportation Authority (MTA) is North America's largest transportation network, serving a population of 15.3 million people in the 5,000-square-mile area fanning out from New York City through Long Island, southeastern New York State, and Connecticut” (Metropolitan Transportation Authority, MTA, 2016). The subway is one of the most important parts of the MTA. With the increasing population and the transit needs of residence and workers, the city's reliance on its underground rapid transit system is greater than ever (MTA, 2016).

On the other hand, the older population is also increasing, based on the census from New

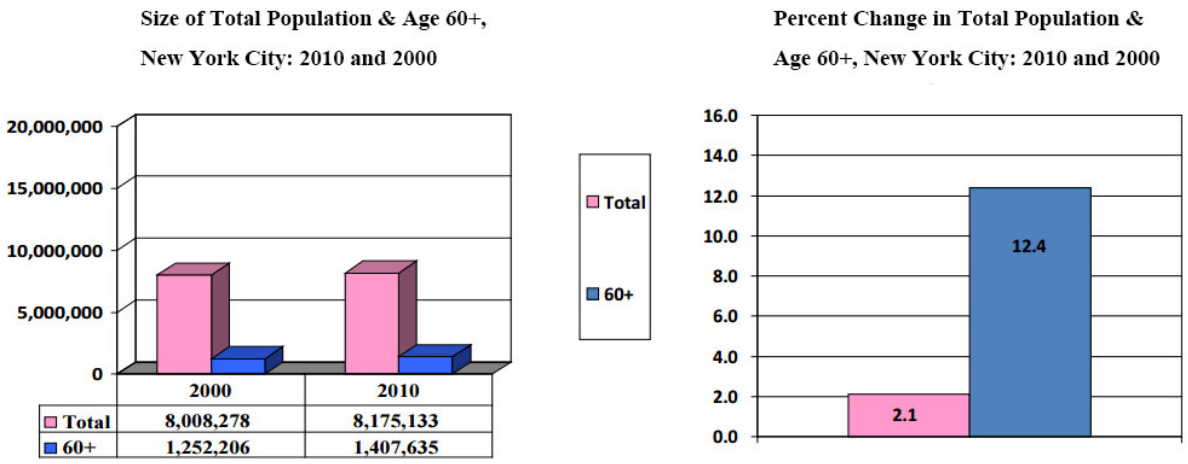

Figure 27: Number and Percentage Changes of Older Population in New York City between 2010 and 2000 (NYC, 2016)

York City government. In Figure 27, the statistics comparing the population changes between the years 2010 and 2000 are shown; the older population has increased both in population number and percentage (NYC, 2016). “Over the past decade, the total population of New York City grew at a rate of 2.1 percent, in contrast, the older population of New York City grew by 12.4 percent” (NYC, 2016, p. 5). The statistics indicates that New York City is experiencing population aging, and public transportation should improve their services and upgrade their facilities and design to meet the needs of the increasing aging population.

The New York City subway opened in 1904, and it has improved and changed considerably during a century (MTA, 2016). Currently, MTA is replacing and updating old metro cars with new ones. One of the latest updated metro cars is called the R160. According to the engineering drawing from Figure 28 (See Appendix 1, NYC Subway, 2016), the R160 cars are designed and manufactured by two different companies, Alstom Transportation, Inc. (A car) and Kawasaki Rail Car Inc. (B car). From the data and engineering drawing, it can be seen that they

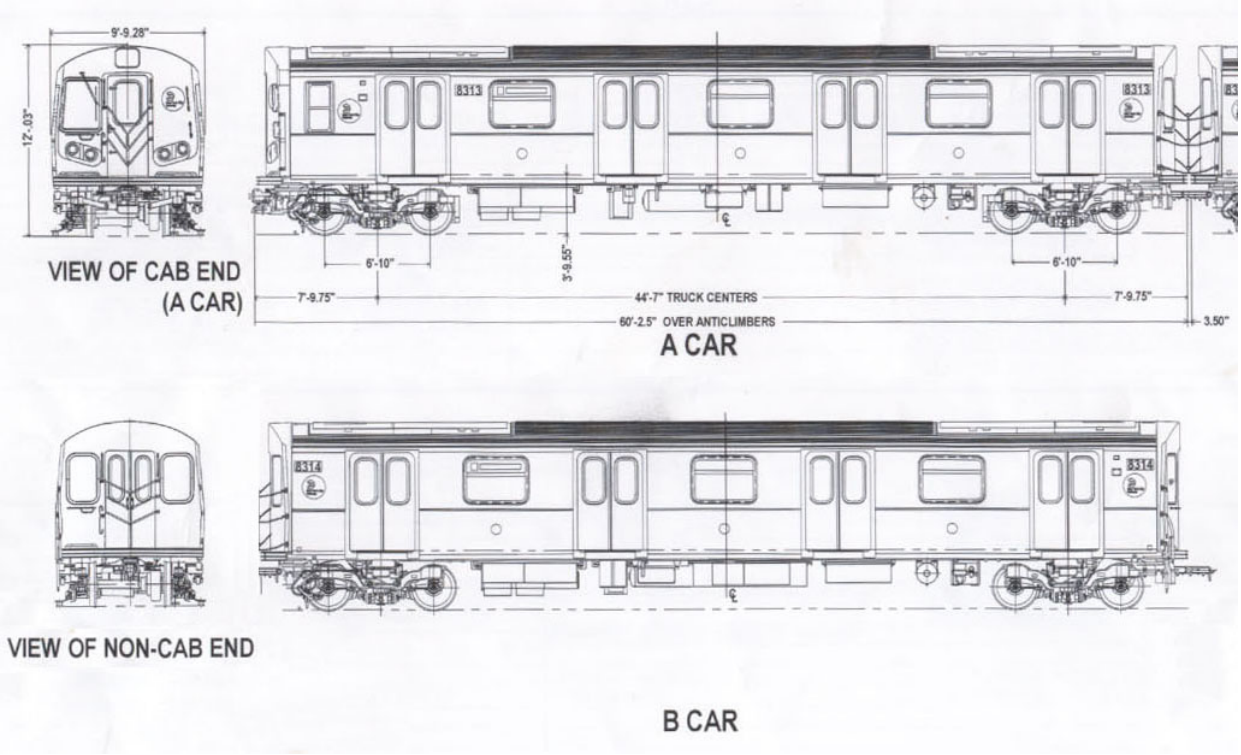

Figure 28: Engineering Drawing of R160 Car (NYC Subway, 2016)

DIMENSIONS	
DOORWAY HEIGHT (END)	6' - 3"
DOORWAY HEIGHT (SIDE)	6' - 3"
DOORWAY WIDTH (END OPENING)	2' - 6"
DOORWAY WIDTH (SIDE OPENING)	4' - 2"
FLOOR TO CEILING HT. (HIGH CEILING)	7' - 1/2"
FLOOR TO CEILING HT. (LOW CEILING)	6' - 7 1/2"
HEIGHT (TOP OF RAIL TO FLOOR)	3' - 9 1/2"
TRACK GAUGE	4' - 8 1/2"
WHEEL DIAMETER	34"
WIDTH (OVER THRESHOLD)	10'-0"

WEIGHT & CAPACITY	
CAR WEIGHT (EMPTY)	
AVERAGE CAR WEIGHT	85,200 LBS
CAR WEIGHT (LOADED)	
AVERAGE CAR WEIGHT (AW3)	122,000 LBS
BUFF LOAD (AT ANTICLIMBER)	
A & B CARS	200,000 LBS
SEATING CAPACITY	
A CAR	42
B CAR	44
STANDING CAPACITY	
A CAR	198
B CAR	202
TRUCK WEIGHT	
AVERAGE TRUCK WEIGHT W/PARKING BRAKE	16,450 LBS

Table 4: Dimensions and Capacity of R160 Car (NYC Subway, 2016).

are slightly different, but the overall size, design and interior facilities are almost the same. The subway car dimension and capacity are shown in Table 4. The data shown in the table would help judge the interior layout based on our guidelines.

Figure 29: Interior of R160 car from New York Subway (Autopilot, 2014)

Figure 29 shows an interior R160 car from New York Subway. The guidelines of public transportation for older adults from last chapter will be used to examine the extent to which the interior environment is use-friendly to older adults, as well as other demographic groups. Both advantages and disadvantages will be discussed based on the guidelines; some suggestions and ideas will be proposed to improve disadvantages and shortcomings. At last, an improved concept of New York Subway R160 car interior will be designed and demonstrated to meet the guidelines as much as possible, to benefit older adults and more urban passengers.

First, Third Place. There are two important aspects of the “third place” theory in the

guidelines. One is social engagement, and the other one is accessibility. Observed from Figure 29, it could be found that the R160 car represents a typical interior of subway cars. The seats are designed along the edge of the car; such design saves space and enables more passengers to stand in the car during rush hour. However, this design also reveals the disadvantage that it is a little bit difficult for people to have eye contact and communications with friends and family members, which are important factors to improve social engagement. Especially older adults usually travel with friends or family members. Even if they only ride public transportation for short period, it is still a valuable period to communicate with others. Thus, considering the social background of population aging, facilities that improve social engagement among older adults are necessary, and the New York Subway car should improve this point.

Also, the interior of R160 car does not show any accessible facilities in the environment, which indicates that it is difficult for people with wheelchairs to take the subway. Such a condition is difficult especially for older adults and people with disabilities to enjoy public transportation. Even though the New York subway takes huge number of passengers every day, the city planners should not neglect the fact that older adults are becoming the largest demographic. It is not too late to consider redesigning the facilities or the arrangement of the public transportation interior to meet the physical and psychological needs from older adults and more people with special travel needs.

Second, universal design (UD). Observed from Figure 29, one of the advantages is the digital information board (Figure 30, Tropiansky, 2010). The information board provides

Figure 30: Digital Information Board in R160 Car (Tropiansky, 2010)

dynamic information and station lists to tell passengers where their location is. Such design is intuitive in use, and all the passengers could understand the instant information. However, there are some disadvantages about the board. Due to the physical body declines, older adults have difficulty in seeing words in low color contrast with the background. Also, the font sizes seem to be relatively small for older adults. Thus, there should be more color contrast between the words and the background, meanwhile increasing the font size according to ADA standards 703.5.5 (see Table 2).

The interior design and layout arrangement are quite simple and intuitive in use. By checking the guidelines, some conclusions could be drawn. Some advantages are that all the

benches are uniform, so passengers could use them equitably. Also, because the benches are long without limiting seat width, people with different body sizes could use them. The facilities in the space are simple and intuitive for passengers to grab, like the handles and bars. Digital information boards are on both sides of the car, providing perceptible information for passengers. It is easier to understand the information in a digital board than in a paper board, because there are indicators (such as flashes) in the digital ones. It looks like there are enough space for passengers to pass and use, especially for standing passengers. That is a major feature of a public transportation in big urban areas; however, not many considerations are given to older adults and other groups of people.

Some disadvantages exist as well. According to the engineering drawing from Table 6, the width of the car is 30 inches. However, the ADA standard recommends a minimum width of 32 inches. Thus, in this case, it is not that convenient for people with wheelchairs to enter the space, or maybe the car designers have not considered the accessibility issues, because there is no space for wheelchairs in the car. Also, the facilities in the car seem to be fixed; no facility can be moved to cater to different situations, especially for accessibility. The cross handles above the head are in equal height, and no bars are provided for relatively short people. Thus, relatively short passengers have to find vertical poles near the door, and it can be difficult for them to stand inside the car areas. The material of the seats seems to be rigid plastic without considering ergonomics; thus, passengers would feel fatigue when seated for a long time.

Third, Evidence-Based Design (EBD). There are two important criteria for EBD,

standardization and sustainability. Standardization aims at forming uniform rules or designs, so that passengers would be familiar with the same or similar design, and they can easily use the facilities with little or no confusion. Sustainability is in line with universal design that aims at meeting multiple needs within the same space. According to the interior space shown in Figure 20, the R160 car has already set some standardization. It uses a uniform handle and bench design, the handles are located on both side of the car and they are symmetric, which means by whichever door passengers enter the car, they would see the same or similar environment. Therefore, they can locate the handle or the bench easily. Such design follows the same-handed room design and benefits many passengers. However, this standardization is commonly seen in subway cars in other cities, and such standards cannot meet the needs of some groups of people, like older adults and disabled people who have special space needs in public transportation. In such circumstances, evidence-based design should determine the specific needs of these groups of people, and integrate standardization, extending the standards to cater to more and more passengers who take public transportation.

Fourth, Preventive Healthcare. Two key words are mentioned in the guidelines: ergonomics and biophilia. Public transportation is a common and inexpensive way to commute for many citizens, designers consider more about quantity than quality, and passengers rarely complain about the inconvenience of the facilities in the public transportation. Nowadays, public transportation is paying more attention to the convenience of the passengers, especially older adults. Such concerns are about using cushions, ergonomic considerations, or facilitative

equipment, trying to prevent fatigue during the travel and providing convenience. Observed from the R160 car, the design and facilities in it are quite simple. The purpose could be to save budget or spaces; thus, not much ergonomics considerations are demonstrated in this space. There are many good examples of ergonomics that could be applied to this space based on existing design and theories from related research. Biophilia is another important part of preventive healthcare. Based on the research summarized in the literature review, images or patterns related to nature help people feel relaxed experience benefits to their psychological health. Not many public transportation designers think about this from the perspective of preventive healthcare, and few public transportation interiors use nature elements. Biophilia is an important design feature from the guidelines and few public transportations have considered this before, thus, the design would be beneficial to passengers, especially older adults.

4.3 Guidelines Application

In this section, the improvements of the interior design and arrangements will be proposed, based on analysis of the disadvantages of the R160 car and the guidelines. Figure 31 shows the overall new design of New York Subway R160 car, with the upper left parts removed to have a better view of the interior facility arrangements and design. A new design will be introduced by following the sequence of the guidelines, as well as comparing to the existing R160 car design to demonstrate the improvements and advantages of the new design.

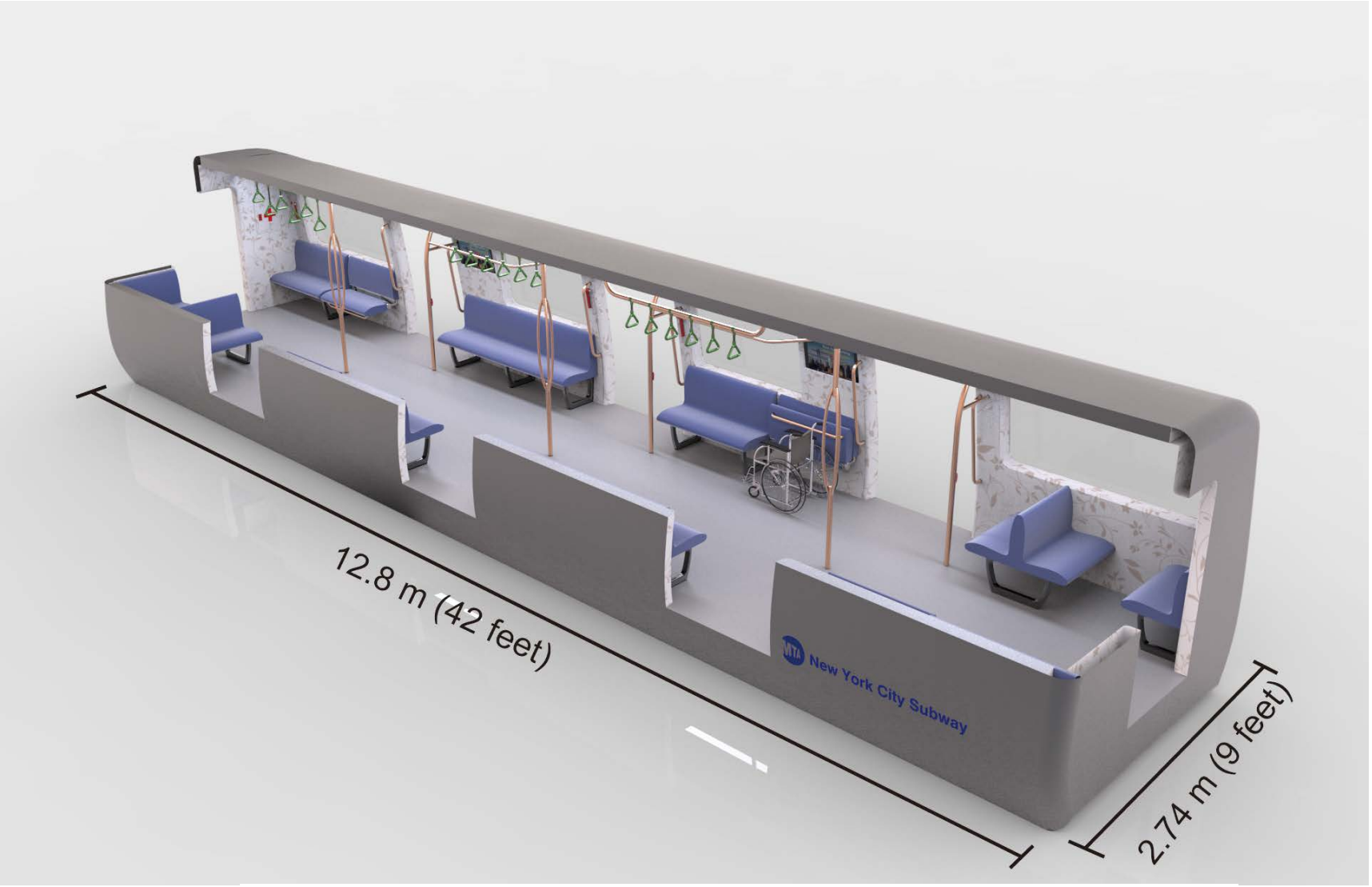

Figure 31: Overall New Design of R160 Car

4.3.1 Third Place

` The guidelines apply the theory of “Third Place”, and recommend improvements from two aspects, social engagement and accessibility. Following the guidelines, Figure 32 shows the improvement to meet the needs of social engagement. The seats in the corner are arranged face-

Figure 32: Face-to-Face Seats Design

to-face; thus, passengers, like older adults with their friends and family could sit face-to-face, and enjoy communication during the travel. Also, passengers can chat with strangers, which lets people feel at ease, and so older adults feel they can engage in social activities. Enlarged windows near the seats enable passengers to see more people, scenery of the streets (some of the subway lines include ground transportation), and feel the vitality of the city. The face-to-face

seats, following the guideline of social engagement, meet the psychological needs of older adults: instead of staying at home alone, by taking public transportation like the subway, they could enjoy eye contact, communication, care and love from our society, which makes them in good mood and allows them to enjoy urban life. In the existing R160 car design, there is no such face-to-face seat design; thus, the improvement would be a feature that benefits older adults. Considering that such face-to-face seats design may take a lot of space, and may limit the space for standing passengers, the unit of the face-to-face seats should be limited to no more than two in a single car.

Again, accessibility is mentioned in the guidelines. However, the R160 car does not show any obvious accessible facilities in the space. One of the most important accessible facilities in public transportation is the wheelchair space. Wheelchair space in public transportation is not a

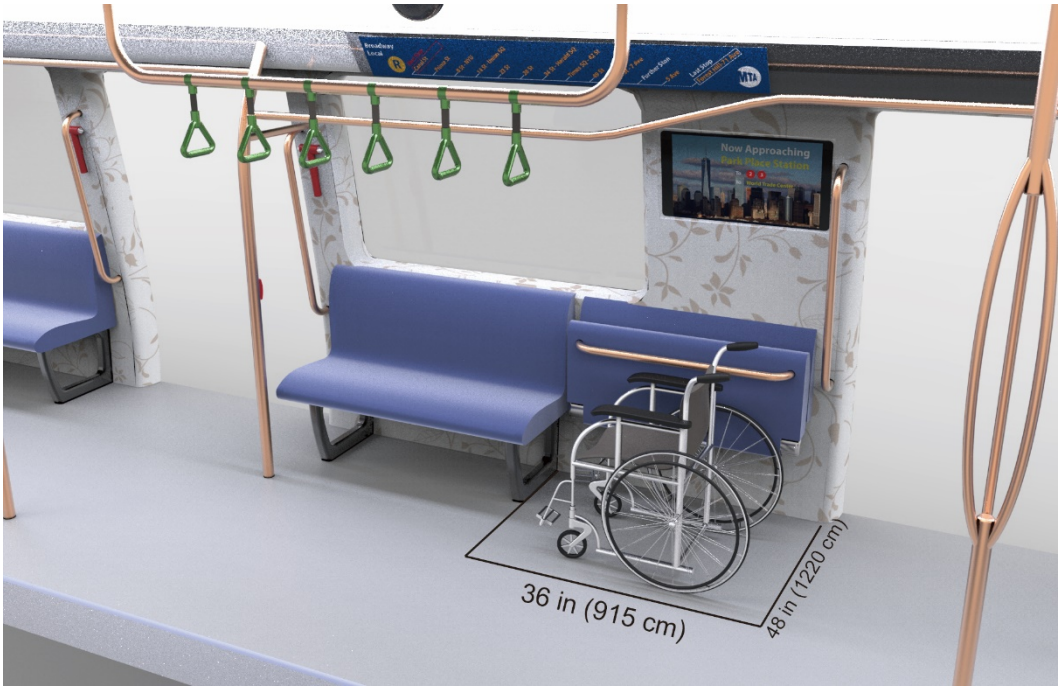

Figure 33: A Unit of Wheelchair Space

creative design, because nowadays, many public transportations in urban areas have wheelchair spaces. Some incorporate wheelchair space with foldable chairs to make the most use of the space. A good example is the S stock from London Underground. However, the S stock uses too many wheelchair spaces, which may limit the maximum number of passengers it could take in rush hour. Figure 33 shows one unit of wheelchair space. The space consists of the wheelchair space, a foldable chair, and a bench. The wheelchair space is located right near the door, which benefits the passengers with wheelchairs, as they can simply enter the metro car and turn right. This design also incorporates the criteria of standardization from Evidence-Based Design that all the wheelchair space is designed on the right side of the door. The foldable chair design in wheelchair space is in line with sustainability in EBD and flexibility in UD, which can be changed for multiple uses to meet the needs either from people with wheelchair or normal passengers, and thus saves space in a public transportation environment. Also, the foldable chair complies with the criteria from preventive healthcare in that it considers ergonomics from the perspective of ergonomic back design and height adjustment, so that passengers with different body sizes could adjust the seats for convenience during travel.

4.3.2 Evidence-Based Design (EBD)

Evidence-Based Design (EBD) originally comes from healthcare space design, but this concept will be applied to the improvement of metro design to benefit the passengers, especially older adults. There are two important criteria from EBD; the first one is standardization, and the

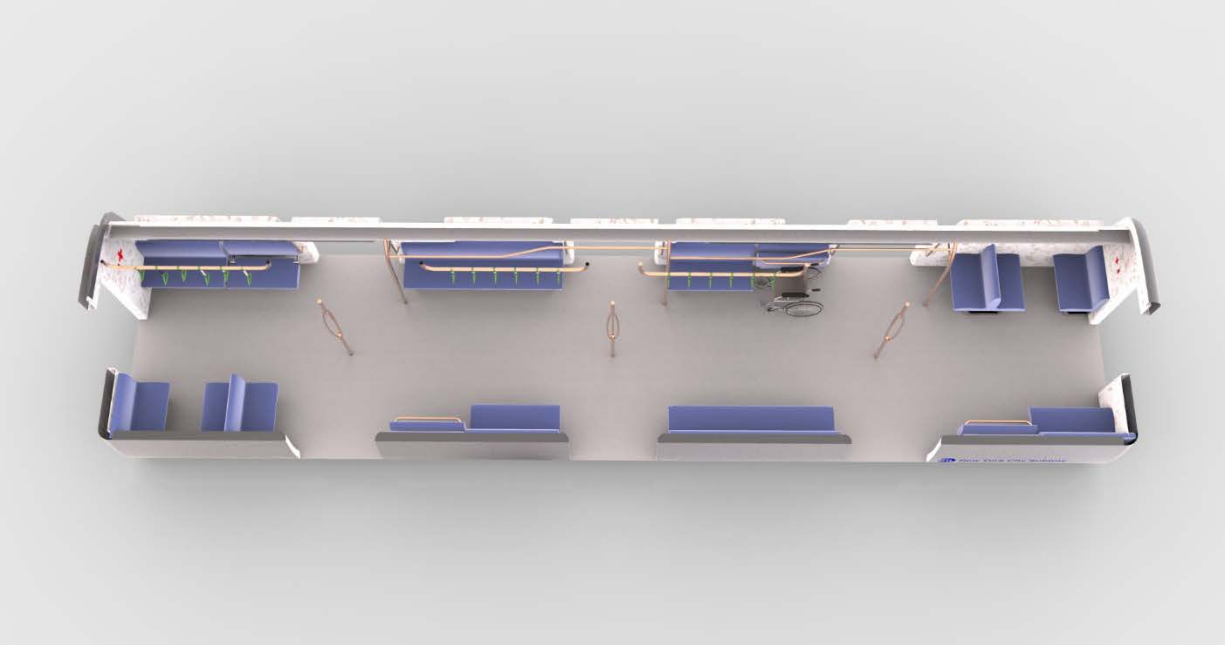

Figure 34: Top View of the Interior

second one is sustainability.

As mentioned in Chapter 3, the same-handed room helps caregivers to be familiar with the room easily so it takes no time for them to find the items and use the facilities in the room, because of the same or highly similar layout design, and such design is a standardization that healthcare institutions could follow. Such design and standards improve work efficiency and reduce work errors. Similarly, in a public transportation layout, Figure 34 shows the top view of the new design of the R160 car. By observation, it could be found that when people with wheelchair enter the door, they could always find the wheelchair space on the right side of the entrance. Such design demonstrates the standardization that the wheelchair space should be located on the right side of the subway door. Also, the standard could be set to locate the wheelchair space on the left side of the subway door, but the point is, a uniform standard should be set up, and is utilized in different kinds of public transportation, to let passenger be familiar

with the standard. In such circumstance, passengers will get used to different subway cars, even in different urban public transportation systems. Therefore, passengers will feel convenient in a familiar environment, and workers will find it easy for maintenance.

Despite the wheelchair space, more other facilities in the new designs follow the criteria of standardization, and have their own standards. For example, the foldable chair has its own standard that it has the ergonomic back design, and the height is adjustable; the width is the double size of a normal seat, so that people with different body size could use the foldable seats.

Other standardization examples may follow existing standards, like ADA standards. One typical ADA standard application is the font size of the digital information board. The font size also follows the perceptible information principle from UD. In this case, people with a decline in eye sight could see the information without problems. This is especially beneficial to older adults and people with disabilities. Specifically, in this new design, because the total width of the car is 120 inches (10 feet), according to ADA 703.5.5 (see Table 2), the height of the sign on the wall ranges from 40 to 70 inches, and the horizontal viewing distance is less than 120 inches. Thus, the minimum character height is 1.125 inches [5/8 + 4*(1/8) =1.125].

The other important criterion mentioned in EBD is sustainability. Sustainability means saving budget, space, and energy to optimize the current condition to meet more needs. Thus, in a public transportation environment, from the perspective of design, sustainability is concerned more about the utilization of space, or how to use limited space to meet the needs of more passengers. As mentioned in Chapter 3, the universal room design in a healthcare environment

could be transformed to cater to different care levels and conditions; thus, it is not necessary to arrange one room for a single purpose. Therefore, a universal room could meet many healthcare needs. Similar to the concept, the new R160 car design shows that the wheelchair space and foldable seats could be transformed between each other. Considering that the wheelchair space would not be occupied all the time, such space should be used for other passengers. The sustainability concept leads us to think whether the space can be used to sit when there is no wheelchair and whether the foldable chair can be designed to adapt to passengers with different body size, especially for passengers with obesity. Those sustainability considerations help form the new design of the wheelchair space, with a larger size and height adjustable foldable seats, and enables multiple uses within a limited space.

4.3.3 Preventive Healthcare

Figure 35: Ergonomic Bench

Considering the physical and psychological needs of older adults during their travel, preventive healthcare is an important concept in our public transportation guidelines. Preventive healthcare helps passengers feel relaxed, and

prevents them from developing some chronic age-related diseases, injuries and disorders when they interact with facilities in public transportation.

Ergonomics and biophilia are two key words of preventive healthcare. Ergonomics concerns interaction with facilities, and tries to reduce fatigue, prevent or delay chronic age-related diseases when passengers take public transportation. Figure 35 demonstrates the ergonomic benches in the new design of the R160 car. In the existing bench design in the current R160 car, the benches are made of rigid plastic without cushions, so passengers, especially older adults, would feel fatigue during long sitting periods. The newly designed benches use cushions, and apply the ergonomic chair design. The back of the bench follows the shape of human spine, which helps relieve fatigue during a long trip, prevent long-term diseases and delay decline in

Figure 36: Plant Pattern Decoration

physical body functions, when older adults take certain public transportation regularly.

Biophilia uses nature elements to amuse passengers, which helps them get rid of stress and feel relaxed. This is especially true for older adults, who may feel extra stress because they usually stay at home alone. The nature elements meet their psychological needs, by getting rid of loneliness caused by bricks so they can enjoy the vitality of nature. This is a kind of intuition inherited in human. Thus, the application of nature or nature elements could let older adults and other passengers feel enjoyment, which is supported by research mentioned in Chapter 2. Figure 36 displays a nature-related pattern on the wall of the car. Because the subway is underground, it is difficult to put large areas of green space in the station; thus, the symbolic is the best option to apply the biophilia concept. Compared to the blank wall in the current R160 car, the new design imbeds the nature elements and try to builds a relaxed atmosphere for the passengers, thus providing relief and confidence in taking public transportation and enjoyment of urban life. Also, passengers would feel bored when they see the same nature-related pictures or patterns everywhere in urban public transportation; thus, in this case, the patterns should be changed regularly, for example, every season, to create interest in the art designs. The public transportation owners and planners could also host nature-related pictures and patterns design competitions, to enrich the pattern designs in public transportation as well as absorbing investments.

4.3.4 Universal Design (UD)

Equitable Use

Accessibility is one of the applications of equitable use, which is also in line with the accessibility criteria in “third place” theory. Accessibility in the interior considers the group of people who suffer from physical body decline and disability, many of whom are older adults, to try to make the public transportation services available to more people. In such a design environment, passengers could choose the seats or the space that they can use, to equitably use the facilities and services in the newly designed R160 car environment.

Another example of equitable use is the ring handles hanging on the ceiling of the car. People are different in anthropometry. In the original design, all the ring handles in the environment are equal in height, which is not equitable for all the passengers, because passengers have different heights. Relatively tall passengers could use the ring handles while shorter ones, like older adults may not. In order to enable more passengers to use the ring handles, and meet

Figure 37: Equitable Use of Ring Handles

the criteria of equitable use, the ring handles should have different height choices. Figure 37 shows that there are two kinds of handle height in the new design. The lower ones are set at 1649 mm high, the upper ring handles are set at 1786 mm high, and the overhead pole heights are set at 1884 mm. In such a design, passengers could choose the ring handles they would feel are the most convenient.

The vertical pole handles are another example of equitable use. Traditionally in many metro car design interiors, the vertical pole is a single pole that could only be used by a limited number of people, because there is not enough space around the vertical pole. The new design divides the single pole into three poles in the middle part of the pole, and extends the arms a little bit outwards. This design, also shown in Figure 37, extends the pole usability area, and more people with different anthropometry could use the vertical poles. Thus, such a design meets the criteria of equitable use by enabling more passengers to use the facility.

Not only should equitable use be applied to physical needs of passengers, but also psychological needs should be considered equally. Accessible facilities in some public transportation design have a wheelchair sign that indicates that such space is especially for people with wheelchairs. To some extent, people with wheelchairs, many of who are older adults may feel that they are treated differently, they need special care from others, and they are hardly able to take the public transportation by themselves. In this case, they are not treated equally, as there are big wheelchair signs, or words on the floor or wall, indicating they need “special care.” They may feel they are different from other passengers and tagged as “require accessibility,”

which may make them uncomfortable. In order to show respect to these people and remove the tag of “dependent people and need special care”, the wheelchair related signs or words should be removed, and more and more universal facilities should be introduced in public transportation to meet the needs of older adults as well as other passengers to be equitable use.

Flexible in Use

Flexibility is another important criterion and is also in line with equitable use and accessibility in “Third Place” theory. This theory aims at providing public transportation to more groups of passengers, especially older adults. Flexible in use is especially important in urban public transportation, because it is usually crowded. If some facilities cannot be flexible to cater to different situation and needs, they would be a waste of space.

The original design shows no flexible facility is available in the car interior, which indicates that the facilities are limited in flexibility and may not appeal to all passengers. Compared to the original design, the new design demonstrates several facilities that are flexible in use. The featured one is the wheelchair space. This unit consists of a wheelchair space with a fastening belt on the floor and a foldable chair which could be pulled down when there is no

Figure 38: 3 Conditions of Foldable Chair

wheelchair space required. The foldable chair is flexible in use in that its height is adjustable, and the seat is wider enough for people with certain needs, like people with obesity or pregnant women. Figure 38 shows how the foldable chair could be pulled down or pushed up, and how the height could be adjusted.

Simple and Intuitive Use

These criteria consider the facilities that may be complicated in use. People usually do not want a complex dashboard or instructions as if operating a jet plane. They just want to use simple motions to use facilities in public transportations. Simple motions, like stand and sit, push a button and pull a line, etc. should be considered in the design of the facilities in metro car design as well as other public transportation methods, because intuitive use enables people to be

Figure 39: Buttons in Poles, Hammers and First Aid Box

familiar with the use of certain facilities quickly and use them safely. If the use of the facilities requires more than simple motions, simple instructions should be used to illustrate the steps of operation, and illustrations are better than words to demonstrate complex steps.

There are several facilities that show simple and intuition use (see Figure 39). There is a red button on the vertical poles in the car interior marked as “attention” to let the drivers or metro operators to be aware of the situations near the button area. For example, when the car stops at a station, there are many passengers getting off the car. If there is a person in a wheelchair wanting to get off, it may take some time to unfasten the wheelchair, and wait for the person to disembark. Thus, it is necessary to push the button to alert the driver that more time is required before closing the door. Meanwhile, driver could see the situation near the door through monitors. Such buttons could also be used in an emergency. Similar buttons like the “stop requested” button in buses also follow the same criteria.

Other small tools in the interior are also intuitive in use. For example, there are many safety hammers hanging near the windows; people would intuitively use them when there is an emergency if they need to break the windows to escape. The first aid boxes located in the corner of the car are also intuitive to use. In additional, passengers would intuitively choose the convenient height when they first see the ring handles with different heights.

Foldable seats explained previously also follow the simple and intuitive use criteria. Because foldable seats are commonly used in movie theaters and many public arenas, people are very familiar with such kinds of facilities. When there is a sign near the foldable seats that shows

the switch between seat mode and wheelchair mode, passengers would easily understand how and when to use the foldable seats. If there is no wheelchair, passengers simply pull down the seat; if there is a need of wheelchair space, passengers simply push up the seat. Such a process is easy to understand without any ambiguity.

Perceptible information

This criterion suggests that the information in public transportation, such as arrival of stations, stop list, facility instructions etc., should be easy to perceive. The information could be informed through formats like words, pictures, digital boards, voice, and the combinations of some of these methods. It is becoming more important to use the combinations of some of these delivery methods, considering the physical perception decline of many older adults, in order to enable them to perceive the information clearly.

The original car interior gives us a good example of perceptible information – the digital information board. The digital LCD information boards are hanging up on the wall, so many people could see them. The biggest advantage of using digital boards is that it provides instant information

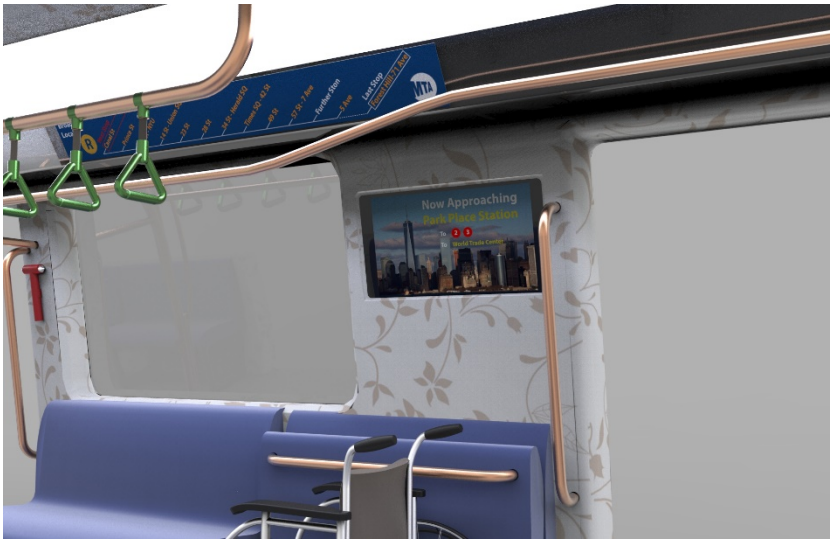

Figure 40: Digital Information Boards

of stops, and informs passengers of their locations and time of travel, as well as the next stops. Also, some small LCD panels on the ceiling of the car would also display the names of the stations, as well as an intercom giving a voice report when approaching stations. Traditionally, there were only stop lists displayed in public transportation; passengers should listen to the voice report to get informed of the stops. If they do not hear the voice clearly, they have to observe the outside environment, or try to find signs or some landmarks outside the public transportation. Compared to the traditional methods, the original R160 car design is much improved to increase convenience for urban passengers more convenient when they use public transportation. The new design (see Figure 40) uses a similar way to display information, but the information not only includes stops and time of travel, but also includes environments outside the stations, like weather and traffic nearby. The stations information board, the small LCD panels and voice report are synthesized as a system to enable passengers, especially older adults, to perceive information clearly and conveniently.

Another example is the instructions. In the new design, the wheelchair space with a foldable seat will be introduced. Even though the use of such space is intuitive, instructions are still needed to guide passengers who are not familiar with the use. As discussed in the criteria of simple and intuitive use, instructions with illustrations are better than words; thus, in the new design, illustrations are used to demonstrate how to use the wheelchair space. Perceptible information not only refers to the ease of seeing, but also understandability by passengers. Thus, the illustration instructions are easy, clear and understandable for older passengers and other

passengers to perceive.

ADA standards are the standard considerations for the design of public transportation interior. ADA has standards of the size of the words and pictures within certain distances (see Table 2). Thus, the design in words and pictures in signs, instructions and digital boards should follow ADA standards to be able to meet the requirements of government laws, as well as making passengers perceive information conveniently.

Tolerance for Error

The criteria of tolerance for error is normally applied when people interact with machines. For example, in elevators, when the door is closing, if the door detects any object across the door, the door would open again. Such features help protect people from getting hurt by the door, because usually the objects are human hands or bodies. This is the so-called fail-safe feature. Such features are also widely applied in public transportations because there are large numbers of people go through the doors every day.

Also, in the new design of the car interior there are buttons in the vertical pole. This design also follows the criteria of tolerance for error. Such “error” happens when it is crowded in the metro car interior, and the person in a wheelchair wants to get off the metro car, it may take some time because of the crowds, while the door may remain open for only seconds. In order to increase tolerance of such an “error”, instead of using hands to hold the door, someone can just push the button to indicate to the driver or the metro system that more time is needed to keep the

door open, because there are more people needing to exit or enter the space. Other fail-safe features include the buffer system in the foldable seats, as discussed in Chapter 3 - universal design, Principle 5. The spring in the spindle of the foldable seats may be very rigid and strong, so if someone pulls it down but it slips from the hand, the seat would quickly go up and it may hurt someone. Thus, in order to provide a fail-safe feature, a buffer system should be installed in the foldable seats so that even when the seats slip out of people's hands when pulling them down, the seats would go up slowly and not hurt anyone.

Low Physical Effort

The criterion of low physical effort is more closely related to ergonomics, which is also in line with preventive healthcare. The criterion is concerned with how to lower effort when passengers interact with facilities and, in the long term, try to prevent or delay some physical illness, which is especially true for older adults. The typical low physical effort example is the ramp or lift, which is used to help wheelchairs enter the public transportation interior. This happens when the entrance of the public transportation is higher than the outer floor, such as with buses. However, in a subway system, most subway station floors are the same level as the entrance of the metro car, so this would not be a problem for metro. In the new design of the R160 car, the low physical effort examples come from mainly two parts: the ergonomics, which is also explained in tolerance for error, and the font size of the signs on the wall. Proper size fonts which meet the ADA standards enable people to spend less effort to see the signs.

Size and Space for Approach and Use

Figure 41 demonstrates how the space meets the criterion of the principle. The original width of the door of R160 is 50 inches (4 feet 2 inches), so the width meets the ADA standards that the minimum width for the wheelchair to pass is 36 inches. However, considering an aging population and the metro has been equipped with handicapped facilities, the door of the metro should be wider. The new design reduces the number of doors from 4 to 3, but sets the width of each door to 72 inches, which is the double size of the minimum requirement of ADA. This also means wheelchairs could get on and off through the same door at the same time.

Wheelchair space in the new design also follows the ADA standards. The width of the car is 120 inches (10 feet); the wheelchair space is 36 inches by 48 inches. So even if both side of the wheelchair spaces are occupied, there is still enough space in the middle for passengers and wheelchairs to pass.

Another size to consider for this approach is the ring handles. In order to cater to passengers with different anthropometry, especially different heights, ring handles of different heights are necessary. The lower ones are set at 1660 mm (65.4 inches) high, the upper ring handles are set at 1760 mm (69.3 inches) high, and the overhead pole heights are set at 1880 mm (74 inches. see Case 3, p. 50). This design is based on data and evidence to make public transportation cater more to older adults, as well as other age groups of passengers. These features are shown in Figure 41: the width of the door way, the wheelchair space, and different

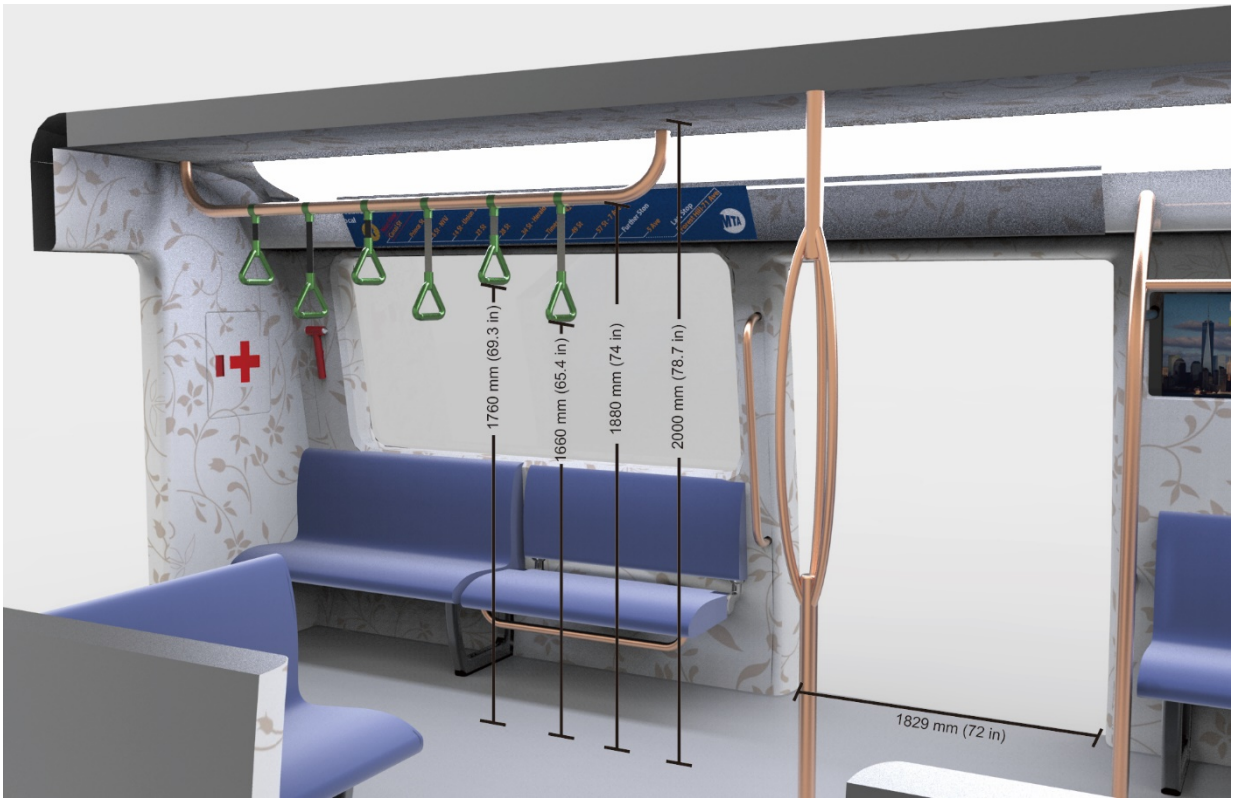

Figure 41: Size and Space for Approach and Use

heights of ring handles follow the criterion of Size for Approach and Use, as well as benefiting both older adults and other age groups.

4.4 Summary

In this chapter, a new design of R160 car is introduced. Compared to the original R160 car design, the new design follows guidelines developed in this thesis, improving the existing design by applying related design theories, concepts and standards. These changes should improve the quality of the experience when older adults take public transportation, enabling them to enjoy social engagement and urban life more fully.

4.5 Model Making Process and Exhibition

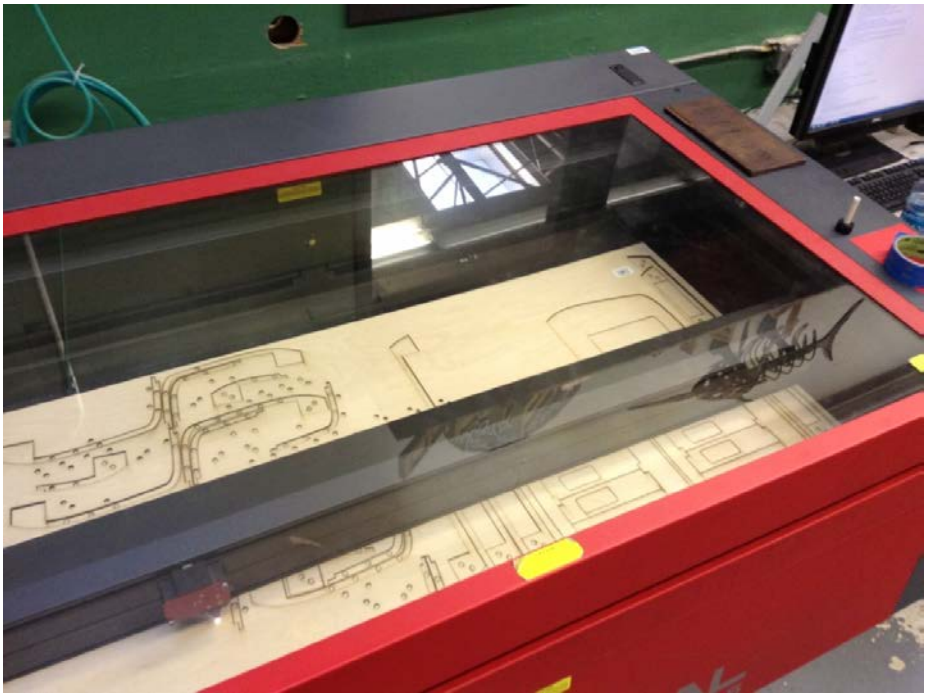

Figure 42: Model Making Process: Laser Cut

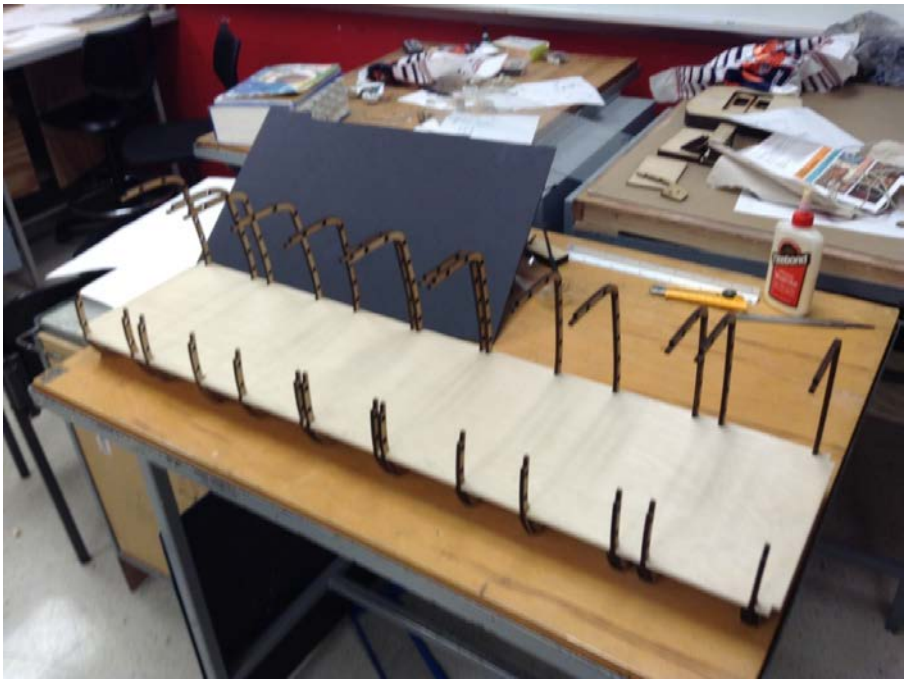

Figure 43: Model-Making Process: Frame Assembly

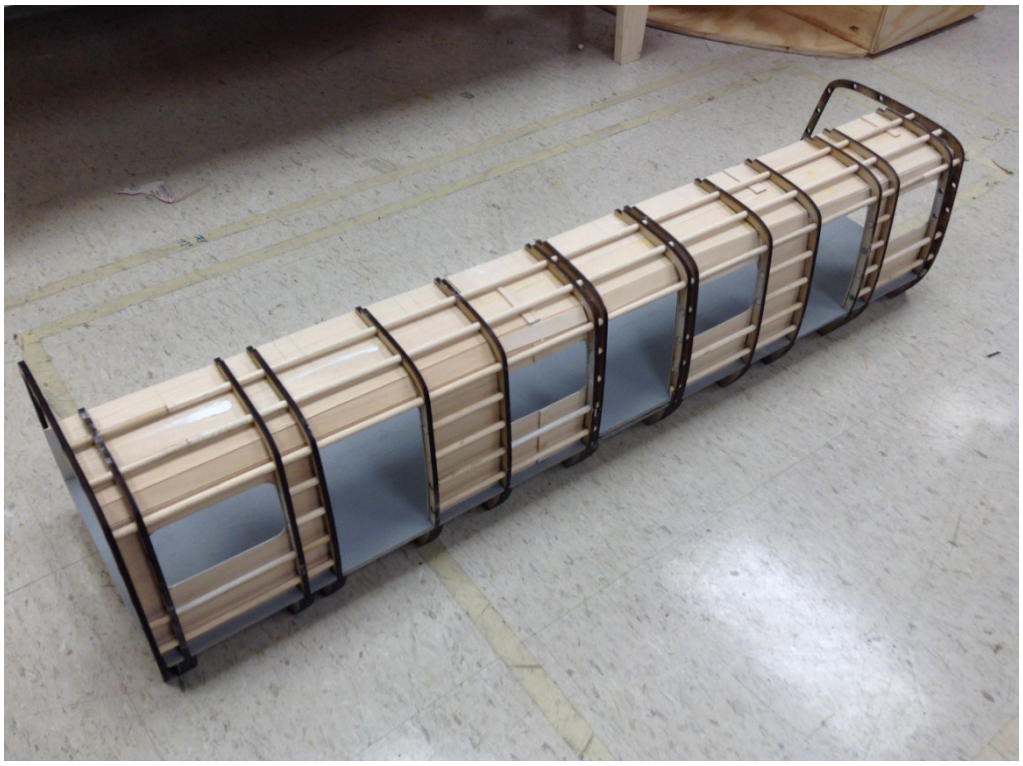

Figure 44: Model Making Process: Frame Assembly 2

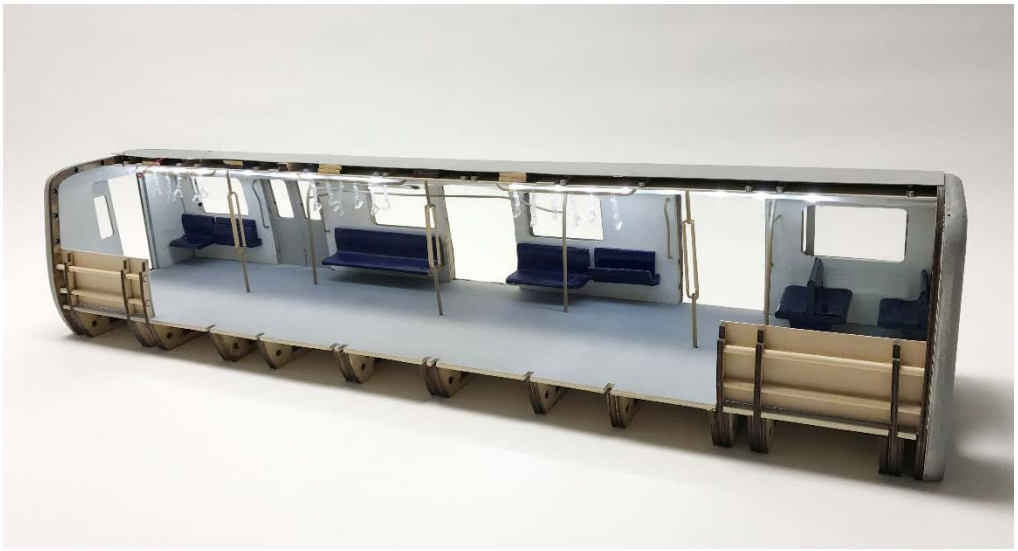

Figure 45: Model Perspective View

Figure 46: Model Details

Chapter 5: Summary and Conclusions

5.1 Summary

An aging population aging is occurring all over the world. Much research which studies population aging and affairs concerning older adults indicate that our society should be aware of the impact of such phenomenon and focus on how to maintain balance to improve living quality and well-being of older adults. Now, more and more countries pay attention to these issues and are trying to improve the social welfare of older adults in our society. Public services and facilities, especially for older adults, are provided in many aspects in our society, and they are beneficial to older adults to some extent. However, our public services still have much space to improve for older adults as well as other groups, as some of the facility designs considered in this thesis did not really consider the actual physical and psychological needs of older adults. Therefore, older adults may feel it is too difficult or are not willing to use the facilities considered here.

This study focused on the public transportation how the interior services and facilities could meet the needs of older adults. First, much research studies the facilities for older adults in static environments, like healthcare institutes, local houses etc. Also, some studies tried to improve the facilities in transportation environment generally. However, there is a research gap in that few studies focused on how to improve facilities especially for older adults. Older adults

need more consideration in design because of physical and cognitive declines. Once the facilities meet the needs of older adults, the environments are also easy to transform to meet needs of other group of peoples in general.

Second, in order to improve public transportation services and facilities for older adults, we should know the transportation needs of older adults. As deducted in Chapter 2, social engagement is a key need of older adults, as social activities and communications enable them to get rid of loneliness or other psychological issues as well as meet their psychological needs of getting involved in our society. Also, improved design meets their physical needs, so even if they suffer from physical body function declines, they can still use public transportation facilities without difficulties, and older adults could use public transportation as easily as other demographics. Thus, the enhancement of public transportation for older adults makes a significant contribution to improved living quality of older adults in urban areas.

Third, in order to fill the research gap, studies from related research areas could be modified and applied to public transportation interior facilities. As discussed in Chapter 3, four theories and concepts from public spaces, product design principles, and the healthcare field are modified and applied to form public transportation design guidelines for older adults in urban areas. Even though these theories and concepts came from different research areas, they interrelated and could be synthesized after application. In other words, many of the design following one criterion could be explained by other concepts in the guidelines; thus, all the criteria form holistic guidelines to help improve public transportation for older adults.

Four, the guidelines were applied to improve a specific public transportation environment to examine whether these guidelines are reliable and appropriate. Guidelines could be modified during and after application. Because the guidelines are general rules, certain changes should be made to cater to particular environments and situations.

5.2 Conclusions

This study tried to fill a research gap by forming holistic design guidelines to improve public transportation interiors to meet both physical and psychological needs of older adults. Four main theories and concepts from different research fields are modified and applied to form the guidelines: “third place” theory, seven principles of universal design, evidence-based design and preventive healthcare. The guidelines are proven and supported by credible research and should help improve travel quality of older adults as well as other people.

The application of the guidelines to a specific public transportation interior, the New York subway R160 car, indicates that these guidelines meet specific needs of older adults, like social engagement in face-to-face seats design, same-handed space design in wheelchair space arrangement, flexible use in foldable seats, etc. Therefore, the guidelines developed in this thesis are proven to ease and benefit the mobility of older adults, enhance their connections to our society and improve their urban living quality, in the background of global population aging.

However, the guidelines also have some limitations, so they will need further refinements to be extended to a broad range of use and application in the future.

5.3 Limitations and Future Applications

As discussed, there are some limitations that, once addressed, could improve the guidelines in the future.

First, the study only reviews limited numbers of design related principles and theories. Thus, more design theories and principles could and should be reviewed so that more essential design principles could be applied to enrich the guidelines, enabling the guidelines to consider design issues for older adults from broader perspectives. More design considerations and principle/theory applications for guidelines dig into issues deeply, thus benefiting the travel of older adults by the addition of more details.

Second, currently, the guidelines are only for public transportation in urban areas, because the case studies in the research were facilities and services from urban areas aimed at benefiting a large population. Because there are limited resources and facilities outside urban areas, non-urban applications were not considered. Rural areas usually have a smaller population and poor road conditions and may not consider the facilities and services for special needs, like older adults, despite the trend that older adults are moving out of urban areas. But in the future, limited conditions outside of urban areas would be improved, and we are looking forward to extending our guidelines to more rural areas to benefit more of the aging population.

Third, the guidelines currently only focus on public transportation. It would be good to see whether the guidelines could be applied to more design fields of use. Design is generally

interrelated, so the designs here could be modified and applicable to other design fields, similar to the study of design principles from healthcare field and application to public transportation interior design. Therefore, a useful extension of these guidelines would be their application to other design fields to benefit more of the aging population in other public services.

Fourth, the guidelines could be refined and improved to apply to more countries in the world. Currently, two aspects could cause limited applicability of the guidelines to other countries. One is the reason that there are huge development imbalances across the world, so there is still a long way for many countries to improve their public facilities and services, regardless of the country's development. The other aspect is compatibility. Because of the gaps in languages, cultures, design and safety standards etc., there is still a long way to apply such transportation design guidelines to other countries. However, because improvement of living quality is a primary goal of design and development, cooperation to enhance application of these guidelines is a real possibility.

Fifth, this study is based on the assumption that the application of the guidelines has full financial, technological and management support. In reality, the application is really subject to government budget, technological limits and passenger flow management. For example, the new metro car design introduced the face-to-face seat design; however, such a design occupies some space and may reduce the capacity of passengers of each car. Thus, either adding one more car to the metro or increasing frequency of the metro line to compensate could be considered. However, whether local government has the budget to add one more car or increase the frequency is

questionable, and how to manage the frequency of the metro system is another field of study, which was not considered. Therefore, in the future, such design guidelines should cooperate with other field of design, like economics, technology, management, etc., to help realize the application of the design guidelines and benefit older adults and more other demographic of people in reality.

Sixth, the judgements of the New York Subway R160 car is based on the car data, engineering drawings, photos of the interior and personal experiences. There may be bias for the judgement when only referring to data and personal experience. Future research could also survey the passengers who have took the R160 train, and statistically analyze the advantages and disadvantages, to avoid the bias and obtain more objective judgements of the car.

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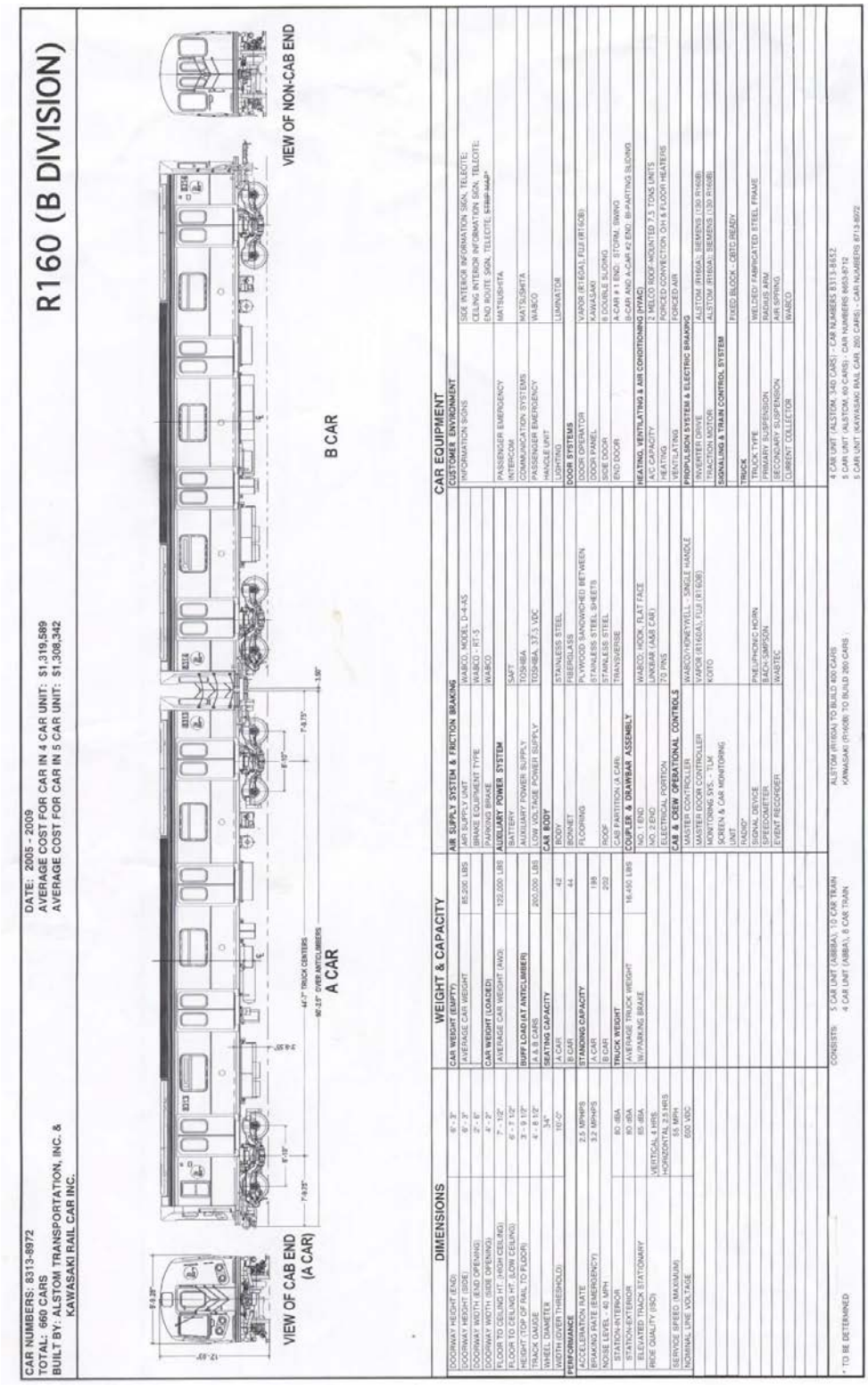
Appendix 1: R160 Car Configurations



CAR NUMBERS: 8313-8972
TOTAL: 660 CARS
BUILT BY: ALSTOM TRANSPORTATION, INC. & KAWASAKI RAIL CAR INC.

DATE: 2005 - 2009
AVERAGE COST FOR CAR IN 4 CAR UNIT: $1,319,589
AVERAGE COST FOR CAR IN 5 CAR UNIT: $1,308,342

R160 (B DIVISION)

VIEW OF CAB END (A CAR)

A CAR

B CAR

VIEW OF NON-CAB END

DIMENSIONS		WEIGHT & CAPACITY		AIR SUPPLY SYSTEM & FRICTION BRAKING		CAR EQUIPMENT	
		CAR WEIGHT (LIGHT)				CUSTOMER ENVIRONMENT	
DOORWAY HEIGHT (END)	6' - 3"	AVERAGE CAR WEIGHT	85,500 LBS	AIR SUPPLY UNIT	WABCO, MODEL D-4-A5	INFORMATION SIGNS	SIDE INTERIOR INFORMATION SIGN, TELECITE; CEILING INTERIOR INFORMATION SIGN, TELECITE; END ROUTE SIGN, TELECITE, ~~STRIP MAP~~
DOORWAY HEIGHT (SIDE)	6' - 3"			BRAKE EQUIPMENT TYPE	WABCO - R1-S		
DOORWAY WIDTH (END OPENING)	2' - 6"	CAR WEIGHT (LOADED)		PARKING BRAKE	WABCO		
DOORWAY WIDTH (SIDE OPENING)	4' - 3"	AVERAGE CAR WEIGHT (AW2)	122,000 LBS	AUXILIARY POWER SYSTEM		PASSENGER EMERGENCY	MATSUSHITA
FLOOR TO CEILING HT. (HIGH CEILING)	7' - 1/2"			BATTERY	SAFT	INTERCOM	
FLOOR TO CEILING HT. (LOW CEILING)	6' - 7 1/2"	BUFF LOAD (AT ANTICLIMBER)		AUXILIARY POWER SUPPLY	TOSHIBA	COMMUNICATION SYSTEMS	MATSUSHITA
HEIGHT (TOP OF RAIL TO FLOOR)	3' - 9 1/2"	A & B CARS	200,000 LBS	LOW VOLTAGE POWER SUPPLY	TOSHIBA, 37.5 VDC	PASSENGER EMERGENCY	WABCO
TRACK GAUGE	4' - 8 1/2"	SEATING CAPACITY		CAB BODY		HANDLE UNIT	
WHEEL DIAMETER	34"	A CAR	42	BODY	STAINLESS STEEL	LIGHTING	LUMINATOR
WIDTH (OVER THRESHOLD)	10'-0"	B CAR	44	BONNET	FIBERGLASS	DOOR SYSTEMS	
PERFORMANCE		STANDING CAPACITY		FLOORING	PLYWOOD SANDWICHED BETWEEN STAINLESS STEEL SHEETS	DOOR OPERATOR	VAPOR (R16GA), FUJI (R16GB)
ACCELERATION RATE	2.5 MPHPS	A CAR	198			DOOR PANEL	KAWASAKI
BRAKING RATE (EMERGENCY)	3.2 MPHPS	B CAR	202	ROOF	STAINLESS STEEL	SIDE DOOR	8 DOUBLE SLIDING
NOISE LEVEL - 40 MPH		TRUCK WEIGHT		CAB PARTITION (A CAR)	TRANSVERSE	END DOOR	A CAR # 1 END - STORM, SWING A CAR # 2 END, B CAR - SLIDING
STATION-INTERIOR	80 dBA	AVERAGE TRUCK WEIGHT	16,450 LBS	COUPLER & DRAWBAR ASSEMBLY		HEATING, VENTILATING & AIR CONDITIONING (HVAC)	
STATION-EXTERIOR	80 dBA	(W/ PARKING BRAKE		NO. 1 END	WABCO, HOOK, FLAT FACE	A/C CAPACITY	2 MELCO ROOF MOUNTED 7.5 TONS UNITS
RELOCATED (TRACK STATIONARY)	85 dBA			NO. 2 END	UNIBAR (A&B CAR)	HEATING	FORCED CONVECTION, DH & FLOOR HEATERS
RIDE QUALITY (SPD)	VERTICAL 4.0 MPS			ELECTRICAL PORTION	70 PINS	VENTILATING	FORCED AIR
	HORIZONTAL 2.5 MPS			CAB & OPER. OPERATIONAL CONTROLS		PROPULSION SYSTEM & ELECTRIC BRAKING	
SERVICE SPEED (MAXIMUM)	55 MPH			MASTER CONTROLLER	WABCO HONEYWELL - SINGLE HANDLE	INVERTER DRIVE	ALSTOM (R16GA), SIEMENS (130 R16GB)
NOMINAL LINE VOLTAGE	600 VDC			MASTER DOOR CONTROLLER	VAPOR (R16GA), FUJI (R16GB)	TRACTION MOTOR	ALSTOM (R16GA), SIEMENS (130 R16GB)
				MONITORING SYS. - TLM	KOITO	SIGNALING & TRAIN CONTROL SYSTEM	
				SCREEN & CAR MONITORING UNIT			FIXED BLOCK - CBTC READY
				RADIO*		TRUCK	
				SIGNAL DEVICE	PNEUPHONIC HORN	TRUCK TYPE	WELDED FABRICATED STEEL FRAME
				SPEED SENSOR	BLECKMANN	PRIMARY SUSPENSION	RUBBER AND COIL SPRING
				EVENT RECORDER	MAINTEC	SECONDARY SUSPENSION	AIR SPRING
						CURRENT COLLECTOR	WABCO

* TO BE DETERMINED

CONSISTS: 5 CAR UNIT (ABBBA), 10 CAR TRAIN
4 CAR UNIT (ABBA), 8 CAR TRAIN

ALSTOM (R160A) TO BUILD 400 CARS
KAWASAKI (R160B) TO BUILD 260 CARS

4 CAR UNIT (ALSTOM, 340 CARS) - CAR NUMBERS 8313-8652
5 CAR UNIT (ALSTOM, 60 CARS) - CAR NUMBERS 8653-8712
5 CAR UNIT (KAWASAKI RAIL CAR, 260 CARS) - CAR NUMBERS 8713-8972