The Evaluation on Walkability in an Aging Society: the Case of Senri New Town, Japan

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Abstract. This study aimed to enhance urban environments for the elderly by assessing walkability in the Takanodai area of Senri New Town, Japan. Seven indicators for walkability were selected through a literature review, and a quantitative evaluation using the seven indicators was conducted. The results are presented in a heat map of walkability, and shows that pedestrian-only paths scored lower than roadways in detached house residential areas. This suggests that slopes and stairs of pedestrian-only paths were not considered obstacles at the time of construction of the new town, and have remained unchanged over time. It is possibly due to a low level of awareness on addressing barrier-free issues by whom? in the past. In contrast, pedestrianized street in public housing zone scored higher than others. The reason for this may be that the public housing zone was designed with better green space and sidewalks. The study's findings could inform improvement areas for future urban development for creating walkable cities accessible to all citizens.

Keywords: walkability, elderly, slopes and stairs, Newtown, urban development

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1.Introduction

In recent years, Japan has experienced a rapid aging of society with a declining birthrate, and there has been growing interest in the concept of compact cities, where urban functions are concentrated, and in the development of cities where people can reach daily amenities on foot. Against this social background, there is a need to develop urban environments that focus on the lifestyles and health promotion of the elderly. In Japan, however, there are still few studies on developing walkability index focusing on the elderly, and only a few of them focus on the evaluation of regional characteristics and real estate values, or on health promotion (Hanibuchi, 2011).

In Japan, the Ministry of Land, Infrastructure, Transport, and Tourism (MLIT) has begun to pursue the applications for "Walkability Promotion Cities" to encourage the development of cities where people can walk to their daily needs from 2019. The program encourages a shift from the car-centered society of recent years to the creation of a walkable city. This initiative is expected not only to create a rich, people-centered living space, but also to increase local consumption and investment, increase tourism, extend healthy life expectancy, prevent loneliness and isolation, and solve various local problems and create a new value for healthy living. The number of walkable cities is increasing every year, and by April 2024, 372 cities nationwide will be designated as walkable cities (The Ministry of Land, Infrastructure, Transport and Tourism, 2024).

The purpose of this study is to obtain key factors that will contribute to the development of urban environments for the elderly in preparation for an aging population in the future. As the first step, walkability indices in previous studies are reviewed, and an index for evaluating walkability for the elderly is developed for this study. Next, using the selected indicators, we evaluate walkability in the Takanodai area of Senri New Town, which has one of the most aged populations in Japan.

2. Literature review of previous studies

2.1 Recent Previous Studies

In this chapter, we conduct a literature review based on recent previous studies and create a simple and objective walkability index for the elderly. In order to develop the walkability index for the elderly, five recent studies were selected and the indices used in each study are summarized. We have selected these five studies because these studies introduced the walkability indices related to factors such as slopes and stairs influencing on the walkability of the elderly. Four of the five papers are published by Japanese authors and it was useful for us to look into previous work which addressed specific Japanese contexts and pointed out the issue of applying walkability indices developed in western countries for Japanese built environment.

Alves et al. (2020) aimed to create a walkability index for the elderly, focusing on "slope" and "stairs". The authors divided the three major categories for qualifying factors of public space into urban tissue (e.g. pedestrian surface quality, sidewalks existence and width, etc.), urban scene (e.g. existence of trees, vegetation, urban furniture), and safety (e.g. street lighting quality, diversity of information signs), and assigned appropriate weights and scores to each of these axes. They also focused on “slope” and “stairs” as factors that affect the ease of walking for the elderly. In order to evaluate the walkability of each street, a set of positive evaluation factors that increases walkability and negative evaluation factors that decreases walkability have been established. The three positive evaluation factors are related to urban tissue, urban scene, and safety, while the two negative evaluation factors are slope and stairs.

The three positive evaluation factors were selected based on a literature review of previous studies identified by Alves et al. (2020). The weighting of the three indicators is also determined based on their work: 60% of the total walkability index is allocated for urban organization, 24% for urban landscape, and 16% for safety. For the two negative indicators, slope and stairs are identified as factors that hinder walking activities for the elderly, and the criteria for the angle of the street slope are classified into three patterns: less than 5%, between 5% and 8%, and more than 8% (e.g. 10% is expressed as a rise of 1 meter after advancing 10 meters). The authors also developed a corresponding index for stairs, which was incorporated into the slope criteria rather than being considered separately from slope.

Morioka et al. (2021) pointed out in their study that walking behavior is classified into three categories based on previous research: 1) "necessary activity" that occurs due to necessity in public areas, 2) "voluntary activity" that occurs based on the individual's positive intention, and 3) "social activity" that occurs when others intervene in necessary or voluntary behavior. The "voluntary activities" are studied in this paper. Unlike "necessary activities," "voluntary activities," require an environment that is not only "easy to walk", but also "makes people want to walk" as a factor that induces walking behavior. The authors have identified "density," "facility density," "street form," "human scale," "landscape," and "public transportation" as urban indicators related to walking behavior based on a literature review of previous studies, and used the five indicators, while "public transportation," was excluded in their study. Of the five indicators, "density," "facility quality," and "street form" are used as environmental indicators that makes it “easy to walk”, while "human scale" and "landscape" are used as promoting factors to walk.

Kato and Kanki (2017) proposed a shift to "smart shrinking," in which residents themselves maintain an independent living environment by promoting community development that makes their own neighborhoods more attractive. As the first step to realize a smart shrinking, the concept of walkability has been developed mainly in the field of public health and used to create a regional evaluation index. From the index, they adopted the four elements of "household density," "convenience of local facilities," "road connectivity," and "local safety," which can be easily obtained by geographic information systems, from among the indicators used in previous studies. In their study, all of the indicators used to calculate walkability are on the scale of the city block, which can be easily processed by a geographic information system.

Shimizu (2020) aimed to develop a walkability index for the Japanese context. The Walkability Index developed by Shimizu (2020) is a 100-point scale that measures the concentration of urban amenities within walking distance of a given point. Urban amenities include convenience stores and drugstores, restaurants and cafes, and bookstores and cultural facilities. This study is similar to the Walk Score®, a well-known index developed in the U.S (Walk Score, 2024). The Walk Score® is a weighted score of neighborhood facilities based on their necessity and distance from a certain point, and is used to measure the neighborhood environment from the viewpoint of walkability. Walk Score® is widely used as an objective index to measure the neighborhood environment in terms of walkability. They have identified "property search," "community development," "real estate strategy," and "survey research" as scenarios for utilizing this index, and has succeeded in creating an intuitive and easy-to-understand index by displaying a heat map of the Walkability Index.

Itoh et al. (2021) classify the elements of walkability into three stages. The first stage is the urban environment and structure, the attributes of individuals (e.g. presence of sidewalks, crosswalk, etc.) and their purposes for walking, the second stage is the effects of the contents of the first stage on the quality of walking and the promotion of walking, and the third stage is the effects of the second stage on the city and individuals. Furthermore, when applying the Walkability Index developed by Frank et al. (2005) in the Japanese context, it is necessary to consider the relationship between the urban environment and structure and the quality of walking. The paper then identified three key indicators of walkability quality: "accessibility," "comfort," and "safety," and examines their relationship to the urban environment and urban structure, respectively.

Based on the above walkability indices used in these previous, we selected several appropriate ones for the elderly and adopted them as the walkability indices in this study.

2.2 Results of Indicator Selection

The following table is a summary of the indices used in the above previous studies (Table 1). We have identified four categories (Street conditions, Land utilization, Landscape, and Safety) which are drawn upon most frequently used indicators from the five studies we reviewed. Then, one or more indicators were adopted from each category Presence of sidewalks, pavement condition, stairs, slopes, and street lighting can hinder the elderly from walking. In contrast, park space and green space can have positive effects for the elderly, as they are encouraging them to walk.

In this study, the following seven items are decided to form a walkability index (Table 2) in order to create an objective and simple walkability index and to evaluate the walkability of each street.

Table 1. Results of the literature review and indexes used in this study

	Street conditions							Land utilization					Landscape			Safety			
	presence of sidewalks	pavement condition	width of a street	stairs	distance to public transportation	Intersection density/road accessibility	slopes	population density/household density	medical and welfare facilities	educational facilities	commercial facilities	park space	green space	percentage of water surface	urban furniture	street lightning	information sign	crime and accident rate	amount of traffic
Alves et al. (2020) Walkability Index for Elderly Health	○	○	○	○		○	○						○		○	○	○		
Morioka et al. (2021) A Study on Walkability grasped from Environment both of "Easy to Walk" and "Encouragement to Walk" that supports Walking			○						○	○	○	○	○	○					
Kato and Kanki(2017) Development and Verification of Indicator about Regional Evaluation based on walkability in Residential Area			○					○	○	○	○	○						○	
Shimizu(2020) Development of Walkability Index					○				○	○	○	○							
Itoh et.al. (2021) A Study on the Conceptual Framework of Walkability and Issues for its Application in Japan						○													○
Indices adopted in this study	○	○		○			○					○	○			○			

Furthermore, the following walkability index and its criteria are defined and applied in one case study area in Senri New Town. The walkability index developed for this study is defined as the average of the scores of all seven items: presence of sidewalks, pavement condition, stairs, slopes, park space, green space, and street lighting. Each item is rated from 1 to 3 points according to conditions identified in Table 2. For example, different scores are given to the presence of sidewalk: 1 for “no sidewalk on both sides of road”, 2 for “only on side walk” and 3 for “sidewalks exist on both sides of the road or street is pedestrianized”. All streets were surveyed using Google Street View. For streets not supported by Google Street

View, the survey was conducted on site by Aida. It is therefore noted that the research is based on a subjective view of the researcher.

Table 2. Indices and Walkability Score

Indices		Criterion	Score
Street conditions	presence of sidewalks	no sidewalk on both sides	1
		on one side only	2
		exists on both sides / pedestrians only	3
	pavement condition	bad coditions	1
		some steps or obstacles	2
		good conditions	3
	stairs	some stairs exist	1
		no stairs exist	3
	slopes	less than 5%	1
		more than 5% and less than 8%	2
		more than 8%	3
Land utilization	park space	Parks are available for rest while walking	1
		no parks to rest while walking	3
landscape	green space	less than 20%	1
		more than 20% and less than 25%	2
		more than 25%	3
safety	street lighting	no lighing on both sides	1
		on one side only	2
		exists on both sides	3

For the selection of the reference value for “slopes,” in the previous study by Alves et al. (2020) was used. The selection of the reference value for “green space” was based on the results of a social experiment conducted by the Ministry of Land, Infrastructure, Transport and Tourism (2005) and the evaluation criteria used at the Voluntary Simplified Assessment Site (2014). According to these studies, more than 25% green space of the total area space of a city is sufficient to be considered to have an attractive urban environment, while less than 20% is considered as insufficient.

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3. Application of walkability index in the Takanodai area

3.1 Site Selection

In this study, Takanodai 2-chome, a neighborhood of within Senri New Town the Suita City, is selected as the site for the field survey.

Senri New Town was the first large-scale new town in Japan, which was planned to cope with the housing shortage caused by population growth in the postwar 1950s. To prevent urban sprawl caused by housing shortages and to provide inexpensive, high-quality housing to the public, Osaka Prefecture began development of Senri New Town in 1960 in the Senri Hills in the northern part of the prefecture. The planned site was 1,160 hectares, which spanned the current cities of Toyonaka and Suita, and had a planned population of 150,000 people. A major feature of the project was the emphasis placed on creating a favorable living environment. The entire new town is surrounded by green areas, and parks and schools are systematically located based on the neighborhood residential area theory systematized by Clarence Arthur Perry (Discover Senri, 2022) in the 1920's. The coverage of green area of the new town is more than 20% of the total area space.

In addition, the walking environment for residents was comprehensively developed. In the early stage of the development, the separation of pedestrians and cars was achieved by arranging cul-de-sacs according to the Radburn method (Discover Senri, 2022), and in the late stage of the development, the separation of pedestrians and cars was achieved by using pedestrian bridges following the idea of Buchanan report (Buchanan, 1963). To contain traffic and segregate cars from pedestrians, the planning of the new town took advantage of the undulating topography of the Hokusetsu area where the main part of the new town was planned.
In the Takanodai area, the current challenges are to cope with the aging of housing and to provide a variety of housing styles. Furthermore, the proportion of elderly residents is particularly high in Senri New Town, with 14.4% of the residents are aged between 65 and 75and 24.5% are older people aged 75 and over, for a total of 38.9% in the 2020 survey. The Takanodai area consists of the highest proportion of elderly residents among all 12 residential districts in the new town. This ratio is much higher than the average of all 12 residential districts in Senri New Town, where 11.7% of the residents are aged between 65 and 75 and 18.1% are older people aged 75 and over, for a combined ratio of 29.8%. Among them, 2-Chome (a small district within a neighborhood) maintains a diversity of urban amenities with a moderate

number of schools and detached houses, and is not limited to residential function of public housing. For these reasons, the area was considered to be as mixed-used area and an appropriate case for applying the walkability index.

Fig.1 shows a street map of Takanodai 2-Chome area. The area can be divided in two zones according to housing styles: A zone shows the public housing zone (predominantly medium and high-rise apartment blocks), and B zone shows the detached housing zone.
In order to conduct the survey systematically, we have decided to assign a point number to the intersection of streets in Takanodai 2-Chome. The streets connecting the two numbered points are given names. (e.g. The street connecting points “m” and “n” is named "Rm,n".). ‘R’ indicates roads.

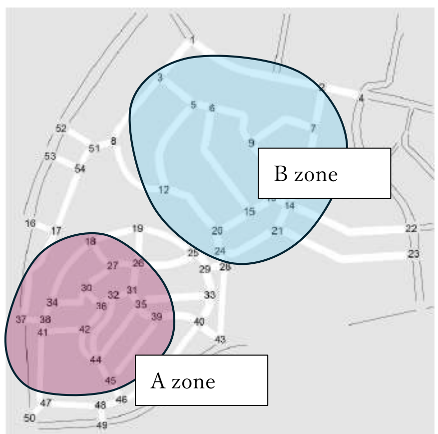

Figure 1. Street Map of Takanodai 2-chome (Source: Aida, 2024)

3.2 Walking Environment in the Takanodai Area

The Takanodai area was one of the first residential areas developed in Senri New Town, and was planned to be separated from pedestrians and vehicles by a cul-de-sac and a pedestrian footpath. A cul-de-sac is a type of street design to prevent through traffic. The cul-de-sac was extensively used in the early development areas of Senri New Town to separate vehicles from pedestrians. The Takanodai area is one of typical applications of the cul-de-sac design.

Figure 2 below shows a street planned as a pedestrian footpath called *Suita-Takanodai private line*. These footpaths were constructed in March 1984, so approximately 40 years have passed from the start of their use. The streets that include these exclusive footpaths are R3,5, R6,9, R6,15, R7,9, R7,10, R10,11, R10,14, R14,21, R16,17, R17,37, R21,23, R21,24, R51,52, R53,54, and 14 street connecting points in total.

In addition, there are streets in the public housing zone (Zone A) that are pedestrianized streets because vehicles cannot enter, and these are shown in Figure 3. These streets include R18,27, R19,26, R26,27, R26,31, R30,36, R31,32, R31,35, R32,36, R32,44, R35,39, R36,42, R37,38, R39,45, R40,43, R41,42, R42,44, R47,50. The 17 streets are applicable.

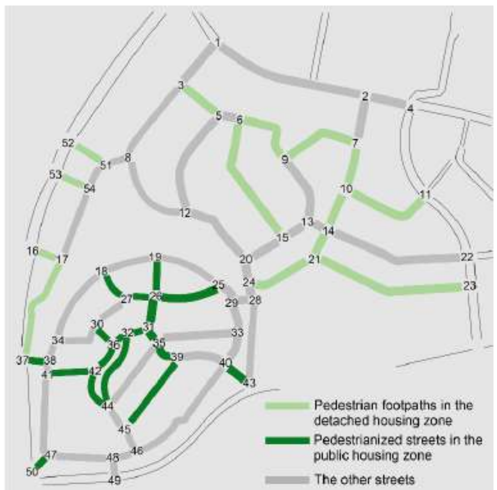

Figure 2. Street Classification in Takanodai 2-Chome area (Source: Aida, 2024)

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4. Results and Discussion

This chapter discusses analysis results from the walkability index applied in selected streets within the Takanodai 2-Chome.

4.1 Results

The following figure shows a heat-map display of the overall Walkability Score. There are different types of streets within the studied areas and 'short pedestrian streets' and 'streets with driveways' are found in the public housing zone. In contrast, two-lane large streets and streets pedestrian lanes are typical examples in the detaching housing zone (Figure 3).

	
footpaths in the public housing zone	streets with sidewalks in the public housing zone
	
two-lane large streets with sidewalks in the detached housing zone	footpaths in the detached housing zone

Figure 3. types of streets in different studies areas (Source: all photos by Aida, 2024)

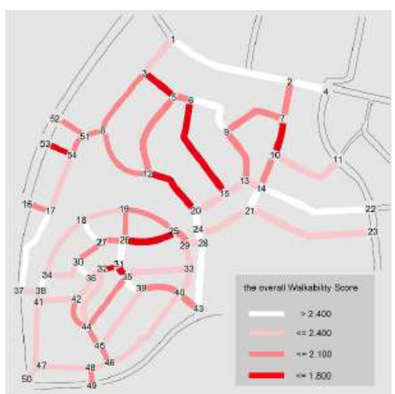

Figure 4. the overall Walkability Score

Figure 4 shows that the streets with high walkability are footpaths in the public housing zone (R18,27, R26,31, R30,36, R35,39), streets with sidewalks in the public housing zone (R34,38), two-lane large streets with sidewalks in the detached housing zone (R1,2, R2,4, R14,22, R20,24,

R24,28, R28,43), footpaths in the detached housing zone (R6,9, R14,21, R17,37).
Figure 5 - Figure 11 below shows a heat map of all 73 streets in respect of each of the seven stems in the walkability index.

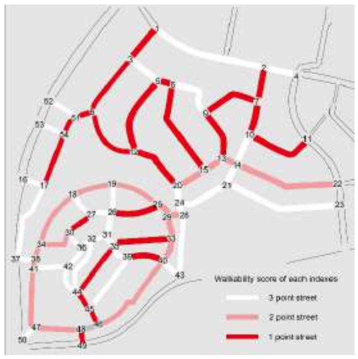

Figure 5. presence of sidewalks

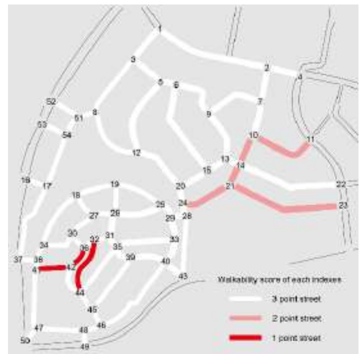

Figure 6. pavement condition

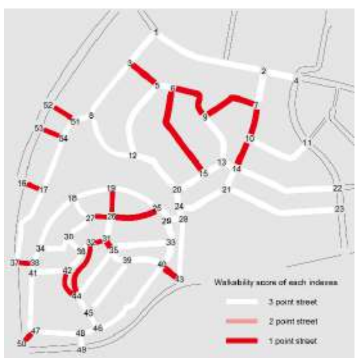

Figure 7. stairs

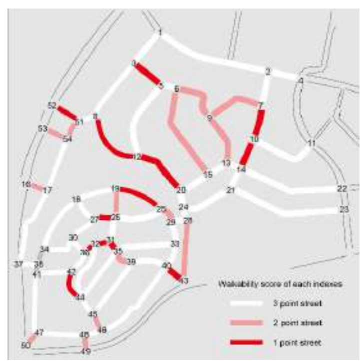

Figure 8. slopes

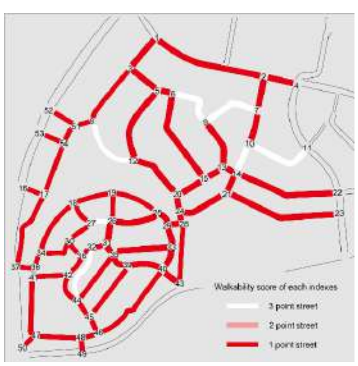

Figure 9. park space

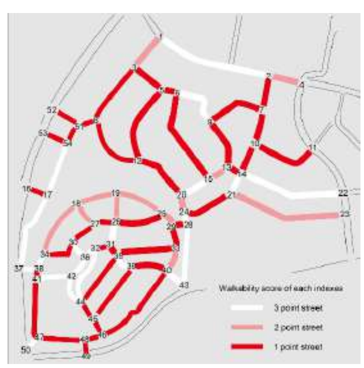

Figure 10. green space

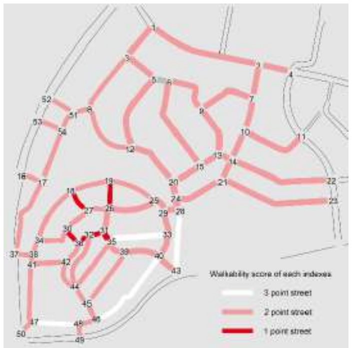

Figure 11. street lighting

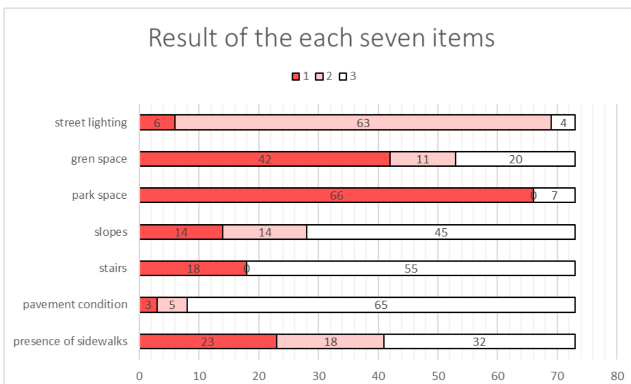

Figure 12. Total results from each of the seven items

The above figures show in terms of green space and park space, the majority of streets studied scores at the lowest (42 streets and 66 streets out of 73 studied). For slopes, stairs and pavement condition, the majority of streets scored with a higher point. Therefore, in Takanodai 2-Chome, there is an urgent need to increase green space and to prepare parks along the streets.

4.2 Discussions

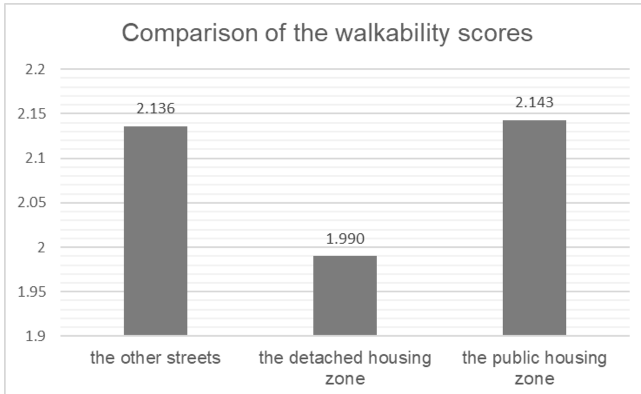

Figure 13. Comparison of Walkability Scores by different study areas

Figure 13 shows that the walkability scores of pedestrian footpaths in the Suita-Takanodai detached housing zone are lower than the other streets which are not footpaths, but streets shared by vehicles and pedestrians (see Figure 2).

On the other hand, average walkability for pedestrianized streets in the public housing zone tended to be slightly higher than the overall.

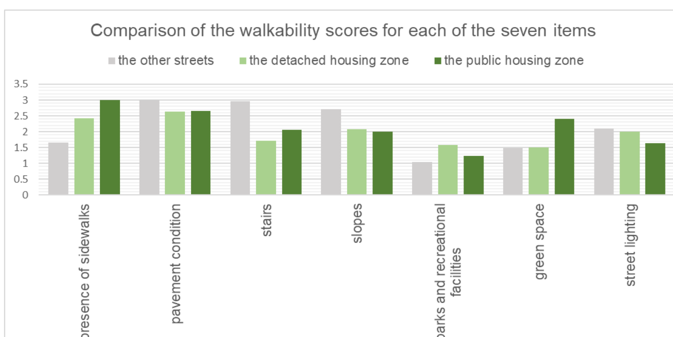

Figure 14. Comparison of scores for seven items by street characteristics

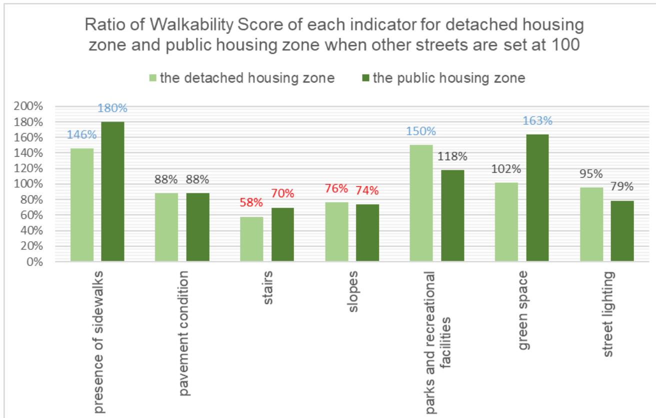

Figure 15. Ratio of Walkability Score of each item for detached housing zone and public housing zone when other streets are set at 100

Figure 14 shows the Comparison of scores for seven items by different study areas, and Figure 15 shows the Ratio of Walkability Score of each indicator for detached housing zone and public housing zone when other streets are set at 100. From these results, two possible factors for the low scores of walkability index in the detached housing zone are the presence of stairs and the slopes. Also, two possible factors for the high scores of walkability index in the public housing zone are the presence of sidewalks and the green space.

Figure 15 shows that stairs and the slopes are the main causes of reduced walkability scored in the detached house zone. Therefore, the walkability score was recalculated using the five indicators excluding the stairs and the slopes, and the result is shown in Figure 16 below.

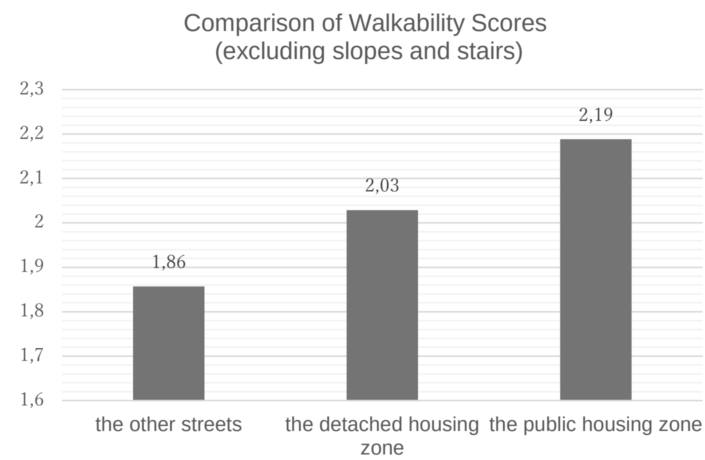

Figure 16. Walkability Score Comparison (excluding stairs and the slopes)

From Figure 16, when walkability scores were calculated for the indicators excluding stairs and the slopes, the results were as follows: pedestrianized streets in the public housing zone scored higher than the other streets. This indicates that all indicators except stairs and the slopes have high scores in the both public housing and detached housing zone compared to those in the other streets.

This suggests that the *Suita-Takanodai private line*, which was developed approximately 40 years ago as a footpath based on the idea of separating vehicles and pedestrians, may have a slightly lower walkability score than the other streets today. This may be related to the age group of residents who moved in at the time of the development of Senri New Town. In the 1970s, when Senri New Town was first developed, many residents were families with small children, and the aging rate in Senri New Town was low compared to the national average. This was due to the fact that the majority of residents were relatively physically healthy in terms of walking at that time. However, the rapid aging of the population in Senri New Town has made streets problematic for the elderly in terms of walking activities, which resulted in low walkability scores in this study. On the other hand, in the public housing zone, apartments surrounded by green spaces, and the entire zone is covered with greenery. Therefore, the amount of green space is considered to be high and the landscape is considered to be well kept.

More than 60 years have passed since the opening of New Town, and there are still problems such as aging public housing and lack of facilities for the elderly. At the time of the opening of the town, there was a shortage of elementary schools due to the large number of people with children moving in at the same time, and after the children became independent and moved out from home, the demand for senior citizen facilities rose dramatically due to the aging of the remaining residents. In 2007, the population of Senri New Town dropped from 129,860 to a minimum of 89,212. The Senri New Town Revitalization Liaison Council was established consisting of the six organizations (Osaka Prefecture, Toyonaka City, Suita City, Urban Renaissance Agency, Osaka Prefectural Housing Supply Corporation, and Osaka Prefectural Urban Development Promotion Center) in order to revitalize Senri New Town for the future. The six organizations have formulated the "Senri New Town Revitalization Guidelines 2018 (Osaka prefecture, 2018)," to maintain and develop the vitality of the town.

In particular, the seventh of the sixteen revitalization policies for New Town, as shown in the Senri New Town Revitalization Guidelines 2018 (Osaka prefecture, 2018), is to "enhance the transportation environment to create a town where people can live comfortably on foot". In particular, the seventh point in the policy is to "enhance the transportation environment to create a walkable town." As explicitly mentioned, 'walkability' in the policy document, it describes the development of safe and comfortable walking spaces from the viewpoint of barrier-free access and signage for wayfinding in order to create a town where residents can live with peace of mind.

As described above, in Senri New Town, several municipalities and organizations are collaborating in various efforts to improve New Town under the initiative to revitalize the town in response to the recent declining birthrate and aging population.

However, the results of this survey showed that the pedestrian footpaths in the detached housing zone, which should have been rated higher, were rated low, and the other streets in the district were rated higher. This suggests that when Senri New Town was developed in 1970, people were not as conscious of barrier-free access as they are today and regulations on barrier-free were not introduced by public authorities. Therefore, it is possible that the slopes and the slopes were not considered to be an obstacle to walking, especially for younger residents, which may have remained unchanged and unimproved up to today. Otherwise, the score of walkability of footpaths in the public housing zone should have been rated higher. This is because public housing zone have a well-developed green environment and a thorough separation of vehicles and pedestrians. However, the both zones have low scores for slopes and stairs, and it will be a challenge for the Takanodai area to improve these obstacles in the future, given the hilly topographic condition.

5. Conclusion and Future Prospects

When evaluating the walkability of an area, the characteristics of its residents and the process of street structure and design can be taken into account. By calculating walkability scores for individual streets that are used only by pedestrian-only or shared with vehicles, it is possible to appropriately identify certain streets that require some development. In addition, the walkability evaluation can visualize the walkability of each street by displaying the numerical values on a heat map, making it possible to create intuitive and easy-to-understand maps. These maps can serve as evidence in discussing improvement areas.

A walkable city for the elderly is also a walkable city for people of other ages. Therefore, walkability evaluation index developed for the elderly can be used as an indicator for the creation of walkable neighborhoods for everyone. We believe that the application of any walkability indices, including this study, is a useful method that will help create walkable cities for all citizens in the future.
As a prospect for future research, we believe that a more multifaceted walkability evaluation can be conducted by combining this research with studies focusing on the relationship of walking time and walking routes. This is especially an important point to be considered in the walkability of older people since their walking speed would reduce by ageing.

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