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An analysis of experience and expectations of urban residents towards accessibility to public transport systems from a number of cities at varying levels of urbanization is presented. A framework suitable to investigate differences of walking time to public transport facilities was initially established. It is then demonstrated that there is a relationship between the level of service of accessibility to public transport systems in a given urban area and expectations of its residents. Access to bus stops as well as railway stations has been considered. The paper provides a framework for planners to identify the perceived value of improvements to accessibility by accounting for the difference between the improvement of a physical measure of accessibility and the increased level of expectation of the subject community. The analysis has shown that it is important to keep the walking time for access to public transport systems below a specific value to ensure that the level of service associated with accessibility is within community expectations.

Keywords: walking time; accessibility; bus tops; railway stations; user expectations

Accessibility to public transport systems in planning context is typically handled in conjunction with the concept known as acceptable walking distance. This is typically the maximum distance a member of community is considered to be willing to walk to a bus stop or a railway station. This distance is a useful input for public transport demand estimation calculations as well. As an extension, the term coverage area is adopted in the literature to refer to a zone of influence of the bus stop based on this acceptable access distance measure. Giannopoulos (1989), Canadian Urban Transit Association (1993) and Ceder (2007) have shown broader applications of the access distance specifications in public transport system analysis and planning work.

Many planning authorities appear to adopt the value of 400 m for the acceptable distance in the context of accessibility to bus services. This value approximates to about 5 min walking distance at the average adult walking speed. For analysis and engineering design work based on topographic information, it is convenient to use the distance unit although the measure based on time unit could be also considered.

Daniels and Mulley (2011) have provided examples of other less common values for access to bus systems, such as 1/4 mile, 250, 300, 600 and 800 m. The origin of these values is hidden in history; while it is interesting to note there is a range of values adopted in different settings.

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Accessibility in this paper is considered in the context of the trip origin. There is an associated concept at the destination of the bus or train trip, referred to as egress access distance. This topic is less researched although Transport and Population Data Centre (2006) has documented data related to egress distance as well as boarding access to trains in Sydney, Australia. Patterns observed from this data may be an outcome of the land-use distribution of the study area.

It is known that the average value of actual access distance is different according to gender and age group. For example, Corpuz, Hay, and Merom (2005) have shown in Sydney, Australia, the access distance experienced by females is greater than males, although it is not intended to mean this is a universal phenomenon. Corpuz et al. (2005) have also investigated and found patterns emerging for access distance of residents with differences in age group as well as car ownership in their study area. Also, they have shown, as expected, that walking distance of urban dwellers in the context of recreational and fitness purpose is greater than for purposes such as public transport access. Cervero, Sarmiento, Jacoby, Gomez, and Neiman (2009) have pointed out that a range of topics within broad categories of aesthetics, environmental factors and physical characteristics of footpaths have an influence on walking.

Other notable empirical studies about access distance have been reported by Dickins (1991) covering 51 cities in North America and a study that has implications for demand modelling presented by Ewing and Cervero (2010) indicating a demand elasticity value applicable for accessibility. According to their study, the elasticity value is −0.29 for accessibility measured as a distance to the nearest public transport stop. This is an interesting observation as this indicates about 3% reduction in demand for 10% increase in access distance.

The present study is an outcome of a series of surveys performed in different cities in Japan to investigate differences among access distance partly to investigate differences in acceptable walking distance standards and more importantly to investigate how accessibility standards relate to community expectations. The analysis indicates that there may be a scope and logic to using different standards and this standard could be related to the level of urbanization. But the data have shown an unexpected trend, in the form of community expectations varying with the existing transport supply conditions and the way this variation manifests depending on the level of urbanization.

Survey description

The selection of cities to conduct field surveys was based on a principal component analysis and successive cluster analysis of the Japanese cities with population more than 100,000. There were 227 cities that satisfied this size requirement. Thirty characteristics of cities were considered in the analysis, including population, land area, number of secondary industry enterprises and number of retail shops. Details of the sample design methodology have been documented by Tsukaguchi, Vandebona, Sugihara, and Yeh (2007). The analysis presented here is based on survey of 15 cities (Figure 1) selected to ensure a reasonable geographical spread and types of cities in Japan.

It was not possible to perform surveys in all cities at the same time. Residents of first 10 cities were surveyed in December 2004. These cities were Sapporo, Sendai, Tokyo, Nagano, Kanazawa, Kyoto, Osaka, Hiroshima, Matsuyama and Fukuoka. The other five cities, namely Fukushima, Kumagaya, Ozaki, Tokushima and Urazoe, were surveyed in December 2008. The survey was based on random selection of 1000 residents from the

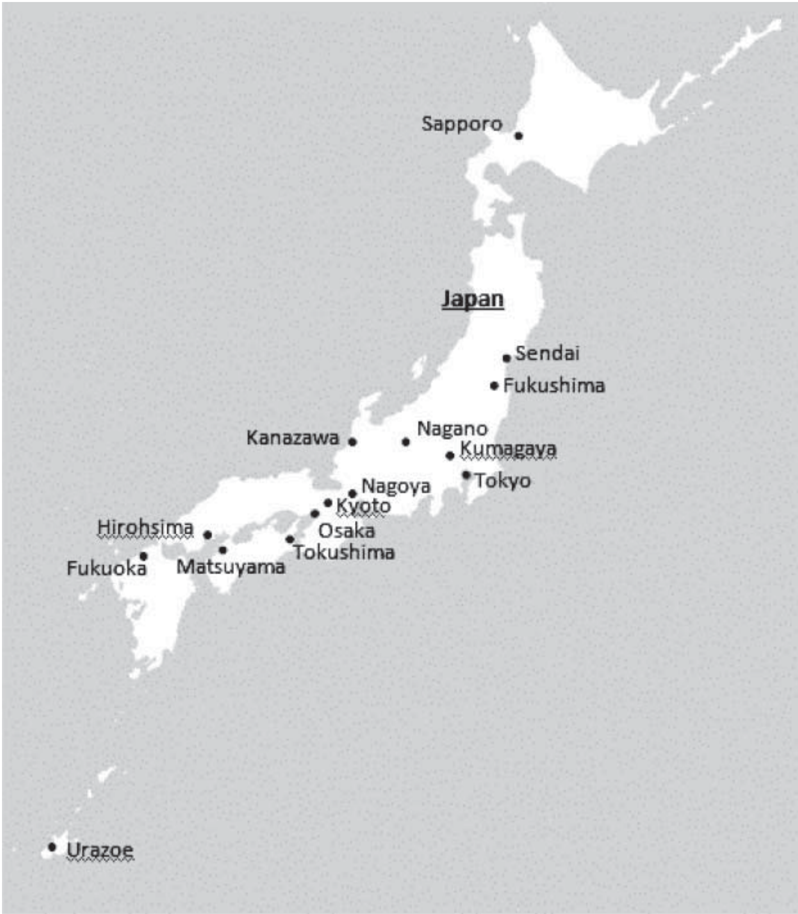

Figure 1. Location map of cities covered in data collection.

telephone directory irrespective of the population count of the city population and asking them to complete a mail-back questionnaire. Table 1 shows response counts which vary from the lowest of 16.7% (in Urazoe) to the highest 30.6% (in Ogaki). The average response rate was 24.2%.

There were four questions posed to the respondents relevant in the context of the analysis presented here. One question is about the current access time to the nearest bus stop. A sequence of typical time bands such as 0–2 min has been presented to the respondents to enable them provide the answer in a tick box form. Readers will encounter these time bands later when analysis results and graphs are presented. The next question is about what the respondents consider to be an acceptable walking distance to a bus stop with their responses recorded in the same sequence of time bands as in the previous question. The next two questions were the same as the above two questions, now reworded to pose in the context of access to the nearest railway station. Other questions included in the survey related to car ownership, type of occupation and length (in years) of residence in the city have not been analysed in the context of the current project.

Preliminary scan of responses indicated that the percentage of responses according to gender breakdown was acceptable, as responses from females were at 54.6% (and males

Table 1. Population and sample size in cities surveyed.

City	Population	Sample size
Tokyo	8,503,000	240
Osaka	2,668,000	222
Sapporo	1,906,000	237
Kyoto	1,464,000	243
Fukuoka	1,462,000	275
Hiroshima	1,174,000	216
Sendai	1,037,000	241
Matsuyama	516,000	242
Kanazawa	459,000	194
Nagano	388,000	259
Fukushima	293,000	216
Tokushima	264,000	246
Ogaki	165,000	306
Urazoe	112,000	167
Kumagaya	103,000	256
Total		3560

45.4%). However, the response composition according to age groups raised some concern because the percentage of respondents over 60 years of age was between 50% and 60% in all cities. The study team speculated that this bias may be attributed primarily to the sample selection technique that relied on telephone directories to randomly select questionnaire recipients as elderly persons are likely to be overrepresented in such database.

Walking time to public transport facilities

The analysis is focused at looking for the relationship between existing access time and desired access time. Walking time is selected here as the measure as it has been considered that respondents are likely to be uncertain and less accurate with distance, and also may get confused between the direct distance and actual path distance if the question was posed in terms of length. The access time to the nearest public transport service available from the survey is a proxy measure for the walking distance that characterizes existing level of service of public transport in terms of accessibility to such systems. It is the perceived access time that is available from the survey and the following analysis explores respondent perception of the present walking times from home to the nearest bus stop and railway station.

As expected, responses from different cities provided different access time distributions. To obtain a semblance of a pattern, these distributions were organized in sequence according to the size of the city as shown in Figure 2. Here the perceived access time to the nearest bus stop is shown, where city names are listed in the vertical axis from the largest at the top to the smallest city at the bottom of the axis. For each city, the horizontal bar chart shows the percentage of responses for six ranges of access time. The darkest segment of the bar represents the proportion for shortest walking time band and the shading of bars is made lighter in sequence with longer access times. The lightest shade on the right-hand edge of the diagram represents residents reporting an access time of greater than 20 min to their nearest bus stop.

Let us focus on those who perceived that they were 2 min or less away from the nearest bus stop. In Tokyo, this group contained about 28%. As we go downward in Figure 2, the city size becomes smaller and so does the percentage of respondents in this particular category.

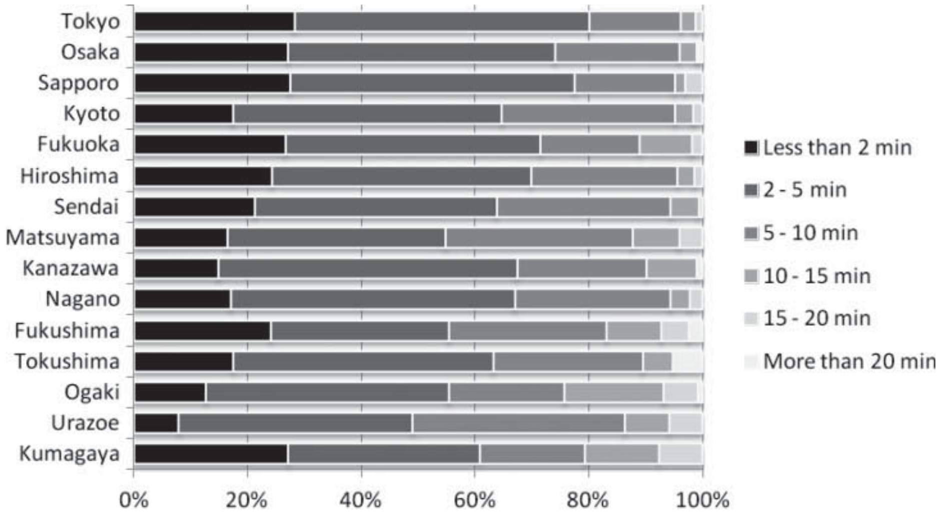

Figure 2. Perceived walking time to the nearest bus stop at present.

The decline is nonlinear, first recognized by the sequence of lower lows as the city size becomes small. A similar pattern exists when we add those who consider they are between 2 and 5 min away from a bus stop. In a large city, residents who consider they are less than 5 min away from a bus stop are about 80%. In a small city, this group of residents is in the range of 50–60%. As a result, the percentage of residents who are more than 15 min distant from bus services grows from negligible in large cities to about 7% in relatively small cities. A classification system for the size of city appropriate for better understanding of this pattern will be presented after the discussion of data related to access to railway stations.

The above pattern supports the common sense observation that large cities provide an extensive bus network, whereas relatively small cities are less likely to possess a dense network. Figure 2 also reveals that even in relatively small cities of Japan almost 95% of the population is within 15 min of walking distance to the nearest bus stop.

The distribution of walking time from home to the nearest railway station is shown in Figure 3. Again, the city names are arranged in the descending order of size, from top to bottom of the vertical axis. Also, the shadings selected for bar segments are as same as in the previous figure for buses. This diagram contains only 14 cities because the smallest city in the previous list does not have a railway service. Figure 3 shows a clear lengthening of lighter shades at the expense of darker shades compared to Figure 2, indicating as generally expected that train passengers are subject to longer access times compared to bus passengers.

In Figure 3, the pattern described in connection to accessibility to buses is not easily recognizable. Anyhow, it is clear that the percentage of residents who consider they are within 5 min from a railway station is about 25% in the large cities in Japan, and this percentage shrinks to about 5% for relatively small cities. Similarly, the percentage who perceive they are less than 15 min from a railway station is as high as 80% for a large city compared to a value between 20% and 40% for small cities. Urazoe city is not shown in Figure 3 as this city does not have an urban railway system.

It could be speculated that the difficulty to see the trend clearly in Figure 3 is a result of lack of correspondence between the size of the city and the size of the railway operation. However, awareness of the trend observed in association with bus services allows the introduction of an aggregation strategy to better observe the trend. For this purpose, it has been decided

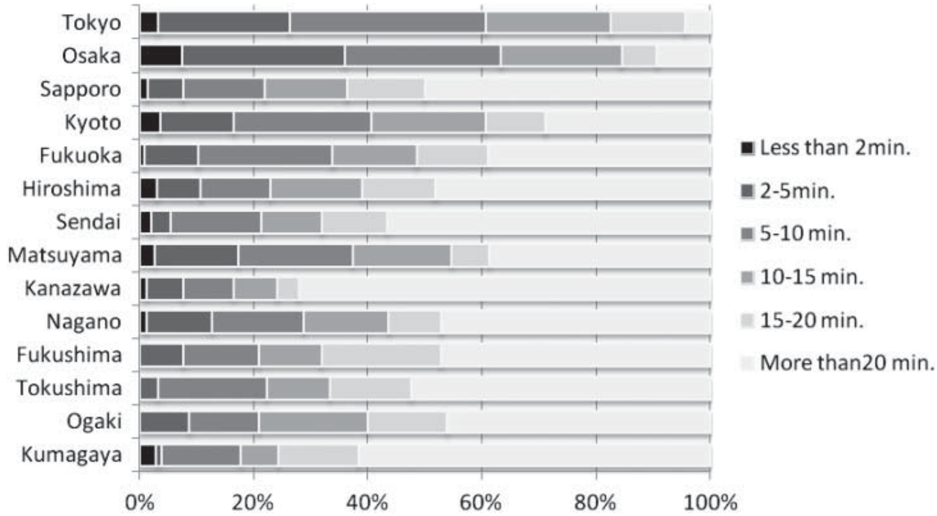

Figure 3. Perceived walking time to the nearest railway station.

to classify cities into three categories according to the population size. Population size is considered here as a proxy variable for the level of urbanization.

Therefore, the cities have been grouped into (i) those with more than 2 million population, (ii) those with population between 0.3 and 2 million and (iii) those with population less than 0.3 million. The first category (henceforth referred to as large cities) contains Tokyo and Osaka. Next eight cities, Sapporo, Kyoto, Fukuoka, Hiroshima, Sendai, Matsuyama, Kanazawa and Nagano, are grouped into the second category (medium size cities). The other five cities, Fukushima, Tokushima, Kumagaya, Ogaki and Urazoe, are included in the third category (small cities). Japan has classification systems according to the status of local government administration that lists cities under different headings such as capital, designated, special and core cities. Although such classifications were not based on population alone, the ranges of population adopted here broadly reflect the status of cites in the nation.

Figure 4 shows results of aggregation of data used in Figures 2 and 3 for perceived walking time to the nearest public transport pickup location. The shading system of bars is same as in the previous figures, the darkest segment representing the shortest access time

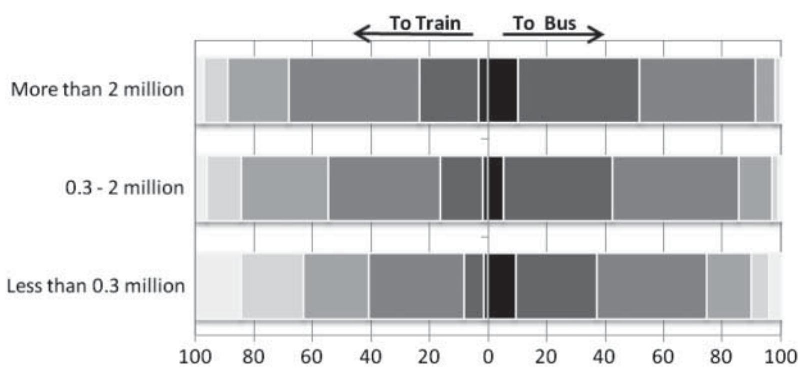

Figure 4. Distribution of perceived walking time to public transport according to the size of city.

band. Responses for large size cities are in the topmost bar and for small cities are in the lowermost bar. The trend is much clearer now. The perceived distance from home to the nearest bus stop at present is small in large cities as seen in the right half of the diagram. In large cities, only a small percentage of respondents feel they have to walk more than 10 min to the nearest bus stop. This group alone is nearly 20% in small cities and invariably served by a less dense bus network.

The left half of Figure 4 shows corresponding results for the aggregation of perceived walking time to the nearest railway station. Much of the randomness that obscured the underlying pattern in Figure 3 is now removed. Here too, it is clear that the perceived walking time at present to the nearest railway station is small in large cities. It is also worth noting that there appears to be less variability with the size category of the city between perceptions of current access to buses and railway stations. An implication of the pattern observed in this figure will be revisited in a later section.

Acceptable walking time to public transport facilities

Another variable available from the survey provides information about what respondents consider as the acceptable walking time to the nearest public transport facilities. It may be obvious even at this stage that it will be of use for planners to compare this information with the current access time profiles reported in the previous section to understand whether the public transport system network density satisfies user expectations. Such a comparison will be presented in a following section. For now, this section is focused on exploring expectations of respondents from above cities about the acceptable level of walking. In particular, this section investigates what respondents consider as an acceptable walking time to the nearest bus stop and railway station. The question posed to the respondents asked for their opinion about acceptable walking time when the walking environment is considered good. There was no specific definition of the term 'good environment for walking' provided to the respondents. It was speculated that respondents may consider aspects such as safety, quality of surface, walkway width, aesthetics and level of foot traffic according to their personal weightings in the interpretation of this term. The qualification about the walking environment being good in their opinion was included during the questionnaire design to obtain a set of comparable responses in relation to the acceptable amount of walking time.

Figure 5 shows acceptable walking time to buses in the same graphical structure presented earlier with Figure 2. It is acknowledged that it may be difficult to observe a clear pattern from the chart shown in Figure 5. Part of the problem is because it is incorrect to add horizontal bars and interpret in the same way as done with Figure 2. For example, in Figure 2, it is possible to visually add two adjacent bars for 'less than 2 min' and '2–5 min' and treat the total percentage as 'less than 5 min' of current access time. In Figure 6, such an interpretation is not possible. The 'less than 2 min' label in Figure 5 refers to the acceptable limit and it is not of a practical meaning to add the next group '2–5 min' that states an acceptable limit in the second range.

Closer examination, while keeping the above interpretation trap in mind, may show that there is a pattern emerging. The 'less than 2 min' group range between 5% and 10% with a less than useful wave pattern across different cities. Now consider the next group, who were willing to walk 2–5 min to the bus stop. Focus only on the bar length of that group, to observer that in large cities this group is about 40%. Keep focus only on the segment of the bar that represents '2–5 min' and scan downward along Figure 6 to appreciate that

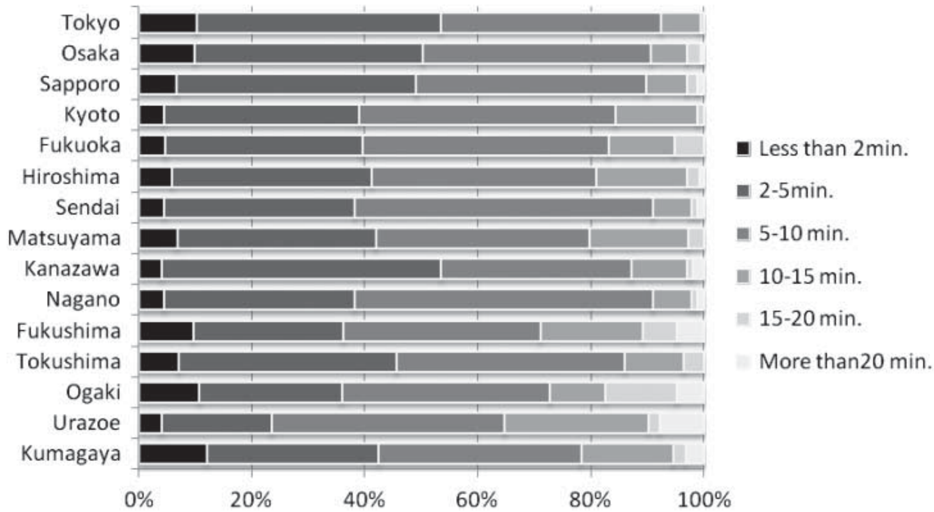

Figure 5. Acceptable walking time to the nearest bus stop.

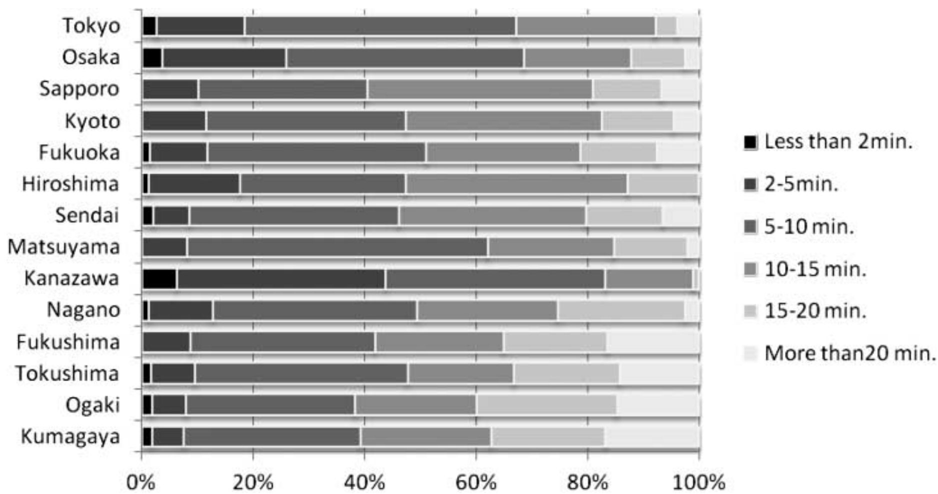

Figure 6. Acceptable walking time to the nearest railway station.

the corresponding percentage gradually reduces to 20% at the small city at the bottom of the chart.

It may be evident that it is possible to add the bar segments from the higher end to make a meaningful interpretation. For example, adding three groups, '10–15 min', '15–20 min' and 'more than 20 min' provide the total percentage for the group that considers acceptable access distance is 'greater than 10 min'. This percentage grows large when we scan downward in Figure 5. For large cities, this is a group less than 10%, and for small cities, this could be up to 35% of respondents.

Figure 6 shows acceptable walking times in the context of the nearest railway station. A visual inspection following the method outlined in the previous paragraph shows that in the context of access to railway systems, the willingness to walk 15 or more minutes is about 10% in large cities and grows to about 40% in small cities.

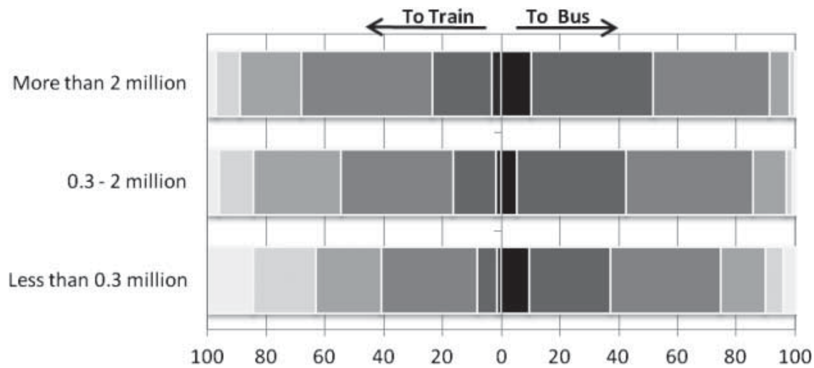

Figure 7. Acceptable walking time to the nearest bus stop according to the size of city.

Aggregation of the above information according to the three categories of city based on size as mentioned earlier would now clarify main features of acceptable walking time. The group of people who consider 2 min or less as the acceptable access time to a bus stop is about 10% of the residents, irrespective of the city size (Figure 7). However, the observation made earlier about the group that is willing to walk greater than 10 min to the bus stop being relatively large in small cities is much clearer in the right half of Figure 7. A similar observation can be made about the group that is willing to walk more than 5 min. This trend indicates that in general residents of small cities are willing to walk more than those in large cities.

As done before, left half of Figure 7 shows aggregate results for acceptable amount of walking time in the context of access to the nearest railway station. The graph reinforces the observation made using data for access to bus stops. In other words, in small cities, residents are willing to walk a relatively long distance.

Relationship between present conditions and the acceptable access distance to public transport

This section is an attempt to compare perceived current conditions seen in Figure 4 with willingness results reported in Figure 7. The discussion from now on will be limited to access to bus services to avoid repetition about similar patterns and outcomes when the analysis is performed with the focus on railway stations.

A cross-analysis is performed to enable comparison between present conditions and acceptable conditions using data aggregated according to the size of the city. Figure 8 shows results aggregated from the two largest cities in the survey. Figure 9 shows cross-analysis for medium size cities and Figure 10 shows the corresponding analysis for small cities. In production of these graphs, further aggregation is performed by combining data for responses where the perceived walking time has been considered larger than 10 min because there were only a small proportion of data where the perceived walking time was greater than 15 min (approximately 1.2 km in distance) to the nearest bus stop, particularly with medium and large cities.

The two characteristics, the perceived access time in the current situation and acceptable access time, are closely related. It is evident that people who think they live a long distance from the nearest bus stop usually accept a somewhat long walk. Conversely, individuals who do not have a long walk from home to the nearest bus stop expect a much higher level

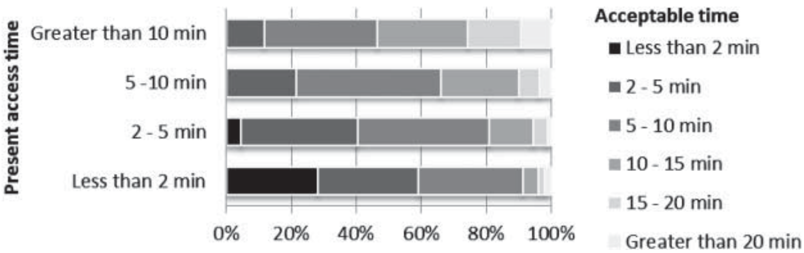

Figure 8. Cross-analysis for access to bus stops in large cities.

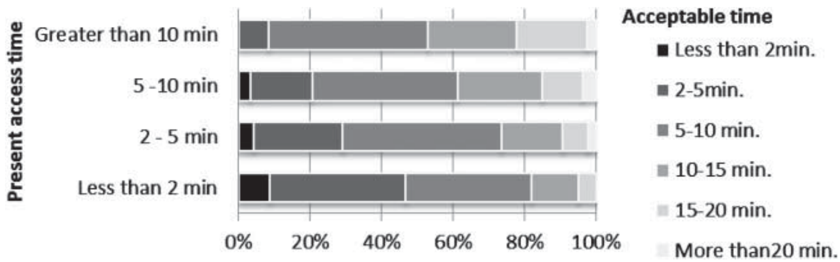

Figure 9. Cross-analysis for access to bus stops in medium size cities.

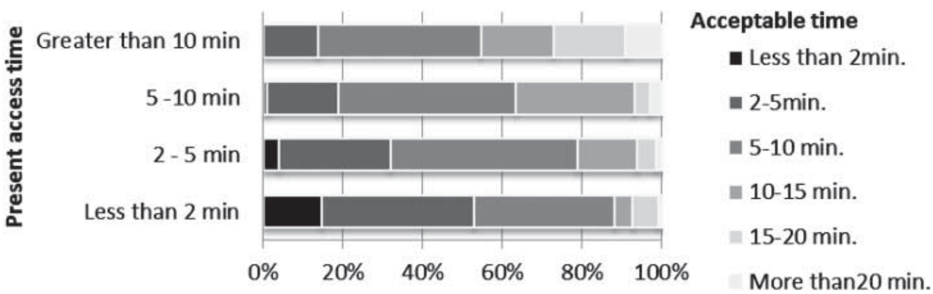

Figure 10. Cross-analysis for access to bus stops in small size cities.

of accessibility. In other words, the level of pedestrian satisfaction is related to the present condition in terms of quantity and level of service of urban systems.

Figures 8–10 have similar patterns, but also show that bar segments shift to the right in small cities. This has been further investigated by looking at weighted averages. Weighted average of acceptable access distance is computed for each of the horizontal bars in the previous three figures. In other words, the average acceptable distance is computed for four categories of respondents who consider the present walking time is 'less than 2 min', '2–5 min', '5–10 min' and 'greater than 10 min'. Figure 11 shows the results of these computations.

The horizontal axis in Figure 11 indicates the perceived access time respondents currently experience and the vertical axis shows the amount of walking time respondents consider acceptable to access a bus stop. Average values for perceived access time is selected as the mid-points of the ranges specified during data collection. Some observations made earlier are supported by this graph as well. For example, respondents who live away from bus stops have a tendency to quote relatively high acceptable access times. Those who live near bus

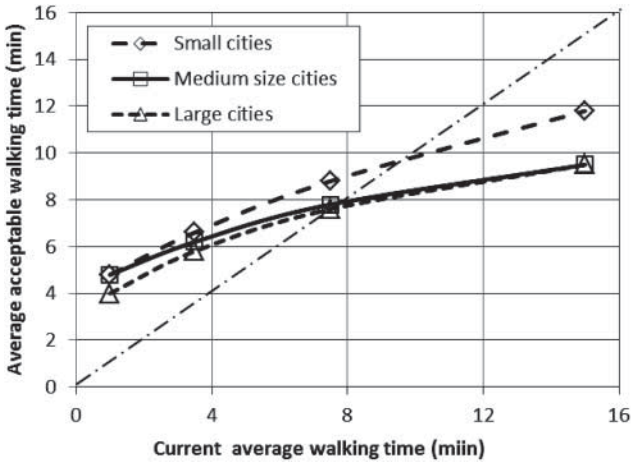

Figure 11. Acceptable level of walking time against the present walking time.

stops tend to state a small amount of time as the acceptable access time limit. Figure 11 reveals three other points not well recognized until now.

The graphs cross the diagonal line in Figure 11 at the middle of the diagram to indicate that within a city there can be some satisfied with the level of service and some dissatisfied. Not surprisingly, it is respondents who live relatively distant from bus stops that are not happy with current access times. Points to the right and below the diagonal line reflect that their perceived current access time is greater than the access time they consider acceptable. Points to the left of the diagonal line indicate conditions where respondents consider the average access time they actually endure is less than what is acceptable to them. Those who live less than 5 min from the bus stop are in this category. Within that, those who live less than 2 min from the bus stop are more pleased with the service than those who live between 2 and 5 min away from the bus stop. This observation can be reached by inspecting how far the data point is relative to the diagonal line.

The next observation relates to what planners consider as an acceptable walking distance to public transport. As indicated earlier, in many countries planners would regard 5 min as a target access distance for bus operations design. The figure shows that this value has merit and in large cities, the average value for the acceptable walking time obtained from this survey varies between 4 and 10 min. What is more interesting to note is that this acceptable limit is a moving target. As public transport accessibility standards are improved (say the average access time is reduced from 16 to 8 min), the community increases its expectations (the average acceptable limit is reduced from approximately 10 to 8 min). This phenomenon may have influence from other aspects of economic development that may increase the value of time of individuals and lifestyle changes associated with increasing wealth associated with the ability to live in such a growth area. Anyhow, Figure 11 shows that bus network level of service improvements that can push the average access time to below 8 min (i.e. move to the left half of Figure 11) is rewarded with community acknowledgement that service standards are satisfactory.

The final observation is about the significance of the size of the city. There is a distinct difference in community expectations about access to public transport between small cities (those with less than 0.3 million population) and large cities (ones with more than 2 million population). The difference is somewhat more pronounced when respondents who live more than 10 min away from a bus stop are considered. It is the character of residents in medium size cities that is even more interesting, as those who live close to bus stops in a medium size city tend to follow the expectations similar to a small town counterpart, and on the other hand, those who live more than 10 min away from bus stops in a medium size city have expectations of a similar resident in a large city. This observation is not completely surprising as one would expect resident characteristics of a medium size city to consist of a spread of features of residents from small to large cities. What is surprising is that the small to medium coincidence happens with superior level of service and the large to medium coincidence occurs with inferior level of service in terms of access time to public transport.

Statistical comparison of estimated values has been carried out to verify above comments made from visual inspection of graphs. For each size category of city in Figure 11, the difference of adjacent values is statistically significant at a commendable 0.01 level. In other words, the increasing trend of each graph with higher value of current walking times is not a statistical aberration. Then, comparison of corresponding values between the graphs for small and large cities has also shown the observed difference is significant at the 0.01 level. Comparison of differences with corresponding values of medium size cities has drawn mixed results, as expected, because that graph is sandwiched between the other two. At the left extreme, the difference with the acceptable walking time of large cities is significant at the 0.01 level, although the difference with small cities is not significant even at the 0.1 level. The converse is true according to the statistical analysis for the third set of values in the sequence (at current average walking time of 7.5 min) where the difference is significant at the 0.01 level between the medium and small cities, but no significant difference could be established between the medium and large cities. Considering the second set of values in the sequence, the difference is significant at the 0.01 level between medium and large cities. There is less confidence about the existence of a difference for the estimated values between medium and small cities at this level of current average walking time as the difference is significant at the 0.1 level but not at the 0.01 level. Essentially, the statistical analysis has indicated that interpretations derived from the visual observation of graphs in Figure 11 are mathematically acceptable.

Conclusions

Relevance of urban planning standards associated with access to public transport systems has been investigated using data from a questionnaire survey carried out in 15 cities in Japan. Each city considered here had a population greater than 100,000. Two cities among these had a population larger than 2 million. The range of population size provided the opportunity to analyse the influence of differences in the level of urbanization on accessibility requirements.

It has been possible to identify the presence of a statistically acceptable trend between the level of service in terms of current accessibility to public transport and acceptable walking distance from the community point of view. It is shown that people who live far from the nearest bus stop usually accept a somewhat long walk. Conversely, residents who do not have a long walk to the nearest bus stop or railway station expect a much higher level of convenience in terms of acceptable walking distance. It is also possible to argue that transit users who are willing to walk a long distance are the ones likely to locate themselves further away from public transport facilities.

It is also observed that the size of the city explains a portion of the accessibility to public transport facilities. Larger cities have the ability to supply a dense public transport network.

Thus, such cities have a superior level of transit network in terms of access to a public transport facility. This relationship was particularly strong in connection with access to the nearest bus stop compared to access to urban railway stations. Adoption of city-specific standards that can be modified with the growth of the city is a better planning approach than the adoption of uniform national standards.

It is shown that acceptable walking distance computed from survey data is a moving target possibly because residents modify their expectations in light of the current level of service experienced. Inspection of Figure 11 has identified two important regions, one where the expectations are lower than the supplied level of service and the other where the supply is superior to community expectations. This aspect has been discussed with relevance to planning standards and level of urbanization. In general, policy makers should aim to facilitate a transit network that minimizes the user population faced with an unacceptable level of accessibility.

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