Evaluation of Road Utilization Needs for Road Space Reallocation

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Abstract: In order to respond to social changes in road utilization, the reallocation of existing road space has been attracting attention. However, the specific criteria for reallocating road space that considers a variety of stakeholders have not been determined, and many problems need to be considered. In this study, we evaluated road space usage and problems, and incorporated the needs and opinions of those using the roads to provide a safe and comfortable road environment for all road users, including pedestrians, bicyclists, and vehicles. We found that the need for improving the quality of local roads and for road space is large. In the future, in order to improve the quality of road space based on the road users’ needs, it is necessary to avoid policies that favor the major roads and vehicle use, and implement road space reallocation considering the needs of the residents and the various stakeholders.

Keywords: Road space reallocation, Local roads, Quality of Road Space, Stakeholder, Road users’ needs

1. INTRODUCTION

In Japan, during the period of rapid economic growth, major road construction was given high priority as a part of the infrastructure development to support the economy and industrial growth and to accommodate the increased traffic demand due to rapid urbanization and increase in vehicle use. However, more recently due to economic maturation and an aging society, huge changes have occurred in road utilization and in the type of traffic on the roads. Also, new needs for transportation have emerged. Therefore, a fundamental shift in the road traffic policy is necessary.

According to the “Survey on living conditions and housing for the elderly” by the Japanese Cabinet Office (2011a), the elderly feel insecure during their daily shopping and visits to the hospital, and fear having traffic accidents. There is also a large unmet need for countermeasures in the transport sector for vulnerable road users and for the elderly. In particular, the proportion of elderly people involved in traffic fatalities is increasing every year. In 2012, the ratio of fatalities involving the elderly to total fatalities was 51.3%. This is more than double the ratio of elderly people in the total population, which was 24.1% (the Cabinet Office, 2013). In addition, as for traffic fatalities involving the elderly by condition, pedestrian fatalities accounted for 49% and bicycle fatalities accounted for 16.1%, which shows that adopting road traffic countermeasures for the elderly in this aging society is
When comparing pedestrian traffic fatalities as a percentage of all road fatalities in 26 OECD countries (ITF, 2012), New Zealand had the lowest level of pedestrian fatalities at 8%, the average fatalities for all 26 countries was 18%, and Japan ranked the second-worst with 35% pedestrian fatalities. Compared with other OECD countries, the walking environment in Japan is relatively unsafe.

Meanwhile, it should be noted that, since traffic accidents involving children during the school commute were greatly increased in 2012, countermeasures were determined based on the results of a very quick and complete inspection of school roads. However, actually only about 50% of the countermeasures were implemented by the end of 2012. In particular, the White Paper on Traffic Safety in Japan (the Cabinet Office, 2006) indicates that the percentages of sidewalks in general on national highways, prefectural roads, and municipal roads are 58.4%, 34.9%, and 7.9%, respectively; and in the case of school roads with a large amount of traffic, these percentages are 80.3%, 60.2%, and 35.2%. These findings indicate that there are many problems on municipal roads for pedestrians. In fact, when comparing the number of traffic accidents resulting in pedestrian casualties on major roads and on local roads, those on local roads (46,280 cases) are more than twice that on major roads (22,181 cases) (the Cabinet Office, 2011b).

Moreover, in recent years, the bicycle is attracting attention as a mode of transportation with a low environmental impact. Its utilization needs are growing against the background of a rise in health consciousness. Bicycle ownership in 2008 exceeded 69 million units (Bicycle Association in Japan, 2012), and the use of the bicycle for transportation in the Tokyo metropolitan area in 2008 was 14%. Especially, in the case of personal use, the bicycle as a means of transportation accounted for a larger percentage at 22% (Tokyo Metropolitan Transportation Planning Council, 2012).

However, the number of bicycle accidents on local roads (101,358 cases) was more than twice that on major roads (77,188 cases) (the Cabinet Office, 2011b) similar to the data on traffic accidents resulting in pedestrian casualties. These statistics indicate that it is vital to consider countermeasures for traffic safety on local roads.

Based on these statistics, the “Principle of people first for traffic safety policy” was written as part of the 8th Fundamental Traffic Safety Program (the Cabinet Office, Japanese Government, 2006), in order to further secure the safety of pedestrians, who are vulnerable to injury or to death by automobile, as well as to secure the safety of those especially vulnerable, such as the elderly, the disabled, and children, when they use any type of transportation. Then, the 9th Fundamental Traffic Safety Program (the Cabinet Office, Japanese Government, 2012) included, as its priority measures, (1) developing safe and secure pedestrian spaces on local roads that prioritize people, (2) promoting the development of walkways on school routes, etc., (3) developing pedestrian space to contribute to the safety of both the elderly and people with disabilities, and (4) comprehensively improving the environment for bicycle use.

However, considering the high number of pedestrian and bicycle accidents on local roads, it is clear that the measures taken to make local roads safer are not sufficient. Also, as shown in Figure 1, the number of traffic accidents and casualties on local roads is similar to that of the major roads. In addition, there are many more local roads than major roads. Nevertheless, the amount of money spent on local roads is lower than that spent on major roads.
In particular, road-related data, such as a road traffic census, have focused mainly on the major roads, whereas quantitative data for the local roads are almost nonexistent. Therefore, it is difficult to understand the issues and problems of local roads unless a field survey of the area is conducted. Such a situation also leads to poor countermeasures for local roads compared to that of major roads.

With the stabilization of the economy, public awareness has increased, and lifestyles are changing from the pursuit of material wealth to a more spiritual direction (the Cabinet Office, 2012). In order to respond to these changes in social consciousness and in the demands of the people on the use of roads for transport, it is urgent to implement measures to develop residential roads designed primarily to meet the needs of all pedestrians, cyclists, and local residents and also allow vehicle access, similar to the home zones in the UK. For this purpose, a conversion from vehicle-oriented road traffic policies to people-first policies is required in Japan. In particular, it is necessary to implement road policies that can achieve the coexistence of vehicles, pedestrians and bicyclists, and contribute to a safe road and a comfortable living environment.

Based on the problems described above, we evaluated the current and desired ideal use of road space, considering the needs and social consciousness of every user, including pedestrians, bicyclists, and vehicle users, for the reallocation of safe and high-quality road space.

2. LITERATURE REVIEW

Road space rationing is a demand management technique that restricts days or times that a car or driver is permitted to use a congested road, instead of charging tolls on users to drive (Kornhauser and Fehlig, 2003). Unlike this concept, road space reallocation involves shifting road space currently devoted to automobile traffic or parking to serve other modes, such as sidewalks, bike lanes, high occupancy vehicle and bus lanes, or rail lines. It also involves reducing total road rights of way in order to make land available for other uses (Victoria Transport Policy Institute, 2014).
In many cities in the world, road space reallocation has been conducted to rejuvenate urban areas with vitality, attractiveness, and a low environmental impact.

In Japan, Yabe et al. (2004) and Shimizu et al. (2006) did a preliminary evaluation of road space reallocation by including Bus Rapid Transit (BRT), and Fujisawa et al. (2008) also examined road space reallocation for sidewalk widening. Fujisawa et al. (2008) estimated the benefit of widening the sidewalk in the central area of Kyoto city using Contingent Valuation Method (CVM), and measured the negative effects of reducing the width of traffic lanes using a traffic simulation model.

Suzuki and Yai (2008), Watanabe et al. (2002), and Elfferding et al. (2006) performed studies on road space reallocation for creation of lanes for bicycles. Suzuki and Yai (2008) conducted a driving simulator experiment to examine the driving characteristics of vehicles after introducing bicycle lanes, and identified problems for the development of bicycle-conscious roads. Watanabe et al. (2002) examined which type of bicycle environment is more advantageous for bicycle users based on the traffic volume and on two different types of bicycle accommodations: bicycle track and bicycle lane. Elfferding et al. (2006) reviewed the bicycle traffic network created by road space reallocation in Germany. These studies described above have focused on only partial road space reallocation for individual transportation systems, such as BRT or bicycles, etc.

Since road space reallocation needs to consider the usage by various stakeholders, Iida and Tsukaguchi (1994) proposed an alternative method of road space reallocation and examined the resulting traffic patterns. For this purpose, they classified streets into groups according to their functions, and clarified road space users’ awareness. Kozasa and Kobayashi (2000) analyzed the behavioral changes and the user evaluation with the physical change in the street space. As the most important research in Japan on road space reallocation, the research results on the formation of “community zones” in residential districts by the Japan Society of Traffic Engineers (1996, 2000, and 2004) should be noted. They proposed a method of road space reallocation involving the formation of “community zones”, which are equipped with a safe, comfortable walking area, a structure to separate pedestrians from vehicles, and regulation of vehicle speed through the installation of humps, etc. Also, they have expanded this type of zone to commercial districts.

However, as described above, in Japan, there are few studies on road space reallocation which take into account various stakeholders, such as pedestrians, bicyclists, public transport users, vehicle users, shopkeepers, persons with disabilities, etc.

Jones et al. (2007) criticized the conventional imbalance of street provision that gave priority to motor vehicles. They proposed a new method for road space reallocation planning and design that considers the needs of all types of street users. McCann and Rynne (2010) also proposed the “complete streets policy” that would serve everyone-pedestrians, bicyclists, transit riders, and drivers, and take into account the needs of people with disabilities, older people, and children. Moreover, relating to the concept described above, the Department for Transport (DfT) in the UK published the “Manual for Streets” (2007), and the New York City Department of Transportation (NYCDOT) also published the “Street Design Manual” (2009).

Meanwhile, there are various stakeholders to be considered in road space reallocation. Accordingly, there is a high possibility that conflicts between stakeholders can occur. In order to prevent or avoid conflicts, a method which flexibly considers various intentions and the influence of external factors is necessary.

In recent years, evaluation methods focusing on Quality of Life (QoL) have been proposed as part of the multidimensional evaluation and management of city planning (Doi et al. 2006). According to Groot & Steg (2006), QoL is the concept representing the subjective and objective living conditions of a person as a reflection of how well individual needs and
values are fulfilled in various aspects of life. Also, there are some studies that have applied the qualitative evaluation method of QoL to the transport sector.

Hayashi et al. (2004) proposed a methodology of Quality of Life Analysis (QoLA) that can measure individual satisfaction with five fundamental elements, and represents QoL as general satisfaction. They applied this methodology to evaluate the impact of an intercity transport system. Doi et al. (2006) also proposed a QoL-based multidimensional evaluation system for urban infrastructure planning. They examined how to enhance the accountability of decision makers, and to ensure social equality in the rejuvenation of port areas vulnerable to flood-tide disasters by this system. Groot & Steg (2006) examined the relationship between value orientation and perceived QoL-changes when the cost of car use is doubled. Carse (2011) examined a methodological tool that can appraise Transport Quality of Life (TQoL) on all modes of transport in one city. They applied the QoL measurement to the transport networks of both Glasgow City and Manchester City, and showed that a Light Rapid Transport provides a significantly better QoL compared with that of the bus. Steg & Gifford (2005) examined the relationship between transportation sustainability and QoL. Also, they stressed that it is important to consider QoL issues when designing and implementing sustainable transport plans, because such considerations are crucial for the acceptability, and consequently the feasibility and effectiveness, of such plans. Banister & Bowling (2004), Metz (2000), Spinney et al. (2009) examined the relationship between transport mobility of older people and their QoL, and found a significant association between transport mobility and QoL for the elderly.

As stated above, even though there are many studies on road space reallocation, there are few studies that have considered the needs and social consciousness of the residents and of the various stakeholders. However, it is important to include the needs and values of the residents and of the various stakeholders in road space reallocation planning, because road space reallocation is closely related to how people live. In this study, we examined the current and ideal use of roads for road space reallocation, including the satisfaction and needs of road space users.

3. METHODOLOGY

In this study, based on the definition of Kato and Takeuchi (2006), we defined major roads and local roads as follows.

- **Major Roads:** Major roads consist of both primary and secondary roads. Primary roads have a large amount of intercity traffic volume as well as vehicles passing through and thus, form the transportation backbone of the metropolitan area. Secondary roads provide traffic movement between primary roads, and thus also form the transportation backbone of the city and of the perimeter of neighborhood units.

- **Local Roads:** Local roads connect secondary roads and internal roads within the neighborhood units. They adjoin housing sites, and provide services to houses and to facilities in the neighborhood units. They serve as a space closely connected to daily life.

As shown in Figure 2, the percentage of traffic accidents associated with both pedestrians and bicycles on local roads is higher than that on major roads. This is due to the different characteristics of road utilization. Vehicle traffic involving relatively long distances usually occurs on major roads, while bicycles and pedestrians concentrate on local roads and travel shorter distances compared to vehicle traffic.
Figure 2. Relative involvement of vehicles, motorcycles, bicycles, and pedestrians in traffic accidents on major and local roads

Figure 3 shows the status of traffic accidents by type of accident. Half of the accidents on major roads are caused by rear-end collisions, while crossing collisions are most common on local roads, accounting for 38%. Furthermore, the percentage of traffic accidents between motor vehicle and pedestrians on local roads is higher than that on major roads. There are several reasons for the higher accident incidence and type of accidents on local roads.

In the case of major roads, the acceleration, deceleration, and speed differences between vehicles caused by traffic congestion and the concentration of vehicles have a high potential to lead to traffic accidents, such as rear-end collisions.
On the other hand, in the case of local roads, the pedestrian and bicycle traffic volume is higher than that of major roads, and in many cases there is no separation of road space for pedestrians and bicycles. Therefore, a collision between vehicles and pedestrians is more likely to occur. In addition, a lack of signal control at intersections, poor visibility at cross streets, and a lack of attention to safety by the user due to the small traffic flow have a high potential to lead to traffic accidents, mainly at intersections.

As described above, there are distinct differences in transportation functions, roles, and transportation features between major roads and local roads. Therefore, it is necessary to evaluate these two types of roads separately for road space reallocation. In this study, we divided the roads into major roads and local roads, and evaluated them individually.

Meanwhile, there are various users of road space besides vehicles, including pedestrians and bicyclists, and their needs also vary considerably. In particular, as mentioned in Section 1, there are critical problems in traffic safety for pedestrians and bicyclists. Therefore, in this study, we divided road users into three user groups, i.e. pedestrians, bicyclists, and vehicle users, and evaluated the road space based on their perspectives. However, in most cases, public transport does not operate on local roads. Also, we wanted to clarify differences between major roads and local roads in terms of road user’s needs and evaluation results. Therefore, the perspective of public transport users is not considered in this study. Moreover, since this study focuses on evaluation of road utilization for road space reallocation, we examined Quality of Road Space (QoRS) which is limited to the satisfaction with the road space. We did not examine QoL which includes different elements, such as the economy, the environment, and society. It should also be noted that rural areas and urban areas have many differences in their life styles, road traffic features, and traffic accident features. In this study, we targeted big cities, which have many traffic accidents and many places with simultaneous use by pedestrians, bicyclists and vehicles. Also, the QoRS was evaluated by transportation experts.

4. MEASUREMENT OF SATISFACTION LEVEL WITH ROAD SPACE

4.1. Implementation of Questionnaire Survey

In November, 2012, we conducted a questionnaire survey of 183 road transportation experts who live in large cities, including Sapporo, Sendai, Tokyo, Nagoya, Osaka, and Fukuoka, using a direct distribution and direct collection method. The response rate was 75% (138 responses). The characteristics of the sample are summarized in Table 1.

The questionnaire contained questions on the road structure and the satisfaction level with both the major roads and local roads in their neighborhood based on the perspectives of each road user, i.e. pedestrians, bicyclists, and vehicle users. Therefore, we designed the questionnaire with variables, including the 2 types of roads (major roads and local roads) and the 3 types of road space (road space for pedestrians, road space for bicycles, and road space for vehicles). Also, as shown in Table 2, we adopted 3 elements for each situation, i.e. “safety”, “comfort”, and “convenience”, and each element was assigned one indicator. An example of the content of the questionnaire was as follows.
Table 1. Summary of the sample (138 responses)

<table>
<thead>
<tr>
<th>Sex</th>
<th>Male</th>
<th>(73%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Female</td>
<td>(27%)</td>
</tr>
<tr>
<td>Age</td>
<td>20-29</td>
<td>31 (22%)</td>
</tr>
<tr>
<td></td>
<td>30-39</td>
<td>45 (33%)</td>
</tr>
<tr>
<td></td>
<td>40-49</td>
<td>48 (35%)</td>
</tr>
<tr>
<td></td>
<td>50+</td>
<td>14 (10%)</td>
</tr>
<tr>
<td>Years of Experience in road transport planning</td>
<td>1-5</td>
<td>20 (14%)</td>
</tr>
<tr>
<td></td>
<td>5-10</td>
<td>33 (24%)</td>
</tr>
<tr>
<td></td>
<td>10+</td>
<td>85 (62%)</td>
</tr>
<tr>
<td>City</td>
<td>Sapporo</td>
<td>5 (4%)</td>
</tr>
<tr>
<td></td>
<td>Sendai</td>
<td>7 (5%)</td>
</tr>
<tr>
<td></td>
<td>Tokyo</td>
<td>65 (47%)</td>
</tr>
<tr>
<td></td>
<td>Nagoya</td>
<td>18 (13%)</td>
</tr>
<tr>
<td></td>
<td>Osaka</td>
<td>31 (22%)</td>
</tr>
<tr>
<td></td>
<td>Fukuoka</td>
<td>12 (9%)</td>
</tr>
</tbody>
</table>

Table 2. Structure of the questionnaire

<table>
<thead>
<tr>
<th>type of road</th>
<th>type of road space</th>
<th>element (indicator)</th>
</tr>
</thead>
<tbody>
<tr>
<td>road space for pedestrians</td>
<td>safety (safety of pedestrians)</td>
<td>comfort (width of sidewalks)</td>
</tr>
<tr>
<td>major roads</td>
<td>convenience (walkability)</td>
<td>safety (safety of bicyclists)</td>
</tr>
<tr>
<td>road space for bicycles</td>
<td>comfort (ease of cycling)</td>
<td>convenience (speed of cycling)</td>
</tr>
<tr>
<td>road space for vehicles</td>
<td>safety (safety of vehicle users)</td>
<td>comfort (ease of driving)</td>
</tr>
<tr>
<td></td>
<td>convenience (road congestion)</td>
<td></td>
</tr>
<tr>
<td>local roads</td>
<td>road space for pedestrians</td>
<td>safety (safety of pedestrians)</td>
</tr>
<tr>
<td></td>
<td>comfort (width of sidewalks)</td>
<td>convenience (walkability)</td>
</tr>
<tr>
<td>road space for bicycles</td>
<td>safety (safety of bicyclists)</td>
<td>comfort (ease of cycling)</td>
</tr>
<tr>
<td></td>
<td>convenience (speed of cycling)</td>
<td></td>
</tr>
<tr>
<td>road space for vehicles</td>
<td>safety (safety of vehicle users)</td>
<td>comfort (ease of driving)</td>
</tr>
<tr>
<td></td>
<td>convenience (road congestion)</td>
<td></td>
</tr>
</tbody>
</table>

1) Status of current road space: For each element, 4 options describing the road space were presented, and the respondents were asked to select the option most closely representing the current status of the road space. For example, regarding the safety of the road for bicycles, the following 4 options of road space status were presented;
• Option 1: the road space for bicycles is not separated from the road space for both pedestrians and vehicles, so sometimes I have been afraid.
• Option 2: although the road space for bicycles is separated from the road space for vehicles, it is not separated from the road space for pedestrians, so sometimes I have been afraid.
• Option 3: the road space for bicycles and for pedestrians is separated from the road space for vehicles.
space for vehicles, and there is a bicycle lane marked on an existing portion of a sidewalk, so I can ride a bicycle safely.

- Option 4: the road space for bicycles, pedestrians, and vehicles is completely separated by curbs and such, so I can ride a bicycle safely.

In addition, illustrations were added in order to make it easier for the respondents to understand the options.

2) Satisfaction level of current road space status: regarding the option selected of current road space selected in 1), the satisfaction level was asked to be evaluated with selection of 1 out of 5 levels: dissatisfied, somewhat dissatisfied, neutral, somewhat satisfied, and satisfied.

3) Status of ideal road space: in order to analyze the gap between the current road space and the ideal road space, the most ideal option from the 4 options presented in 1) was given as choice to be selected.

4) Satisfaction level of the road space on major road, local roads, and total roads

5) Personal attributes

4.2. Results of the Questionnaire Survey and Current Satisfaction Levels

As mentioned above, the satisfaction level was evaluated with a choice of 5 levels. In this study, regarding the satisfaction level of current road space, the evaluation was implemented by the following 5-point scale: dissatisfied (20 points), somewhat dissatisfied (40 points), neutral (60 points), somewhat satisfied (80 points), and satisfied (100 points). Also, we applied a logarithmic function to reflect the satisfaction levels, as shown in Figure 4.

Figure 4 shows the current state of satisfaction on the safety of road space for bicycles on major roads, and shows that if the quality of road space improves from option 1 to option 4, the satisfaction level will also be higher. The other elements also have similar results, that is, the satisfaction level was greatly improved when the quality of road space improved from option 1 to option 4.

\[ y = 41.066 \ln(x) + 28.7 \]

\[ R^2 = 0.8918 \]

Figure 4. Current level of satisfaction for the safety of road space for bicycles on major roads (Average value)

The average satisfaction value of each element from the questionnaire is shown in Figure 5. The satisfaction values for local roads are lower than that for major roads. This means that local roads are more problematic when compared with major roads. In particular, in the case of local roads, the satisfaction values of the road space for pedestrians were relatively lower, and the satisfaction value for pedestrian comfort on the road space was the
lowest value (40.1 points). Furthermore, the satisfaction values of the safety of local road space for bicycles (43.3 points) and for vehicles (43.0 points) were lower when compared to the other elements.

![Figure 5. Current level of satisfaction for each element (Average value)](image)

On the other hand, in the case of the major roads, the satisfaction value for the convenience of road space for bicycles showed the highest satisfaction value (61.7 points), while the value for bicycle safety had a lower score (48.0 points). The data suggest that bicyclists find the major roads more convenient, but they also feel danger on the major roads due to the vehicular and pedestrian traffic volume.

As mentioned above, we conducted a survey to determine the status of the current road space and to analyze the gap between the current road space status and the ideal road space. The results showed that there is a large gap between the current and ideal road space. For example, Figure 6 shows the gap between the current and ideal road space status for pedestrian safety. Approximately 80% of the current road space for pedestrians on major roads was identified as being in the category of “although the road space for pedestrians is separated from the road space for vehicles, it is not separated from the road space for bicycles”. Two of the other categories which represent a more ideal status, including “the road space for pedestrians and bicycles is separated from the road space for vehicles, and a bicycle lane is marked on an existing portion of a sidewalk” and “the road space for pedestrians, bicycles, and vehicles is completely separated by curbs and such” account for about 49% and 45%, respectively.

In contrast, in the case of road space for pedestrians on local roads, approximately 50% of the current road space is in the status of “the road space for pedestrians is not separated from the road space for both bicycles and vehicles”. For the ideal status, the category of “the road space for both pedestrians and bicycles is separated from the road space for vehicles, and a bicycle lane is marked on an existing portion of a sidewalk” accounts for about 60%. This result shows that the problem of the local roads is more severe when compared to that of the major roads.

It should be noted that, the category of “the road space for pedestrians, bicycles, and vehicles is completely separated by curbs and such” which is the safest status, only accounts for 20% on the local roads and 45% on the major roads. It is possible that the respondents answered the questionnaire with the feasibility of an ideal status in mind, because they were
road transportation experts. Actually, it is possible to achieve the status of “the road space for pedestrians, bicycles, and vehicles is completely separated by curbs and such” on major roads. However, on local roads, this feasibility is quite low. Therefore, the ideal status was selected mostly for local roads.

As mentioned above, the satisfaction level of current road space and the requirements for an ideal road space are different according to the road type. Therefore, it is necessary to analyze them separately.

![Figure 6. The current status and ideal road space for the safety of pedestrians](image)

5. EVALUATION OF ROAD SPACE BASED ON THE QUALITY OF ROAD SPACE (QoRS)

5.1. Measurement of the QoRS

In this study, we evaluated the QoRS comprehensively, incorporating the road user’s satisfaction levels and values (weights), for reallocating a safe and comfortable road environment for all road users, including pedestrians, bicyclists, and vehicles. The evaluation of road space considered the combinations of 3 types of road space (road space for pedestrians, bicycles, and vehicles) and 2 types of roads (major roads and local roads) on the basis of the satisfaction values of each element.

Overall the QoRS for general satisfaction is formulated in the following equation (1).

$$QoRS = \sum_{i=1}^{m} \alpha_i S_i , \quad \sum_{i=1}^{m} \alpha_i = 1$$ (1)

Where,

$$S_i \equiv \sum_{j=1}^{n} \beta_{ij} S_{ij} , \quad \sum_{j=1}^{n} \beta_{ij} = 1,$$

$$S_{ij} \equiv \sum_{k=1}^{k} \gamma_{ijk} S_{ijk} , \quad \sum_{k=1}^{k} \gamma_{ijk} = 1,$$

$$S_i : \text{satisfaction value by road type } i ,$$

$$S_{ij} : \text{satisfaction value by road space type } j \text{ of road type } i ,$$
\[ S_{ijk} \]: satisfaction value by element \( k \) of road space type \( j \) in road type \( i \),

\[ \alpha_i \]: weight by road type \( i \),

\[ \beta_{ij} \]: weight by road space type \( j \) of road type \( i \),

\[ \gamma_{ijk} \]: weight by element \( k \) of road space type \( j \) of road type \( i \)

However, in order to evaluate the QoRS comprehensively, it is necessary to understand the relationship between the elements and the 3 types of road space and 2 types of roads. But, incorporating all of these factors into the questionnaire survey can be a burden for the responders, and lead to a reduction in the reliability of the survey results. In addition, since weight in the multi-criteria analysis, such as Analytic Hierarchy Process (AHP), measures merely preference relations, it is important to note that the overall evaluation value used in the multi-criteria analysis is ambiguous in both its meaning and scale (Hayashi et al., 2004). Therefore, we analyzed the causal relationship by covariance structure analysis, and used path coefficients as weights. The weight is formulated as shown in the following equation (2).

\[ \gamma_{ijk} = \omega_{ijk} / \sum_{k=1}^{n} \omega_{iink} \]  

(2)

Where,

\[ \gamma_{ijk} \]: weight by element \( k \) of road space type \( j \) of road type \( i \),

\[ \omega_{ijk} \]: path coefficient by element \( k \) of road space type \( j \) of road type \( i \)

As described above, based on the results of the survey, the covariance structure analysis was conducted by SPSS Amos software. Also, the model of the hierarchical structure was constructed for estimation of weights shown in equation (1). As a result, the path coefficients shown in Figure 7 were obtained, and the goodness of fit index (GFI) was 0.688, and the adjusted goodness of fit index (AGFI) was 0.613. Weights were calculated by using the path coefficients as shown in equation (2). Also, the QoRS was calculated using the weights as shown in equation (1). The results are shown in the Table 3.
### Table 3. Calculated results of satisfaction values and the QoRS

<table>
<thead>
<tr>
<th>type of road</th>
<th>type of road space</th>
<th>Element (indicator)</th>
<th>by element satisfaction value</th>
<th>weight</th>
<th>by road space satisfaction value</th>
<th>weight</th>
<th>by road type satisfaction value</th>
<th>weight</th>
<th>QoRS</th>
</tr>
</thead>
<tbody>
<tr>
<td>major roads</td>
<td>road space for pedestrians</td>
<td>safety (safety of pedestrians)</td>
<td>52.2</td>
<td>0.323</td>
<td>56.1</td>
<td>0.349</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>comfort (width of sidewalks)</td>
<td>54.2</td>
<td>0.320</td>
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<td>0.336</td>
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<td>safety (safety of vehicle users)</td>
<td>53.9</td>
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<td>road space for vehicles</td>
<td>safety (safety of vehicle users)</td>
<td>43.0</td>
<td>0.379</td>
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5.2. Evaluation of Road Space

As shown in Table 3, the weight for the “local roads” is 0.576, which is higher than that of the “major roads” (0.424) by 0.152. The findings show that road transportation experts are concerned about the current status of the local roads and strongly feel the necessity for improving the quality of the local roads in comparison with the major roads.

The weight of road space for vehicles is the highest (0.362) for the major roads due to the prioritized vehicle traffic on major roads. The weight of “comfort” is the highest (0.350) for the road space for vehicles, that of “convenience” is second highest (0.334), and that of “safety” is lower (0.316). This finding may indicate that road transportation experts expect a higher level of service on the major roads for vehicles.

On the other hand, the weight of the road space for pedestrians is the highest (0.359) on the local roads. This result indicates that road space for pedestrians on the local roads has many problems and that the level of service is very low as described in Section 1, even though the road space for pedestrians is closely related to the quality and way people live. In addition, the weight of “safety” is higher than that of both “comfort” and “convenience” in the road space for both vehicles and bicycles. The results indicate that bicyclists and vehicle users are concerned about the safety of the local roads.

Meanwhile, Table 3 also shows the calculated results of satisfaction values of the road space. The overall QoRS is 50.7 points, and the satisfaction value of the local roads is 46.7 points, which is lower by about 10 points when compared to that of the major roads (56.3 points). This result also indicates that there are lots of problem on the local roads. As for the satisfaction value by road space type, the satisfaction value of road space for vehicles is the highest on the major roads as well as on the local roads. The results are likely due to conventional vehicle-oriented road planning and development. On the contrary, the satisfaction value of road space for pedestrians on the local roads is the lowest in the value by road space type (43.5 points), which is lower by about 15 points compared to the highest value for vehicles on the major roads (58.3 points). This indicates that the large number of pedestrian-associated traffic accidents as shown in Section 1 is an inevitable problem caused by the low quality of the local roads. As for the major roads, the satisfaction value of road space for bicycles is the lowest in the value by road space type. The reason for the low satisfaction is likely the lack of the provision of road space for bicycles despite the increase of bicycle utilization as shown Section 1.

As described above, in order to improve the QoRS, it is more effective to improve the quality of the local roads, which have a larger weight compared with the major roads. As for the local roads, improving the quality of road space for pedestrians is more effective. In particular, in order to improve the quality of road space in response to the needs of the road users, it is important to shift from vehicle-oriented road development to people-oriented road development and road space reallocation.

As shown in Table 3, in this study we used the average as the satisfaction value because the sample populations were made not of local residents in a local area but of road transportation experts with relatively similar characteristics. We also wanted to clearly show the differences between elements, types of road space, and types of roads. In our future practical application of road space evaluation in a local area, the individual attributes of the various stakeholders will be considered more carefully.
6. CONCLUSIONS

Japan has recently suffered infrastructure deterioration and severe financial constraints with about 45% of the revenue coming from government bonds and 20% of the expenditure devoted to debt repayment. Japan has entered into a period when effective utilization and maintenance of existing roads has become more important than constructing new roads. Furthermore, with the maturation of the economy and social changes, such as an aging society, the type of road traffic has also changed. In particular, although vehicle traffic accidents have declined, traffic accidents involving pedestrians and bicycles, especially on the local roads, are increasing and becoming more serious.

Despite these changes in society demographics and in road usage, road policies are still focusing on vehicle-oriented road policies and on major roads. Local roads and road space for pedestrians and bicyclists have less priority than road space for vehicles and major roads. Also, there is little quantitative data on local roads.

Since reallocation of road space is becoming more and more important, we evaluated road space utilization and the need for new types of road space reallocation taking into consideration the needs and perspectives of all users, including pedestrians, bicyclists, and vehicle users. For this study, we used a questionnaire survey completed by road transportation experts.

As a result of our road space evaluation based on the survey questionnaire, we found that the experts were concerned about the current status of the local roads in their daily life, but they usually focused their attention on the major roads. In particular, it was shown that, in order to improve the QoRS, it was more effective to improve the quality of the local roads which have a larger weight compared with the major roads. Furthermore, improving the quality of road space for pedestrians would be more effective. Therefore, in order to improve the quality of road space based for the road users’ needs, it is necessary to retreat from the construction of major roads and from vehicle-oriented road policies, and to implement road space reallocation considering the needs of both the residents and various stakeholders.

As mentioned above, there are various stakeholders in road space, and they have different needs. Therefore, it is vital to take into consideration the various stakeholders and their needs when we examine road space evaluation and develop road transport policies.

As a method reconciling conflicts between different stakeholders and incorporating their needs for road space reallocation, Jones et al. (2007) emphasized the importance of involving stakeholders in design development of road space, particularly through the use of the design workshops. In practice, the practical trials carried out in the ARTISTS project in several European cities showed that the results of design workshops can be of great benefit to the overall design process (Jones et al., 2007). McCann and Rynne (2010) also emphasized the necessity to involve a wide variety of stakeholders in the policy development process to ensure that all needs are addressed.

In a future study, we will consider the viewpoints of various stakeholders in carrying out a case study of road space reallocation, and examine the effectiveness of involving them in the design development of road space through design workshops.

REFERENCES

Institute for Traffic Accident Research and Data Analysis (ITARDA) (2011) ITARDA traffic accident statistics 2010, Tokyo: ITARDA.


