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Integrated impacts of public transport travel and travel satisfaction on quality of life of older people

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A R T I C L E I N F O

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A B S T R A C T

This study identifies the relationship between individual's travel and their perceived Quality of Life (QoL). We consider two variables for travel reflecting its objective/quantitative and subjective dimensions. The observed one is a measure based on public transport trip frequency and travel duration obtained from smart card data. The second is the perceived level of *Travel Satisfaction* which is obtained by survey data. This study is conducted in Shizuoka city, a mid-size city in Japan where we could obtain and link both data sets. We focus particularly on aging effects and therefore divide the data samples into three groups, non-elderly (less than 65 year), younger-old (65–74 years), and older-old (over 75 years). Older people show in general higher travel satisfaction. Regression analysis with travel satisfaction as dependent variable indicate the importance of travel opportunity for older-old. We then identify the relative importance of mobility on QoL considering both objective and subjective one and discuss transport policy implications for an aging society based on these results. The results provide support that public transport systems are determinants of its usage, travel satisfaction and eventually QoL. These relationships are most evident for younger-old but less significant for older-old.

1. Introduction

Population ageing is occurring over the world, especially in Asia. According to a report published by the World Bank Group, more than 211 million aged people lived in East Asia in 2010 (36% of the global population in that age group) and between 2015 and 2034 the older population will grow by about 22% every five years in East Asia (World Bank Group, 2016). This increase will bring significant changes to city life including the need for changes in the transportation system. One common concern is traffic safety. Japan's National Police Agency Statistics report published in 2016, showed that elderly drivers are very prone to accidents. The report also noted that the accounted ratio of elderly traffic fatalities last year was the highest so far. Therefore, in Japan and other countries, strategies to significantly decrease elderly driving are sought. For this, it is believed that improving the public transport system is required. At the same time, with the declining birth rate, the aging population, and the mass retirement of the baby-boomer

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generation, the social structure has been changing at a remarkable rate in recent years. In particular a strong urbanisation trend in Japan has made it in fact difficult to even maintain the current public transport level in rural areas. Given these trends, there is a need to better justify the need for a public transport service to improve older person's mobility and, more fundamentally, to better establish whether there is a causal chain from better public transport to better and safer mobility to finally improved Quality of Life (QoL) which can be seen as the ultimate goal. Establishing the validity of this casual chain motivates this paper. In support of the second part of this causal chain we note that there are studies such as Ettema et al. (2011) and Olsson et al. (2013) who establish a link between travel satisfaction with "well-being" though without focus on older people.

Particularly in local cities with high dependence on automobiles, it is necessary to establish the importance of specific countermeasures to a decline in the transport service quality within a super-aged society. Recent papers such as Lättman et al. (2018) and Pyrialakou et al (2016) argue that with upcoming issues of ageing populations worldwide, modal changes make it increasingly important to ensure that levels of accessibility are and remain sufficient for daily travel needs of all population groups to avoid transport disadvantages and with it social exclusion (Church et al, 2000). This in turn likely reduces QoL, though any conception of QoL should consider its multiple determinants. It is clearly more than satisfaction with the activities that are enabled by travel or that people undertake during trips and that allow one to achieve purpose and meaning in life (De Vos et al., 2013). Cummins (2000) reviewed the relationship between objective and subjective QoL indicators and identified that these are normally poorly correlated due to the capacity of QoL to adapt to varying environmental circumstances. In order for QoL to embrace the totality of human life both objective and subjective dimensions must be included (Lawton, 1991; Romney et al., 1994; Cummins, 2000).

Following this argumentation, this study is based on the assumption that there may be a large difference between perceived travel and objectively measured travel. In addition this difference may increase according to an individual's socio economic situation, i.e. by age, gender, income level, residence location, travel patterns, and social exclusion, etc. Supporting the findings of Cummins (2000), we refer again to Lättman et al. (2018) who identified that perceived accessibility is consistently different from objective accessibility. They used a scale for perceived accessibility developed by Lättman et al. (2016) and aimed at capturing the perceived accessibility for a certain travel mode. They concluded by pointing out the importance of this perceived accessibility as a complementary measure when planning for transport systems.

In order to represent objective and subjective dimensions related to travel needs, this study adopts what we will refer to as "*Potential Travel"* from observed actual travel behavior and *Travel Satisfaction* for perceived level of daily travel. Both the objective and the subjective part could be measured in a number of ways. For the objective part, taking for example trip frequency as a measure is one dimensional and does not account for the fact that especially some older persons might prefer substituting several shorter trips with a few longer trips. Kaufmann et al. (2004) explains that an "objective measure" should be defined as "the capacity of entities (e.g. goods, information or persons) to be mobile in social and geographic space, or as the way in which entities access and appropriate the capacity for socio-spatial mobility according to their circumstances". De Vos et al. (2015) noted that the potential to move could be partly explained by the capabilities approach (Sen, 1993), according to which well-being can only be realised through freedom and the ability to conduct the activities which lead to the life one values.

The reminder of this paper is structured as follows: The following section reviews in more detail the established literature on travel and QoL. In Section 3, we discuss the model structure to identify impact of travel on QoL and generally explain our rationale for using public transport travel frequency and travel time for "Potential travel" which describes the likelihood that a person is able to make bus journeys of a certain length given a usage frequency. We then describe our study area and public transport usage data in Section 4. Section 5 analyses the smart card usage data to obtain expected travel frequencies and then travel times for different age groups depending on trip frequency. Section 6 firstly discusses the survey questions and data of the psychological factors and other related determinants that are used to estimate subjective travel satisfaction of a subset of the smart card users analysed in previous section. The results of Sections 5 and 6 are then combined in Section 7 where a regression model with QoL as dependent variable is estimated. Finally, Section 8 concludes the study by summarising the results and deriving some policy implications.

2. Travel and quality of life

Metz (2000) was one of the first authors to explicitly note the need to focus on the QoL and the travel relationship among older people. Through several studies, it has been verified that there is a strong relationship between Mobility and Quality of Life (QoL). Nakanishi and Doi (2003) noted that mobility is positioned as "one of the factors that increase the range of individual choice" in the evaluation of QoL. Having to abandon activities negatively influences satisfaction of life and people who feel inconvenient to move usually evaluate their levels of "happiness" as lower (Sasaki, 2014; Delbosc et al., 2011). Independence and mobility are important elements constituting the well-being of elderly (Schwanen et al., 2011, Schwanen et al. 2012). Hudakova (2011) also investigates the impacts of transport mobility and their impacts on the quality of life for non-working older people and argues that, compared to younger people, this relationship is stronger. Moriyama et al (2002) use the concept of QoL as an evaluation index for transport and other life-supporting services for elderly people in depopulated areas in Japan. They suggest that elderly people who are restricted in mobility from covariance structured analysis do not select activities with narrow service ranges and low service levels.

Accessibility also has been adopted to explain transport and social exclusion. Lättman et al. (2016) point towards accessibility as a key issue for research development on social inclusion and sustainable transport planning. Various previous studies demonstrated some degree of relationship between accessibility and social exclusion (Church et al., 2000; Casas, 2007; Engels and Liu, 2011; Delbosc and Currie, 2018). Bayram et al (2012) make the link between accessibility and QoL clearer by looking at the relationship between the former and "psychological life quality". Musselwhite and Haddad (2010) carried out a study to identify the role of accessibility in older people's self-reported quality of life, through an in-depth examination of older people's travel needs. They found accessibility is related to an individual's perception of QoL, in particular when older people give-up driving and face a lack of public transport services. Doi et al (2008) developed a QoL-based accessibility measure describing that accessibility is an essential factor in land-use and transport planning, as well as in performance measures for policy evaluation from the viewpoint of individuals' QoL.

In above literature and numerous further studies, mobility and accessibility have been used in planning and evaluating the transportation system through activity-based approaches such as choice theory and travel behaviour. Mobility is usually measured in these studies in its various forms that can describe "ability and need to move", e.g., number of trips, time use or out of home activities, (Delbosc and Currie, 2018; Lättman et al., 2016); while accessibility has conventionally been closely linked to mobility, and more specifically defined and operationalized through objective measurements such as distance and travel time to a selection of destinations (Lättman et al., 2016). Especially De Vos et al. (2013) and Mokhtarian (2015) describe that the combination of mobility and accessibility contribute to well-being, or the ability to lead a full and meaningful life. According to Delbosc and Currie (2018) both transport measures are likely to have an impact on QoL as well as on social exclusion by developing a theoretical framework. Therefore this study also considers both mobility and accessibility as influential factors in an individual's perception of life quality.

The following section will describe how we conceptualise the "travel" aspects of accessibility and mobility. In contrast to Delbosc and Currie (2018), we aim to quantify both aspects into a joined "objective indicator" and in addition measure *travel satisfaction* as a "subjective indicator". This way we aim to quantify the relative impact of these two dimensions on QoL.

3. Study methodology

3.1. Relationship between QoL and indicators

Following Felce and Perry (1995) and Doi et al (2008), Eq. (1) is a conceptualisation of QoL as general satisfaction obtained from a range of possible factors

$$Q_m(S_m; w_m) = \left[\sum_{k=1}^{k} w_{i(m)k} S_{mk}(x_{mk})^{-\rho} \right]^{-1/\rho} \tag{1}$$

where, S_{mk} is the vector of satisfaction level by element k for individual m, w_{ik} are the weights of element k for person group i to which individual m belongs, x_{mk} is the indicator level of element k; and ρ is a parameter for elasticity of substitution across element k. We note that this functional form is a type of multi-attribute utility function and one might argue whether this form of adding up satisfaction scores is the most appropriate form for measuring QoL.

In this study we adopt a simplified functional form as we only focus on the relationship between overall life quality and individual's travel by public transport. The following model will be constructed based on our assumption that potential travel and travel satisfaction as well as socioeconomic indicators affect individual QoL. Obviously a wide range of other factors, in particular health will also affect QoL. Therefore our model should not be used for QoL prediction but for understanding correlation of travel factors with QoL. We presume therefore a general functional form as in (2) where we expect the "error term" ε_m to be large.

$$Q_m = f(S_m^o, S_m^s, \boldsymbol{x}_m) + \varepsilon_m \tag{2}$$

S_m^o is a sub model for measuring "potential travel" estimated by public transport usage records of individual m. S_m^s is a sub model for a latent variable of travel satisfaction for a population group. The latter is measured by a survey and direct questions on how overall satisfied a person is with his/her travel. $\boldsymbol{x}$ is a set of socioeconomic variables describing person m. We describe our definition of potential travel in the following subsection. Our measure of travel satisfaction is directly obtained from a questionnaire as well as an adopted ordinal regression for estimating travel satisfaction as will be explained in Section 6.

We will group persons according to their age bracket i as well as their public transport usage frequency n as these are attributes of main interest to us. Several studies have classified older people by age, distinguishing in particular younger people from younger-old and older-old. Younger-old are generally defined as those aged between around 60–75 and older-old as persons with age above 75. Among others Forman et al (1992), Schmöcker et al. (2010) and Gareri et al (2014) have shown that younger-old can be even more active than younger people as they are often healthy and have more free time than working younger people. Only with the onset of more severe aging related health decline, often trip numbers reduce. In this study, we therefore also distinguish these three groups i.e. non-elderly (30–64 year), younger-old (65–74 years), and older-old (over 75 years). We use 65 as the separating age for non-elderly and younger-old as this age is often associated with retirement in Japan. Furthermore, from 65 years old onwards one can obtain a so-called "Silver Pass" for a fairly low fee that allows unlimited local public transport usage.

3.2. Definition of public transport potential travel

For the objective measurement of travel quality we identify trips per person and the average travel time per trip. Partially due to data limitations and partially due to our focus on the relationship between public transport and QoL we focus on public transport trips, that is, we only measure mobility partially. We suggest that public transport travel might be to some degree a good indicator to understand the relationship between mobility, accessibility and QoL as public transport allows persons to remain active even after driving cessation. In other words, if the ability to travel by public transport, irrespective of other trips, can support QoL, this provides good support for the need of such services. We note, however,

that in our database described in the following section, we only have those persons who have made at least one public transport trip. Therefore we can mainly make statements about changes in public transport usage and not whether only car users would have a higher QoL.

Whereas trip numbers can be seen as an index of mobility, average travel time per trip can be considered an indicator for accessibility as well as activity space. That is, the longer the time per trip the more likely the person is either living in a less well-served public transport area and/or is using public transport for trips that are outside one's neighborhood. Also for this measure of travel time only, we acknowledge though its shortcomings. For one, changing lines is often more of a burden to people than time spent on the bus. This is especially the case for older people. Furthermore, there will be self-selection issues and persons less using public transport will also tend to value public transport travel time less.

To be able to compare the relative importance of an "objective" travel indicator and travel satisfaction we define "potential travel" as a composite measure of both public transport trips and travel time. Therefore, we suggest that the following measure encompasses both mobility and accessibility.

$$S_m^o = PoT_{i,n}(t_m) = f(1 - \varphi_{i,n}(t_m)) \tag{3}$$

where $\varphi_{i,n}(t_m)$ denotes the cumulative probability function of making a journey of travel time t, n the weekly travel frequency of individual m, I the age group of person m and t_m his/her average travel time per trip. (Strictly, one might hence use the subscripts $i(m)$ and $n(m)$ which we omit for brevity.) f denotes a function to be specified.

Our rationale is as follows: Clearly persons with more trips tend to make (on average) shorter trips. If a person is therefore able to – or "has the potential" – to make long trips despite making many trips s/he might be considered to have more ability or need for travel. We therefore define PoT as the potential travel for journeys with duration t. In the context of commuting one would expect that more trips and longer travel time lead to less travel satisfaction and ultimately QoL. In the context of leisure trips and if one wants to describe "opportunities" we would expect though a reverse relationship.

Note in the following, for brevity, we only use subscripts i, n to describe the age and travel frequency groups of person m. We estimate $PoT_{i,n}(t_m)$ with a simple linear approximation from our data as will be described in the following, i.e.

$$PoT_{i,n}(t_m) = \alpha_{i,n} + \beta_{i,n} t_m \tag{4}$$

4. Target area

Our case study site is Shizuoka city, a mid-size city in Japan. As of the end of April 2015, the city had an estimated population of 715,752 and a population density of 507 persons per km^2. The city also faces a serious aging problem making it a good case study for our research. The elderly population was 86,043 (11.6%) in 1990, 152,939 (21.1%) in 2005 and 204,354 (28.8%) as of the end of September 2017. It is predicted that the elderly population will likely exceed 30.5% by the end of 2020.

The city has one major CBD (city center) with JR Shizuoka Station (see Fig. 1) in its center. There is one additional, privately operated local rail line, but the bus network is well spread inside the city and the main public transport mode for local travel. Our database consists of these bus trip records of the whole network for January 2015. Shizuoka city offers people aged 65 and older

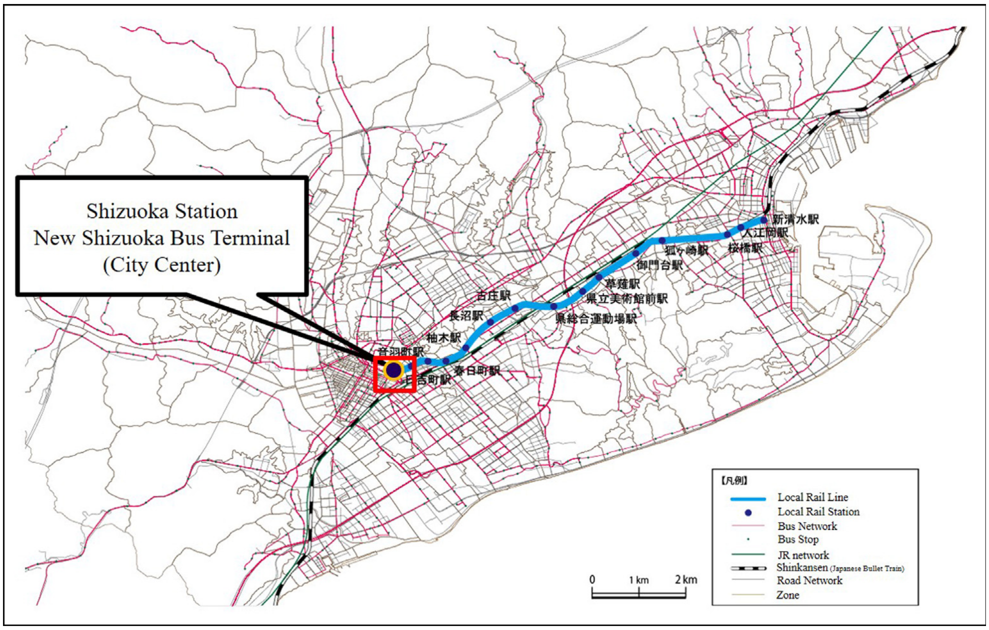

Fig. 1. Transportation network in Shizuoka city.

Table 1
Averaged monthly on-bus time per trip by age groups (non-signifcant group differences indicated with dashed line). (unit: minutes).

Average weekly bus use frequency (n)	Sample size by n	Mean (Std)			ANOVA	
		Non-elderly (30–64 years)	Younger-old (65–74 years)	Older-old (> 75 years)	F	p-value
Seldom (< 1 times, n = 1)	28,311	18.09 (11.81)	18.97 (11.65)	17.05 (11.51)	24.32	0.000
Occasionally (1–2 times, n = 2)	26,324	17.62 (8.94)	17.77 (8.76)	16.49 (8.51)	28.72	0.000
Regularly (3–6 times, n = 3)	16,649	17.07 (7.82)	17.37 (7.54)	16.18 (7.48)	13.98	0.000
Frequently (7 + times, n = 4)	20,437	19.23 (9.16)	18.35 (7.54)	17.13 (6.81)	47.76	0.000
Sample size by age group		68,981	11,808	10,932	–	

reduced public transport fares through registering for the local smart card called "LuLuCa" so that almost all older people with interest in public transport hold one. Through these LuLuCa records we can obtain trip frequency as well as boarding and alighting stops of users. As will be described in the following, for a subset of these people, we were able to match the individual user records of older people and a formerly conducted survey regarding their perceived travel satisfaction and QoL. Through the survey and the smart card data registration information we further hold information on some socio-demographic information including, age, gender and home location. In line with aforementioned literature we targeted both younger-old (65–74 years) as well as older-old (over 75 years). In addition we analyze smart card data and obtain a survey sample from non-elderly (30–64 years) as a control group.

5. Estimation of objective travel indicators

5.1. Average travel time by trip frequency and age group

Table 1 indicates the mean and standard deviation of bus journey time t_m for the three age groups and four frequency groups based on average weekly usage. Chi-square tests indicated that the assumption of a normal distribution for each group is acceptable. The usage frequency categories are obtained by dividing the sample in nearly equal quartiles. We further show that the group differences are significantly different among the age groups according to ANOVA testing. Additional t-tests between all combination of two adjacent cells confirm that all differences are significant except for Non-elderly and younger-old in the "Occasionally" and "Regularly" groups.

Among the non-elderly those using the bus very frequently have on average the longest travel time per trip indicating that these are likely (fairly long) commuting trips from suburban areas to Shizuoka's central station. In contrast among younger-old those who use the bus seldom tend to make slightly longer trips. These might be occasional activities that tend to be at a further distance compared to for example regularly food shopping trips made by public transport. For old-old the differences between the four frequency groups are within one minute. In general their trip times are reduced indicating the reduced spatial activity range with the onset of old-age. This reduction in time per trip with increasing age we can in fact observe for all frequency groups except for the seldom group.

5.2. Model estimation for potential travel

We now construct the cumulative probabilities curves of having a specific average travel time t_m or less by trip frequency and age groups as shown in Figs. 2a to 2c. These curves are the basis for our estimation of potential travel following our discussion in Section

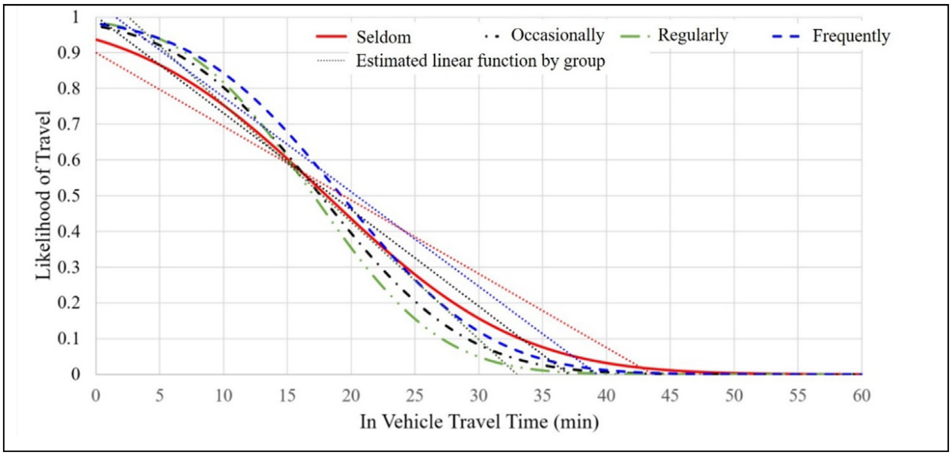

Fig. 2a. Probability curve and estimated function for potential travel. among non-elderly persons (30–64 years).

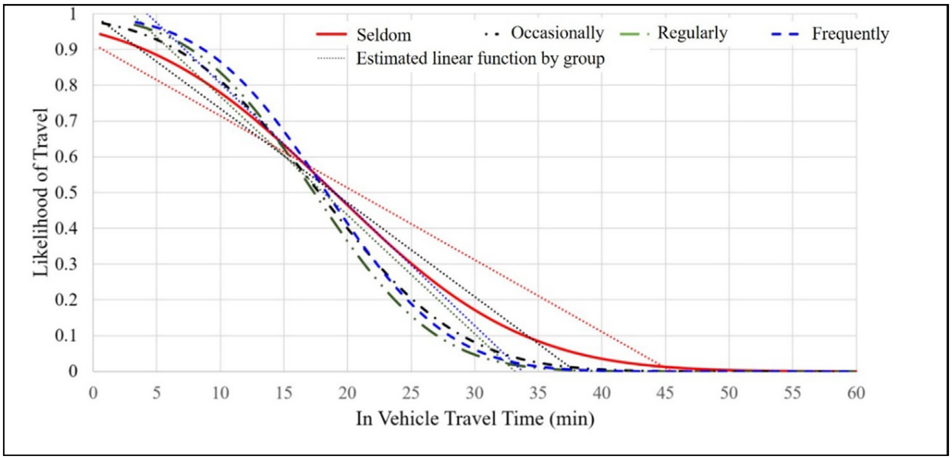

Fig. 2b. Probability curve and estimated function for potential travel. for younger-old (65–74 years).

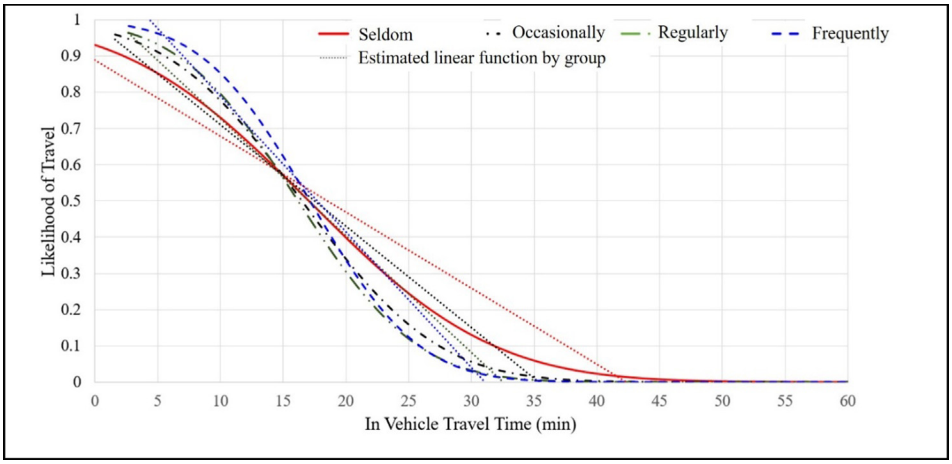

Fig. 2c. Probability curve and estimated function for potential travel for older-old (> 75 years).

3.2. The curves are approximated with a linear function as described in Table 2. We observe for older-old and younger-old who use the bus frequently a steeper slope than for younger people. In line with our above discussion in previous section this implies that older people who use buses frequently are less likely to travel long distances.

Based on these estimated functions, two scenarios for short and long travel are constructed, characterised with thresholds of 10 min and 30 min of t_m respectively. As shown in Fig. 3, the short travel potential for journeys of 10 min or less increases as the

Table 2
Estimated models for Potential Travel.

Age (i)	Average weekly bus use frequency (n)	Estimated coefficients for Potential Travel, PoT(t)		R^2	Averaged IVTT (min)
		$\alpha_{i,n}$	$\beta_{i,n}$		
Non-elderly (i = 1)	Seldom (n = 1)	0.9009	−0.0206	0.85	18.09
	Occasionally (n = 2)	1.0022	−0.0271	0.85	17.62
	Regularly (n = 3)	1.0836	−0.0328	0.89	17.07
	Frequently (n = 4)	1.0401	−0.0265	0.87	19.23
Younger-old (i = 2)	Seldom (n = 1)	0.9157	−0.0201	0.85	18.97
	Occasionally (n = 2)	0.9972	−0.0263	0.83	17.77
	Regularly (n = 3)	1.0998	−0.0332	0.87	17.37
	Frequently (n = 4)	1.1446	−0.0339	0.89	18.35
Older-old (i = 3)	Seldom (n = 1)	0.8886	−0.021	0.86	17.05
	Occasionally (n = 2)	0.9914	−0.028	0.85	16.49
	Regularly (n = 3)	1.0498	−0.0323	0.86	16.18
	Frequently (n = 4)	1.1633	−0.0374	0.89	17.13

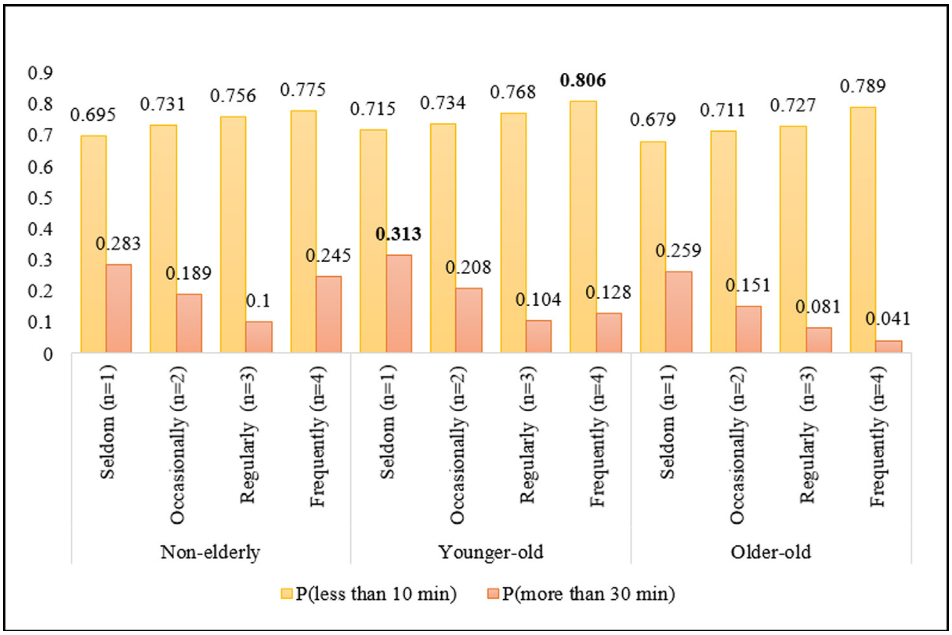

Fig. 3. Probability of short (< 10 min) and long (more than 30 min) trips by groups.

frequency of bus usage rises in all age groups. For long journeys of 30 min of travel time or more, older-old are less likely to travel this duration if their travel frequency decreases. However, in case of non-elderly and younger-old, those who use the bus regularly are more likely to move for 30 min by bus than those who use the bus occasionally. These results illustrate the similarity in bus usage patterns of younger-old and non-elderly persons. In addition, younger-old who use a bus less than once a week have the highest potential travel for both t_m values and younger-old who use buses every day have the highest probability to travel for at most 10 min on average.

6. Model for travel satisfaction

6.1. Survey data

To measure travel satisfaction as well as QoL, we distributed a survey among smart card users (12th–22th January 2016). Social activities and use of public transportation might be influenced by season and weather, therefore we considered both potential travel and travel satisfaction in the same season and month. In Section 5, the smart card usage data of January was analysed, thus we also surveyed bus users in January to reduce bias in travel activities that might occur due to weather differences as discussed in for example Horanont et al. (2013). The sample size is 386 including 108 younger-old and 46 older-old. *Satisfaction of travel* is taken as the dependent variable and its determinants are the psychological variables shown in Table 3, i.e. *Perceived travel opportunity, Residence area satisfaction, Bus system satisfaction, and Satisfaction of activities by trip purpose (leisure, shopping and medical)*. *Perceived travel opportunity* was also measured on a 5-point Likert scale (5: strongly agree – 1: Strongly disagree) with three items that describe one's agreement to having enough or more opportunities to travel. The reminder of the questionnaire is as below and all answers

Table 3
Determinants for travel satisfaction.

Variables (Cronbach's alpha)	Question, all asked on a 5 point Likert scale with endpoints "Strongly disagree" and "Strongly agree"
Travel satisfaction *	Are you satisfied with your daily movement?
Perceived travel opportunities (0.740)	Do you have sufficient opportunities to go out?
	Do you have more opportunities to go out compared with last year?
	Do you think there will be increased opportunities to go out in the future?
Residence area satisfaction (0.78)	Is it easy to go to the city center or downtown area from your house?
	Do you think that the transportation environment (stations, bus stops, roads) around your home is good?
Bus system satisfaction (0.81)	In general I am satisfied with the current bus service.
	The bus service is available whenever I want to use.
Satisfaction of activities by trip purpose	Are you satisfied with travel for *leisure* activities that you participated?
	Are you satisfied with travel for daily *shopping* in general?
	Are you satisfied with travel for outpatient visits to *medical* institutions for general consultation?

* Dependent variable.

Table 4
Results of ANOVA test by age group.

Variables	sum of squares	Mean square	F	p-value
Travel satisfaction	1.175	0.588	0.583	0.559
Perceived opportunity to travel	0.564	0.282	0.429	0.652
Residence area satisfaction*	5.512	2.756	2.578	0.077
Bus system satisfaction	2.448	1.224	1.138	0.321
Satisfaction with bus system for leisure trip***	17.736	8.868	10.395	0.000
Satisfaction with bus system for shopping trip	0.412	0.206	0.273	0.761
Satisfaction with bus system for medical trip**	7.476	3.738	4.705	0.010
Perceived usual travel time for shopping trip**	2341.368	1170.684	3.141	0.044
Perceived usual travel time for medical trip*	2862.763	1431.382	2.988	0.052

*** < 0.001, ** < 0.05, * < 0.1.

were also measured on a 5-point Likert scale (5: fully satisfied – 1: not at all satisfied). Construct reliability analysis showed acceptable Cronbach reliability values (internal consistency, i.e. the degree to which items belonging to the same construct are answered consistently) for all constructs (Perceived travel opportunity, 0.74; Residence area satisfaction, 0.78; Bus system satisfaction, 0.81) as values above 0.7 are generally acceptable (Kline, 2000). As constructs are reliable we then take the mean for the item responses for each person as construct measure. Besides, perceived usual travel time (minute) for shopping/medical trips, age, car ownership and living status (live with family members or alone) were also surveyed. For measuring the perceived travel time, we used the question of "Please answer the time required to go to shopping/hospital (as well as approximate waiting time when using transit)".

6.2. Descriptive analysis

To understand satisfaction differences between age groups the results of an ANOVA test are shown in Table 4 and selected mean values are illustrated in Fig. 4. Residence area satisfaction, leisure trip satisfaction, medical trip satisfaction and perceived travel time for shopping and medical trips significantly differ by age group. We observe that older-old are in general more satisfied with their residential and travel circumstances, in particular they are significantly more satisfied with their leisure and medical travel. This is despite the perceived travel time for shopping and medical service increasing by age. One possible explanation for this is that in general with high age, as trip frequencies decrease, the expectations on the transport system are less demanding. We further remind that we have a bias in our data in that only those having used public transport at least once over the past year are in the database. As proportionally more older-old will not be in the database we therefore can conclude about general higher travel satisfaction only for the population subgroup that is able to use public transport. Nevertheless, we suggest our observation is noteworthy and highlights different expectations depending on age.

Comparing further younger-old and non-elderly, we can observe a similar aging trend in that satisfaction levels of younger-old are higher than those of non-elderly. In particular satisfaction levels with the possibility to make leisure trips with the local buses are

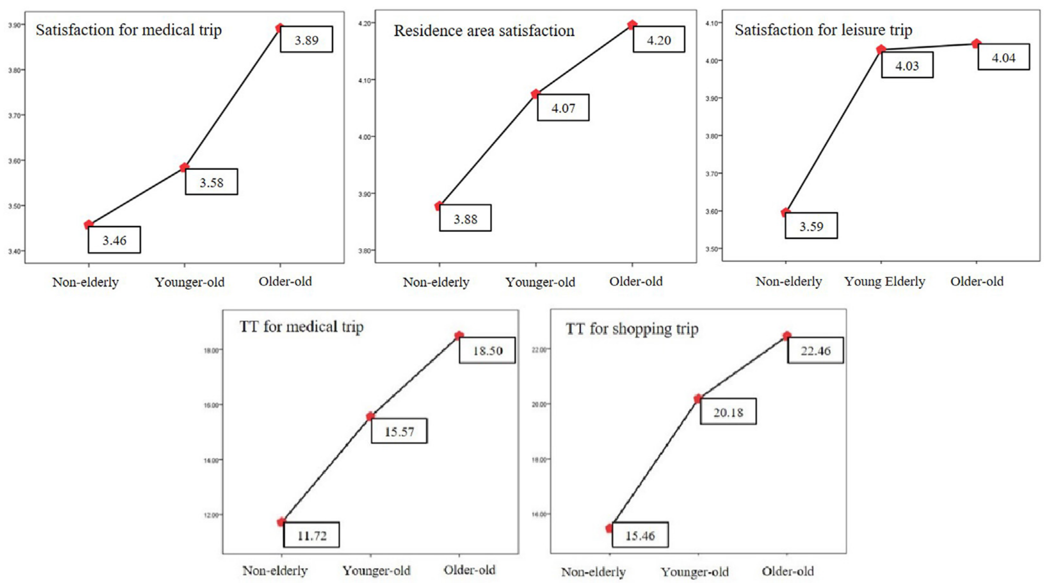

Fig. 4. Comparison of mean value for significant determinants by ANOVA test.

Table 5
Results of model estimation for travel satisfaction.

	Non-elderly ($i = 1$)		Younger-old($i = 2$)		Older-old($i = 3$)	
	γ	Std.	γ	Std.	γ	Std.
Opportunity to travel	–	–	0.810***	0.284	1.393***	0.422
Bus system satisfaction	0.510***	0.135	0.665***	0.234	–	–
Trip satisfaction for leisure activities	0.421***	0.144	0.497**	0.234	0.952***	0.321
Trip satisfaction for shopping activities	0.592***	0.160	1.070***	0.285	–	–
Residence area satisfaction	0.375***	0.133	0.445*	0.242	–	–
Perceived travel time for medical trip	−0.019**	0.008	–	–	–	–
Age	–	–	−0.116*	0.066		
Age above 80 (binary var.)	–	–			−1.079*	0.652
Single living (binary var.)	–	–	−1.141**	0.486		
μ_{i1}	2.129**	0.851	–	–	3.796**	1.870
μ_{i2}	4.451***	0.815	1.044	4.623	5.064***	1.888
μ_{i3}	5.604***	0.841	3.155	4.624	6.414***	1.976
μ_{i4}	8.020***	0.921	6.536	4.664	9.525***	2.250
LR chi2 (p-value)	520.005 (< 0.001)		193.680(< 0.001)		81.067(< 0.001)	
Cox & Snell R^2	0.314		0.486		0.397	
Nagelkerke R^2	0.337		0.531		0.430	

*** < 0.001, ** < 0.05, * < 0.1

higher for younger-old.

6.3. Travel satisfaction model

In order to identify what factors determine (subjective) satisfaction with daily movements, we estimated travel satisfaction models. We hypothesized that different factors influence travel satisfaction according to the age group so that we estimate separate models for the three age groups. The dependent variable "Satisfaction with Travel" is measured as ordinal outcome, y, ranging from 1 to 5. Therefore we adopted ordinal regression as below where as before $i(m)$ indicates the age group of person m. In Eq. (5) j denotes the satisfaction level ($j = 1,\ldots,5$), $\boldsymbol{\mu}_{i(m)}$ the estimated age group specific thresholds. In Eq. (6) $\boldsymbol{x}_z$ are the set of z independent variables to explain the travel satisfaction of individual m.

$$y_m = \left\{ \begin{array}{c} if y_m{}^* \leq \mu_{i(m)1} \\ 1 \quad f\mu_{i(m)1} < y_m{}^* \leq \mu_{i(m)2} \\ 2 \quad if\mu_{i(m)2} < y_m{}^* \leq \mu_{i(m)3} \\ 3 \quad if\mu_{i(m)3} < y_m{}^* \leq \mu_{i(m)4} \\ 4 \quad if\mu_{i(m)4} < y_m{}^* \leq \infty \\ 5 \end{array} \right\} \tag{5}$$

$$\ln(y_m) = \ln\left(\frac{\pi_m(s)}{1-\pi_m(s)}\right)\backslash; = \backslash; \sum_{5}^{j=1} (\mu_{i(m),j}) - \gamma_{i(m)1}x_{m1} - \cdots\gamma_{i(m)z}x_{mz} \tag{6}$$

Table 5 indicates the estimated coefficients and their significance by age group after testing various model forms and keeping only the significant variables. We keep in our model factors related to specific trips as well as factors with the transport system so that there are some weak correlations among our independent variables.

We firstly observe that we find only "travel satisfaction for leisure activities" to be significant in all groups. We can further observe a marked difference in the model for older-old compared to the models for the other two age groups. For non-elderly, the most influential variable is trip satisfaction for shopping activities. Satisfaction with the bus system is further important for non-elderly as well as travel time of medical trips which has negative effects on travel satisfaction. The opportunity to travel, bus system satisfaction, travel satisfaction for leisure activities, and residence area satisfaction, in this order, show further high importance. Moreover, in the case of younger-old, the closer their age to the upper limit of this group (74 years), the lower their travel satisfaction. The result also indicates that the satisfaction level decreases in the case of single-person households. Finally, focusing on the estimated results for older-old, only opportunity to travel and satisfaction for leisure are significant. It is noteworthy that the need to have good (leisure) travel opportunities until high age remains highly significant. Furthermore, the results show that there is a difference between elderly aged 75–80 years and elderly over 80 years in their evaluation of their travel satisfaction. This may imply that an age of 80 could be another potential boundary to distinguish younger- and older-old. Especially in Japan with its high life expectancy older people stay active until high age.

Table 6
Questionnaire for Quality of Life.

Dependent Variable	Question	Reliability test
QoL (Quality of Life)	Are you satisfied with your current life? Are you satisfied with your current life compared to last year? Do you think your everyday life is complete? Do you feel insecurity and trouble in your everyday life? (inverse) Do you think that you are happy? Do you think that you are healthy?	0.82

7. QoL as function of observed and subjective travel satisfaction

Measuring Quality of Life (QoL) is a difficult task. Early research such as Dalky (1968) suggests that "individual' sense of well-being" captures QoL well, whereas later research argues that measures such as income should be included. Partly following Easterlin and Angelescu (2009) we developed items which include the overall satisfaction to life, anxiety and health aspects as well as happiness as shown in Table 6. This was investigated together with the determinants for travel satisfaction. The questions were given on a 7-point Likert scale with endpoints from "not at all satisfied" to "fully satisfied". The construct appears to be reliable with a Cronbach alpha value of 0.82.

We firstly aim to understand if there are significant differences in QoL according to area of residence. Fig. 5 is a plot of QoL by GIS analysis in consideration of respondents' house location. It appears difficult to observe spatial patterns, suggesting that perceived life quality is not strongly associated with residence location in the city. We tested among others respondents' home address and distance to city centre which does not reveal any correlation to QoL.

We now perform the final analysis step which is to estimate our model for QoL as in Eq. (5).

$$ln(Q^m) = [\beta_o S_m^o + \beta_s \hat{S}_m^s + \beta_g x_m + c] \quad (5)$$

S_m^o is potential travel of individual m as estimated in Section 5 and $\hat{S}_m^s$ denotes the normalized travel satisfaction obtained from the

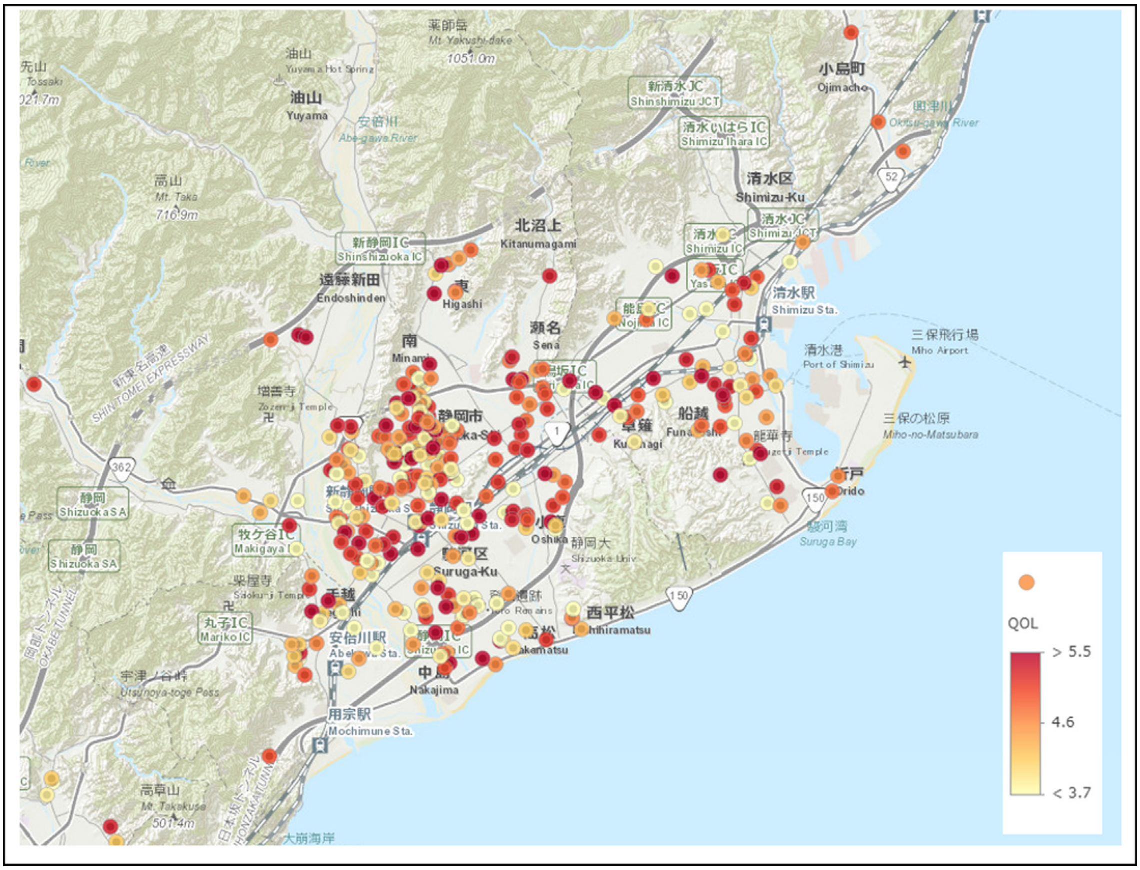

Fig. 5. QoL by respondents' home (higher resolution not possible due to data confidentiality).

Table 7
Results of QoL model estimation with.

Model	All (N = 386)		Non-elderly (N = 232)		Younger-old (N = 108)		Older-old (N = 46)	
	Β	Std.	β	Std.	β	std	β	Std.
Constant	1.184***	0.052	1.188***	0.078	1.222***	0.081	1.086***	0.127
S^o(potential travel)	−0.126***	0.047	−0.134*	0.067	−0.123*	0.069	−0.067	0.103
$\hat{S}^s$(travel satisfaction)	0.546***	0.058	0.527***	0.082	0.525***	0.092	0.660***	0.151
Gender (Male)	−0.036*	0.022	−0.034	0.031	−0.042	0.034	−0.034	0.055
R^2	0.201		0.164		0.266		0.332	
Adj R^2	0.194		0.153		0.245		0.284	
D-W	1.862		1.921		1.770		1.653	
ANOVA	31.984 (0.00)		14.897 (0.00)		12.543 (0.00)		1.658 (0.00)	

*** < 0.001, ** < 0.05, * < 0.1.

survey. Normalizing S_m^s makes it hence comparable to the measure S_m^o which is also in the range of zero to 1. This allows a direct comparison as to which factor is more relevant for QoL.

We note that we also tested alternative models with "fitted travel satisfaction" obtained from the models reported in the previous section but found the observed one to provide better results. We further tested in our model a number of socioeconomic variables but found only gender to be significant besides a constant c.

Table 7 shows that all coefficients were statistically significant for at least one of the age groups. In particular both our latent mobility constructs significantly influence QoL. According to Durbin-Watson and ANOVA tests for significance of the models shown in Table 7, the models are significant. From these tests as well as the R^2 values we observe that QoL is, however, more difficult to explain for older people.

The coefficient of observed potential travel, S_m^o, is significant for the model with all samples but only significant on the 10% level for the non-elderly group and decreasingly significant with age, both in terms of parameter magnitude as well as significance level. We suggest this finding has potential policy implications in that bus travel is less important for the older-old age group, controlling for overall travel satisfaction.

The coefficient of S_m^o has a negative sign. Given its definition and the curves shown in Fig. 2 this implies that longer travel time is in fact associated with higher QoL. Getting the causality (as far as we can be certain from our data) correct is important. As our term "potential for travel" suggests we propose that this implies that those who are able to make longer travel times have in fact a higher QoL. We suggest that these are active younger-old who tend to use the bus not only for short neighbourhood trips but also for trips to get around in the area. We remind further that the curves of potential travel in Fig. 2 have a different slope depending on travel frequency. The reduction in potential travel is especially pronounced for those travelling frequently. Therefore, those who travel frequently longer trips tend to be those with the highest QoL. Returning to the insignificance of the parameter for younger people we suggest that one reason is that longer, more frequent bus trips are a mix of "negative duty" and "positive potential" explaining its non-significance. For older-old bus trips in general are less frequent and the positive potential of an increase in activity space due to bus travel appears to be of less significance.

In contrast travel satisfaction affects QoL positively and is highly significant for all age groups. This means that high travel satisfaction is associated with higher QoL. We also note that that the influence of S^s is four times larger than the influence of S^o for our total sample. The difference in magnitude is fairly constant among non-elderly and younger-old and even more pronounced for older-old. We conclude that subjective perceptions are therefore a more suitable indicator for QoL (though clearly also more difficult to measure.)

The estimated coefficient for gender implies that women in general perceive their QoL as higher than men. This result is in line with literature referred to before which also reported in general higher life quality of female respondents. We note that the parameter is, however, not highly significant, in particular for older-old it is insignificant.

8. Conclusion

This study identifies the interrelationship between individual's mobility and perceived Quality of Life (QoL) with a case study of Shizuoka, Japan. We considered two latent variables that describe the travel behaviour regarding its subjective and objective dimensions. The subjective measure is based on a survey and the objective on smart card data from this person group. For the objective measure we define "potential (bus) travel" considering bus usage frequency and average travel time per trip. The results indicate that in general, as expected, the higher the bus usage at all ages, the higher the likelihood that one makes short short-distance trips.

We aimed to specifically understand differences between non-elderly, younger-old and older-old. We identified that younger-old have similar bus usage patterns as non-elderly but that the behaviour of older-old differs significantly. This is in line with a growing body of literature discussing the importance of ageing related mobility decline only in old age. Similar marked differences between the age groups can be observed for travel satisfaction. We observe a general trend of increasing satisfaction with age and suggest that this might be due to less pressured schedules as well as reduced expectations.

We used in this analysis 75 as threshold between younger-old and older-old following previous research using also 70 or 75 to distinguish the groups. We note that especially for subjective mobility one might even consider a threshold of 80 instead of (or in addition to) 75. Compared to literature written ten or more years ago, with increasing life-expectancy and better support to maintain mobility this increase is not surprising.

We conducted two sets of regression analysis. First with travel satisfaction as dependent variable, then with QoL. For the first set of models we suggest following findings are important: The opportunity to travel and the satisfaction for leisure trips play an important role in increasing the overall travel satisfaction of both younger-old and older-old. For older-old, in particular those above 80 years of age, significant reductions in travel satisfaction can be expected which are difficult to be countered with a good public transport service as service characteristics appear to be less important for this age group.

With our second set of regression models we confirm that bus travel is of primary importance for non-elderly and younger-old. We further conclude that making bus travel faster or more accessible is not likely to lead to more bus travel and more travel satisfaction as there appears to be a significant amount of life-style choices among younger-old whereas for older-old overall public transport plays a less important role determining their life quality.

We show that younger-old who make high frequent, short trips as well as those making low-frequent, long trip can have a high QoL. Our main policy implication therefore is that improving the bus transport system should be targeted to those in need. A “Silver Pass” policy with public funds providing older people with heavily discounted public transport can be useful for the younger-old but providing large public subsidies to allow also older-old to use public transport at a lower fee might not be the best use of limited resources. The argument might though also be used in a different way in that our analysis suggests that it can be argued that a free public transport pass for older-old should not be priced as high as less trips and shorter distance trips are much more frequent. Instead of subsidizing public transport, other forms of door-to-door mobility might be better supported. The importance of this is emphasized in our study through the findings that “opportunity to travel” is highly significant for older-old people’s travel satisfaction.

Clearly our study has a number of shortcomings, some of which have been acknowledged throughout the manuscript. Methodologically, one might argue that the two regression models should be integrated into a latent choice model with only quantifiable data as non-latent variables. However, we appear to miss sufficiently rich socio-demographic to explain travel satisfaction and furthermore it is rather explained by other perceptions such as satisfaction with specific trip purposes. We close by mentioning the two other data related shortcomings that appear most important to us. Firstly, this study only considered those using at least once per year public transport and we could not control for car usage. This must be further analyzed in future studies. Secondly, our regression models implicitly presume the causal relationship “mobility → QoL” and “travel satisfaction → QoL” though the opposite will also be true to some degree. Those with higher QoL, due to non-transport related factors such as income, will have more opportunities to go out. Here, with respect to income, however, our first limitation, in that we consider only public transport, might reduce this effect as income effects are more likely reflected in car and taxi trips. The ability to take public transport is instead strongly related to health. Therefore the causal chain “better health → QoL → more public transport travel” will be an important causal chain for older people. We reflect this in our discussion on the role of “potential mobility” for younger-old and suggest that also here it is noteworthy that the missing correlation between QoL and public transport travel for older-old is noteworthy. Nevertheless, we suggest that in future work direct measures of health should be better integrated. Even if such data are available, however, controlling for causalities will remain a challenge unless panel data of QoL, travel patterns and travel satisfaction become available.

CRediT authorship contribution statement

Junghwa Kim: Conceptualization, Methodology, Writing - original draft. **Jan-Dirk Schmöcker:** Methodology, Writing - review & editing, Supervision. **Toshiyuki Nakamura:** Resources, Project administration. **Nobuhiro Uno:** Resources, Project administration. **Takenori Iwamoto:** Resources.

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