Travel Behavior and Health-related QOL: Analysis based on an interdisciplinary approach

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Abstract: This study examines the relationship between travel behavior and health-related quality of life (QOL) based on an interdisciplinary approach, which integrates the knowledge of health science, behavioral economics, transportation and urban planning. The health-related QOL covers physical, mental, and social health. The health behavior is measured by activity frequency, length of activity time, activity place, travel mode to activity place, affective experience during the activity, and change of activity frequency over time, etc. The travel behavior is measured by trip purpose, frequency by activity, frequency by travel mode, travel distance from home by activity, and affective experience during travel. Residential forms are also investigated. Finally, the life satisfaction is measured with respect to different life domains. The analysis was conducted using a web-based survey implemented in November 2010, in which 1,213 respondents from the whole Japan participated.

Key Words : *Travel behavior, physical health, social health, mental health, SEM approach.*

1. INTRODUCTION

Enhancing people's quality of life (QOL) is one of common goals of public policies. To evaluate the QOL, health is an indispensable element (Knox, 1975; Diener, 1984; Phillips, 2006). Indicators regarding Health and Life Satisfaction are included in the OECD Better Life Index[1].

In 1964, the World Health Organization – WHO – defined that "health is a state of complete physical, mental and social well-being and not merely the absence of disease of infirmity". In other words, a healthy life means a balanced condition of not only physical health, but also social and mental health. QOL directly linked with health is usually called health-related QOL (Keller at al., 1998; Ware, 2004; Suzukamo et al., 2011). It is considered that little has been done with respect to the study of the health-related QOL in a comprehensive way.

As a part of the health-related QOL studies, it is considered that passenger transport and travel activities in the urban areas have an influence on the health conditions of the citizens, but the level or degree of influence between these aspects of citizens'life has not been yet sufficiently investigated.

2. TRANSPORT AND HEALTH

Transport and health are interlinked at many levels, with transport directly and indirectly influencing health, and health status influencing transport options (e.g., Le Tertre et al., 2002; Hodgson et al., 2012). Dhondt et al (2013) evaluated the health impact of a policy resulting in an increase of car fuel prices by 20% on active travel, outdoor air pollution and risk of road traffic injury, and found that a 20% fuel price increase leads to an overall gain of 1650 (1010-2330) DALY (Disability Adjusted Life Years). In the Australian context, Mulley et al. (2013) estimated that each additional hour spent in a car per day was associated with a 6% increase in the likelihood of obesity while each additional hour spent walking per day was associated with a 4% decrease in the chance of obesity, and also suggested to include the health benefits of sustainable transport in transportation

[1] http://oecdbetterlifeindex.org

appraisal frameworks.

In Japan, Muromachi (2008) confirmed that BMI (Body Mass Index) is higher in residential areas with higher share of car-dependent commuting trips and BMI is lower in areas with more walk trips. Although there are more relevant studies; still little has been done to look at all these factors affecting the health-related QOL jointly in a consistent way. The reviews of existing studies were a motivation to design a comprehensive questionnaire that contains major factors included and measure all the three aspects of health-related QOL and evaluate the influence of these factors in a unified modeling framework. It is expected that such challenges could provide seamless views that are crucial to decisions on health policies.

3. THE DIMENSIONS OF HEALTH

Several typical methods have been proposed to measure the health-related QOL. One of the most widely used generic measures of health-related QOL is the SF-36 (Short-Form 36)[2], which has been adopted by more than 110 countries.

The Measures of health-related quality of life are often based on explicit conceptual models. The model associated with the original, US-English version of the SF-36 has eight subscales, measuring physical functioning, limitations on role because of physical health, bodily pain, general health, limitations on role functioning because of emotional problems, social functioning and vitality.

The adopted model – based on the recent research findings -, is the three-component model of SF-36 (Susukamo et at. 2011) rather than the conventional two-component model, which considers a summary on physical and mental health. The three-component model of SF-36 considers additionally the importance of role and social participation to health-related quality of life, thus, the social health is the newly included health dimension in this model.

4. SURVEY CONTENTS

The survey was implemented in November 2010 with respect to residents residing in major japanese cities: three megacity metropolitan areas (Tokyo, Osaka, Nagoya) and other 17 cities in Japan, for a total of 20 cities. Respondents were randomly selected by reflecting the representative attributes (e.g. age, gender and residential location) of the population. The survey was done with the help of a mayor internet survey company, which had more than 1.4 million registered members. As a result, 1,213 samples were successfully collected.

The original questionnaire consists of health conditions, lifestyle habits, health promotion activities, park usage, daily activity and travel, residential environment, quality of life and individual and household attibutes.

Table 1. Indicators measuring health-related QOL.

INDICATORS		Physical health	Social health	Mental health
PF	Physical functioning			
RP	Limitations on role functioning because of physical health			
BP	Bodily pain			
GH	General health			
MH	Mental health			
RE	Limitations on role functioning because of emotional problems			
SF	Social functioning			
VT	Vitality			

The relevant contents for the health QOL and travel behavior analysis are exposed in detail below. However, not all the contents of the original survey are being here explained or taken into account for the posterior model implementations.

a) Individual attributes

The gender, age, residence location, occupation, rrelationship with the householder, ownership of car and driving license are included as individual attributes. The information of height and weight is used to calculate the body mass index – BMI – that is a simple index of weight-for-height that is commonly used to classify underweight, overweight and obesity in adults. It is defined as the weight in kilograms divided by the square of of the height in metres, so expressed in kg/m^2 (WHO, 2000).

b) Lifestyle habits

The occurrence of 8 types of habits is evaluated: to take breakfast, to sleep the recommended number of hours, to eat balanced meals, not to smoke, to play sports regularly, not to drink alcohol, to work 9 hours a day and to feel little stress.

c) Health conditions

Under this category, respondents are required to talk about disesases, hospitalization cases, a subjec-

[2] www.sf-36.org

tive evaluation of the health conditions and health transtition in comparison to the previous year, and a subjective evaluation of their interpersonal communication situation.

d) Physical functioning

Respondants give a subjective evaluation of activities that people might do during a typical day, which are: vigorous activities, moderate activities, lifting or carrying groceries, climbing several flights of stairs climbing one flight of stairs Bending, kneeling, or stooping, walking more than 1 km, walking several blocks, walking 1 block, and bathing or dressing by themselves.

e) Limitations on role functioning

The problems or limitations to do work activities, or to accomplish as much as expected due to either a physical health reason or emotional problems are inquired.

f) Vitality and mental health

A diverse range of emotional conditions that the respondants have possibly experienced is addressed, e.g. happiness, depression, vigor, energy, pep, joy, nerviousness, exhaustedness. Respondants were expected to tell how much did they have those semptations in the previous month.

g) Social functioning

The subjective perception of the extent of normality to do social activities as usual and the affective experience during social activity and communication with the family are here considered.

h) Daily activity and travel

The frequency, main travel mode and travelled distance are utilized as attributes to characterize daily activities for which travelling is necessary: commuting/schooling, business, shopping, leisure, sports, non-academic learning and research, social activity, health care, eating out, personal affairs, and other affairs.

5. AGREGATE RESULTS

The aggregate results of the analysis of the attributes for each group of indicators are exposed.

a) Individual attributes

In the sample, 49.7% of the respondents are in possession of a car and 83.8% are in possession of a driving license. The proportion of men and women in the sample is 50.5% to 49.5%. The most common occupations of the respondents are office worker (37.1%), homemaker (20.9%), part-time worker (11.3%) and student (8.7%). A proportion of 52.3% of the respondents are householders, 30.8% are the spouse of the householder and 15.6% of the respondents are a householder's child. The percentage of respondents that are living alone (only household members) is 19.3%.

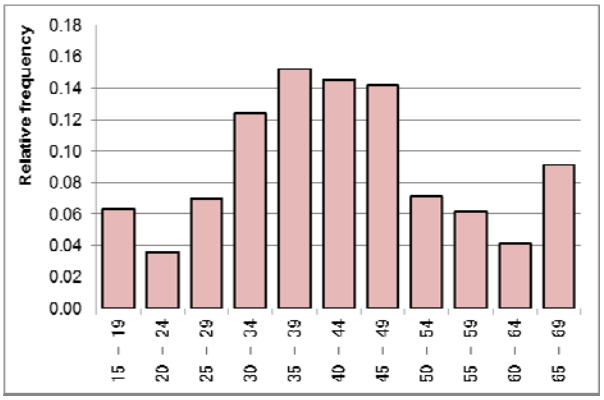

Figure 1. Age distribution of the respondents in the sample.

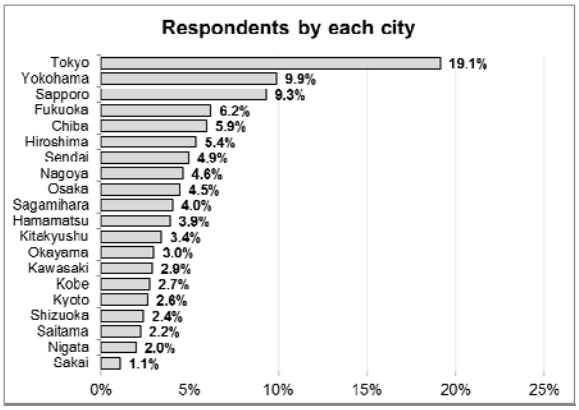

Figure 2. Cities in the survey and number of respondents.

According to the World Health Organization (WHO, 2000), a person with a BMI of less than 18.5 as underweight and may indicate malnutrition, an eating disorder, or other health problems, while a BMI greater than 25 is considered overweight. A number of 877 respondents were found to have a BMI between 18.5 and 25 kg/m^2, equivalent to a 72.3% of the total sample.

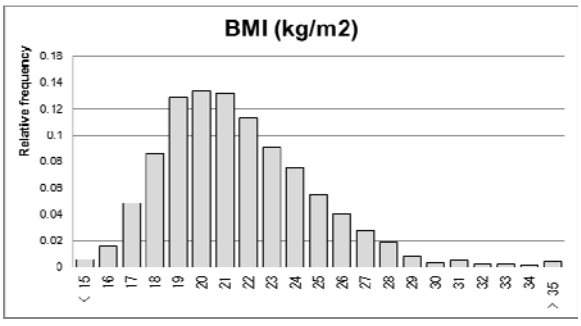

Figure 3. Histogram for BMI values of the respondants.

b) Lifestyle habits

Respondants were asked to evaluate the frequency of the 8 listed habits in a scale from 1 to 5, where 1 is "affirmative" and 5 is "not applicable". It was found

that eating breakfast every morning was the most practiced health habit, while playing sports regularly is the least frequently habit among the respondents. The average weighted sum of the indicators is shown in the Table 2.

Table 2. Lifestyle habits.

HABIT	SCORE
You eat breakfast every morning.	1.83
You sleep per day for 7-8 hours on the average.	2.76
You consider the nutrition balance of the meal.	2.53
You do not smoke.	1.85
You play exercise and periodical sports.	3.29
You do not drink alcohol that much every day.	1.86
You keep working hours within nine hours a day.	2.58
You do not feel conscious stress that much.	3.01

c) Health conditions

The percentage of respondants (over the sample size n=1213) that answered in an affirmative way to the proposed health condition statements is shown in Table 3.

d) Physical functioning

In the Figure 4, it can be observed the percentage of respondants who say not to have a hard limitation to do the listed activity due to a bad health condition.

e) Limitations on role functioning

The respondants were asked to describe the limitations on role functioning that they experience due to either physical health problems or emotional problems; by using a scale from 1 to 5, where 1 is equivalent to “always” and 5 is equivalent to “never”, passing through “usually”, “sometimes” and “rarely”. The results of the average weighted sum of these results can be observed in the Table 4.

f) Vitality and mental health

As in the previous numeral, the questions related to vitality and mental health are evaluated by the respondents by using a five-stage frequency scale: always, usually, sometimes, rarely and never. The results of the weighted average sum are listed in Table 5.

According to the results in the table above, it can be said that the most common vitality sensation of the respondants in the sample is to have feelings of calm and peace, while the most common mental health problem is to feel tired.

Table 3. Statements about the health conditions.

Your health condition is good, very good or absolutely good (Healthcond)	75%
Your health condition is not as good as in the previous year (HealthC-1)	22,3%
You suffered a big disease leading to to hospitalization (Hospitaliz)	31,2%
You have feelings of trust to other humans (OthReliable)	68,1%
You think a person is going to helpful to another person (OthHelpful)	62,7%
You participate in a community organization	13,3%

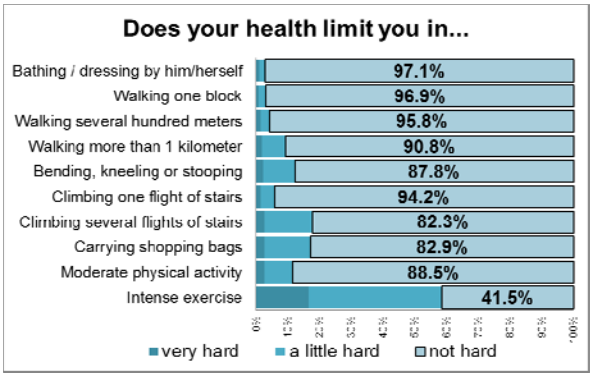

Figure 4. Limitations due to problems in physical functioning.

Table 4. Lifestyle habits.

DUE TO PHYSICAL HEALTH	
Cut down the amount of time spent on work or other activities	4.54
Accomplished less than you would like	4.47
You were limited in work and other activities	4.49
It took extra effort to do work or other activities	4.55
DUE TO EMOTIONAL PROBLEMS	
Cut down the amount of time spent on work or other activities	4.48
Accomplished less than you would like	4.43
Didn't do work or other activities as carefully as usual	4.38

Table 5. Scores for vitality and mental health problems.

VITALITY	
Did you feel full of pep?	2.73
Have you ever felt calm and peaceful?	2.65
Did you feel full of energy?	3.01
Have you been a happy person?	2.82
MENTAL HEALTH PROBLEMS	
Have you been a very nervous person?	3.53
Have you felt so down in the dumps that nothing could cheer you up?	3.98
Have you felt downhearted and blue?	3.86
Did you feel worn out?	3.47
Did you feel tired?	3.03

g) Social functioning

The answers to "to what extent has your physical health or emotional problems interfered with your normal social activities with family, friends, neighbors or groups?" are depicted in Figure 5, in terms of extension and frequency.

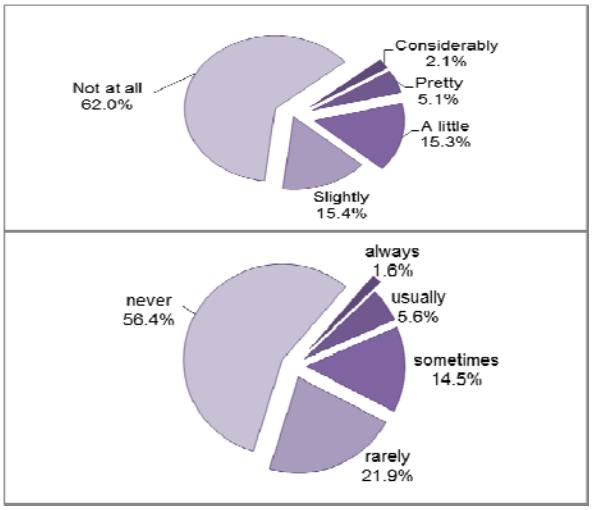

Figure 5. Limitations due to problems in physical functioning.

h) Daily activity and travel

Since not all the respondents in the sample mention to do the activities that are listed as possible daily activities that would make necessary to travel, the number of respondents for each listed activity is listed in Figure 6.

As seen in Figure 6, the most common activities of the respondents are commuting and shopping, while the self-study or volunteer activities are the least common. Based on the most common activities, travelling behavior is to be analyzed, specially on the commuting.

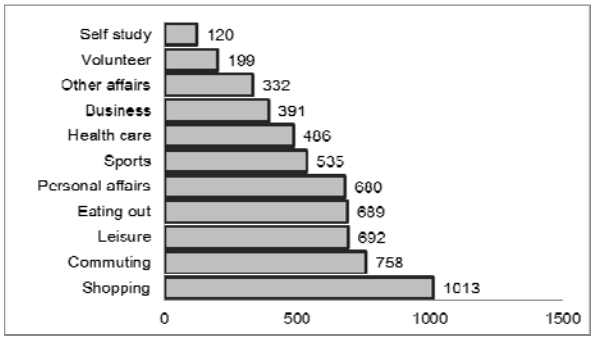

Figure 6. Activities that demand travelling.

For the main travel mode chosen by the users, the possible selection options were: walking, bicycle, motorcycle, car (as driver), car (as passenger), train streetcar, monorail, bus, taxi and others.

In the Figure 7, the relative frequency of users who select non-motorized travel modes, i.e. bicycle users and walkers for each activity is listed.

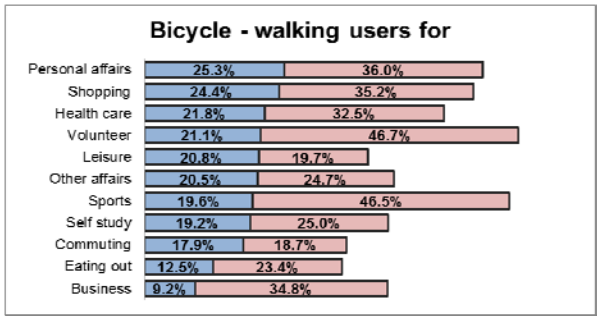

Figure 7. Non-motorized users by activity.

Under the "public transportation category", the users who do the corresponding activities by train, steetcar, monorail o similar and bus are listed. The users who use motorcycle, car or taxi are listed in the column "Private" (see Table 6).

Table 6. Use of public and private motorized transport modes by activity.

	Public	Private
Commuting	38.9%	24.4%
Business	23.0%	33.0%
Shopping	4.5%	35.8%
Leisure	22.3%	37.3%
Sports	7.3%	26.5%
Self study	25.8%	30.0%
Volunteer	8.5%	23.6%
Health care	13.0%	32.7%
Eating out	13.4%	50.8%
Personal affairs	6.8%	31.9%
Other affairs	17.8%	37.0%

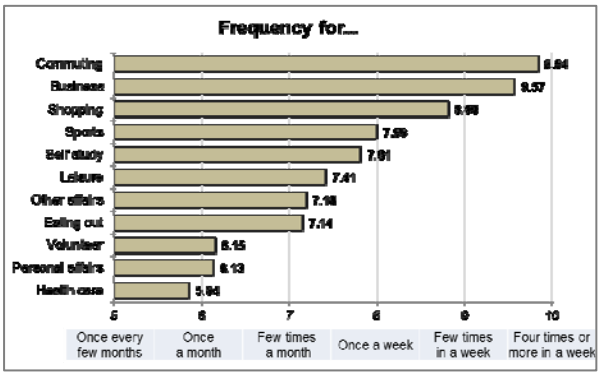

Figure 8. Frequency by activity.

Commuting, business, shopping and sports are most frequently activities in the sample. The average travelled distance (in km) is one of the questions to the respondents, in the Figure 9 the results are shown as the arithmetic mean, where the standard error has been substracted and added to the mean value and corresponds to the left and right extremes of the box showing the travelled distance for each activity.

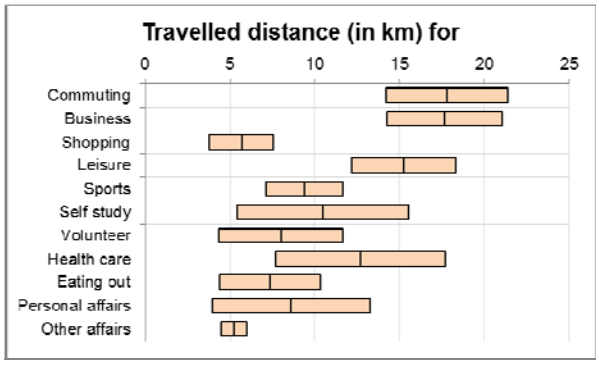

Figure 9. Average travelled distance by activity.

In the Table 7 the descriptive statistical indicators for the available data about travelled distance for commuting, shopping and leisure are calculated, whereas they are the activities with the major number of participants in the sample.

Table 7. Descriptive statistical summary for travelled distance.

	Commuting	Shopping	Leisure
Mean	17.79	5.68	15.24
Standard deviation	97.84	59.51	80.83
Kurtosis	300.51	471.75	203.29
Skewness	16.51	20.73	13.02
Count	758	1013	692
Confidence Level (95.0%)	6.97	3.66	6.03

6. THE SEM MODEL

Structural equation modeling (SEM) is a statistical technique for testing and estimating causal relations using a combination of statistical data and qualitative causal assumptions.The structural equation models have been developed to substantiate theory and have furher helped to establish the relationship between latent variables or constructs given a theoretical perspective (Schumacker, 1996).

The use of SEM is predicated on a strong theoretical model by which latent constructs are defined (measurement model) and these constructs are related to each other through a series of dependence relationships (structural model). The path analysis calculates the strength of the relationships between the variables using only a correlation or covariance matrix as input.

Both confirmatory and exploratory modeling are allowed by the structural equation models, meaning they are suited to both theory testing and theory development. Confirmatory modeling usually starts out with a hypothesis that gets represented in a causal model. The concepts used in the model must then be operationalized to allow testing of the relationships between the concepts in the model. The model is tested against the obtained measurement data to determine how well the model fits the data. The causal assumptions embedded in the model often have falsifiable implications which can be tested against the data.

7. MODEL APPLICATION

Due to the complexity of implementation of several variables and in order to to simplify the application of the model, 4 different association cases have been assumed, as shown in Table 8.

Table 8. Categorical division of the applied SEM.

MODEL	DESCRIPTION
Travelling behavior and wellness	Including lifestyle habits and wellness (taken as latent variable in function of happiness and satisfaction)
Travelling behavior and physical health	Including PH indicators
Travelling behavior and social health	Including SH indicators
Travelling behavior and mental health	Including MH indicators

The model implementation examples for the cases of perception of wellness and physical health can be observed in the Figure 10 and the Figure 11 respectively. The results for the Maximul likelihood esti-

mations are shown in the Figure 12 for the model of travelling behavior and wellness, and the Figure 13 depicts the results for the estimation of physical health and travelling behavior, as originally shown in AMOS software estimation.

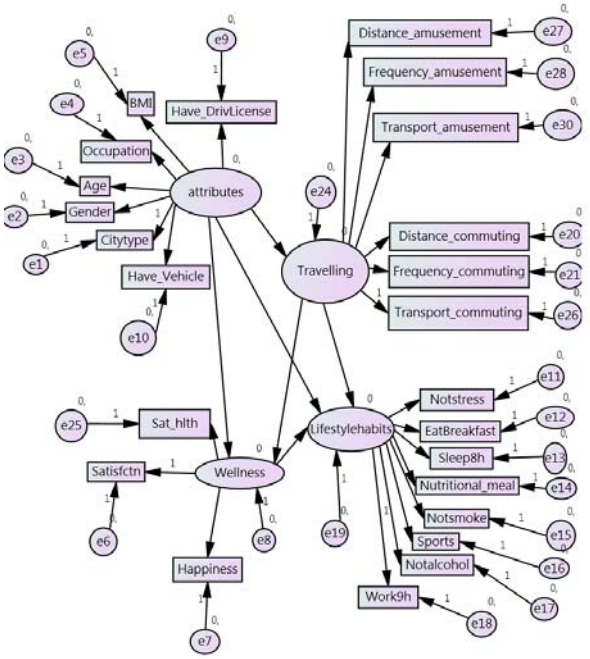

Figure 10. First estimation of model using AMOS software.

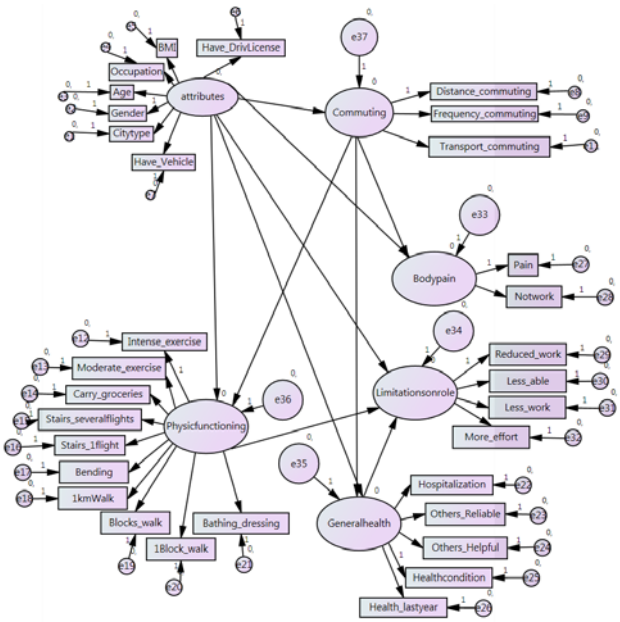

Figure 11. SEM model for travelling behavior and physical health indicators.

8. DISCUSSION ON RESULTS

For the first estimation, the regression weight for attributes in the prediction of Travelling is significantly different from zero at the 0.001 level (two-tailed), meaning a p-value less than 0.001, under the assumptions that observations are independent, the exogenous variables meet the necessary distributional requirements, e.g. a multivariate normal distribution, that will suffice. Otherwise, there is one other, general situation under which maximum likelihood estimation was applied. If some exogenous variables are random while others are fixed, i.e., they are either known beforehand or measured without error, then the fixed variables may have an arbitrary joint distribution, provided that for any value pattern of the fixed variables, the remaining (random) variables have a (conditional) normal distribution, the (conditional) variance-covariance matrix of the random variables is the same for every pattern of fixed variables , the (conditional) expected values of the random variables depend linearly on the values of the fixed variables.

Estimation on means and intercepts must be explicitly estimated by using the software AMOS, in order to analyse data with missing observations, e.g. in the case of the travelling behavior analysis. The available information regarding travelling behavior is limited depending on the selected activity – as shown in the Figure 6. The models have to be adjusted in function of the activity that demands travelling, affecting the effective sample size for calculation of the model. Thus, the influence of only the most frequent activities for travelling behavior and health-related indicators could be studied by using an SEM model.

Characterization of the travelling behavior can eventually made by using only one type of activity. By reducing the sample size being restricted to only one travelling activity (e.g. commuting), we can have a complete estimation of the model including the goodness-of-fit indicators. The calculation of the goodness-of-fit indicators are omitted when the means and intercepts must be explicitly estimated when using AMOS software.

Future estimations for finding the best suitable model are to be made, in order to find the models that provide the most accurate fit by exploring the different possibilities of determining the real influence that travel behavior have on health habits ofd the citizens, and in a reciprocal way, how the travel behavior is influenced by the health conditions and habits of the citizens. Further investigation can provide useful evidence for decisions on policy-making regarding to encourage more strongly the use of more ‘healthy’ transportation modes by the citizens and the practice of ‘healthier activities’, which would have benefits reflected in the reduction of health care costs and the improvement of health-related QOL.

Maximum Likelihood Estimates

Regression Weights: (ｸﾞﾙｰﾌﾟ番号 1 - ﾓﾃﾞﾙ番号 1)

			Estimate	S.E.	C.R.	P	Label
Travelling	<---	attributes	-4.360	1.019	-4.280	***	par_20
Wellness	<---	Travelling	.042	.104	.407	.684	par_18
Wellness	<---	attributes	.411	.676	.608	.543	par_22
Lifestylehabits	<---	Travelling	.166	.072	2.324	.020	par_17
Lifestylehabits	<---	attributes	-.114	.445	-.255	.798	par_21
Lifestylehabits	<---	Wellness	.382	.041	9.303	***	par_26
Citytype	<---	attributes	1.000				
Gender	<---	attributes	2.380	.555	4.286	***	par_1
Age	<---	attributes	-46.797	11.749	-3.983	***	par_2
Occupation	<---	attributes	11.169	2.587	4.318	***	par_3
BMI	<---	attributes	-11.197	2.830	-3.956	***	par_4
Satisfctn	<---	Wellness	1.000				
Happiness	<---	Wellness	-1.980	.096	-20.684	***	par_5
Have_DrivLicense	<---	attributes	2.691	.595	4.526	***	par_6
Have_Vehicle	<---	attributes	4.915	1.076	4.569	***	par_7
EatBreakfast	<---	Lifestylehabits	1.058	.118	8.949	***	par_8
Sleep8h	<---	Lifestylehabits	1.176	.129	9.150	***	par_9
Nutritional_meal	<---	Lifestylehabits	1.223	.122	9.996	***	par_10
Sports	<---	Lifestylehabits	1.034	.125	8.282	***	par_11
Notsmoke	<---	Lifestylehabits	.884	.126	6.993	***	par_12
Notalcohol	<---	Lifestylehabits	.502	.089	5.632	***	par_13
Work9h	<---	Lifestylehabits	1.000				
Notstress	<---	Lifestylehabits	1.308	.134	9.761	***	par_14
Distance_commuting	<---	Travelling	13.497	8.629	1.564	.118	par_15
Frequency_commuting	<---	Travelling	.146	.070	2.092	.036	par_16
Sat_hlth	<---	Wellness	.780	.041	18.873	***	par_19
Transport_commuting	<---	Travelling	1.000				
Distance_amusement	<---	Travelling	16.011	7.374	2.171	.030	par_23
Frequency_amusement	<---	Travelling	.070	.152	.457	.648	par_24
Transport_amusement	<---	Travelling	1.205	.137	8.783	***	par_25

Figure 12. Regression weights of travelling behavior and wellness model by AMOS software estimation..

Maximum Likelihood Estimates

Regression Weights: (ｸﾞﾙｰﾌﾟ番号 1 - ﾓﾃﾞﾙ番号 1)

			Estimate	S.E.	C.R.	P	Label
Commuting	<---	attributes	-40.031	22.984	-1.742	.082	
Physicfunctioning	<---	attributes	-2.296	1.143	-2.008	.045	
Generalhealth	<---	attributes	11.681	5.954	1.962	.050	
Generalhealth	<---	Commuting	.295	.219	1.346	.178	
Physicfunctioning	<---	Commuting	-.055	.041	-1.328	.184	
Bodypain	<---	attributes	21.335	10.714	1.991	.046	
Limitationsonrole	<---	attributes	-.296	.129	-2.290	.022	
Limitationsonrole	<---	Physicfunctioning	.854	.109	7.866	***	
Limitationsonrole	<---	Generalhealth	-.499	.046	-10.759	***	
Bodypain	<---	Commuting	.523	.391	1.338	.181	
Citytype	<---	attributes	.340	.090	3.802	***	
Gender	<---	attributes	1.000				
Age	<---	attributes	-19.059	3.006	-6.340	***	
Occupation	<---	attributes	4.548	.577	7.886	***	
BMI	<---	attributes	-4.665	.736	-6.341	***	
Have_DrivLicense	<---	attributes	1.046	.115	9.120	***	
Have_Vehicle	<---	attributes	1.796	.191	9.422	***	
Distance_commuting	<---	Commuting	1.000				
Frequency_commuting	<---	Commuting	.002	.005	.326	.744	
Transport_commuting	<---	Commuting	.043	.025	1.740	.082	
Intense_exercise	<---	Physicfunctioning	1.000				
Carry_groceries	<---	Physicfunctioning	1.138	.100	11.363	***	
Stairs_severalflights	<---	Physicfunctioning	1.140	.100	11.354	***	
Bending	<---	Physicfunctioning	1.034	.091	11.418	***	
1kmWalk	<---	Physicfunctioning	1.154	.096	12.073	***	
Blocks_walk	<---	Physicfunctioning	1.008	.082	12.340	***	
1Block_walk	<---	Physicfunctioning	.783	.064	12.190	***	
Bathing_dressing	<---	Physicfunctioning	.766	.063	12.120	***	
Stairs_1flight	<---	Physicfunctioning	.969	.080	12.045	***	
Moderate_exercise	<---	Physicfunctioning	1.116	.096	11.622	***	
Hospitalization	<---	Generalhealth	-.137	.026	-5.195	***	
Others_Reliable	<---	Generalhealth	.242	.027	8.832	***	
Others_Helpful	<---	Generalhealth	.244	.028	8.598	***	
Healthcondition	<---	Generalhealth	1.000				
Health_lastyear	<---	Generalhealth	.575	.047	12.342	***	
Pain	<---	Bodypain	1.000				
Notwork	<---	Bodypain	.817	.045	17.957	***	
Reduced_work	<---	Limitationsonrole	1.000				
Less_able	<---	Limitationsonrole	1.173	.027	42.819	***	
More_effort	<---	Limitationsonrole	1.060	.026	41.275	***	
Less_work	<---	Limitationsonrole	1.150	.027	42.642	***	

Figure 13. SEM model for travelling behavior and physical health indicators.

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