A Study on Integrated Intercity Travel Demand Model

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Abstract

It is well reported that induced travel is an important component of travel demand, and an increasing attention has been paid to build analytical model to get more precise travel demand forecasting. With the advancement of transportation condition, some short run behavioural effects (changes in travel departure times, routes switches, modes switches, longer trips, changes of destination, and new trip generation) and long run behavioural effects (household auto ownership level, and spatial reallocation of activities) will be resulted, and these behavioural effects are thought to be possible to result in induced travel. This paper aims to introduce a comprehensive accessibility measure known as expected maximum utility in a multidimensional mode/route choice and destination choice context to capture these short run behavioural effects. With the inclusion of the accessibility measure in the trip generation model as an explanatory variable, the induced travel can be estimated. A consideration of estimating the induced travel resulted from the long run behavioural effect (spatial reallocation of activities) is also suggested in the paper. As the case study, an integrated travel model with nested structure including trip generation model, destination choice model, mode choice model, and route choice model is presented for an intercity high speed rail project planed in Japan, and the demand considering the induced travel resulted from short run behavioural effects is forecasted. Furthermore, based on the collective choice theory, a new consideration for business travel modelling is suggested, and it is expected to make the decision-making process more rational and correct the user benefit that is underestimated in the conventional travel model.

Keywords

induced travel, behavioural effects, integrated intercity travel demand model, accessibility, collective choice

Preferred citation

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1. Introduction

It is reported that with the introduction of road capacity expansion project, travel demand growth within the specific corridor had seen greater than expected travel growth and this growth was probably not just influenced by the effects such as increase in income or population growth, the improvement of transportation properties (travel cost, price, etc.) likely induced some additional travel demands. This additional travel is called “induced travel”. However, most conventional demand models usually assume that the travel demand is totally inelastic to transportation properties, i.e., they are failing to forecast or tending to underestimate this kind of travel demand growth.

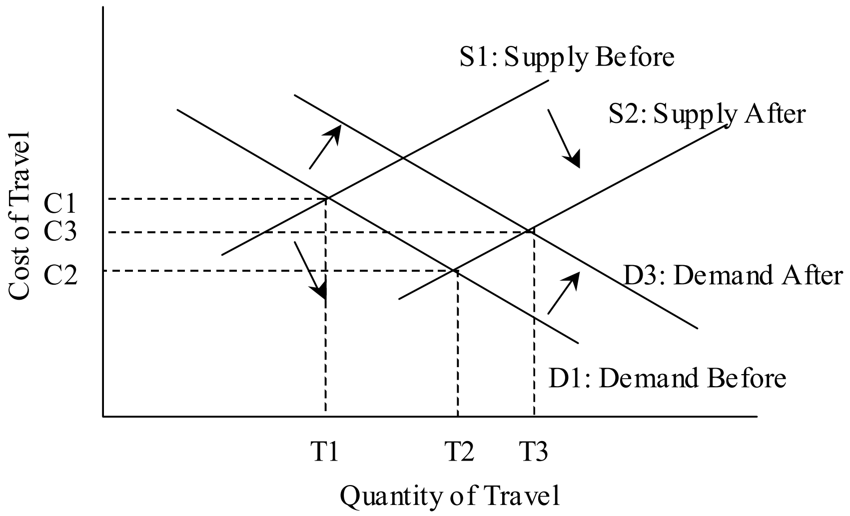
A study leaded by U.K. transportation economists concludes that the elasticity of travel volume with respect to travel time is –0.5 in the short term (Standing Advisory Committee on Trunk Road Assessment: SACTRA, 1994). This means that reducing travel time on a roadway by 20% typically increases traffic volumes by 10% in the short term (Litman, 2001). In practice, in the case of road construction project in UK, averagely, the actual use of a road during the first year after its completion was more then 10% greater than the forecast usage (Noland & Lem, 2002). This means that some additional travels happened, but the estimated demand model cannot reflect these changes. In a study of the relative contribution of induced travel to overall vehicle miles of travel (VMT) by Noland and Cowart (2000), the induced travel effect accounts for range from 15% to 40% of annualized growth in VMT. In the part of rail transportation, on average, “HSR in France and Japan has produced generated or induced traffic as high as 35% and typically greater than 30% of diverted traffic” (King, 1996). Furthermore, because of the existence of additional travel, the effects of transportation condition improvement will be influenced. Especially, for some road capacity expansion project, the congestion reduction benefits of project will be reduced because of the unpredicted existence of induced travel. Therefore, there are sufficient evidences to say that the induced travel is a real phenomenon, and it “can and does occur, probably quite significantly” and “can affect the economic evaluation” of the transportation project as the SACTRA (1994) report stated.

However, with the conventional 4-step method, it is difficult to measure this change in trip generation because the “conventional trip generation methods are not sensitive to changes in the level of service and are not able to capture the effects of such travel time reductions” (Kitamura, et al., 1997). So to speak, the most likely reason of inaccuracy of some forecasting model is nothing but the failure in adequately capturing induced travel effects. Accordingly, the travel demand model with the ability to actually measure the induced travel is highly expected.

1.1 The Economic Interpretation of Induced Travel

According to the simple economic theory of supply and demand, any reduction in the cost of goods will result in an increase in the demand for the goods. In the case of travel demand, the increase in travel speed or decrease in travel cost will reduce the generalized cost of travel, and result in an increase in travel demand. The relation of travel supply curve and demand is illustrated in Figure 1, where, S1 and S2 are the supply curves before and after improvement of transportation condition respectively. Meanwhile, many changes in socioeconomic factors (such as population growth, increases in income, the development of regional economy, and so on) also drive the travel demand growth. With the advancement of socioeconomic factors, the demand curve usually has a shift from D1 to D3. Therefore, travel demand is the result of a combination of both exogenous factors that determine the location of the demand curve (such as increase in population, economy development), and endogenous factors that determine the price-volume point along the demand curve (such as reduction of travel time, and travel cost).

Figure 1 Induced Travel



Source: Relationships between highway capacity and induced vehicle travel: Noland, R.B. (2001) page 4

As the result of simultaneous shifts of demand curve and supply curve, the travel demand will increase from T1 to T3. However, the induced travel is just measured as the part of demand change between T1 and T2, as the result of the decrease in generalized cost of travel from C1 to C2, i.e., induced travel is only resulted from the changes of endogenous factors. In fact, because the changes in exogenous and endogenous factors usually occur simultaneously, it is difficult to isolate the changes derived by exogenous and endogenous factors. It is a reason why the induced travel is hard to recognize and measure.

As for the definition of induced travel, based on the above explanation of the economic theory, it can be broadly defined as the net increase in travel demand derived from some endogenous factors (e.g. the improvement in transportation capacity or transportation level of service). As Noland and Lem argued (2002), it is more rational that the induced travel should be measured as the increase in MVT rather than trip, i.e., not only the count of trip, but also the distance of trip should be considered to indicate induced travel. In detail, the induced travel may come from the travel shifted from parallel routes and other transportation modes, the travel in another time of day, new trips not previously being made, and longer trip. Certainly, the measurement of induced travel is dependent upon the market for which the demand curve is defined, i.e., all these factors doesn't always contribute to induced travel. It means that induced travel defined at the facility level will include travel diverted from parallel routes, and travel switched from other transportation modes, while induced travel at the regional level will include only trips that are new to the region (Lee, 1999).

1.2 The Behavioural Effects

With the improvement of road capacity or other transportation properties in a corridor, as the result of rational choice, some behavioural changes will occur and can be categorized as long run and short run effects of induced travel. As Hills (1996) and Litman (2001) stated, short run effects include: changes in travel departure times, routes switches, modes switches, longer trips, and increase in trip generation. It is usually believed that some changes like mode/route switches, and travel change of departure times don't result in induced travel directly at a regional level, however, these changes result in the changes in transportation condition that will induce additional travel. For example, mode/route shifts make some congested road free from capacity and result in induced travel. In this meaning, these effects are viewed as the stimulators of induced travel and indirectly result in induced travel. As the result of time period lagged responses to the changes in transportation conditions, the increases in household auto ownership levels and spatial allocation of activities are considered as the long run effects of induced travel.

All these behavioural effects are considered as the responses to the changes in the transportation properties (endogenous factors of transportation demand-supply market), so these behavioural mechanisms provide an idea that induced travel is possible to be indicated by a measure which capturing these behavioural effects.

1.3 The Accessibility Measure

There are two frameworks of interpreting the induced travel. Zahavi (1977) assumed that total time budgets allocated to travel remain relatively constant over time. People tend to average about 75 minutes of daily travel time regardless of transport conditions (Levinson & Kumar, 1995). It means, under the assumption of constant travel time budgets, when travel time is reduced through the improvement of transportation conditions, a traveller will travel more or further. As the result, induced travel happens. However, the assumption about the saving time allocation conflicts with the utilitarian hypothesis that a rational person could allocate the available time optimally to different types of activities while considering trade-offs (Kitamura, et al., 1997).

Another theoretical framework is the use of generalized cost or some transportation system indicators to measure trip generation or VMT. As the result of the improvement of endogenous factors, the generalized cost is reduced. With the economic theory of supply and demand, the induced travel is measured. Hansen et al. (1993, 1997) applied time series data on VMT and lane mile for state highway in California at county-level and metropolitan level data respectively, to indicate the relationship of VMT to lane mile, and found the elasticities of VMT with respect to lane mile range from 0.3 to 0.7 (1993), and 0.5 to 0.9 (1997) respectively.

However, because all the studies are based on the aggregate analysis, they failed to reflect the response of individual to the changes in transportation properties, consequently, the relationship of induced travel and the behavioural effects can't be established. On the other hand, for large regional transportation projects, the effect of destination change would likely be significant. However, the generalized cost measure is likely failing to capture this effect of destination change. Therefore, a study about induced travel based on the disaggregate analysis is made in the research. In which, a new comprehensive measure which captures these behavioural effects is used to measure induced travel.

In 1979, Burns proposed a framework in which accessibility is associated with an individual's freedom to participate various activities, and is specified by three components: transportation, temporal factor, and spatial factor. In a multidimensional mode/route and destination choice context, the indirectly utility functions are defined with the good incorporation of transportation factors (travel time, travel cost, etc.), temporal factors (the constraints that affect the individual's time allocation and activities participation), and the spatial factors (the constraints related to zone), so the individual specific expected maximum utility value can be defined as an accessibility measure (Ben-Akiva & Lerman, 1985).

On the other hand, the expected maximum utility, which summarizes the expected "worth" of a set of travel alternatives, and reflects the difference in how various individuals evaluate their alternatives (Ben-Akiva & Lerman, 1985), is thought to be capable of capturing traveller's short run behavioural effects (rational mode/mode choice and destination choice) based on the maximum utility. Consequently, with the inclusion of this measure in trip generation model, the induced travel considering these behavioural effects can be estimated. However, because all the effects (mode/mode shifts and trip redistribution) are synthesized in a comprehensive measure, the contribution of each effect can't be determined here.

Mode/route choice utility usually is determined by the properties of transportation mode/route alternatives and the individual characteristics of traveller, travellers react to the changes in transportation condition immediately, so mode/route switches are viewed as short run effects. On the other hand, destination choice utility is defined by the demographic and social-economic properties of destination and the transportation condition between the travel origin and destination. With the relative changes of transportation conditions for different destinations, travellers tend to change their trip destinations based on a rational destination choice. As the result, longer trips and more trips become possible, i.e., induced travel occurs. Meanwhile, if speeds are higher, many residences, employees, and business will tend to relocate over time often resulting in longer distance trip (Gordon and Richardson, 1994). These changes of activities will result in destination changes or more trips in the later, so the spatial reallocation of activities is viewed as a long run effect for induced travel. Theoretically, if the demographic and social-economic properties of a destination as the result of transportation advancement are predicted, the effect of spatial reallocation of activities can be reflected in a later destination choice behaviour.

In a conventional four-step procedure, because conventional trip generation methods are not sensitive to changes in the level of service, the effects of such travel time reductions and the induced travel cannot be captured. On the other hand, in an integrated intercity disaggregate model with nested structure including trip generation model, destination choice model, mode choice model, and route choice mode, through using the expected maximum utility of lower level model as explanatory variable in the higher level model's utility function, the accessibility defined here can be obtained. Consequently, it is possible to reflect the effects of mode switches, route switches, and redistribution of trips into the trip generation model, and finally estimate the induced travel. As for the effect of spatial reallocation of activities as a long run effect of induced travel, because the demographic and social-economic properties of a destination are usually included in the destination choice utility function, if the changes in the demographic and social-economic properties of a destination (the results of lagged spatial reallocation of activities in response to the changes in generalized travel costs) can be predicted, theoretical the induced travel considering the subsequent effect of spatial reallocation of activities can also be obtained. In other words, it avoids the underestimation of induced travel as the result of failing to capture the subsequent effect of location change (especially for the large regional transportation projects, in which, the effect of location change would likely be significant (Rodier, et al., 1998)).

2. The Case

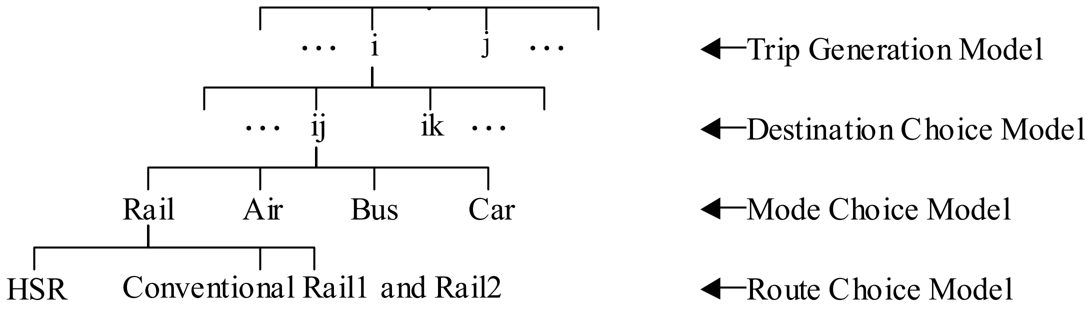
With the introduction of a high-speed rail (HSR) system with total distance about 500km and maximum speed over 500km/h planned to link Tokyo, Nagoya, and Osaka metropolitan areas in Japan, a significant change of transportation market is predicted. As the most population concentrated area in Japan, the three metropolitan areas has approximate 30 million, 8.5 million and 16 million population within 50 km of each city centre respectively. As for the other main service properties of the HSR, the service frequency is 10 times/h, the travel cost and the line-haul time between Tokyo and Osaka are 15000 Japanese Yen and 70 minutes respectively, and the access times to the HSR stations in these three cities are presumed to be same to that of the existing conventional rail 1. As the first step of forecasts required in the transport planning, an integrated intercity travel demand model with nested structure including trip generation model, destination choice model, mode choice model, and route choice model is estimated. The nested structure of model is shown in Figure 2.

Through surveying the trips within the six main metropolitan areas in Japan, two types of datasets used for model estimation are obtained from personal trip questionnaire investigation: the revealed preference data (RP) (which reflects actually used status of modes at the latest intercity travel opportunity) and the stated preference data (SP) (which elicits the preference for the non-existing HSR). Given the project's large scale and the imaginable huge potential impacts on the specific corridor as well as other areas in Japan, a large scale nationwide aggregate intercity trip data is also used in the model's estimation. In this data-sampling scheme of aggregate trip data, the surveying area is stratified into 147 zones covering the area of Japan, and the demographic and socio-economic data are investigated at the zone level. As for the segmentation, the models are built for two travel purposes: business and non-business.

In the case of business travel, traveller has higher willingness to pay for choosing a faster transportation mode than in a non-business purpose. As the result of travel time saving, more work times become available, i.e., not only the traveller but also the employer is expected to obtain the benefit of travel time saving. Actually, this can account for why the travel cost is usually shared by employee and employer even paid by employer completely in most business travel cases to some extent. Accordingly, when the travel choice behaviour is analyzed, both traveller (employee) and employer's utilities should be considered in the process of mode choice decision-making. However, up to now, almost all the travel analytical models for business purpose (conventional models) have been analyzed just based on the traveller's choice behaviour, i.e., the utility of employer is neglected in a business travel analysis. Moreover, according to the analysis of value of travel time saving (VOTT) for business purpose shown in Appendix A and B, it is clear that the value of travel time saving estimated from conventional model for business travel is underestimated.

Based on the collective choice theory, a new consideration of modelling the travel for business purpose is presented, i.e., the travel choice is viewed as a collective choice problem with traveller and employer as the decision making members. Accordingly, the choice result is based on social outcomes, i.e., every member's preferences should be considered in the decision-making processes. Furthermore, the relative weights of all members' preferences and the collective choice rule (CCR) also affect collective choice. When a special CCR is applied, in which the group's benefit rather than every member's individual utility is emphasized, the social choice result is thought to be efficient and rational from a social perspective, though every member's maximum benefit doesn't always be guaranteed. With the analysis of the VOTT, it is clear that the collective choice model can evaluate the value of travel time saving more precisely than the conventional model (see Appendix B).

Figure 2 The Nested Structure of Integrated Intercity Travel Demand Model



3. Models

3.1 Integrated Mode/Route Choice Model

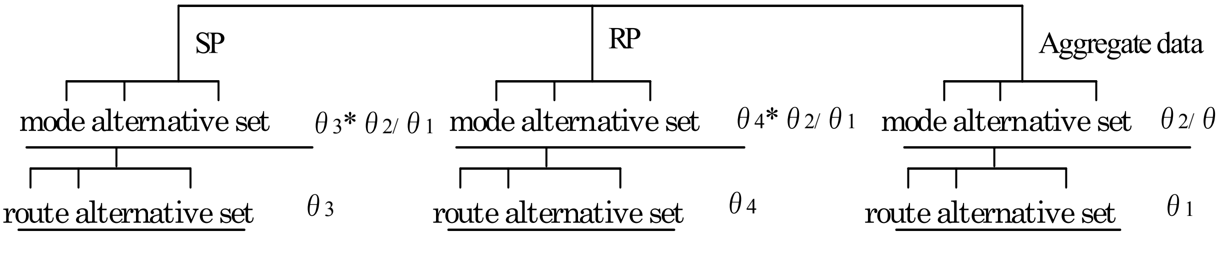
There still are two other conventional rail routes besides the HSR as the of route choice alternatives set, and the other travel modes are bus, car and air. Figure 3 expresses the joint estimation structure consisting three sub-models (SP, RP and aggregate datasets (AD)), and the three sub-models share same nested mode/route choice model structures. Certainly, for the RP and aggregate data, the alternative HSR doesn’t exist. In the joint model, all the SP, RP and the aggregate data are considered as the indicators of the utilities and these three random utility equations are shown below:

$$\text{RP model:} \quad U_{in}^{RP} = V_{in}^{RP} + \varepsilon_{in}^{RP} \tag{1}$$

$$\text{SP model:} \quad U_{in}^{SP} = V_{in}^{SP} + \varepsilon_{in}^{SP} \tag{2}$$

$$\text{AD model:} \quad U_{in}^{AD} = V_{in}^{AD} + \varepsilon_{in}^{AD} \tag{3}$$

Figure 3 Model Structure with Combined SP, RP Data and Aggregate Data



In this case, the aggregate data set is combined with disaggregate SP/RP data sets in the estimation of integrated mode/route choice model in order to catch the effects coming from other regions, as well as correct bias that may exist in the SP responses, and improve statistical efficiency of the parameter. To treat all datasets simultaneously, a joint likelihood function will be derived.

$$L^{RP+SP+AD} = L^{RP} + L^{SP} + L^{AD} \tag{4}$$

where, L^{SP}, L^{RP}, and L^{AD} are log-likelihood function for SP, RP, and aggregate data set respectively.

However, with the introduction of the aggregate trip data, there are two problems needed being solved before the model estimation: 1) how to use the aggregate data and disaggregate data simultaneously, and 2) how to identify the relation between variance of disturbance term in SP/RP sub-models' utility and that in aggregate data sub-model' utility.

As the first problem is concerned, given the non-efficiency of the Berkson-Thile Method used in aggregate logit model, it is better to use the data in disaggregate form in the estimation. Based on the concept of representative individual, a record of aggregate data is viewed as representing the choice of numbers of persons with same choice. With the theory of weighted exogenous sample maximum likelihood estimator (WESML), a weight factor is introduced into the likelihood function of aggregate data set to calibrate the bias between the sample and population data. For the second problem, similar to the assumption of joint RP/SP model, it is assumed that the nested structures are invariant for all datasets. Furthermore, the scaling approach is applied that allows for differences in the amounts of unexplained variation in different types of data, in which the relation between variance of disturbance term in the utility of SP/RP sub-models and that of aggregate data sub-model can be expressed by a scale parameter (see Eq. (7) and Eq. (8)). In practice, the scale parameter of variance in aggregate dataset sub-model is set to a fixed value 1 (i.e., $\theta_1=1$), while the scale parameters in SP and RP data are denoted as θ_3 and θ_4 respectively which needed to be estimated in the joint model (θ_1, θ_2, θ_3, θ_4 are shown in Figure 3).

$$\mu^{SP} = \theta_3 / \theta_1 \tag{5}$$

$$\mu^{RP} = \theta_4 / \theta_1 \tag{6}$$

$$Var(\varepsilon_{in}^{AD}) = \mu^{SP^2} Var(\varepsilon_{in}^{SP}) \tag{7}$$

$$Var(\varepsilon_{in}^{AD}) = \mu^{RP^2} Var(\varepsilon_{in}^{RP}) \tag{8}$$

For all sub models, the same log-sum scale parameters for the nested structure are defined as $\theta2/\theta1$. As for the systematic terms is concerned, same to the fundamental assumption of joint SP/RP model, the same trade-off relationships between major attributes are held for all three datasets. This is helpful to correct the bias that may exist in the SP responses, improve statistical efficiency of parameters, and involve the effects from other areas.

3.2 Destination Choice Model

The residence-based trip data in aggregate form is used in the estimation of destination choice model. For the same reason mentioned in mode/route choice model estimation, the data is transformed from aggregate form to disaggregate form. Moreover, there are too many destination alternatives for an origin zone to be dealt with in a discrete choice model. So it is necessary to make simple random sampling for all of the available destination alternatives to enhance the estimation efficiency. In our case, we randomly select 10 destinations in addition to the practically selected destination as the alternative set. In a large choice sets context, it has been proved that estimation may be conducted on a choice variable subset without loss of consistency (Ben-Akiva & Lerman 1985).

Besides some socioeconomic factors directly obtained from investigation such as the GDP per capita, and the rate of working population to population, two inclusive variables indicating the degree of the attractiveness of a zone for business and non-business purpose are also used as explanatory variables in the utility function. The attractiveness is calculated with the AHP analytical method. In detail, in the case of business travel, the attractiveness is defined by some influencing factors (the number of headquarter, the number of international conference, the regional location indicator, the production of IT industry, etc.). On the other hand, the indicator for non-business travel case mainly indicates the degree of aspiration for leisure activities, which influenced by the number of resort, sport centre, museum, cinema, shopping centre, and so on.

With the inclusion of the expected maximum utility derived from mode/rout choice stage as an explanatory variable in the utility function of destination choice, the effects from the change in modes and routes' level of service between OD pairs on the destination choice is possible to be reflected.

3.3 Trip Generation Model

Multiple regression analysis approach is applied in the trip generation modelling. The expected maximum utility value derived from the destination stage is used as an explanatory variable in the trip generation model.

The expected maximum utility, interpreted as the accessibility measure for an individual in origin i, is used as an explanatory variable in the trip generation model for zone i. Because the expected maximum utility has the ability to capture the behavioural effects of mode shifts, route shifts, and redistribution of trips, travel demand including the travel induced from the advancement of accessibility can be estimated.

4. Estimation Results

4.1 Integrated Mode/Route Choice Model

Based on the collective choice, the gross travel cost rather than the cost paid by traveller is used in the estimation for business purpose. And the estimation results with combined SP/RP and aggregate datasets are listed in Table 1 and Table 2:

(1) All parameters are statistically significant and consistent with their hypothesized effects on utility. For example, travel time and cost with negative parameters means that the more travel cost or more travel time, the less the selected possibility.

(2) As for the value of travel time, with the combination, it is possible to get more reasonable result evolving all data sets' characteristics, and these results are also coincident with the results from other studies in Japan. The value of travel time (VOTT) of business purpose is larger than that of non-business purpose. This is consistent with common sense that the saved time in a business travel is possible to be used for production, while a travel time saving in non-business purpose is likely to accrue to and be retained by individual as an increase in the amount of time available for all leisure activities (Mackie, et al., 2001). For each travel purpose, the line-haul VOTT of Rail/Air is bigger than that of Bus/Car. Meanwhile, the access and egress VOTT of Rail/Bus is less than that of the Air, it means that the accessing resistance to airport located in suburb is larger than that to rail station located in inner city.

(3) The constant terms indicate mean preferences for HSR relative to conventional rail for both business and non-business travels. The logsum scale parameters of business and non-business model are both smaller than 1.0, it means the assumption of nested structure of mode/route choice is reasonable.

(4) In the joint model for business purpose, the scale parameters reflecting the relationships of variance of SP/RP to that of aggregate dataset (μ^{SP}= 0.627, μ^{RP}= 0.476) are both smaller than 1.0, means that the SP and RP data's stochastic variance component is larger than that of aggregate data. In the non-business case, on the contrary, the SP and RP data's stochastic variance component is smaller than that of aggregate data (μ^{SP}= 1.467 μ^{RP}= 1.234).

(5) For business purpose, each VOTT estimated from collective choice model is larger than the corresponding result from conventional model (Line-haul VOTT of Rail/Air: 107.0 JPY/Min, Line-haul VOTT of Bus/Car: 90.1 JPY/Min, Access/Egress VOTT: 77.3JPY/Min). It is consistent with our analysis that the VOTT estimated from collective choice model should be larger than the result from conventional model.

Table 1 The Estimation Results of Mode/Route Choice (t-statistics are in parentheses)

	Business		Non-Business	
	SP/RP	Aggregate	SP/RP	Aggregate
Constant: HSR	0.450		0.587	
	(5.2)		(19.76)	
Constant: Conventional Rail1	0	0	0	0
	-	-	-	-
Constant: Air	-1.280	-1.56	1.887	-0.796
	(-4.2)	(-5.9)	(11.82)	(-5.69)
Constant: Conventional Rail2	0	0	0	0
	-	-	-	-
Constant: Exp. Bus	-11.3	-2.99	-2.270	-1.884
	(-8.5)	(-11.2)	(-13.65)	(-14.25)
Constant: Car	-5.17	1.40	-0.603	3.592
	(-8.5)	(7.7)	(-7.49)	(28.97)
Travel Cost（10000En）		-3.326		-2.442
		(-14.9)		(-25.93)
Line Haul Time: Rail/Air (60 minutes)		-2.136		-0.562
		(-19.4)		(-22.79)
Line Haul Time: Exp. Bus/Car (60 minutes)		-2.06		-0.562
		(-19.1)		(-22.79)
Terminal Time: Rail/ Exp. Bus (60 minutes)		-1.65		-0.519
		(-15.9)		(-11.61)
Terminal Time: Air (60 minutes)		-1.65		-1.150
		(-15.9)		(-12.09)
Service Frequency: Rail/ Exp. bus（Times/60 Min.）		0.248		0.164
		(12.0)		(20.5)
Service Frequency: Air (Times/60 Min.）		0.489		0.164
		(21.5)		(20.5)
Scale parameter (θ_2/θ_1)		0.820		0.558
		(6.8)		(34.9)
Number of sample		18798		32202
$\bar{\rho}^2$		0.495		0.456
Line Haul VOTT: Rail/Air (JPY/min.)		107.0		38.4
Line Haul VOTT: Exp. bus/ Car JPY/min.)		103.3		38.4
Terminal VOTT: Rail/ Exp. Bus (JPY/min.)		82.6		35.4
Terminal VOTT: Air (JPY/min.)		82.6		78.5

Note: JPY (Japanese Yen)

4.2 Destination Choice Model

The estimation results of destination choice model are presented in Table 2 and Table 3.

Table 2 The Estimation Results of Destination Choice (Business Purpose)

Explanatory Variable	Parameter	t-statistic
The Expected Maximum Utility Value	0.169	50.7
The GDP per capita of the Zone Area (Million JPY)	1.69	24.4
Working Population in Production Industry/ Working Population（%）	-0.437	-29.2
Attractiveness	10.6	2.5
Number of Sample	5975	
$\bar{\rho}^2$	0.268	

The parameters of the expected maximum utility value derived from the mode/route choice model are 0.169 and 0.335 for business and non-business travel respectively (between 0 and 1.0). It means the nested structure assumption of destination and mode/route choice is reasonable.

Table 3 The Estimation Results of Destination Choice (Non-business Purpose)

Explanatory Variable	Parameter	t-statistic
The Expected Maximum Utility Value	0.335	55.6
Working Population/Population（%）	0.037	11.9
Working Population in Production Industry/ Working Population（%）	-0.172	-15.6
Working Population in Service Industry/Working Population（%）	0.033	3.5
Attractiveness	30.833	5.0
Number of Sample	5601	
$\bar{\rho}^2$	0.179	

All parameters are statistically significant and consistent with their hypothesized effects on utility. For example, in business purpose case, besides the expected maximum utility value, the ratio of the working population in production industry to the working population has a negative parameter, while the GDP per capita of the zone area and destination's attractiveness degree have positive parameters. This means that the destination with higher share of production industry, lower GDP per capita, and lower attractiveness degree has lower possibility to be selected as business travel destination. Similarly, for the non-business travel, the higher the share of working population in service industry, the higher the possibility of this zone to be selected as the destination of non-business travel.

4.3 Trip Generation Model

The individual specific accessibility, which captures the effects of mode/route switch and the destination shifting effects, is used as an explanatory variable in the trip generation model. To improve the accuracy of trip generation model, all the zones are classified into three sub regions as shown in Table 4 based on the geographic distribution and the transportation characteristics of each zone. The estimation results of trip generation model for business and non-business purpose are presented in Table 5, and Table 6.

Table 4. The Region Division

No.	Business	Non-business
1	The three metropolitan areas along the HSR	The Capital metropolitan areas
2	The regions along the conventional rail Sanyou	The Chukyou metropolitan areas
3	The others	The Kansai metropolitan areas
4		The Kyushu, Sikoku, Okinawa prefectures
5		The others

For all regions, the term of accessibility timing population has a positive parameter, i.e., with the improvement of individual accessibility, people are tending to increase their travel frequency. Certainly, the more population, the more trips are generated. For some regions, the term of working population in service industry is introduced in the generation model as an explanatory variable for business travel. This means that the people working in service industry tend to make more business travels than the people with other vocations.

With the introduction of accessibility term into the trip generation model, through calculating the change of the expected maximum utility (accessibility) resulted from endogenous factors' improvements (transportation system factors), the induced travel resulted from these behavioural effects of mode/route switches, and trip distribution can be estimated. Moreover, if the changes in the demographic and social-economic properties of a destination zone resulted from spatial reallocation of activities can be predicted, the induced travel considering the subsequent effect of spatial reallocation of activities can also be obtained. However, it usually needs to build an additional land use model to indicate these changes in the demographic and social-economic properties.

Table 5.Trip Generation Model (Business Purpose) (t-statistics are in parentheses)

	Region1	Region2	Region3
Constant	260.1 (0.9)	-2803.8 (-1.6)	213.5 (0.7)
Accessibility * Population (1000000 Persons)	174.1 (7.7)	824.5 (7.0)	186.2 (3.5)
Working population In Service Industry (1000000 Persons)	2146 (2.6)		9342.8 （6.3）
Number of sample	63	13	71
R^2	0.838	0.801	0.715

Table-6. Trip Generation Model (Non-business Purpose) (t-statistics are in parentheses)

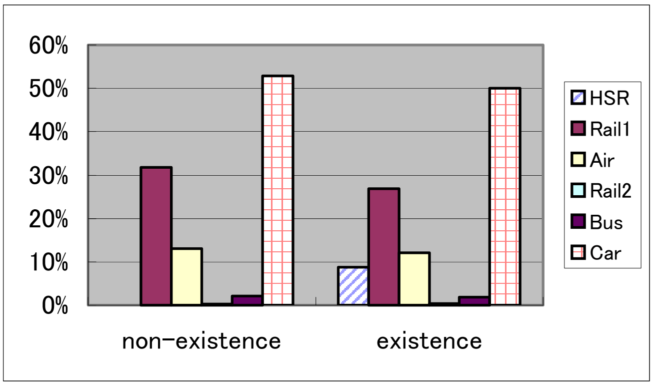
	Region1	Region2	Region3	Region4	Region5
Constant	2999.48 (1.78)	286.44 (0.38)	89.68 (0.15)	-5385.5 (-1.27)	1253.32 (1.69)
Accessibility * Population (1000000 Persons)	200.54 (2.91)	228.16 (5.58)	193.94 (4.10)	1461.04 (5.36)	583.66 (7.10)
Number of sample	23	17	16	13	78
R^2	0.253	0.653	0.513	0.698	0.391

5. Analysis of Travel Demand in the Future

To analyze the potential share of the HSR system and the change of the transportation market in the future, according to the tendency of socioeconomic development, the demographic and socioeconomic data of the analytical year (2020, when the HSR will be put into operation) are estimated. Then, with the accessibility measure method presented above, the travel demand considering the induced travel in the future is analyzed.

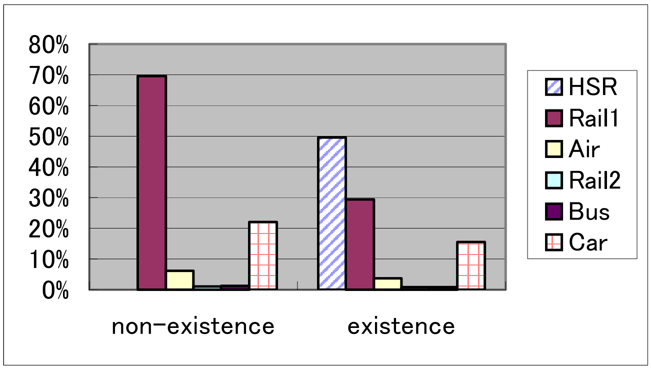
With the comparison of mode share estimated in the analytical year for two cases shown in Figure 4 (the HSR is constructed and non-constructed), there is a great change in transportation market at nationwide level. With the introduction of the HSR service, the HSR will take on about 8.7% of transportation demands at the nationwide level. In detail, the demand for HSR are mainly shifted from the conventional rail 1, there are also significant reductions in the shares of air and car. This is thought to be a contributory cause of alleviating the congestion in conventional rail1. As for the rail service (including the HSR and the conventional rail), the share increases from 32.1% to 35.9%, and the change is mainly from car. Because the introduction of HSR successfully stimulates the shift from automobile transportation to rail transportation, this change is viewed desirable from the environmental viewpoint. As for the trip generation, about 1.1% new induced trips generates with the introduction of the HSR service in the analytical year at nationwide level.

Figure 4 Mode Share Comparison for Nationwide (Business and Non-Business)



For the three special metropolitan areas along the HSR, the transportation market changes significantly. The share of HSR reaches to 49.6%, whereas the share of car decreases from 22.0% to 15.6%, and the majority of the travel demand is dealt by rail service (about 79.1%). The comparison of mode share between the two scenarios with and without HSR is shown in Figure 5. Meanwhile, a great number of additional trips are shifted to or newly generated in the three special metropolitan areas, and the induced travel will account for 14.5% of travel demand in the analytical year (only trips that are new to the region are viewed as induced travel at a regional level). As for the results obtained here, for the lack of detailed information (capacities, performance factions) about nationwide road network and the road cargo traffic volume, the changes in road transportation properties can not be estimated, i.e., the results estimated in our research tends to underestimate the effects of alleviation of congestion in road network. Furthermore, for the sake of holding land use fixed, the effects of spatial reallocation of activities (long run behavioural effects) are not considered here. Among the travel demand generated in the three special metropolitan areas, the rate of trips selecting the three special metropolitan areas as destinations changes from 23.0% to 25.9%. This means that about 89.2% of newly increased travel demands are shifted from other areas.

Figure 5 Mode Share Comparison for the Three Special Metropolitan Areas (Business and Non-Business)



As for the breakdown of travel demand within the three metropolitan areas for HSR is concerned, about 74.5% of the trips are shifted from other transportation modes or routes, and the newly generated travel accounts for 25.5% of total HSR trips.

As for the contributors to the travel demand increase are concerned, exogenous factors (population growth, economic growth, etc.) and endogenous factors (travel speed up, reduction in travel cost, etc.) are considered. At nationwide level, because of the low birth rate (1.36-1.39, data obtained from national institute of population and social security research in Japan) and the low growth rate of GDP (1-2%) in the next century in Japan, the travel demand annualized growth in the analytical year is only 0.16%. However, with the introduction of HSR, the travel demand annualized growth in the analytical year will be 1.28%. Therefore, the improvement of accessibility as the result of introduction of HSR will account for 87.5% of increase of travel demand in the analytical year. In other words, the induced travel effect accounts for 87.5% of annualized growth of travel demand in 2020.

For the three metropolitan areas, the effect of accessibility's improvement is more obvious. The travel demand annualized growth in the analytical year is only 0.34%. However, with the introduction of HSR, the travel demand annualized growth in the analytical year will reach to 14.9%. Correspondingly, the induced travel effect accounts for 97.7% of annualized growth of travel demand in analytical year. This means that this HSR project has greater effects on these three special metropolitan areas than other areas in Japan.

Noland and Cowart (2000) found that the induced travel effect accounts for average from 15% to 40% of annualized growth in VMT for metropolitan area. In our case, both figures for nationwide and the three metropolitan areas are far above the figures obtained by Noland and Cowart. As the most important reason, the low birth rate and the low growth rate of GDP in Japan are raised, and this make the effect of accessibility improvement become relatively greater.

6. Conclusions and Future work

It was broadly reported that induced travel is an important component in the travel demand. With the advancement of transportation condition, some short run (changes in travel departure times, routes switches, modes switches, longer trips, changes of destination, and some trip generation increases) and long run (household auto ownership level and spatial reallocation of activities) behavioural effects will happen, and these behavioural effects are thought to result in induced travel. However, it is not always true that all these behavioural effects definitely contribute to induced travel at different analytical level (e.g., regional or facility).

In this paper, an attempt is made to establish the relationship of induced travel and possible behavioural changes in traveller resulted from the change of endogenous factors (such as reduction of travel time, and travel cost). Then with the inclusion of a comprehensive accessibility measure (which is thought to be capable of effectively capturing these behavioural effects of induced travel in a multidimensional mode/route and destination choice context) into the trip generation model, the induced travel is estimated. As for the spatial reallocation of activities, which is viewed as a long run behavioural effect, a land use model is needed to indicate the changes in land uses resulted from transportation improvement. Theoretically, if the changes in the demographic and social-economic properties of a destination zone resulted from spatial reallocation of activities can be predicted, the induced travel considering the subsequent effect of spatial reallocation of activities can also be obtained with the method presented here.

As a case analysis, with the introduction of a HSR planed in Japan, an integrated travel model with nested structure including trip generation model, destination choice model, mode choice model, and route choice model for an intercity high speed rail system planed in Japan is built, and the change of transportation market and the induced travel resulted from the short run behavioural effects are also estimated.

The models are estimated for business and non-business purpose respectively. Based on the collective choice theory, a collective choice based model for business purpose is presented in order to make the decision-making process clear. With the analysis of value of travel time saving, the result from the collective choice based model is more rational than that of the conventional travel model. As for the induced travel, about 1.1% additional travel will be induced at nationwide level and the induced travel effect will account for 87.5% of annualized growth of travel demand in analytical year (2020). For the three metropolitan areas along the HSR corridor, about 14.5% additional travel will be induced.

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Appendix A: The value of travel time saving from the travel for business purpose

Based on the analysis of time use, benefit derived from the travel time saving in the case of business travel is mainly affected by labour contract (in brief, a. travelling time is paid as working time, b. otherwise) and the relationship between travelling hours and working hours (I. travelling hours is in working hours, II. travelling hours is out working hours, III. both cases). Under the assumptions that it is completely unproductive in travelling hours and neglecting the disutility of travelling time, the values of travel time saving for all possible cases are listed in Table I (where, p is the marginal product of labour, w is the rage rate). Except from the case of b-II, the benefit with volume of p is derived from the travel time saving at the social evaluation level (both employee and employer), and the assignment of benefit is decided by labour contract.

Table I The Values of One Unit Travel Time Saving

Cases	Traveller	Employer	Total
a-I, a-II	0	p	p
b-I	w	p-w	p
b-II	w	0	w

Appendix B: The value of travel time saving from conventional model

The travel choice behaviour of traveller for business purpose under individual's income and time use constraints is expressed with the traveller's individual utility maximization below:

$$Max(U^p) = U^p(P_l^p, t_l, t_w, t_i, Q_i) \tag{1}$$

Subject to:

$$wt_w = P_l^p + \sum_i \delta_i P_i^p \tag{2}$$

$$T = t_l + t_w + \sum_i t_i \tag{3}$$

$$t_i \geq \bar{t}_i \tag{4}$$

where, U^p: Utility for an employee. P_l^p: The monetary value of other goods that an individual can consume besides the travel cost. t_l : Leisure time. t_w : Working time. t_i : Time used for travel. P_i^p: Travel cost paid by an employee. $\bar{t}_i$: The minimum necessary time for travel. w : The wage rate. δ_i : Choice indicator (1 if alternative i is chosen and 0 otherwise). Q_i : The other service quality of alternative i.

With the Lagrange approach, the utility maximization problem can be changed to:

$$Max(U^p) = U^p(P_l^p, t_l, t_w, t_i) + \lambda(wt_w - P_l^p - \sum_i \delta_i P_i^p) + \mu(T - t_l - t_w - \sum_i t_i) + \kappa(t_i - \bar{t}_i) \tag{5}$$

Therefore, the value of saving time in travel activity, defined as κ/λ (Oort, 1969, DeSerpa, 1971), comprises two components (the willingness to pay to shift the time from travel to another activity and the discomfort and anxiety in travelling period) :

$$\frac{\kappa}{\lambda} = (\frac{\partial U^p}{\partial t_w} \Big/ \lambda + w) - (\frac{\partial U^p}{\partial t_i} \Big/ \lambda) \tag{6}$$

where $\lambda = \partial U^p \big/ \partial P_l$ is the marginal utility of income for employee.

However, for the business travel, the result is suspicious. In a special context in which travel time saving is during the course of work and employer purchases the time of employee, within Eq. (6), $(\partial U^p/\partial t_w - \partial U^p/\partial t_i)/\lambda$ accrues to the employee and w attributes to the employer from a social point of view. Especially, when the marginal money value of working and travelling time equals to each other just like a truck driver's case, the value of time saving means nothing to the driver, on the other hand, there is benefit w for employer. At the social evaluation level (employee as well as employer), this means the size of time saving benefit is w but not marginal product of labour. In fact, as Hensher pointed out, when the social value of time saving is evaluated with this equation, it is necessary to assume that the wage rate is equal to the marginal product of labour. Obviously, this assumption can't be held in most cases. Because the p is usually larger than w, the conventional method tends to underestimate the benefit of business travel, and a portion of benefit is missed.

Appendix C: The value of travel time saving from collective choice model

Similar to the case of employee, the utility maximization for an employer can be expressed as:

$$Max(U^c) = U^c(P_l^c, t_w) \tag{7}$$

Subject to:

$$pt_w = P_l^c + wt_w + \sum_i \delta_i P_i^c \tag{8}$$

p : Marginal product of labour (Productivity). P_i^c : Travel cost paid by employer. P_l^c : The monetary value of other goods that employer can consume besides the travel cost.

Based on the principle maximizing the group's benefit, the collective utility (social decision function) can be converted to:

$$Max(U) = U((P_l^p + P_l^c), t_l, t_w, t_i, Q_i) \tag{9}$$

Meanwhile, with the combination of the constraints (2) and (8), the group income budget constraint is:

$$wt_w + pt_w = P_l^p + \sum_i \delta_i P_i^p + P_l^c + wt_w + \sum_i \delta_i P_i^p \Rightarrow pt_w = (P_l^p + P_l^c) + \sum_i \delta_i (P_i^p + P_i^c) \tag{10}$$

Accordingly, the gross travel cost (the cost paid by employee and employer) rather than the cost just paid by employee should be used in the social decision utility function for business purpose.

With the Lagrange approach, the utility maximization problem can be changed to:

$$\begin{aligned} Max(U) = U((P_l^p + P_l^c), t_l, t_w, t_i) + \lambda[pt_w - (P_l^p + P_l^c) - \sum_i \delta_i (P_i^p + P_i^c)] \\ + \mu(T - t_l - t_w - \sum_i t_i) + \kappa(t_i - \bar{t}_i) \end{aligned} \tag{11}$$

With the definition of VOTT, the value of travel time in business travel can be expressed as:

$$\frac{\kappa}{\lambda} = \frac{\partial U}{\partial t_w}\Big/\lambda + p - \frac{\partial U}{\partial t_i}\Big/\lambda, \tag{12}$$

This means that the value of a saving in travel time for business travel is equal to the marginal product of labour plus the difference between the marginal money values of working and travelling time. Different from the VOTT deduced from conventional model, productivity term is involved in the VOTT equation in place of the wage rate term. Normally, because the productivity is larger than the wage rate, the VOTT calculated by this equation is larger than the result with the conventional VOTT equation averagely. Then looking back to the case of a truck driver, the value of travel time is p. It is consistent with the theoretical analysis of business travel time use in Appendix A. In practice, because of the indefiniteness of labour and product market conditions, though the final beneficiaries of business travel time saving are unidentifiable in most cases, at social evaluation level, it is clear that this result is more rational than the conventional one.