Telecommunication Demand Analysis Model Integrating Ordinary, Mobile and Public Phones：

Does Mobile Phone Substitute for Ordinary and Public Phones?

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The purpose of our research project is to develop a new integrated model for explaining interregional telecommunication demand not only by traditional phones such as ordinary and public phones but also by mobile phones such as personal handy and cellular phones. In the empirical research, the first traffic data on ordinary, public and mobile telephone services is used. This paper attempts to explain the demand on interregional phone services based on the same framework of travel demand analysis, unlike most economic models which estimate the demand or supply curve without considering information flow from origin to the destination.

Keywords: *Information, Telecommunication, Mobile Phone, Public Phone and Demand Analysis*

1. INTRODUCTION

This paper aims to develop a new model for explaining interregional telephone services by ordinary, public, PHS and cellular phones. We have presented some earlier papers on our research project in the Institute for Posts and Telecommunications Policy (IPTP) in the Government of Japan (Takita, Miyata and Takaya (1997)[1] (1999)[2]).

In telephone services of Japan, the subscriber's number of mobile phones has been increasing because of more flexibility and less communication costs compared to fixed types of telephones such as household and public phones. Under these circumstances, when empirical research on phone demand is made, it is also necessary to consider cellular and PHS phones. However, a model for explaining interregional phone services including mobile phones has not yet been systematized. The introduction of the concept of travel demand to this new type of telecommunication model enables a new model which can consider the different natures between telecommunication and transportation.

Both telecommunication for information transmission and transportation for personal trips and commodity shipping are essentially similar spatial flows (Okano and Nanbu (1987)[3], Takita (1997a)[4]). In the field of transportation research, an estimation of travel demand is very important to present urban public policy on traffic jams.

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A fundamental concept is to make future transportation planning to satisfy traffic allocation to each link between the nodes in transportation networks according to the future total traffic demand. This travel demand analysis model is complicated, and is generally used (JSCE (1981)[5] Takeuchi, Honda and Aoshima (1986)[6]. On the other hand, in the field of telecommunication, from the viewpoint of price policy includes economic studies to estimate the demand and supply curves (Oniki, Kawamura and Noguchi (1993)[7], Kuriyama, Hatta, Nakazora, Ohta, Ohmura and Noguchi (1993)[8], Mitomo (1995)[9], etc.). Geographical studies to clarify the spatial pattern of demand on interregional telephone services based on gravity model or statistical methods (Morikawa (1961)[10] (1978)[11], Tanabe (1982)[12], Hasegawa, Nakamura el. (1983a)[13] (1983b)[14] (1985)[15] (1990)[16], National Land Agency (1987)[17], IPTP (1992)[18], Higuchi and Shimane (1998)[19], etc.). Other research has integrated transportation and telecommunication (IATSS (1984)[20]. Moore and Jovanis (1988)[21], Takita, Yuzawa and Suda (1991)[22](1993)[23](1995)[24], Hidano, Sasaki, Inaba and Adachi (1994)[25], Takita (1997b)[26], Okumura and Tsukai (1998)[27]). Though these studies had specific characteristics, they did not consider mobile or public phone services.

This paper concentrates on telephone services, and constructs a new demand analysis model to explain the volumes of telephonic communication generation and attraction in each region as well as information flows between regions by ordinary, public, cellular and PHS phones. This model considers the differences between transportation and telecommunication and proposes some units of information flows.

2. STATISTICAL DATA ON TRANSPORTATION AND TELECOMMUNICATION TRAFFICS.

The traffic means the flow of both transportation and telecommunication basically. However, in transportation studies, traffic is the flow of transportation. And, in telecommunication studies, traffic is the flow of telecommunication. This paper redefines traffic as consisting of transportation traffic and telecommunication traffic. Furthermore, telephone traffic is a part of telecommunication traffic. First, statistical data on telecommunication traffic is explained. Next, we discuss how future telecommunication traffic data should be collected.

Fundamental surveys about travel demand analysis have been performed. The Ministry of Land Infrastructure and Transport (MLIT) of Japan, and others have performed Personal Trip Survey (PT Survey) to survey personal travel behaviors within each regional central city and the surrounding cities in Japan. In addition to this, the MILT has regularly performed *Survey on the Net-flow of passengers* to grasp interregional flow of passengers.

And in the field of telecommunication research, the Ministry of Post and Telecommunication (MPT) of Japan started *Information Census* (MPT(1997)[28]) to measure sent, supplied, selectable, consumed and stocked information volumes in each prefecture of Japan. Annual telecommunication traffic data on telephone services between prefectures has been updated by the Ministry of Internal Affairs and Communications (MIC). And another annual traffic data has been opened by the Nippon Telegraph and Telephone (NTT).

Report on telecommunication traffic for telephone services, which is one of fundamental statistics on telecommunication, has been published by the MPT and the MIC. And also, traffic data for telephone services has been collected and analyzed every year.

Furthermore, some trial information statistics are made from original questionnaires or various traffic data. The National Land Agency (1987)[17], The *power of regional information*, and the then Institute for Posts and Telecommunication Policy (IPTP) of the MPT, *Research report on interregional information flows* (IPTP(1991)[29]), presented interregional information flows. However, survey on personal use of telecommunication, which is similar to personal trip survey in transportation research, does not exist.

The MILT and the other related organizations have systematically performed transportation research for city and urban planning. However, the MIC has not systematically performed telecommunication research. The reason is that telecommunication has been private investments by the NTT and others, while transportation projects, such as airports, the Shinkansen railroads and highways, has been public investments from budgets of the MLIT.

For the 21st century, telecommunication, especially the Internet, will have been one of the most important infrastructures for national and regional policies. For the future, various types of information demand analysis will be needed using the national and regional surveys on information flow.

3. FRAMEWORK ON TELECOMMUNICATION DEMAND ANALYSIS MODEL TO MAESURE INFORMATION

Takita (1997)[4] has developed a framework to analyze information demand in the information society, as shown in Figure 1. It presents a novel model integrating transportation and telecommunication

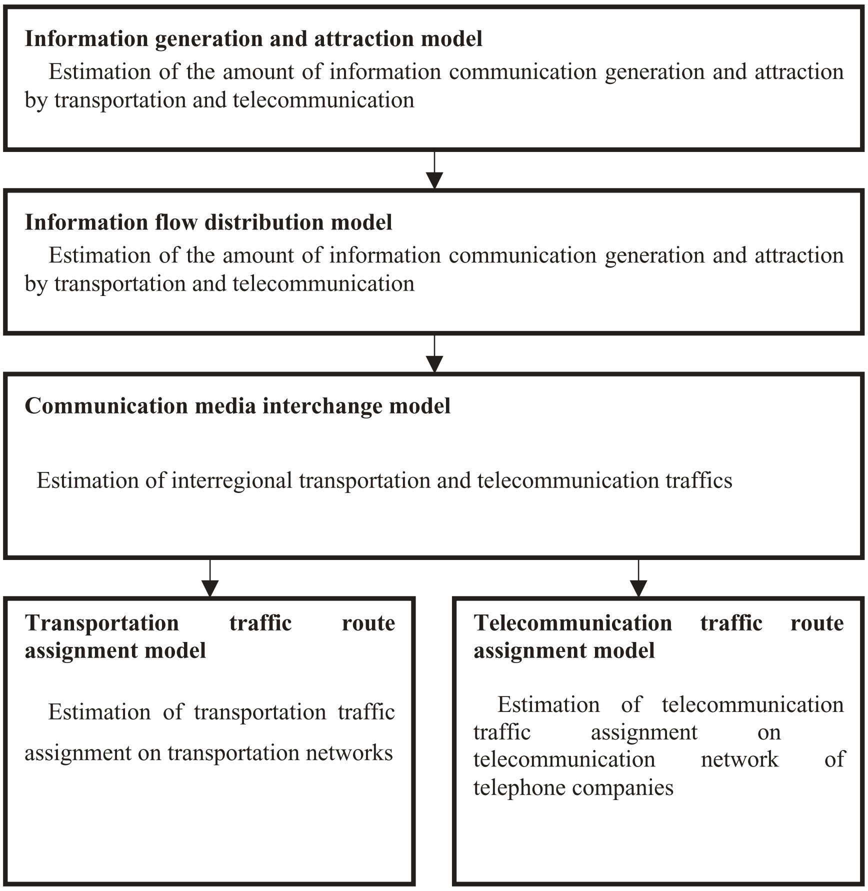

Figure 1 : Framework of information demand analysis (Takita (1997))

to measure information. The model consists of the following four-stage sub-models:

1) Information generation and attraction model,
2) Information flow distribution model,
3) Communication media interchange model including transportation and telecommunication,
4) Transportation and telecommunication traffic route assignment models to assign information flows on transportation and telecommunication networks

Many transportation researchers and government officers have proposed transportation policy using the four sub-models of transportation. However, in the information society, it is important to analyze information demand by travel and communication. Takita (1997)[4] extends the previous research in the field of transportation and telecommunication.

In addition, a framework on telecommunication demand analysis model including mobile and public phones is explained below. We focus on telecommunication demand analysis including mobile and public phones. Our project in the Institute for Posts and Telecommunications collects the earliest traffic data including mobile phones from some telecommunication companies. The model considers the tradeoff between these phones in the near future: fixed-type phones (ordinary and public phones) vs. mobile-type phones (cellular and PHS phones).

Here, the telecommunication demand analysis model consists of four sub-models as shown in Figure 2：

1) Telecommunication generation and attraction model (Telecommunication sent and received model),
2) Telecommunication distribution model (Interregional telecommunication flow model),
3) Telecommunication media interchange model,
4) Telecommunication traffic route assignment model.

These four sub-models are related to the trip generation and attraction model, the trip distribution

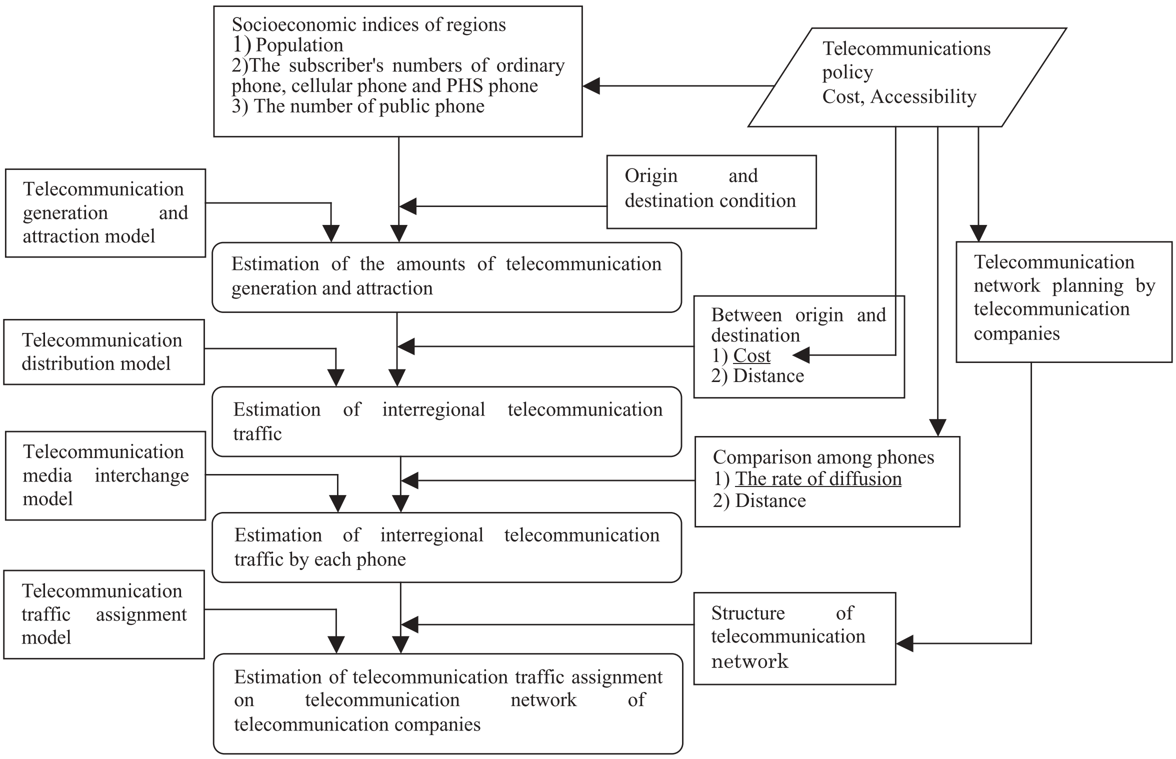

Figure 2 : Framework of telecommunication demand analysis model

model, the trip modal spirit model and the trip route assignment model in transportation research. This model considers the differences between transportation and telecommunication. In this paper, telephones in Table 1, - ordinary, public, cellular and PHS phones, are examined.

Table 1 : Types of phones

1. Ordinary phone
2. Public phone
3. Cellular phone
4. PHS phone

Note : PHS is Personal Handy Phone System in Japan

(1) Unit of information and scale of zone

The units of information are defined as words, time consumed, packets, bits and bytes in Table 2.

Table 2 : Units of information

Units	Definition
Words	the smallest units of language used for making phrases and sentences
Time consumed	the amounts of time that is needed to understand, or that is needed to consume.
Packets	the number of telecommunications
Bits	information volume decided by combinations of 0 or 1
Bytes	=8 bits

'Words' are the smallest units of language used for making phrases and sentences that usually represent objects, ideas and actions etc. This unit enables us to measure how many contents are transmitted. 'Time consumed' is something that is measured in 'minutes', 'hours', 'years' etc. This unit can be used to measure the amounts of time that is needed to understand, or that is needed to consume. In the case of the telephone, this is the amount of time that is needed to talk. 'Packets', or 'calls', can be used to measure how many communications are done. Here, we need to note that the ability of communication media to transmit information, or information volume per bucket differs depending on the situation.

Furthermore, in Information Engineering, 'bits' and 'bytes' are used to measure information and its flows. In Transportation Studies, 'trips' are used to express personal flows between regions. And 'tons' or 'pounds' (U.S. or U.K. unit of weight) is used to express weights of commodities and commodity flows.

In this subsection, we discuss better units of information for telephonic communication. In order to grasp the total volume of telephonic communication, the total time for telephonic communication is better than the number of telephonic communication. And the consuming time of information is equal to this telephonic communication time.

The total time, for telephonic communication enables us to analyze how we allocate total time for telephonic communication into indoor phone (ordinary phone) and the other outdoor phones (public, cellular and PHS phones). As a result, the unit, the total time for telephonic communication, helps the model to analyze interregional information flow quantitatively.

On the other hand, the total number of telephonic communication can not necessarily explain the volume of information flows between regions. For example, telephonic communication by ordinary phone is generally longer than that by cellular phone and PHS. It is important to select most appropriate unit of information according to the analytical model.

One of the other important units for measuring information is 'words'. The unit of information, 'words', can be transferred from the other unit, 'time consumed,' using the transferred coefficient, words per minute. This 'time consumed' corresponds to telephonic communication time. This unit of information is useful to measure volumes of contents of information. Otherwise, bits and byes are the most important units of information in the fields of information engineering.

(2) Concept of telecommunication demand analysis

This subsection presents a framework on telecommunication demand analysis model (information demand analysis model for telephone services.) This model consists of telecommunication generation and attraction models (telecommunication sent and received models), telecommunication distribution model (interregional telecommunication flow model), and telecommunication traffic route assignment models. Compared to the travel demand analysis model, this telecommunication demand analysis model is discussed below.

(a) Telecommunication generation and attraction models (telecommunication sent and received model)

The telecommunication generation and attraction model (telecommunication sent and received model) is explained by socioeconomic valuables in regions (population, employees, income, total production and so on) and the degree of diffusion of each type of telephone (for example, the number of subscribers for each phone service). This model corresponds to the travel generation and attraction model in transportation studies. And it aims to explain and forecast the total amount of telecommunication sent from each region (summation of all columns in telecommunication OD table) and the total amount of telecommunication received from each region (summation of all rows in telecommunication OD table). Here, OD means Origin and Destination in the field of Transportation Studies. Like the travel demand model, standard unit method and regression model method can be used as the method to estimate the total amount of telecommunication sent and received. The standard unit method has a fundamental concept that the amount of telephonic communication per index of a regional socioeconomic condition, such as population, is constant. In the regression model method, some socioeconomic variables explain the amount of telecommunication generation and attraction.

There are characteristic differences between telecommunication generation and attraction and trip generation and attraction. The trip generation and the trip attraction are generally the same volumes. Travel is generally a round trip, and consists of two trips between two regions. But the telecommunication generation and the telecommunication attraction are not generally the same volumes. The information-sent volume from each region is more than or less than the information-received volume to the region. Generally, prefectures including important central cities of the country are that the information-sent volume is more than the information-received volume.

(b) Telecommunication distribution model

The telecommunication distribution model (interregional telecommunication flow model) is related to the trip distribution model. This model is to explain and forecast interregional telephonic communication from the amounts of telecommunication generation (summation of columns of telecommunication OD table) and that of telecommunication attraction (summation of rows of telecommunication OD table) and from patterns of interregional telecommunication flow. In order to decide telecommunication distribution, current pattern method, opportunity model, spatial interaction model (unconstrained gravity model, origin constrained gravity model, destination constrained gravity model, and doubly constrained gravity model) can be used.

We discuss the fundamental differences between telecommunication distribution and trip distribution. As we understand generally, travel is one pair of two trips, or round trip. When we travel, we go from a point to another point and return to the starting point finally. However, telecommunication exists only one way from a point to another point, and the total volume is aggregated. Because of these different characteristics, the number of trip from region A to B is similar to that from region B to A, but the number of telephone calls is not similar. These lead to a deference between the nature of travel OD table and that of telecommunication OD table.

In travel OD table, each cell has approximately symmetry with respect to the diagonal line (cells of intra-travel). And in the telecommunication OD table, each cell has not. Takita(1998)[30] presented a model for explaining information flows between head office and branch office and between their offices and the other firms. And the paper explained characteristics of the travel OD table, the telecommunication OD table and information flow table.

(c) Telecommunication media interchange model

The telecommunication media interchange model is related to the trip modal split model in Transportation Research. This model is to explain and forecast interregional information flow by each telephone, using the given amount of interregional telephonic communications and the rate of telephonic communication by ordinary, public, cellular and PHS phones. The estimation of this model is made by the rate curve of media interchange, the table-type function or the disaggregate model. The rate of media interchanges is described by one variable such as telephonic distance or communication cost. This disaggregate behavior model is used to explain the individual probability of each person choosing phones from the values of the characteristics of each phone type. This model is also called the individual choice model or discrete choice model. Especially, the disaggregate logit model is used in a general sense. Otherwise, the probit model exists.

In this paper, the table-type function is used. The reason is explained in Section 4 (3).

(d) Telecommunication traffic route assignment model

The telecommunication traffic route assignment model is related to the trip route assignment model. This model is to explain and forecast how interregional information flows by each telephone on telecommunication network. In the case of telecommunication, it needs to be divided this process into two-step process that consists of choice of a telecommunication company and that of a route from origin to destination on the telecommunication network.

In the first step, users' choice behavior of telecommunication company is explained by Jitsuzumi, Ota and Ohishi (1997)[31], members of IPTP, using questionnaire data from households. For the second step, the route assignment of telecommunication traffic to telecommunication equipments and networks inside each tele-communication company needs to be explained. In this second step, traffic route assignment on telecommunication network inside telephone companies is managed by their own companies in technologies such as dynamic routing. Because of this, we think this part is generally not important. However, the better telecommunication traffic assignment will reflect on lower unit price of telecommunication. At the same time, in the future, efficiency of telecommunication network to satisfy steady increase of information flow is needed. Consequently, it is important for social scientists to discuss whether we examine traffic route allocation. In travel demand analysis, this telecommunication traffic route assignment is the final stage of a four-step estimation, and is recognized as the most important stage. That is because construction and improvement of roads in urban and regional planning is one of the most important infrastructure projects.

4. ESTIMATION OF TELECOMMUNICATION DEMAND ANALYSIS MODEL

This telecommunication demand analysis model is estimated using the 1995 telephonic communication traffic data (ordinary phone, public phone, cellular phone and PHS) from telecommunication companies.

We have a reason that we use this data. In 1995, most telephones including mobile phones became available first. The zone to analyze these telephonic communication traffic data is set as a prefecture. That is because traffic data of ordinary phone and public phone are aggregated in the MA (Message Area), and that of cellular phone and PHS are aggregated in prefecture. Telephonic communication within these MAs uses the lowest unit price area in most cases. However, the area code does not always correspond to the MA.

(1) Telecommunication generation and attraction model

This paper proposes an analytical model to explain the effects of the spread of mobile phones on telecommunication traffic. The amounts of telecommunication generation and attraction per person of each prefecture are written as:

$$\frac{O_i}{P_i}=\alpha_o+\beta_o Ordinary_i+\gamma_o Public_i+\delta_o Cellular_i+\varepsilon_o+PHS_i \quad (1)$$

and

$$\frac{D_j}{P_j}=\alpha_D+\beta_D Ordinary_j+\gamma_D Public_j+\delta_D Cellular_j+\varepsilon_D+PHS_j \quad (2)$$

O_i and D_j are the amount of information generation and attraction in the region i and j. P_i and P_j are populations in the region i and j. $Ordinary_i$ and $Ordinary_j$ are the subscriber's numbers of ordinary phones per person in the region i and j. $Public_i$ and $Public_j$ are the numbers of public phones per person in the region i and j. $Cellular_i$ and $Cellular_j$ are the subscriber's numbers of cellular phones per person in the region i and j. PHS_i and PHS_j are the subscriber's number of PHS phones per person in the region i and j. α_o, β_o, γ_o, ε_o, α_D, β_D, γ_D and ε_D are parameters.

When it becomes possible to use time series data on the number of phones after this year, we can estimate the time-series analysis model for explaining changes of subscriber's number of cellular phone and PHS every year. Here, demand on each telephone in the future will be forecasted. At the same time, the amounts of telecommunication generation and attraction (the amounts of telecommunication sent and received) can be explained.

Furthermore, trends on change of the number of cellular phone and PHS per person, which means the degrees of diffusion of these mobile phones. And they are explained by the cost indices of cellular phone and PHS (subscriber's charge, telecommunication fee and so on) or the others (the covering rate of service area and so on)[4], an additional demand analysis model to link with telecommunication demand analysis model can be estimated.

4 These functions are written as follows:
$Cellular_i = f\,(P_{Cellular}, SL_{Cellular})$ and ,
$PHS_i=g\,(P_{PHS}, SL_{PHS_i})$,
where $P_{Cellular}$ and P_{PHS} are the cost indices of cellular and PHS phones such as subscriber charge and communication cost.
And $SL_{Cellular_i}$ and SL_{PHS_i} are degrees of the service level of cellular and PHS phones. The rate of living area to the total area of prefecture excludes mountains and forests. The total amount of telecommunication traffic including cellular and PHS phones is surveyed in 1995 for the first time. The successive empirical research on telecommunication traffic including cellular phone and PHS is needed to explain the wider diffusion of cellular and PHS phones.

Table 3 : Estimation of telecommunication generation model

Parameters	Partial regression coefficients	t-value	Significance
α_O	-5.6813	-3.06	at 1% level
β_O	66.615	13.57	at 1% level
γ_O	-	-	
δ_O	76.556	8.65	at 1% level
ε_O	96.210	3.19	at 1% level
Multiple correlation coefficient adjusted for the degrees of freedom		0.9496	

Table 4 : Estimation of telecommunication attraction model

Parameters	Partial regression coefficients	t -value	Significance
α_D	-7.0288	-4.03	at 1% level
β_D	70.222	15.22	at 1% level
γ_D	-	-	
δ_D	70.719	8.50	at 1% level
ε_D	103.62	3.66	at 1% level
Multiple correlation coefficient adjusted for the degrees of freedom		0.9567	

In Tables 3 and 4, the telecommunication generation and attraction models were estimated using socioeconomic indices and the total amount of telecommunication generation and attraction from/to each prefecture by all phones (ordinary phone, public phone, cellular phone and PHS) in 1995. It can be shown by these models presented that there was no correlation between the total amounts of telecommunication generation and attraction and the number of public phone. The increase or decrease of public phone does not influence these amounts because it is easy to find public phone in any places of Japan in 1995.

Furthermore, the order of effects of increase in each phone on the amounts of telecommunication generation and attraction is PHS > cellular phone > ordinary phone, as shown in Figure 3.

(2) Telecommunication distribution model

Next, the telecommunication distribution model is presented. Here, the doubly constrained gravity model (origin and destination constrained gravity model)[5] is adapted. The amounts of telecommunication generation and attraction are given.

$$T^{ij} = \frac{A_i B_j O_i D_j}{d_{ij}^{a}} \tag{3}$$

T_{ij} is the total time of telephonic communication

5 In this following model type, telecommunication cost d_{2ij} between region i, j is examined, but this model type could not satisfy the condition of sign b, or $b > 0$.

$$T^{ij} = \frac{A_i B_j O_i D_j}{a_{1ij}^{a} b_{2ij}^{b}}$$

This is because the differences of telecommunication unit prices among regions are smaller.

When this cost distance d_{2ij} needs to be considered, the odds method considers the modified coefficient of distance k using the following liner function.

$$In\left(\frac{T_{ij} T_{ji}}{T_{ii} T_{jj}}\right) = c_1 + c_2\, In\left(\frac{l_{1ii} l_{1jj}}{d_{1ij} d_{1ji}}\right) + c_3\, In\left(\frac{d_{2ii} d_{2jj}}{d_{2ij} d_{2ji}}\right)$$

From three coefficients, c_1 $(=2a\ in\ k)$, c_2 $(=a)$ and c_3 $(=b)$, including k, a and b can be calculated.

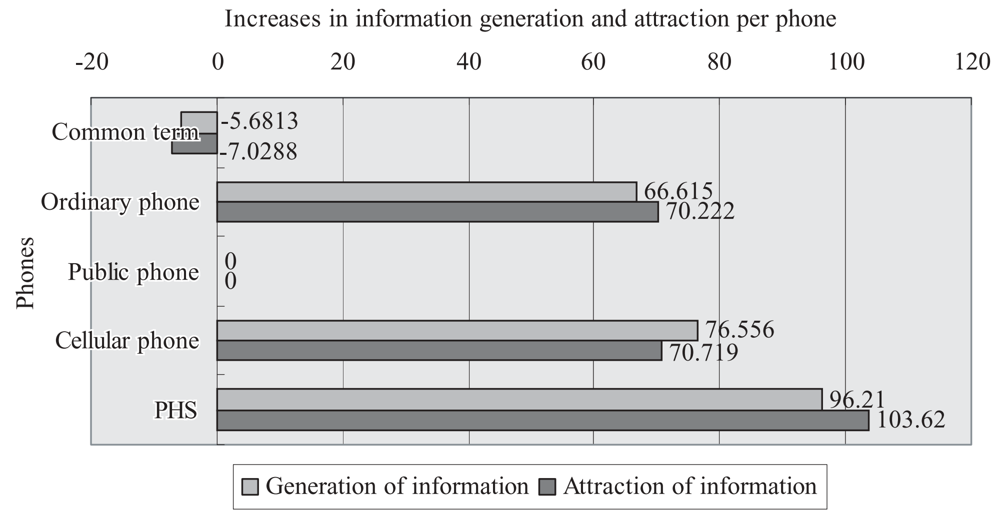

Figure 3 : The effects of increase in phone usage on information generation and attraction

Note : These values are derived from the model estimation of parameters of the telecommunication generation and attraction model in Tables 3 and 4. In the case of ordinary phone, the number of subscriber is not always the same as the number of phones.

from the region i to j (thousand hours), A_i and B_j are balancing factors[6] in the region i and j. d_{ij} is distance[7] between the region i and j. a is a parameter of distance.

And the total amounts of telecommunication generation and attraction need to satisfy the following equations.

$$\sum_{j=1}^{n} T_{ij}=O_i \quad (4)$$

$$\sum_{i=1}^{n} T_{ij}=D_j \quad (5)$$

6 The spatial patterns of balancing factors A_i and B_i mean the inaccessibility of each sent region to each received region and that of each received region to each sent regions. $A_i O_i$ and $B_j D_j$ mean the relative degree of telecommunication generation from each region（degree of importance of each region as to the sent region）and the relative degree of telecommunication attraction to each region（degree of importance of each region as the received region）.(See Thomas (1977)[32] for commuter data , Griffith and Jones (1980)[33] and Ishikawa (1988)[34] p.80）

7 "distance between prefectures" is distance between MA (Message Area) including the prefectural capital.

The doubly-constrained model consists of Equations (3) - (5). In order to estimate Equation (3), the balancing factors andneed to be calculated.

From Equations (3) - (5), andare written[8] as

$$A_i=\frac{1}{\sum_{i=1}^{n}\frac{B_j D_j}{d_{ij}^{a}}} \quad (6) \quad \text{and} \quad B_j=\frac{1}{\sum_{i=1}^{n}\frac{A_j O_j}{d_{ij}^{a}}} \quad (7).$$

Given initial values to these balancing factors andin these Equations (6) and (7), these balancing factors are calculated with iteration process.

Furthermore, the intra-regional distance[9] is discussed. Generally, in spatial interaction model, a way to decide intra-distance should be considered.

8 If unit price of telephonic communication between region is considered, balancing factors are written as

$$A_i=\frac{1}{\sum_{i=1}^{n}\frac{B_j D_j}{d_{1ij}^{a} d_{2ij}^{b}}} \quad \text{and} \quad B_j=\frac{1}{\sum_{i=1}^{n}\frac{A_i O_i}{d_{1ij}^{a} d_{2ij}^{b}}}$$

9 There are several ways to decide intra-regional distance (Takeuchi, Honda and Aoshima (1988)[6]). The personal trip survey in Great Hiroshima considers the radius of each zone as the radius of the circle equivalent to the housing area.

In this study, a new method to specify intra-regional distance is developed. This intra-regional distance is decided, according to patterns of intra- and inter-regional telecommunication traffic.

First of all, assumed that shape of each region is circle, the regional radius l_{ii} (initial intra-regional distance) is calculated by the area of each region. And then, a modified coefficient is introduced to calculate the intra-regional distance.

The intra-regional distance is written as

$$d_{ii} = k \cdot l_{ii} = k \cdot \sqrt{\frac{S_i}{\pi}} \quad (8),$$

where is the modified coefficient of intra-regional distance. l_{ii} is radius of circle equal to the area of region *i*. S_i is the area of region *i*.

Furthermore, the calibration process of the model is explained. Here, Sen and Scott (1981)[35] has a merit that, in calculation of balancing factors, not considering the term of distance, a simplified liner function is estimated by intra- and inter- regional distances and telecommunication flow data, and a distance parameter. This is called the odds method, where the terms of $A_i O_i$ and $B_j D_j$ are reduced. (See Ishikawa (1988)[34] p.54). In this paper, considering the modified coefficient k, logarithm of the ratio of odds

$(\frac{T_{ij} T_{ji}}{T_{ii} T_{jj}})$ is written as

$$In \left(\frac{T_{ij} T_{ji}}{T_{ii} T_{jj}}\right) = c_1 + c_2 \text{ In } \left(\frac{l_{ii} l_{jj}}{d_{ij} d_{ji}}\right) \quad (9),$$

where $c_1 = 2a \; In \; k$ and $c_2 = a$. After estimating Equation (9), the distance parameter and the modified coefficient the modified coefficient of intra-regional distance can k be get. This is the odds method considering the modified intra-regional distance.

Finally, from inter-regional telecommunication traffic data and the initial intra-regional distance (the regional radius calculated by the area of each region), Equation (9) is estimated. And then, from coefficients $c_1 (=2a \; In \; k)$ and $c_2 (=a)$, which are estimated by $In \left(\frac{T_{ij} T_{ji}}{T_{ii} T_{jj}}\right)$ and $In \left(\frac{l_{ii} l_{jj}}{d_{ij} d_{ji}}\right)$ in Equation(9), k and a are calculated. The result of coefficients estimation is shown in Table 5. Finally and are determined.

$a = 1.1684$ and $k = 0.03912$ are determined.

As a result, the telecommunication distribution model is written as

$$T^{ij} = \frac{A_i B_j O_i D_j}{d_{ij}^{1.1684}} \quad (10).$$

The balancing factors A_i and B_j are displayed in Table 6. The spatial patterns of these balancing factors are shown in Figure 4.

First of all, the accessibility of each sent region to received regions (for instance, small value of balancing factor A_i) results as follows. In Japan, Kanagawa (rank 3) , Saitama (rank 4) and Chiba (rank 6) surrounding Metropolitan area Tokyo (1st) , Aichi (rank5) , the central prefecture of Chukyo District, and Osaka (rank 2), the central prefecture of Kansai District are large[10]. On the other hand, Iwate (rank 44) and Akita (rank 43) in Tohoku district, Tottori (rank 46) and Shimane (rank 47) in Sanin district, Miyazaki and Kochi (rank 45) are low level prefectures[11] of accessibility to received regions.

Next, the accessibility of each received region to sent regions, low level of balancing factor B_j, is explained. Tokyo (rank 1), Kanagawa (rank 3), Saitama (rank 4) and Chiba (rank 6) in the metropolitan area of Japan, Osaka (rank 2) in Kansai district, Aichi (rank 5) in Chubu district, are the higher prefectures[12] of accessibility of each prefecture to the sent regions.

10 Less than 0.003
11 More than 0.007
12 Less than 0.003

Table 5 : Result of coefficients estimation

	Coefficients	t-value	Significance
$c_1(=2a\,In\,k)$	-7.2396	-40.88	at 1% level
$c_2(=a)$	1.1684	29.77	at 1% level
Multiple correlation coefficient adjusted for the degrees of freedom	0.4505		

Table 6 : The values of $\boldsymbol{A}_i$ and $\boldsymbol{B}_j$

Prefectures	A_i	B_j	Prefectures	A_i	B_j
Hokkaido	0.0061957	0.0071035	Shiga	0.0055419	0.0049033
Aomori	0.0070174	0.0086205	Kyoto	0.0037876	0.0035006
Iwate	0.0084536	0.0094920	Osaka	0.0014831	0.0014239
Miyagi	0.0048528	0.0051728	Hyogo	0.0037936	0.0032414
Akita	0.0083188	0.0092571	Nara	0.0052336	0.0046049
Yamagata	0.0078075	0.0082488	Wakayama	0.0065404	0.0059734
Fukushima	0.0067151	0.0069270	Tottori	0.0086426	0.0079485
Ibaragi	0.0046359	0.0042833	Shimane	0.0093964	0.0092798
Tochigi	0.0055305	0.0052641	Okayama	0.0055700	0.0050836
Gunma	0.0053029	0.0052251	Hiroshima	0.0046405	0.0045114
Saitama	0.0024753	0.0024479	Yamaguchi	0.0062459	0.0059379
Chiba	0.0029596	0.0027842	Tokushima	0.0073192	0.0068879
Tokyo	0.0010569	0.0013727	Kagawa	0.0051470	0.0047545
Kanagawa	0.0019122	0.0017328	Ehime	0.0059053	0.0058139
Niigata	0.0062042	0.0065027	Kochi	0.0085614	0.0083575
Toyama	0.0068385	0.0063032	Fukuoka	0.0030166	0.0030133
Ishikawa	0.0061150	0.0059419	Saga	0.0067143	0.0069013
Fukui	0.0075251	0.0070776	Nagasaki	0.0052639	0.0059736
Yamanashi	0.0069190	0.0066699	Kumamoto	0.0058966	0.0061508
Nagano	0.0064916	0.0063075	Oita	0.0066684	0.0067805
Gifu	0.0061509	0.0055970	Miyazaki	0.0071351	0.0080822
Shizuoka	0.0043660	0.0039130	Kagoshima	0.0057092	0.0074984
Aichi	0.0026869	0.0024517	Okinawa	0.0045412	0.0068956
Mie	0.0056617	0.0049234	Geometric mean	0.0051976	0.0051976

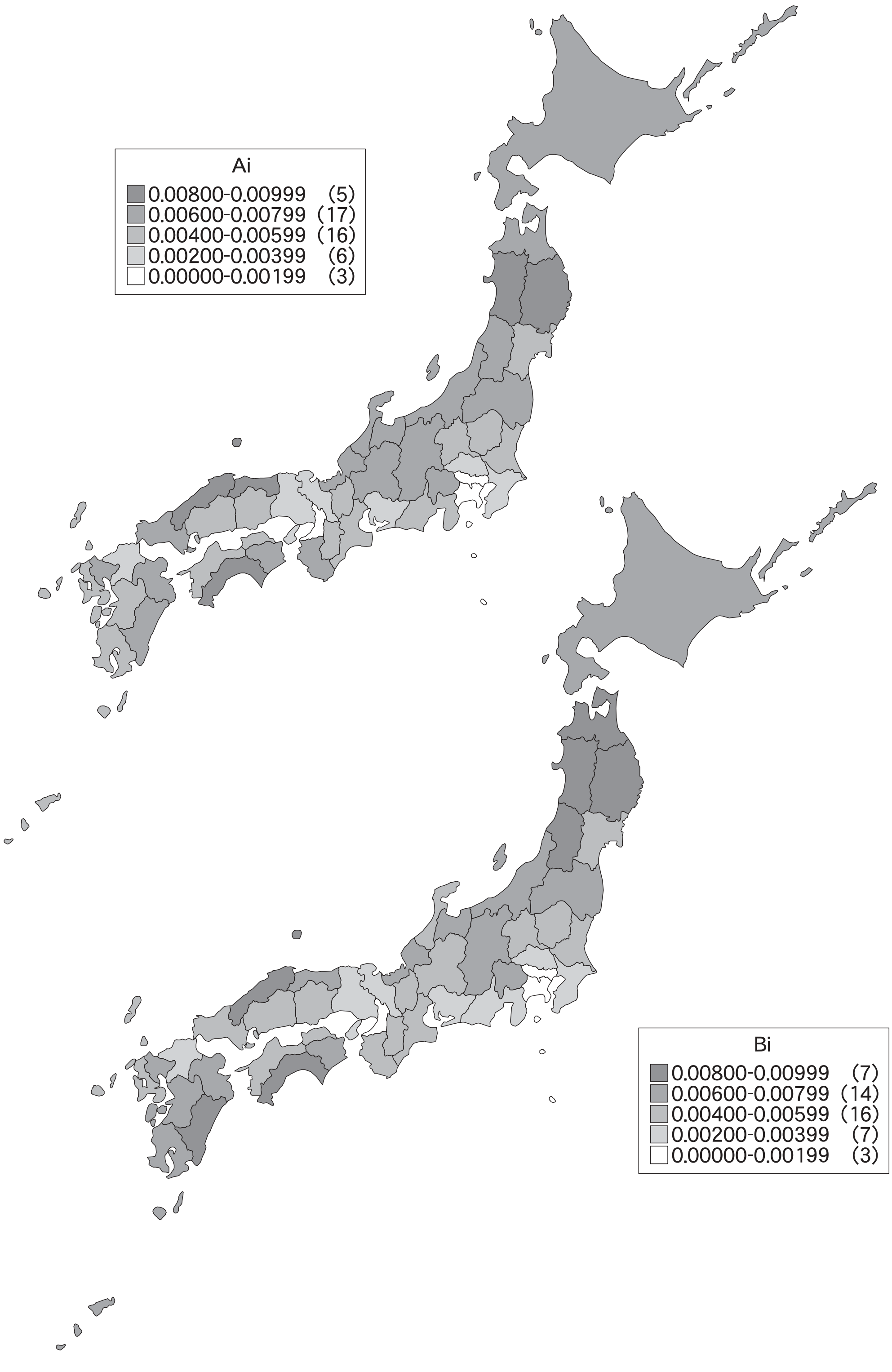

Figure 4 : Spatial distribution of A_i and B_j (47 prefectures in Japan)

On the other hand, Iwate (rank 47), Akita (rank 45), Akita (rank 45), Yamagata(rank 43) in Tohoku district, Shimane (rank 46) in Sanin district, Kochi (rank 44) and Miyazaki (rank 42) in Shikoku and Kyusyu districts are the lower prefectures[13]on the accessibility of each prefecture to the sent regions.

Moreover, the real intra-regional distance is

$$d_{ii} = 0.03912 \cdot l_{ii} = 0.03912 \cdot \sqrt{\frac{S_i}{\pi}}.$$

The real intra-regional distance is about 4 percent[14] of initial intra-regional distance. This means that the average distance of telecommunications within prefectures is much shorter. It is because we call persons near us in most cases.

Furthermore, because distance parameter is near 1, the amounts of telephonic communication between regions are an inverse proportion to the distance between regions.

(3) Telecommunication Media Interchange Model

In this subsection, telecommunication media interchange model using table-type function method is presented, as show in Figure 5. The merit of this method is to be able to check the movements of telecommunication media interchange in direct.

First, the table-type function method is explained. The table-type function is to indicate relationships between the rates of telecommunication media interchange[15] and the factors to decide them such as the rate of diffusion of mobile phone and distance. Using this method, the amounts of interregional telecommunication traffic by phones (ordinary phone, public phone, cellular phone and PHS) can be presented.

The process of telecommunication media interchange consists of three steps: media interchange 1 (indoors-type vs. outdoors-type), media interchange 2 (fixed-type vs. mobile-type) and media interchange 3 (cellular phone vs. PHS). The table-type function in Tables 7- 9 and Figures 5-7 is explained as follows.

(a) Media interchange 1 (indoors-type vs. outdoors-type)

When we want to make telephonic communication, we need to select indoor-type phone such as ordinary phone or outdoor-type phone such as public phone, cellular phone and PHS.

The way to use table-type function such as Table 7 is explained thus. As more business activities and leisure activities are activated, we spend more time outdoors. At the same time, when more settings of public phone are fully provided and when more purchases of cellular phone or PHS becomes wider,

13 More than 0.007

14 This model has the same modified coefficient in all prefectures. Actually, the modified intra-distance of each prefecture depends on the concentration of intra-telecommunication inside each prefecture. In particular, prefectures, which include large areas of daily life activity, will tend to have large coefficients, and some correction for this becomes necessary. This model has the same modified coefficient of intra-regional distance in all prefectures. Actually, the modified intra-distance of each prefecture depends on the scale of the intra-telecommunication traffic inside each prefecture. This modified intra-regional distance is larger in specific prefectures with a wider range of activities. This problem needs to be addressed further.

15 The rate of telecommunication media interchange needs to be tested for fitness in the cross table between distance and the rate of subscriber's number of each phone (the number of public phone). The merit of using this cross table, or using table-type function method, is to be able to understand the trends of the rate of telecommunication media interchange directly. Finally, after estimating the logistic curve in the rate of telecommunication media interchange to distance and each rate of subscriber's number of each phone, we can obtain the logistic curves of each phone. It is necessary to check the fitness of these curves. However, there were no clear changes in the curve to explain the rate of modal split in the field of transportation research.

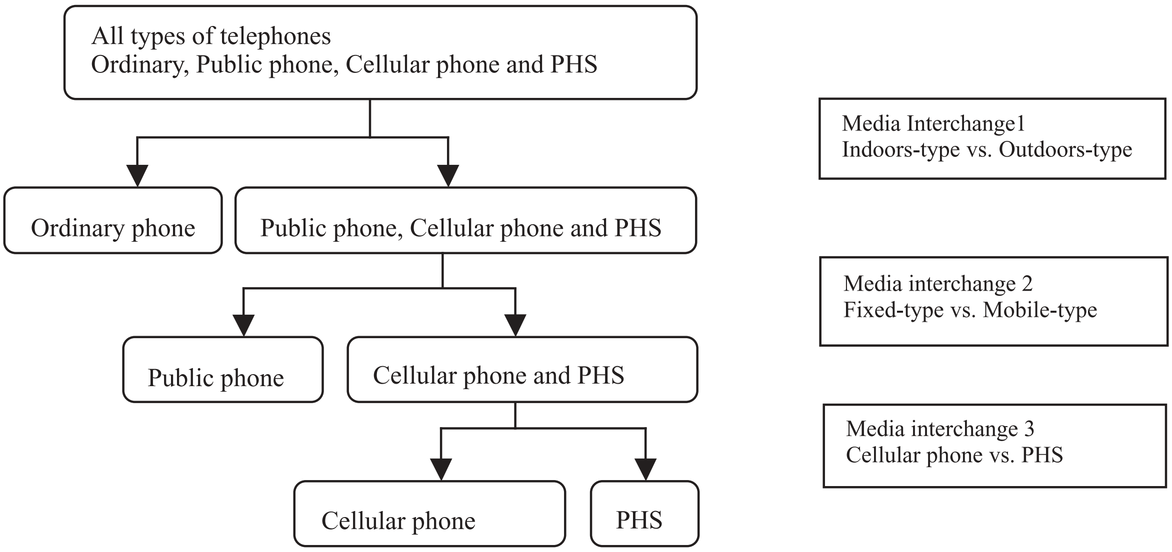

Figure 5：Telecommunication media interchange

the rate of subscriber's number of ordinary phone to all phones becomes lower. (See values in Table 7 from bottom to top) This rate depends on each region. According to telecommunication distance and the rate of subscriber's number of ordinary phone in each region, the interchange rate of indoor-type media (ordinary phone) and outdoor-type media (public phone, cellular phone, PHS) changes. (See values in Table7 from left to right.). In this way, using this table-type function, the rate of ordinary phone interchange depending on telecommunication distance and the rate of subscriber's number of ordinary phone in each region can be determined.

The characteristics of this telecommunication traffic data are explained in Table 7 and Figure 6.

The probability of ordinary phone interchange is over 90 percent. And for local and long distance calls, as decrease in the rate of subscriber's number of subscriber phone, the rate of total communication time by outdoors-type phone increase, or that by subscriber phone decrease. In middle distance call, there are no clear between these. And if distance is longer, the rate of use of ordinary phone is higher generally. Though the general tendency can be observed in Table 7 (1), the table-type function brought about results exactly the opposite of what we had expected.

This tendency means the changes of feelings about indoors-type (ordinary phone) and outdoors-type (public phone, cellular phone and PHS)

(b) Media interchange 2 (fixed-type vs. mobile-type)

When we want to make telephonic communication in the outdoors, we need to select a fixed-type phone such as public phone or a mobile-type phone such as cellular phone and PHS. The table-type function in Table 8 and Figure 7 is explained thus

When we have telecommunications with anyone outdoors, it is easier to use a mobile-type phone such as cellular phone and PHS than fixed-type phone such as public phone. As a result, if the number of purchases of mobile-type phone such as cellular phone and PHS are more than that of settings of public phone, the rate of the number of public phone to the number of outdoor-type phones will become lower. (See values in Table 8 from bottom to top)This rate of number of public phone depends on regions. According to telecommunication distance and the rate of number of public phone in each region, the interchange rate of fixed-type media

Table 7 : Telecommunication media interchange model (Table-type function 1)

Media interchange 1: indoor-type (ordinary phone) vs. outdoor-type (public, cellular and PHS phones)

Distance / The rate of subscriber's number of ordinary phone	Within the prefecture	- 100km	-200km	-300km	-400km	-500km	More than 500km
0.76-0.80	0.902	0.893	0.922	0.929	0.928	0.934	0.920
0.80-0.84	0.915	0.907	0.922	0.933	0.933	0.938	0.922
0.84-0.88	0.922	0.918	0.922	0.935	0.937	0.933	0.929
0.88-0.92	0.932	0.917	0.914	0.929	0.914	0.941	0.929

Note : The table-type function uses the average rate of total communication time by indoors-type phones (ordinary phone) to that of all-phone types in 1995.

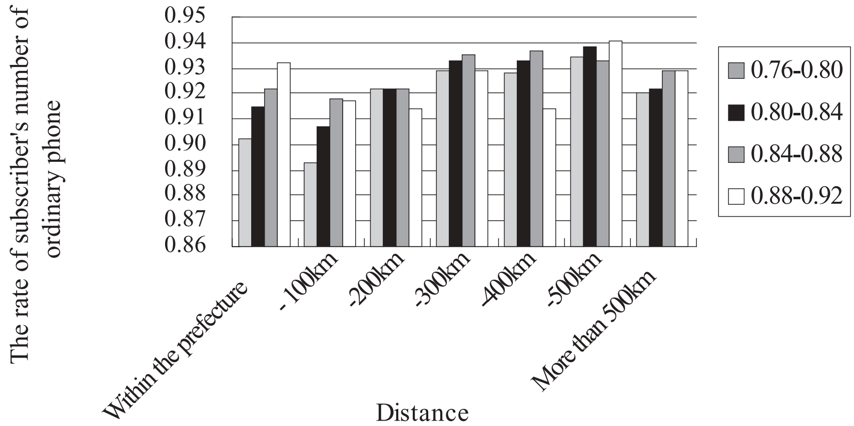

Figure 6 : The rate of total communication time by indoor-type phones (ordinary phone) to that of all -phone types

(public phone) and mobile-type media (cellular phone and PHS) changes. (Check values in Table 8 from left to right.). In this way, using the table-type function, the interchange rate of public phone can be got. We can call anyone outdoors by cellular phone or PHS easily without looking for public phone, if we have cellular phone or PHS. And also we can use these phones as private phone. Because of this, the increase of mobile-type phone leads to the decrease of public phone.

Next, the interchange rate of public phone is shown in Table 8. When we go out, the rate of use of public phone is approximately between 0.6 and 0.7. But in some regions, where the rate of number of public phone is higher, the rate of telephonic communication by public phone inside each prefecture is around 0.75.

There are not clear differences between public phone and mobile-type phone depending on telecommunication distance. Telecommunication price of mobile-type phone is generally higher than that of public phone. And regardless of this reason, users of mobile-type phones do not like frequent use of public phones.

(c) Media Interchange 3 (cellular phone vs. PHS)

Finally, when we use mobile-type phone, we need to select cellular or PHS phone. The table-type function in Table 9 and Figure 8 is used to explain this choice behavior as follows.

Judging from accessibility, cellular phone is better than PHS. But telecommunication price of cellular

Table 8 : Telecommunication media interchange model (Table-type function 2)

***Media interchange 2: Fixed-type (public phone) vs. Mobile-type (cellular phone and PHS)**

Distance / The rate of number of public phone	Within the prefecture	- 100km	-200km	-300km	-400km	-500km	More than 500km
0.04-0.08	0.615	0.578	0.582	0.612	0.626	0.583	0.685
0.08-0.12	0.691	0.567	0.640	0.645	0.683	0.645	0.705
0.12-0.16	0.757	0.642	0.630	0.684	0.653	0.706	0.685

Note : The table-type function uses the average rate of total communication time by fixed-type phones (public phone) to that of outdoor-phone types in 1995.

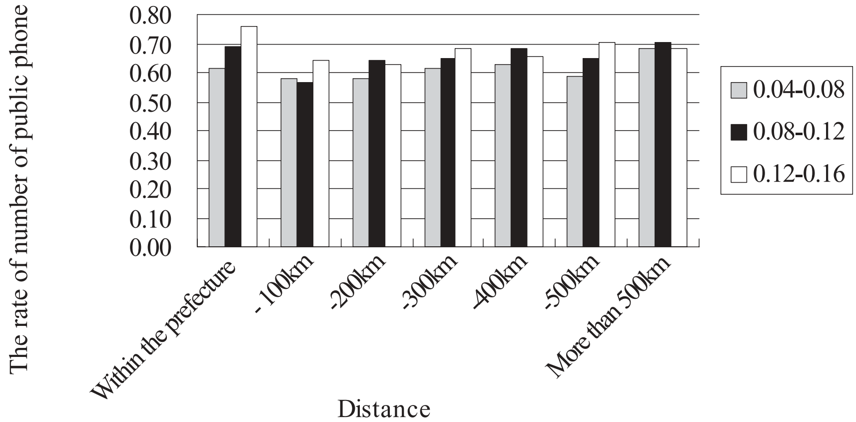

Figure 7 : The rate of total communication time by fixed-type phone (public phone) to that by outdoor-type phones (public phone, cellular phone and PHS)

phone is higher than that of PHS. If the difference of telecommunication price between these phones becomes lower, cellular phones will show a rapid increase in the share of cellular phone. The rate of subscriber's number of cellular phone to mobile-type phone will become higher. (See values in Table 9 from top to bottom)

This rate of subscriber's number of cellular phone to mobile-type phone depends on regional characteristics. The interchange rate of cellular phone is decided by this rate of subscriber's number of cellular phone and telecommunication distance. (See values in Table 9 from left to right.) In this way, the table-type function gives us the media interchange rate.

Next, characteristics of this table-type function are explained thus. As is shown in Table 9, the rate of media interchange between cellular and PHS phones does not change depending on telecommunication distance. This is because most persons do not use both a cellular phone and a PHS phone. The user of cellular phone generally tends to have longer communication times than that of PHS users.

5. CONCLUSION

In this paper, a model for explaining telecommunication demand was constructed, applying 4-step estimation process of travel demand analysis model to telecommunication. As a case study, demand on telephonic communication was estimated. Finally, we can come to the following

Table 9 : Telecommunication media interchange model (Table-type function 2)

***Media interchange 3 : cellular phone vs. PHS**

Distance / The rate of subscriber's number of cellular phone	Within the prefecture	- 100km	-200km	-300km	-400km	-500km	More than 500km
-0.80	0.915	0.965	0.954	0.957	0.957	0.966	0.956
0.80-0.90	0.944	0.957	0.976	0.966	0.958	0.962	0.947
0.90-1.00	0.987	0.992	0.992	0.989	0.989	0.985	0.988

Note: The table-type function uses the average rate of total communication time by cellular phone to that of mobile-phone types in 1995.

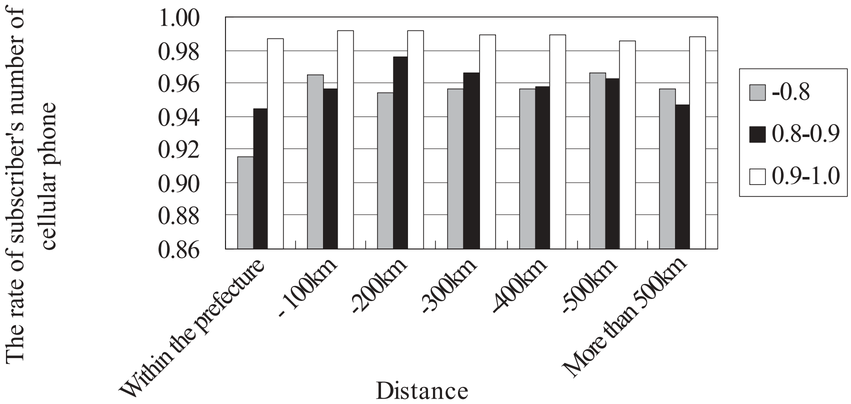

Figure 8 : The rate of total communication time by cellular phone to that by mobile-type phones

conclusions:

(1) The amounts of telecommunication generation from each prefecture and attraction to each prefecture were explained by the degree of diffusion of phones and population in each prefecture. Especially the diffusion of mobile phone gives great influence to these amounts of telecommunication generation from each prefecture and attraction to each prefecture.

(2) Considering the modified coefficient of intra-distance, the new calibration process for estimating parameters of doubly constrained gravity model was developed.

(3) After the estimation of telecommunication demand analysis model, it was presented that the telecommunication time was in inverse proportion to the telecommunication distance.

(4) Telecommunication media interchange was explained by the rate of subscriber's number of each phone (in the case of public phone, the rate of number of public phone) and telecommunication distance.

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Takita (1997)[4] has proposed the novel concept of information demand analysis with transportation and telecommunication at the 46th North American Meetings of Regional Science Association (Takita (1999)[2]), the Seminar in the Center for Transportation in Massachusetts Institute of Technology (Takita (1999)[36]), and this paper focuses on telecommunication demand analysis including ordinary, public, PHS and cellular phones.

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加入電話，移動型電話，公衆電話による通信需要分析モデル

— 移動型電話は，加入電話と公衆電話の代替手段であるのか？ —

田北　俊昭[1]・宮田　拓司[2]・高谷　　徹[3]

この論文の目的は，これまでの加入電話や公衆電話だけでなく，PHSや携帯電話といった移動型電話による地域間の通信需要を説明するための新しい統合モデルを開発することである。ケーススタディでは，日本における通信需要のトラフィックデータが使用される。この論文の特色は，従来の交通需要分析と同じフレームワークに基づいて地域間の通話需要を説明することにある。この分析では，空間な要素である「情報流動」の起終点を考慮することなく需要または供給曲線を推定する従来の通信経済モデルとは異なったやり方を用いている。

Keywords：情報，通信，移動型電話，公衆電話，需要分析