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A Fundamental Study on Evaluation of Public Transport Transfer Nodes by Data Envelop Analysis Approach Using Smart Card Data

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Abstract

This research proposes a method of evaluating transfer nodes based on smart card data with the objective of making a contribution to public transportation restructuring in regional cities. The study seeks to better comprehend the use of public transportation systems (trams and buses) in central Kochi City in Japan based on the transportation mode transfers recorded on user Smart Cards. Specifically, this study seeks to use the Data Envelop Analysis (DEA) model, which allows us to reference multiple indices, in order to evaluate the efficiency of user transfers between transportation systems while also considering transfer times and user age groups. The study results show that efficiency varied according to the time of day and user age groups, even at the same transfer nodes, and identified the need for more thorough understanding of the properties of each transfer point based on the efficiency values of multiple indices.

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Keywords: smart card data; data envelop analysis; evaluation of public transport taransfer

1. Introduction

Numerous existing bus routes have been expanded based on the idea of ensuring the first and last stations cover central urban district areas where the movements of large numbers of people are concentrated. As a result, these

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routes are often very complex and present difficulties in terms of ease of use[Hayashi, 2003]. In an earlier study, Takase [2007] et al. interviewed bus operators in 30 cities, excluding the three major metropolitan regions, regarding their bus routes. Their study results showed that excess services were being provided in certain central urban areas where the routes provided by 60% of all public transportation operators were found to be overlapped. Kochi City in Kochi Prefecture, Japan offers a concrete example of this problem. This city is currently implementing the development of the Kochi City Regional Transport Restructuring Plan [2010], which seeks to build a sustainable system that invigorates public transportation over the entire city, including tram and bus services. The initiative also seeks to provide future indices for public transportation by establishing transfer node that ensure user convenience when transferring between different public transportation systems. However, while the nature of transfers performed when utilizing public transportation has previously been examined via user surveys, no studies have yet been conducted aimed at under-standing how user transfers between systems, which fluctuate by the minute at various transfer nodes scattered over a wide range of areas, are actually made.

Some recent studies that seek to analyze how users make transfers have focused on integrated circuit (IC) card data because such cards have come to be used widely across the country, and around the world, as a fare payment method. For example, Seaborn [2009] et al. conducted an analysis to determine how users choose from among the various public transportation services available by considering how they make their transfers between services. To this end, they established a threshold value for the time required to make transfers among subways and buses using the data recorded on “Oyster Cards”, which are Smart Cards used in London's subways and buses. In an earlier study aimed at facilitating the restructuring of public transportation systems in regional cities and improve efficiency, the authors [Nishiuchi et al, 2011] also sought to improve their understanding of how users make transfers by analyzing the data recorded on public transportation Smart Cards. Specifically, authors referenced the use of public transportation systems recorded on “DESUCA” Smart Cards, which are commonly used for tram and bus payments in Kochi Prefecture. Their objective was to gain a clearer understanding of the time required to make transfers from one public transportation system to another. In that study, they analyzed the number of users making transfers, the types of cards used to make the transfers (and their composition ratios), as well as the time required to switch from one type of public transportation mode to another.

However, to evaluate the actual convenience of transferring between public transportation types, we must more thoroughly examine its multiple aspects, including the nodes at which, and the extent to which, the services are offered, as well as how much time the users must expend to make transfers. Moreover, by using the data recorded on Smart Cards, from which we can retrieve information continuously, we can determine how transfers are made in a manner that considers multiple factors. This will allow us to make a positive contribution to the formulation of public transportation routes and transportation system operation plans that respond to user needs, and which are based on consistently large records of actual public transportation usage. Such improvements are possible, even in Japan's regional cities, many of which are dealing with the affects of aging populations.

Accordingly, this study seeks to acquire basic knowledge necessary to evaluate transfer nodes. Specifically, we will focus on the transfers made by users as, which was defined in our previous research [Nishiuchi et al, 2011], and then seek to determine the amount of time spent by various numbers of users when making transfers, what differences exist in the ways they make transfers at nodes, and which each age group make transfers most frequently.

To this end, the paper will propose an index that can be used to evaluate user transfers based on the data envelopment analysis (DEA) model, which allows us to perform a composite analysis of the public transportation system operations along with an analysis of information related to user age groups and the time of use, which can be retrieved from their Smart Cards. The ultimate goal is to evaluate and more thoroughly understand Kochi City area transfer nodes by focusing on time zones and age groups.

2. Study Subjects

2.1. DESUCA Smart Card

DESUCA is an Smart Card that became available on January 25, 2009 and can be used for trams and buses in Kochi Prefecture. It is accepted by the Tosa Electric Railway Co., Ltd., Tosaden Dream Service K.K., Kochikenkotsu, Inc. rail services, and the buses operated wide area in Kochi Prefecture such as Kenkohokubukotsu

Co., Ltd., and Kochikenkotsu Inc. between Susaki, Suginokawa, and Yusuhara (Refer to Fig. 1). These cards can be issued anonymously, with personalized data recorded so that they can be returned if lost, or issued in the form of commuter passes. Moreover, five card types are issued, including a card for children up to elementary school age and "Nice Age" cards for users 65 years old and over. Cards are available for adults include personalized and unpersonalized types, as well as a special card for the handicapped users.

The data used in this study was acquired from DESUCA records collected over 29 days from June 1, to June 20, 2010 (the data from June 4 is missing). During the 29 days examined, there were 21 weekdays and eight weekend days (Saturdays and Sundays). Table 1 shows a summary of the data used in the analysis. There were 31,788 people that used Smart Cards over the 29 days of the study period. Figure 1 shows the distribution of stations where DESUCA Smart Cards can be used.

2.2. Definition of transfer trips

This study considers the usage records that satisfy the following requirements (transfer nodes and time required to make transfers) as transfer trips. These requirements are consistent with those used in our previous research [Nishiuchi et al, 2011].

Definition of transfer nodes

Based on the user data obtained in this study, there were 1,312 stations where DESUCA cards can be used. However, only a limited number of stations were used for transfers if we focus on stations where passengers possible to transfer. Therefore, in this study, only those stations that meet the following criteria were examined:

(1) The route is crossed
(2) The routes are separate
(3) The station is the origin or the destination of the route(s)
(4) Both trams and buses run on the route

Definition of time required to make transfers

Among public transportation users, there are those who immediately make transfers after getting off the vehicle and those who go shopping or other activities as part of the transfer process. Accordingly, the time required to make transfers varies and it is impossible to make simple judgments as to the amount of time required to make transfers simply by using the data recorded on smart cards. Moreover, since no previous research or findings exist that define the maximum time required to make transfers, in this research, we decided to define transfer trips as changes between two separate transportation types that were made at stations that function as transfer nodes (as explained in the previous section) within one hour or less.

Fig 1: The distribution of stations at which DESUCA can be used

Table 1: Summary of DESUCA data used in this study

Data Collection Term	1-30 June 2010 (4 June data not available)
Data Collection Hours	05:00 to 23:00
Collected Data Items	Date: Year, Month, Day Card ID: Provided for all DESUCA cards (always the same once given) Type of Card: With/Without Registration, Handicapped Passenger, Child Passenger, Elderly Passenger Bus/Tram Company: one tram and four bus companies Time (Boarding): Hour and Min when boarding bus/tram Time (Exiting): Hour and Min when exiting bus/tram
Bus/Tram Companies	Tram: Tosa Denki-Testudo Bus: Tosa Denki-Testudo Tosaden Service Kochi-ken Kotsu Kenko Hokubu Kotsu

3. Evaluation of Transfer Nodes by DEA Model

3.1. Concept of DEA Model

This study uses the DEA model to evaluate transfer nodes. This model is used to measure efficiency by looking at the process of converting input to output. To measure the efficiency of a Decision-Making Unit (DMU), the ratio scale of output/input is used. If multiple DMUs with the same output and input exist, it is then possible to make a comparison using the size of the ratio scale. Additionally, the DEA mod-el makes it possible to define multiple input and out-put items, change the items according to the objectives, and simultaneously consider items using different measurement units.

There are the two main DEA model types: the Charnes, Cooper & Rhodes (CCR) model and the Banker, Charnes, Cooper (BCC) model. Fig. 2 shows the production possibility sets of the CCR and BCC models. The CCR model assumes consistent returns to scale, while the BCC model does not make that assumption. The production possibility sets comprise a convex hill, which is a set of existing nodes, and input nodes that are bigger and output nodes that are smaller than the nodes in the set. The public transportation service elements studied in this research, such as the number of services and routes, vary according to user demand. Therefore, it is correct to assume that the returns to scale are inconsistent. Accordingly, this study conducted its analysis using the BCC model. Formula (1) shows the model formula of the BCC model [Charnes et al, 2007].

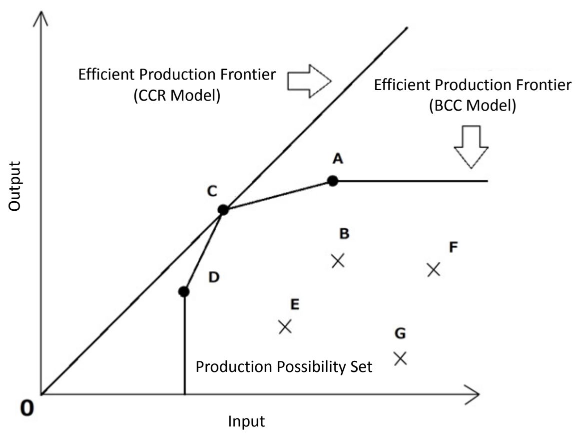

Fig 2: The CCR model and the BCC model production possibility set

$$\max . \quad \sum_{q=1}^{t} u_q y_{q0} + \delta \tag{1}$$

subject to

$$\sum_{i=1}^{t} u_{sj} y_{i0} = 1 \tag{2}$$

$$\sum_{s=1}^{t} u_s y_{sj} - \sum_{i=1}^{t} v_i x_{ij} + \delta \le 0 \tag{3}$$

$$u_s, v_i \ge \varepsilon$$

$$i = 1, \cdots, m \quad j = 1, \cdots, n \quad s = 1, \cdots, t$$

Here,

x_{ij}, y_{sj}: *Input and output number of each variable i and s of each DMUj*
u_s: Weight against output variable s
v_i: Weight against output variable i
n: Number of DMU_j (j=1, ..., n)
m, t: Number of input and output variables
ε: Non-Archimedes infinite decimals
σ: Dual variable against a new constraint $\sum_{j=1}^{n} \lambda_i = 1$
λ: Variable to connect the input and output variables of each DMU

The CCR and BCC models are efficient if large out-puts can be obtained from small inputs. The number calculated to express this efficiency is called a D-efficiency value. This D-efficiency value can be obtained between 0 and 1.0. When the value is closer to 1.0, the model is more efficient. Because the efficiency value is calculated based on the most efficient node (D-efficiency value of 1.0), we can determine how the numbers of nodes that do not reach the value of 1.0 differ from efficient nodes.

There have been a number of studies on transfer nodes using DEA. From the perspective of the level of service and the transfers made, Tomoto [2007] et al. used a DEA model to evaluate the efficiency of bus terminals and propose specific ways to restructure them, whilst Sun [2010] et al. used the DEA model to analyze the mobility efficiency of urban public transportation terminals from the results of multiple efficiency indicators.

These previous studies indicate that it is possible to consider multiple indices made by combining input and output items obtained from various data, and then make a composite evaluation. The data used in the previous section, such as the time required and the number of transfer trips, can only allow us to deter-mine the overall properties of the transfer nodes. However, in the DEA model, such data can be used as evaluation indices in order to determine discrete transfer nodes. This makes it possible to identify the specific uniqueness of each transfer point by studying the differences between multiple evaluation indices and the D-efficiency value. Additionally, the improved input and output values for each evaluation index that inefficient nodes require can be determined against efficient nodes by focusing on the differences between the input and output values used in the evaluation indices obtained from the determined D-efficiency value. For this reason, we decided that the DEA model would also be a useful method and applied it to Smart Card data, which was used to analyze DMUs as transfer nodes.

3.2. Defining the Indices for Transfer Nodes Evaluation

In this study, when evaluating the transfer nodes using the DEA model, the following three indices were used: "transfer efficiency," "transfer reliability," and "transfer dependency." The input and output values for the DEA model are shown in Table 2.

The input and output items are common for all three indices. Efficiency levels were evaluated from the point of view of public transportation services provided to users. The results obtained from the DEA model were considered efficient if more output is achieved from less input. Therefore, it was necessary to use fewer input items and more output items.

In this study, the average time required for output items and time required for distribution were indices that produces favourable results if their numbers were low. Therefore, these output items were treated as reciprocals. The number of services and routes used in this analysis was obtained from the website of Tosa Electric Railway and Access Kochi, a public transportation search engine.

Transfer Efficiency

Transfer efficiency was evaluated based on the public transportation services available at transfer nodes (number of services and routes) and the transfer time required, as well as the ease of making transfers. If the transfer point offered a shorter time requirement on a certain public transportation system, the D-efficiency value became higher. If it took more time to make transfers, the value became smaller.

Transfer Reliability

Transfer reliability was evaluated based on the dispersion of transfer time at nodes with varying public transportation service times. If the transfer point offers less transfer time dispersion on a certain public transportation service, the D-efficiency value became high-r. If there is more dispersion, the value became smaller.

Transfer Dependency

Transfer dependency was evaluated based on the to-al number of previous and following trip nodes passed by users on a public transportation service and at a transfer point. The number of previous trip nodes is the total number of departure nodes during the trip before arriving at the transfer point. The number of nodes for the following trip is the total number of destination nodes from the transfer point to the destination. A higher transfer point number indicated a bigger D-efficiency value. Conversely, a lower number of following trip nodes resulted in a smaller D-efficiency value.

Table 2: Proposed indices and Input and Output Variables for indices

Index Name	Input Variables	Output Variables
Transfer Efficiency	Frequency of bus/tram per day Number of available route	Average of transfer time at the point
Transfer Stabilization	Frequency of bus/tram per day Number of available route	Variance of transfer time at the point
Transfer Dependency	Frequency of bus/tram per day Number of available route	Number of bus/tram stops used for departure Number of bus/tram stops used for destination

3.3. Transfer Nodes Evaluations by DEA

Comparison Using the Three Proposed Indices

Using the obtained data described in the previous section, we calculated the D-efficiency value for each transfer point using the proposed DEA model. In this study, we focused on the top 40 transfer nodes with the highest number of people making transfers, and where there was an average of at least 1.0 person making a transfer each day.

The users making transfers in this section refer to the total number of people making transfers, which is different from transfer trips. Among the D-efficiency values determined for the three indices, the nodes showing the largest difference in D-efficiency values, or those approximating 1.0 ("efficient"), are shown in Table 3. The averages in Table 3 are the averages for the three indices, and it can be seen that there are multiple nodes with D-efficiency values of 1.0 ("efficient"). This is because the BCC model considers the efficiency of scale (efficiency of transfers in terms of the number of services and routes). Thus, even if differences in scale are observed among nodes, the efficiency value will remain the same if the efficiency is the same.

The transfer nodes showing higher than average efficiency values for all three indices were Nakayama, Asakura-ekimae, Gomen-machi, and Kochi-ekimae. These efficiency values were high because Asakura-ekimae and Kochi-ekimae are transfer nodes that connect with other public transportation systems. Additionally, because Gomen-machi is the final stop for trams, it accommodates a large number of users making transfers. The efficiency for Nakayama was the highest because it has a large number of commuter pass users, and also because transfers could be made easily in a short period of time, even though a limited number of services were provided. Furthermore, even though there are fewer buses in operation than trams, it takes more time to make a transfer from a tram to a bus than vice versa. Like Ohashidori and Horizume, the D-efficiency of "transfer dependency" is high and the D-efficiency of "transfer reliability" is low because the number of buses is not optimized for the number of users making transfers. Efficiency is high for the limited number of services operating because the schedule allows easy transfers, and because there are many users who know the schedules well enough to make transfers efficiently. In contrast, the efficiency value is low, despite the high number of services in operation, because the schedule makes it harder for users to make transfers, there are few commuter pass users (excluding commuters and students), and long waiting times are required to make transfers to public transportation systems that offer fewer services.

Table 3: Efficiency evaluation of the three transport indices

Transfer Point	Transfer Efficiency	Transfer Reliability	Transfer Dependency	Ratio of Commuter Pass
Nakayama	1.00	1.00	1.00	0.76
Asakura-ekimae	1.00	0.80	0.95	0.47
Kochi-ekimae	0.66	1.00	1.00	0.39
Gomen-machi	1.00	0.76	0.89	0.20
Monju-dori	1.00	0.82	0.49	0.23
Harimayabashi	1.00	0.47	0.69	0.05
Kochibashi	0.26	1.00	0.85	0.43
Kagamibashi	0.95	0.64	0.48	0.22
Kamimachi-ichome	0.53	0.60	0.81	0.45
Kenritsu Bijutsukan dori	0.58	0.77	0.45	0.57
Kamimachi-nichome	0.44	0.60	0.75	0.38
Horizume	0.55	0.25	0.95	0.48
Ohashidori	0.35	0.36	1.00	0.44
Masugata	0.39	0.56	0.76	0.40
Kamimachi-gochome	0.36	0.60	0.71	0.36
Hotarubashi	0.26	0.60	0.81	0.47
Hasuikemachi-dori	0.29	0.75	0.60	0.48
Kera-dori	0.34	0.84	0.38	0.41
Ground-dori	0.28	0.53	0.76	0.44
Dentetsu Terminal Buld. Mae	0.59	0.31	0.63	0.18
Kencho-mae	0.37	0.37	0.77	0.43
Kochijo-mae	0.31	0.38	0.80	0.43
Average Value	0.57	0.64	0.75	-

Comparison of Transfer Efficiency by Hour

Among the three indices evaluated, the D-efficiency of transfer efficiency was calculated based on time of day (morning, mid-day, and night). As with the previous section, Table 4 shows transfer nodes that demonstrate differences in their D-efficiency values. During the morning hours, the services are operating at a high tempo because there are numerous commuters and students using the services. During the mid-day, there are many persons who use the services for shopping, visiting hospitals, and taking care of other chores. As a result, the services operate at a lower tempo compared to the morning. When it takes shorter time to make transfers, given a fewer number of services in operation, efficiency is higher. The D-efficiency value is higher during the mid-day than the morning.

Therefore, we can observe that there are no significant differences in the time required between the morning hours and mid-day. The efficiency values for Asakura-ekimae and Kochi-ekimae at night are lower compared to morning and mid-day, possibly because there are few services operating at night, thus making transfer times longer for users. In contrast, transfer nodes where the D-efficiency values for the morning and mid-day were low, specifically the stations at Horizume, Umenotsuji, Kamimachi-ichome, and Kenritsu Bijutsukan dori, showed high night time D-efficiency values. This is because there are more users who visit these areas when going home at night. Therefore, more services are in operation compared to mid-day in order to accommodate the increased number of users.

Table 4: Evaluation of transfer efficiency by hour

Transfer Point	5:00 - 9:59	10:00 - 17:59	18:00 - 23:59
Monju-dori	1.00	1.00	1.00
Asakura-ekimae	1.00	1.00	0.54
Kochi-ekimae	1.00	1.00	0.76
Gomen-machi	1.00	1.00	1.00
Harimayabashi	1.00	1.00	1.00
Dentetsu Terminal Buld. Mae	1.00	0.83	0.80
Kagamigawabashi	0.84	1.00	1.00
Masugata	0.61	0.48	0.48
Kenritsu Bijutsukan dori	0.52	0.44	1.00
Kamimachi-ichome	0.50	0.59	1.00
Horizume	0.48	0.55	1.00
Chiyoricho	0.42	0.37	0.50
Chiyoricho-nichome	0.40	0.43	0.37
Kamimachi-nichome	0.39	0.44	0.57
Kencho-mae	0.34	0.41	0.43
Umenotsuji	0.33	0.39	1.00
Ohashi-dori	0.25	0.39	0.36
Average Value	0.46	0.53	0.55

Comparison of the Transfers Efficiency by User Type

Next, in Table 5, it shows the calculations of the efficiency values by user type. The input and output items used in the analyses were the same as the indices for the efficiency of transfers.

When comparing the number of users and the D-efficiency values of Table 5, we can see that the transfer efficiency is not necessarily high when the number of users making transfers is high. This shows that other elements, such as the time required to make the transfers and the frequency of services, impact the efficiency.

Children use public transportation primarily for commuting to and from schools. Therefore, there are few users who make transfers in this user type. There were only 11 nodes that satisfy the requirements to be considered as analysis subjects. The D-efficiency values for Masugata Shotengai and Kochi Eki Bus Terminal were high because there are few users making transfers and because the users' purposes and times for riding public transportation were mostly predetermined. Although the number of users making transfers is small, the time required is also short. These factors likely improved the efficiency, as the users' purposes and public transportation riding times were mostly predetermined. The efficiency value for Harimaya Bashi, which has the highest number of users making transfers, was low for all age groups. Here, the average time required is generally short, but the number of bus and tram routes and services in operation are high. This is because the number of services varies greatly by route. As a result, the imbalance in supply and demand led to poor efficiency.

Among adults and "Nice Age" users, transfer nodes differ in efficiency values because their purposes of use are different. However, at more than half of the transfer nodes, the D-efficiency values did not show significant differences, or fell lower than average among the three indices. Looking at the time required at these transfer nodes, we found no differences among the age groups. This phenomenon is most likely explained by the fact that the users share the same purposes of use, such as commuting and shopping.

Fig. 3 plot the evaluated transfer nodes on maps, as was done in the previous section. These figures plot bus stations near schools and reflect the differences in high efficiency locations by age group. Here, focus was given on determining which age group should be given priority when improving efficiency.

Table 5: Evaluation of transfers efficiency by card type (Children; Left, Adult; Middle, Nice Age; Right)

Transfer Point	Children	Num of Transfer (person/month)
Masugata-shotengai	1.00	116
Kochieki Bus Terminal	1.00	87
Asakura-ekimae	0.69	37
Dentetsu Terminal Buld. Mae	0.67	61
Minami Harimayabashi	0.60	49
Kochi-ekimae	0.55	176
Enokuchihendensyo-mae	0.46	47
Kamimachi-ichome	0.40	69
Kencho-mae	0.24	30
Harimayabashi	0.22	641
Average Value	0.58	-

Transfer Point	Adult	Num of Transfer (person/month)
Dentetsu Terminal Buld. Mae	1.00	2606
Kagamigawabashi	1.00	690
Sanbashishako-mae	1.00	238
Nakajima	1.00	100
Monju-dori	1.00	1097
Minami Harimayabashi	0.90	611
Kochi-ekimae	0.82	653
Asakura-ekimae	0.77	288
Gomen-machi	0.75	157
Nishi Takasu	0.75	565
Masugata	0.56	417
Ground-dori	0.53	263
Gomen-nishimachi	0.46	139
Harimayabashi-higashi	0.45	1635
Sakai-machi	0.44	1920
Chiyoricho-sanchome	0.41	339
Kochieki Bus Terminal	0.39	538
Kencho-mae	0.36	742
Ohashi-dori	0.36	1437
Saemba-cho	0.35	317
Hariyamabashi	0.34	16977
Chiyoricho-nichome	0.32	589
Umenotsuji	0.32	199
Sanbashi-yonchome	0.90	168
Horizume	0.25	2244
Average Value	0.58	-

Transfer Point	Nice Age (elderly)	Num of Transfer (person/month)
Dentetsu Terminal Buld. Mae	1.00	963
Kamobe	1.00	43
Kochi-eigyosho	1.00	187
Nakayama	1.00	99
Asakura	1.00	148
Asakura-ekimae	1.00	100
Monju-dori	1.00	323
Minami Harimayabashi	0.93	392
Ryoseki-dori	0.89	77
Gomen-machi	0.89	348
Kagamigawabashi	0.86	297
Kochieki-mae	0.82	304
Obiyamachi	0.71	614
Nishi Takasu	0.60	500
Masugata	0.56	346
Groud-dori	0.53	208
Hariyamabashi-higashi	0.45	976
Kochieki Bus Terminal	0.44	201
Sakai-machi	0.44	959
Chiryoricho-sanchome	0.41	143
Kochijo-mae	0.38	182
Harimayabashi	0.37	5553
Kencho-mae	0.36	518
Ohashi-dori	0.36	1173
Chiyoricho-nichome	0.32	675
Horizume	0.26	1493
Average Value	0.68	-

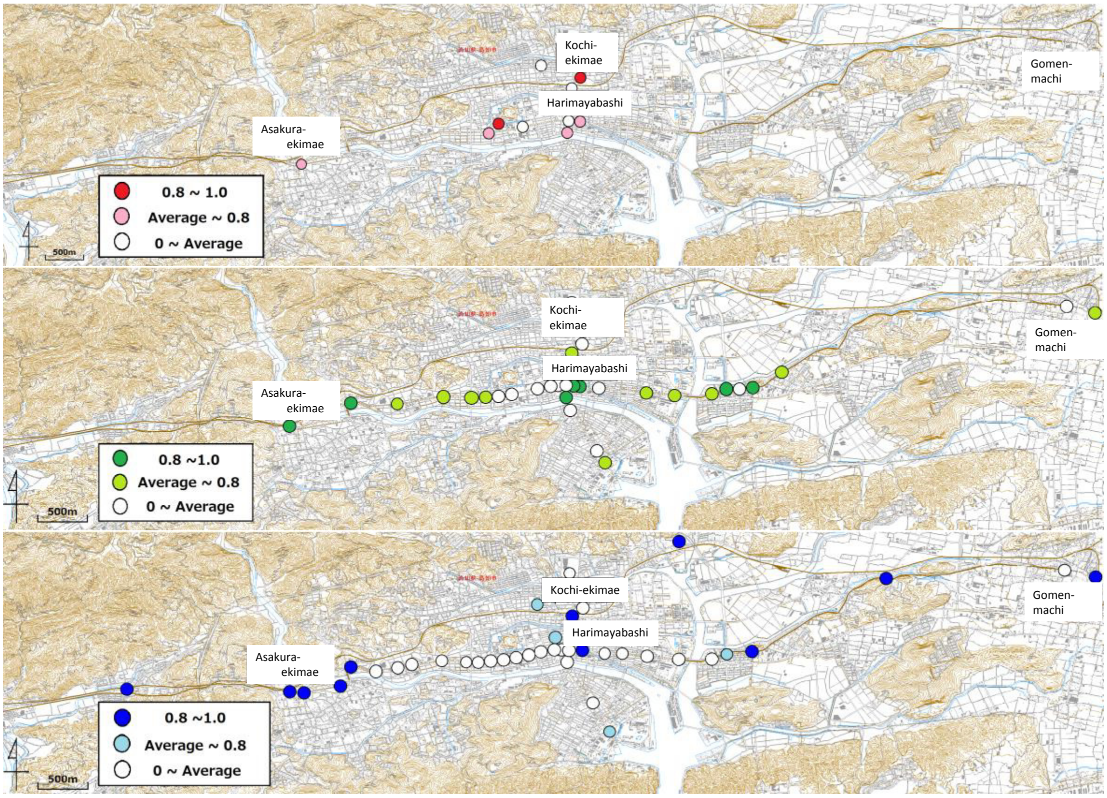

Fig 3: Mapping of the transfers efficiency evaluations by card type (Children; Top, Adult; Middle, Nice Age; Bottom)

Difference of D-efficiency value between efficient and inefficient DMUs

DEA can show us how different between inefficiency DMU (transfer nodes in this paper) and efficient DMU. Value of the difference is called projection value in DEA. Means of projection value is the distance between point of input of inefficient DMU and frontier curve which drew by connecting efficient DMUs. Therefore the values suggest us how we can improve inefficient DMUs to be more efficient DMU. This paper shows distribution of projected values in case low level of D-Value which is calculated by the indices for the efficiency of transfers.

Table 6 shows proportion of the gap between value of input data which are number of tram and bus in a day and number of route and projection value. In case inefficiency transfer nodes such as score is less than 0.4, there are existing high level of number of tram and bus and many routes, but almost same level of averaged transfer time. Therefore projection value suggested that it should be reduced to be more efficient transfer point from all three card type point of view, and it can be said at almost same transfer nodes. Actually, those nodes are located for many bus route which directly connected the bus from suburban area to JR Kochi station (Kochieki-mae) to consider accessibility of passengers. Therefore tram and bus frequently arrive to those transfer nodes even if number of passengers in a bus is not always high level. For this operation, Staffs of transport company already knows and it sometime cause waste of vehicles since number of passengers in a bus is not always full (according to the interview to them by authors), but they didn't know it quantitative point of view. Therefore proposed evaluation method by DEA can show the possibility to evaluate public transport performance and make knowledge quantitatively by using smart card data.

Table 6: Difference of D-value between Efficient DMU and inefficient DMU by card type

Card Type	Transfer Point (DMU)	D-Value	Variables for Input Data		Proportions of Gap between Input Data and Projection to Projection Value	
			Number of vehicle per day (a)	Number of Route (b)	Number of vehicle per day ((projection value - (a))/projection value)	Number of vehicle per day ((projection value - (b))/projection value)
Children	Kamimachi-ichome	0.40	464	15	-85.99	-60.00
	Kencho-mae	0.24	507	25	-87.18	-76.00
	Harimayabashi	0.22	917	27	-92.91	-77.78
Adults	Kochieki Bus Terminal	0.39	281	60	-61.21	-85.00
	Kochijo-mae	0.37	539	24	-62.50	-62.50
	Kencho-mae	0.36	507	25	-64.00	-64.00
	Ohashi-dori	0.36	540	25	-64.00	-64.00
	Saenbacho	0.35	687	26	-65.38	-65.38
	Harimayabashi	0.34	917	27	-66.48	-66.48
	Sambashi-ichome	0.32	633	28	-67.86	-67.86
	Sambashi-nichome	0.32	633	28	-67.86	-67.86
	Chiyoricho-ichome	0.32	645	28	-67.86	-67.86
	Chiyoricho-nichome	0.32	646	28	-67.86	-67.86
	Umenotsuji	0.32	633	28	-67.86	-67.86
	Sambashi-sanchome	0.31	633	29	-68.97	-68.97
	Hoeicho	0.30	699	30	-70.00	-70.00
	Sambashi-yonchome	0.29	639	31	-70.97	-70.97
	Horizume	0.25	690	36	-75.00	-75.00
Nice Age (Elderly)	Kochijo-mae	0.37	539	24	-62.50	-62.50
	Harimayabashi	0.37	914	27	-63.19	-63.19
	Kencho-mae	0.36	507	25	-64.00	-64.00
	Ohashi-dori	0.36	540	25	-64.00	-64.00
	Saenbacho	0.35	687	26	-65.38	-65.38
	Sambashi-ichome	0.32	633	28	-67.86	-67.86
	Sambashi-nichome	0.32	633	28	-67.86	-67.86
	Chiyoricho-ichome	0.32	645	28	-67.86	-67.86
	Chiyoricho-nichome	0.32	646	28	-67.86	-67.86
	Umenotsuji	0.32	633	28	-67.86	-67.86
	Sambashi-sanchome	0.31	633	29	-68.97	-68.97
	Hoeicho	0.30	699	30	-70.00	-70.00
	Sambashi-yonchome	0.29	639	31	-70.97	-70.97
	Horizume	0.26	690	36	-74.02	-74.02

4. Conclusion

This paper presented a basic case study that evaluated how users make transfers between public transportation types in order to demonstrate that one way Smart Card data can be used when implementing the restructuring and improving of public transportation systems in regional cities. The maximum frequency values for transfer trips and the time required to make transfers each day, at each transfer point, was tallied for each card type, which also enabled us to identify the age group of each user.

Furthermore, to consider operational and Smart Card data, we used the DEA model and presented our evaluation method and obtained results, which allowed us to comprehend transfer nodes from multiple perspectives. Nodes with low efficiency values will require value improvements for input and output items in each evaluation index. When formulating restructuring and improvement plans for public transportation operations, it will be important to refer to the trip data of users making transfers and consider the trip times and age groups of the users. In doing so, we successfully demonstrated the utility of Smart Card data when considering variables, such as age groups and hours of use, when formulating routes and operation plans in regional cities, many of which are experiencing the effects of an aging population.

Going forward, it will be necessary to extend the period of data acquisition and consider other factors, such as the unique characteristics of the users' trips, Origin-Destination properties, seasons, and weather conditions, so that we can create a more comprehensive method of evaluating public transportation system transfer nodes. It will also be necessary to re-fine the ways in which we extract transfer trip data from Smart Cards.

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