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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