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# The Ridership Analysis on Inter-County/City Service for the Case Study of Taichung City Bus System

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**Abstract.** In order to find passengers' behaviors when the passengers take buses, more than 82 million records of electronic ticket transactions of Taichung City Bus in 2015 and 8 inter-county/city bus routers are analyzed in this article. There are three statistical/analytic results. First, about 5.26 million electronic ticket users received benefits from Taichung City Government's policy; however, less than 0.5% users still used cash. The situations of 8 inter-county/city bus services in adjacent counties were little similar to that of Taichung City. Second, route 208 was the major route took by most people between Taichung City and Miaoli County among the routes supported by Taichung City Government. Routes 108 and 101 were the major routes connecting Nantou County and Taichung City, and Changhua County and Taichung City, respectively. Finally, in three adjacent counties, the names of top 5 bus stops for each county are almost same, but the order of top 5 bus stops for each county are quite different.

**Keywords:** Intelligent transport system · Smart Transportation · Big Data · Electronic ticket · Bus passenger · Ridership · Taichung bus · Inter-county · Inter-city

## 1 Introduction

Developed countries effectively not only develop public transportation systems (PTSs) but also integrate related transportation systems. This is because the PTSs are so-called shared transport services providing energy saving, air pollution reduction, traffic congestion reduction, and convenience enhancement in some place, and tackling deteriorating traffic by the private transportation. In order to make the public transportation to be the major transport for people, the PTSs have to be seamless integration and improve people's willingness to take them. For example, in order to establish a comprehensive public transport network and increase the service coverage ratio,

Taichung City Government aggressively enhances the smart transport services and promotes the policy for a free bus ride within 10 km with an electronic ticket [1].

In the past, it was difficult to collect the passengers' thoughts and feedbacks by telephones, roadside interviews, simple surveys, and household visits. Moreover, this method was not only costly but also had bias problem and a large gap between research and realistic world. Fortunately, with the advancement and development of science and technology, the charging system has been changed from coin-based to electronic ticket-based system. In the future, it may include the third party payment and mobile payment. Currently, all buses in Taiwan equip with electronic ticket readers to support electronic ticket payment. In addition, according to the statistics from EasyCard Corporation (2000–2017) [2], the number of Easy Card in March 2012 exceeded 30 million, and in 2017, the number of Easy Card exceeded 73 million. Similarly, according to the statistics from iPASS Corporation (2008–2017) [3], the number of iPass in 2014 exceeded 5 million, and in 2017, the number of iPass was close to 15 million. The statistics of these two corporations show that the electronic tickets are increasing gradually and are popularly used every year.

The electronic ticket itself implies the identity of a user, such as general/full-fare, student, preferential/half-fare, senior, and concessionaire, while a transaction record of an electronic ticket in the public transport implies the user's boarding record. For example, the information may include the type of transportation tool, route number, boarding or alighting station (depending on the charging method) and so on. Through the statistic and analysis methods, more information can be obtained, such as the number of passengers getting on and off the bus/train and the type of passengers. This is a great and valuable reference to the traffic and city management and policy. Therefore, it is extremely important to study in a lot of research areas in recent years. In this article, to understand the electronic ticket usages of Taichung City Bus and the ridership on inter-county/city service by Taichung City Bus system from Taichung City to adjacent county/city, and vice versa, the electronic ticket transaction records of 2015 used in Taichung City Bus, totaling 82,820,553 records, and 8 inter-county/city bus routes are analyzed.

The remainder of this article is organized as follows. Section 2 briefs the background of Taichung City, Taichung City Bus, and the classification of electronic tickets. Literature review is presented in Sect. 3. Section 4 shows the case study and analytic results of electronic ticket usages and the ridership. Finally, Sect. 5 concludes the article with a brief summary.

## 2 Background

### 2.1 Taichung City

Taichung City is a special municipality located in center-western Taiwan. In fact, it is located in the Taichung Basin along the main western coastal plain that stretches along the west coast from northern Taiwan almost to the southern tip. The adjacent countries/cities of Taichung City, as shown in Fig. 1, are Miaoli County, Hsinchu County, Yilan County, Hualien County, Nantou County, and Changhua County.

The Central Mountain Range lies just to the east of Taichung City. Lower, rolling hills run to the north leading to Miaoli County. Flat coastal plains dominate the landscape to the south leading to Changhua County and the Taiwan Strait to the west.

Since July 2017, Taichung City has been officially ranked as Taiwan’s second most populous city because of its population of approximately 2.79 million people. One of the possible reasons is that Taichung City has not only a warm humid subtropical climate but also a suitable humidity. Furthermore, Taichung City has an average annual temperature of 23.3 °C (73.9 °F) with the highest temperature of the year occurring in July and August, while the lowest temperature occurs in January and February. Day-time temperatures remain warm to hot year-round, though night time temperatures during the winter months are significantly cooler than those during the summer and the warm daytime temperature. The average annual rainfall is just above 1,700 mm (67 in) and the average humidity is around 75%.

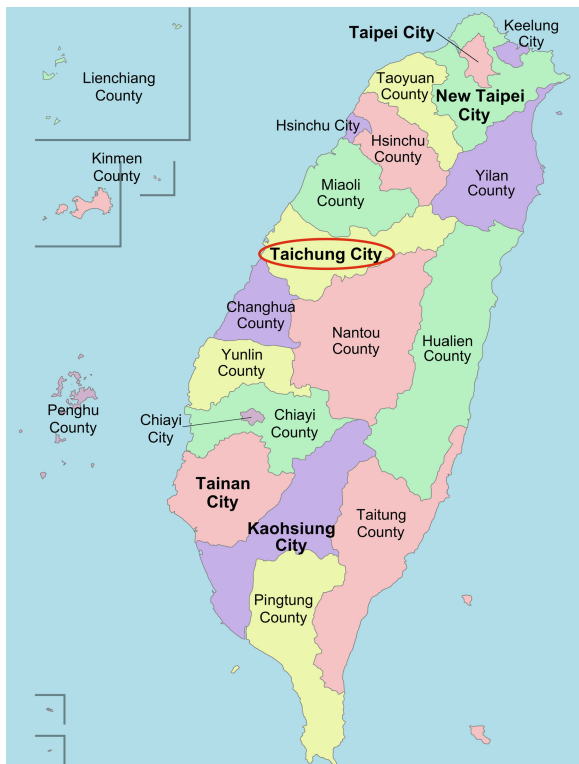


Fig. 1. Taiwan map, location of Taichung City and adjacent counties.

## 2.2 Taichung City Bus

Taichung City Bus, managed by the Transportation Bureau of Taichung City Government in Taichung City, Taiwan, includes at least 200 bus routes, which are numbered from route 1 to route 999 and operated by different 15 bus companies. Furthermore, Taichung City Bus provides major services in downtown area and for residents in rural or remote areas in Taichung City, and supplies minor services to connect different counties, such as Changhua and Nantou Counties, which are south on Taichung, and Miaoli County, which is north on Taichung.

The bus fare is calculated by mileage per ride. The basic fare is NT\$20 for 8 km, and the extended fare is calculated by  $NT\$2.431 * (1 + 5\% \text{ tax included})$  per km and round to the nearest integer. Due to the policy of Taichung City Government, from July 1st, 2015 to date, a passenger with an electronic ticket (i.e., either an EasyCard or an iPass) can take buses for free below 10 km when the route numbers of buses are between route 1 and route 999.

## 2.3 Classification of Electronic Tickets

There are five types of electronic tickets in “Taichung City Smart Transportation Big Data Database” which is provided by the Bureau of Transportation. The electronic ticket types and their owners’ qualifications are as follows.

- Taichung City Senior Card: (1) The person who aged 65 and over establishes his/her household registration in Taichung and (2) The Taiwanese aborigine who aged 55 and over establishes his/her household registration in Taichung.
- Other City/County Senior Card: The senior card was not issued by the Taichung City Government. This means the person/Taiwanese aborigine aged 65/55 and over, but he/she established his/her household registration in other city/county, not in Taichung.
- Half-fare Card: (1) Children whose ages are between 6 and 12 years old, (2) Elderly whose age is over 65 years old and does not have a Senior Card, and (3) The person with a disability and his/her one of companions.
- Full-fare Card: The person does not meet the qualifications of above descriptions.
- Token: The passenger takes a bus with cash, i.e., without using an electronic ticket. In practice, when the passenger gets on the bus, the driver will issue a token to the passenger. When the passenger wants to get off the bus, he/she needs to check the fare by tapping the token to the electronic ticket reader, then pays the fare by cash, and returns the token to the driver.

## 3 Literature Review

This section will introduce relevant researches on the application of electronic ticket data in public transport.

Bagchi and White [4] used the origin and destination records in the electronic ticket data to adjust the transportation service that increased the performance and improved

the quality of the transportation service. Chapleau and Chu [5] observed the changes in passenger carrying capacity on the specific routes by analyzing variation of the number of passenger in electronic ticket data. Seaborn et al. [6] developed a method based on the maximum elapsed time to explain the transfer behaviors of passengers traveling on the London public transport and divided the transfer behaviors into pure transfer, incidental activity transfer, and non-transfer. Wang et al. [7] used the Automatic Data Collection System (ADCS) to collect electronic ticket data and tried to deduce passengers' destinations and analyze the transfer service information, such as the transfer waiting time. Pelletier et al. [8] divided the use of electronic ticket data in public transport into three levels: (1) strategical level: setting a long-term plan; (2) tactical level: dynamically arranging the most suitable shifts to improve the quality of service; and (3) operational level: estimating various indicators of the public transport network. Alsgar et al. [9] used the South East Queensland (SEQ) data to study the effect of different data sample sizes on the accuracy level of the generated public transport O-D matrices and to quantify the sample size required for a certain level of accuracy.

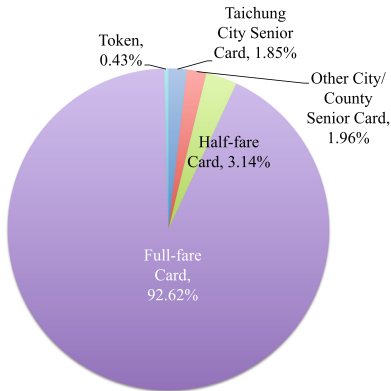
## 4 Case Study

In this Section, 82,260,553 electronic ticket transaction records of Taichung City Bus in 2015 and 8 inter-county/city bus routers are analyzed and discussed by the number and utilization of electronic ticket type, and passengers' behaviors for boarding and alighting bus stops at adjacent county/city of Taichung City.

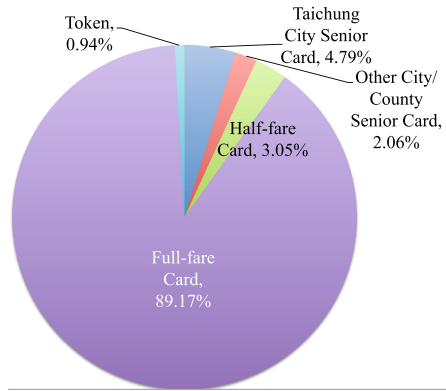
### 4.1 Statistics of Type of Electronic Ticket for Taichung City

By classifying the number of tickets (i.e., no matter how many times an electronic ticket is used), it can be found that the preferential policy for the free 10 km with an electronic ticket supplied by the Bureau of Transportation, Taichung City Government has been achieved a certain result. As shown in Fig. 2, there are about 5.26 million electronic ticket cards and nearly 99.57% of passengers use electronic tickets to take buses and only 0.43% of passengers use cash. There are three most possible reasons for using cash: (1) the balance of the electronic ticket has been negative, (2) the electronic ticket does not belong to any series of Easy Card and iPass, and (3) the passenger is the first time to take a bus in Taichung City and he/she does not have any electronic ticket.

According to the electronic ticket type utilization, as shown in Fig. 3, it can be found that the utilization of the full-fare card is about 89.17% of the total number of utilizations, equaling to 73.85 million rides. It is interesting to note that the Taichung City Senior Card loses Other City/County Senior Card in the number of electronic tickets, but the utilization of Taichung City Senior Card is much higher than that of Other City/County Senior Card. This means the seniors who established their household registrations in Taichung have more locomotion abilities than other seniors.



**Fig. 2.** Number of electronic ticket type.



**Fig. 3.** Electronic ticket type utilization.

## 4.2 Inter-County/City Bus Service and Routes

There are 8 inter-county/city bus services in Taichung City Bus system: (1) Taichung City  $\leftrightarrow$  Miaoli County: routes 97, 181, 208, 253, and 258; (2) Taichung City  $\leftrightarrow$  Nantou County: route 108; and (3) Taichung City  $\leftrightarrow$  Changhua County: routes 101 and 180. The monthly passenger carrying capacities of these 8 bus routes are described in Table 1. From Table 1, it can be found that every route omits some data except routes 97 and 180. The possible reasons are as follows. (1) Bus companies forgot to upload the electronic ticket transaction records to Bureau of Transportation, Taichung City Government in some month, such as Aug. and Oct. of route 181, Mar., Jun., Jul., Aug., and Sep. of both routes 108 and 180. (2) After the format of records was modified, one party (either the bus company or Bureau of Transportation) did not follow the changes that resulted in data loss during automatic data format conversion. For example, the passenger carrying capacity data of routes 208, 253, and 258 is missing after Jun. 2015.

According to the data in Table 1, it can be inferred that route 208 is the major route took by most people between Taichung City and Miaoli County among the routes supported by Taichung City Government. Moreover, the passenger carrying capacity of route 208 is about 4 times larger than that of the second place, route 181. The possible reason is that the population and liveliness of Fengyuan District where route 208 connected to Miaoli County are higher than those of Dajia District where route 181 connected to Miaoli County.

The possible reasons for routes 108 and 101 with huge passenger carrying capacities are that route 108 passes through lots of schools, including high schools and universities, traditional markets, and Taichung Railway Station, and drives along the main roads of Taichung while route 101 passes through less schools and traditional markets, but it crosses two main traffic concentrations, Taichung Railway Station and Taiwan High Speed Rail Taichung Station.

**Table 1.** Passenger carrying capacities of 8 inter-county/city bus routes for every month in 2015.

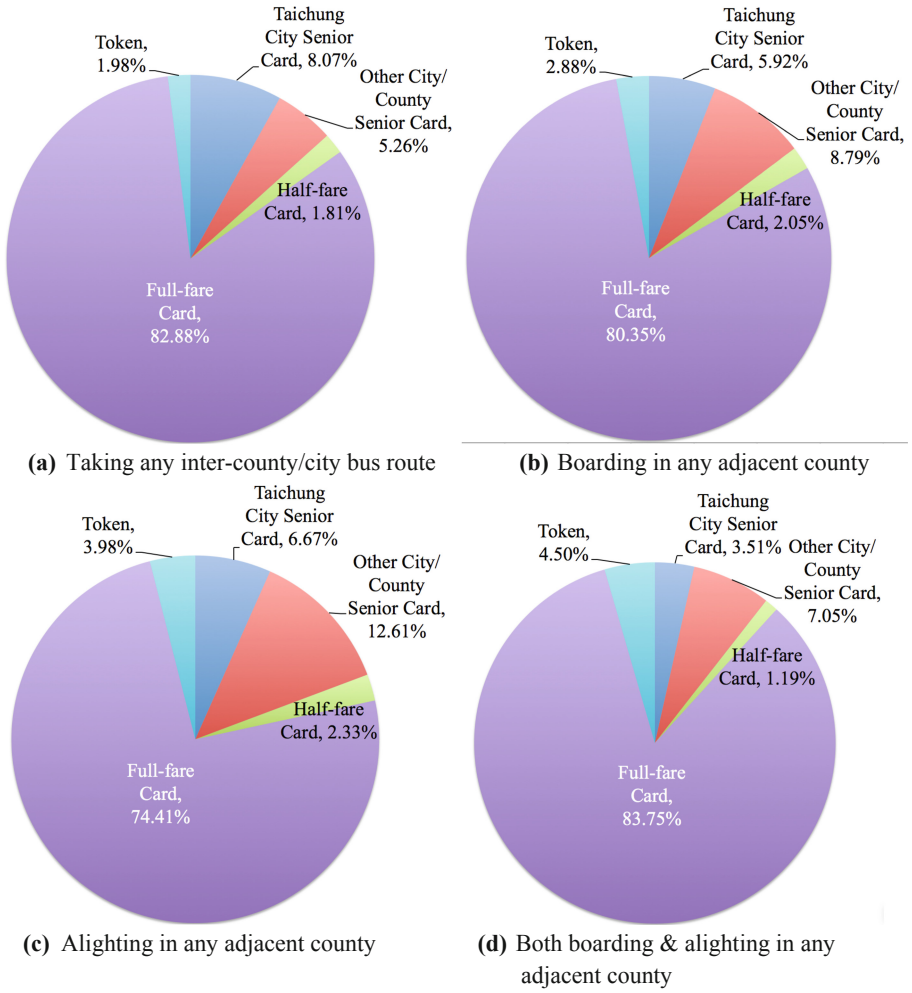
County	Route	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Miaoli	97	3,642	3,163	3,373	3,458	3,229	3,317	3,532	3,065	3,483	4,069	3,909	3,979
	181	14,426	8,926	15,473	14,770	15,388	13,884	11,816	—	13,876	—	14,317	14,765
	208	64,367	34,719	51,825	49,240	49,551	—	—	—	—	—	—	—
	253	7,365	3,547	5,884	5,661	5,809	—	—	—	—	—	—	—
	258	5,015	3,354	3,353	3,244	3,310	—	—	—	—	—	—	—
Nantou	108	79,372	60,841	—	79,346	81,799	—	—	—	—	93,302	89,298	93,793
Changhua	101	69,606	56,531	—	74,484	79,726	—	—	—	—	78,718	80,801	84,938
	180	7,474	4,588	8,729	8,104	8,130	7,522	5,660	3,991	6,200	6,582	8,710	8,813

Figure 4(a) classifies the 1,663,162 electronic ticket transaction records of 8 inter-county/city bus routers in Table 1 by the electronic ticket type utilization. According to Fig. 4(a), it can be found that the utilization of the full-fare card is about 82.88% of total number of utilizations, equaling to 1,378,350 rides. It is interesting to note that the percentage of Taichung City Senior Card and Other City/County Senior Card rise from 4.79% and 2.06% to 8.07% and 5.26%, respectively. This may mean that the senior citizens take inter-county/city routes more frequently. Furthermore, Figs. 4(b) and (c) respectively show the electronic ticket type utilization results with passengers boarding and alighting buses in adjacent counties. The numbers of transaction records in Figs. 4(b) and (c) are 186,901 and 157,681, respectively. From both Figs. 4(b) and (c), it can be observed that the percentages of full-fare card are less than that in Fig. 4 (a), about 80.35% and 74.41%, respectively. On the other hand, the percentages of Other City/County Senior Card are increased, especially with passengers alighting buses in adjacent counties. The possible reason is the senior citizens live and establish their household registrations in adjacent counties, so they naturally take buses by the Other City/County Senior Cards. Figure 4(d) shows the electronic ticket type utilization result with passengers both boarding and alighting buses in adjacent counties. The number of transaction records in Fig. 4(d) is 39,132. It can be found that the proportional allocation is quite different from that in Fig. 3 and guessed that the passengers' activity ranges may be within adjacent counties.

**4.3 Top 5 Hot Bus Stops in Adjacent Counties**

Tables 2, 3 and 4 present the top 5 hot hop-on and off bus stops in Miaoli, Nantou, and Changhua Counties, respectively. From three tables, it can be found that, in three counties, the names of top 5 bus stops for each county are almost same, but the order of top 5 bus stops for each county are quite different. For example, in Miaoli County, the orders between hop-on and hop-off bus stops are almost same except Jiuzhan and Xizhou bus stops. However, in Nantou County, the variations in the order of hop-on and hop-off bus stops are very large. As for the orders of hop-on and hop-off bus stops in Changhua County, it seems that the third top bus stop is a boundary line to separate the first and second top bus stops to be a group and the fourth and fifth top bus stops to be another group.





**Fig. 4.** Electronic ticket type utilization of 8 inter-county/city bus services.

**Table 2.** Top 5 hot hop-on/off bus stops in Miaoli county.

Hop-on		Hop-off	
Count	Bus stop name	Count	Bus stop name
20,911	Zhongjie	27,277	Zhongjie
4,595	Zhuolan	3,281	Zhuolan
3,599	Jiuzhan	1,559	Toll Station
852	Toll Station	940	Xizhou
626	Post Office	833	Post Office

**Table 3.** Top 5 hot hop-on/off bus stops in Nantou county.

Hop-on		Hop-off	
Count	Bus stop name	Count	Bus stop name
29,190	First Bank Caotun Branch	2,774	Tongder Voca.High School
7,671	Daguan	1,929	Xinfeng
7,309	Tongder Voca.High School	1,919	Nanan
5,250	Xinfeng	1,269	Yushi Village
5,245	Yushi Village	1,181	First Bank Caotun Branch

**Table 4.** Top 5 hot hop-on/off bus stops in Changhua county.

Hop-on		Hop-off	
Count	Bus stop name	Count	Bus stop name
15,191	Changhua County Yuanzhumin Shenghuoguan	16,684	Changhua Station
13,791	Changhua Station	14,730	Changhua County Yuanzhumin Shenghuoguan
11,490	Hediao Village	10,370	Hediao Village
5,450	Irrigation Association	8,848	Chang-Hua Girls Senior High School
2,984	Zhongzhuangzi	8,225	Irrigation Association

## 5 Conclusions

In this article, more than 82 million records of electronic ticket transactions of Taichung City Bus in 2015 and 8 inter-county/city bus routers are analyzed. The analytic results are as follows. (1) About 5.26 million electronic ticket users received benefits from Taichung City Government’s policy; however, less than 0.5% users still used cash. The situations of 8 inter-county/city bus services in adjacent counties were little similar to that of Taichung City. (2) Route 208 was the major route took by most people between Taichung City and Miaoli County among the routes supported by Taichung City Government. Routes 108 and 101 were the major routes connecting Nantou County and Taichung City, and Changhua County and Taichung City, respectively. (3) In three adjacent counties, the names of top 5 bus stops for each county are almost same, but the order of top 5 bus stops for each county are quite different. In the next step, the electronic ticket transaction data of Taichung City Bus within a specific application, district, area, or bus route will be analyzed to create more value and relevant applications for smart city.

**Acknowledgments.** The database used in this article is called “Taichung City Smart Transportation Big Data Database” which is provided by the Bureau of Transportation, Taichung City Government. We would like to give special thanks to Taichung City Government, Asia University, and Tableau for their immense supports.

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