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Intelligent Transportation Systems in Smart Cities: Application to Taichung City Bus, Taiwan*

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Abstract

Intelligent transportation system is more and more important in smart cities, especially in developed countries. In Taichung City, Taiwan, buses are the major form of public transportation. When a passenger boards and alights from a bus, they need to swipe their electronic ticket. In this article, the electronic ticket transaction records were used for many analytical purposes, such as understanding passenger behaviour/patterns and finding the coefficient of variation for some bus routes, and even used for an online analysis website database. These analytical results may find the pressure point and gap of bus supply and demand, and make the Taichung City Government enhance intelligent transportation system performance and design more suitable public transportation policy in the future.

Keywords: Intelligent transportation system, Smart transportation, Big data analytics, Case study.

JEL: C46, I28, R40, R41, R48.

1. Introduction

Developed countries do their best to establish public transportation systems (PTSs) and integrate transportation systems with smart computers and/or artificial intelligence in order to develop an intelligent transportation system (ITS) and build an ecosystem. This is because PTSs and ITSs can reduce air pollution, traffic congestion, and engage in energy saving, sharing transport services, and enhancing convenience, while tackling deteriorating private traffic transportation. When PTSs and ITSs are integrated seamlessly, they tend to be the major form of public transportation.

In Taichung City, Taiwan, buses are the major form of public transportation because the Taiwan High Speed Rail (THSR) is used for connecting the cities along the west coast of Taiwan, from the national capital Taipei to the southern city of Kaohsiung. The first line of the Taichung Mass Rapid Transit (MRT), which is a monorail, is still under construction, although much of the infrastructure has been completed. Consequently, the Taichung City Government has aggressively enhanced smart transport services and promoted a policy of free bus rides of up to 10 kilometers using an electronic ticket [1] in order to establish a comprehensive public transportation bus network system and increase the bus service coverage ratio.

In the past, it was difficult to collect passenger feedback and thought through simple surveys, roadside interviews, telephone interviews, or household visits. These survey methods not only had problems of bias, but could also be costly. Furthermore, there was a large gap between the real world and research outcomes. Fortunately, with the progress of technology and science, the charging system has been changed from coin-based to an electronic ticket-based system. In the future, the charging system will include mobile payments and third-party payments.

Today, all buses in Taiwan are equipped with electronic ticket readers to support electronic ticket payment. In addition, there are two major electronic ticket cards in Taiwan, namely EasyCard and iPass. The number of EasyCards exceeded 40 million in September 2013, and by the end of 2017, the number of EasyCards exceeded 73 million, based on statistics from the EasyCard Corporation (2000~2019) [2]. Similarly, the number of iPasses in 2014

exceeded 5 million, and by 2017, the number of iPasses had risen to over 12 million, according to statistics from the iPass Corporation (2008~2019) [3]. The statistics from these two corporations are such that, in every year, the use of electronic tickets has been gradually increasing.

The identity of a user can be determined by an electronic ticket itself, such as student, senior, concessionaire, general (aka called full-fare), and preferential (aka called half-fare); while user boarding records can be obtained from the transactions record of an electronic ticket that is used for public transport. The information may include route number, boarding or alighting station (depending on the charging method), and the type of transportation used, among others. The statistical analytical results provide additional information, such as the type of passengers in terms of electronic ticket that is used, and the number of passengers boarding and alighting from a bus or train.

For developing traffic and city management policies, these analytical results provide invaluable data. In recent years, the analysis of related public transportation data has become an important focus in this research area. In this paper, the electronic ticket transaction records were used for many analytical purposes, such as understanding passenger behavioural patterns, finding the coefficient of variation for some bus routes, and also for an online analysis website database.

The remainder of this paper is organized as follows. Section 2 briefly describes the background of Taichung City, the classification of electronic tickets, and the Taichung City Bus system. Section 3 provides a literature review. The analytical use of the electronic ticket transaction records is presented in Section 4. Finally, Section 5 gives concluding comments, together with a brief discussion of future work.

2. Background

In this Section, we give a brief overview of Taichung City, the Taichung City Bus system, and the classification of electronic tickets. Furthermore, service areas, bus fares, and the free bus ride policy of the Taichung City Bus system are described, with five electronic ticket types also to be discussed.

2.1 Taichung City

Taichung City is a special municipality located in centeral-western Taiwan. 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 location of Taichung City is shown in Figure 1, and the adjacent counties, which have recently been converted to cities, to Taichung City are Changhua County, Nantou County, Hualien County, Yilan County, Hsinchu County, and Miaoli County.

Taichung City has been officially ranked as one of the most populous cities in Taiwan since July 2017, with a population of approximately 2.79 million. One overriding reason is that Taichung City has not only suitable year-round temperatures, but also has a warm and humid subtropical climate.

2.2 Taichung City Bus

The bus system of Taichung City is called Taichung City Bus, and is managed by the Transportation Bureau of the Taichung City Government. Taichung City Bus covers at least 200 bus routes that are numbered from Route 1 to Route 999, and are operated by different bus companies.

Moreover, Taichung City Bus mainly provides services in the downtown area, rural, and remote areas around Taichung City. It also supplies some services to connect Taichung City and adjacent counties, such as Changhua and Nantou, which are the southern counties of Taichung, and Miaoli County, which is a northern county of Taichung.

The bus fare is determined by the distance travelled, involving a basic fare plus extended fare. Within 8 kilometres is a basic fare, NT$20. After 8 kilometres, the extended fare is counted as NT$2.431*(1+5% tax) per kilometer, and is rounded to the nearest integer. However, from 1 July 2015, according to the policy of the Taichung City Government, when a passenger uses an electronic ticket, an EasyCard or an iPass, they can take bus journeys for free below 10 kilometres on route numbers 1 to 999.

2.3 Classification of Electronic Tickets

In the "Taichung City Smart Transportation Big Data Database," there are five types of electronic tickets. These five electronic ticket types and their owner qualifications are as follows:

- Taichung City Senior Card:

  (1) a person aged 65 or over, with an established household registration in Taichung; or
  (2) a Taiwanese aborigine aged 55 or over, and with established household registration in Taichung.

- Other City or County Senior Card:

  A senior card is not issued by the Taichung City Government. This means a person (or Taiwanese aborigine) aged 65 (or 55) or over, and without established household registration in Taichung, but in another city or county.

- Half-fare Card:

  (1) Children between the ages of 6 and 12 years;
  (2) Elderly people over 65 years , and without a Senior Card; and
  (3) a person with a disability, and a companion.

- Full-fare Card:

  A person who does not meet the above criteria.

- Token:

  A passenger pays for a bus journey without using an electronic ticket but pays in cash. In practice, the driver issues a token to the passenger when this passenger boards a bus. When they alight from the bus, they have to check the fare by tapping the token on the electronic ticket reader, pay the fare in cash, and then return the token to the driver.

3. Literature Review

The relevant analysis of research relating to electronic ticket data for public transportation and applications are examined in this section.

In [4], the origin and destination records for electronic ticket data are used to adjust transportation service, increase performance, and improve the quality of the transportation service. In [5], the electronic ticket data are used to analyze variations in the number of passengers, and to determine changes in passenger-carrying capacity on specific routes. Seaborn et al. (2009) develop a method according to the maximum elapsed time to explain the transfer behaviour of passengers traveling on London public transportation [6]. The transfer behaviour can be divided into different types, such as pure transfer, incidental activity transfer, and non-transfer.

An Automatic Data Collection System (ADCS) is proposed in [7]. It collects electronic ticket data, deduces passenger destinations, and analyzes some transfer service information, such as the transfer waiting time. In [8], Pelletier et al. (2011) divide the use of electronic ticket data in public transport into three levels: (1) strategic level, (2) tactical level, and (3) operational level. The meanings of each level are, respectively: (1) setting a long-term plan, (2) dynamically arranging the most suitable shifts to improve the quality of service, and (3) estimating various indicators of the public transport network.

In order to evaluate the effects of different sample sizes on the accuracy levels of the generated public transport O-D matrices, South East Queensland (SEQ) data are used in [9]. Moreover, SEQ is also used to quantify the sample sizes required to achieve certain levels of accuracy.

4. Case Study and Analytical Results

In this section, we analyze 82,260,553 electronic ticket transactions records of Taichung City Bus in 2015, and classify them according to the use and number of electronic ticket types, monthly passenger carrying capacity, missing data, the behaviour of passengers with different

electronic ticket types, passenger special patterns of 151 route on Fridays, inter-county and city bus service and routes, and the online analysis website database.

4.1 Analysis of the Type of Electronic Ticket

As shown in Figure 2, it is observed that the preferential policy for the free 10 kilometres with an electronic ticket supplied by the Bureau of Transportation, the Taichung City Government has achieved a clear outcome by classifying the number of tickets (that is, regardless of how many times an electronic ticket is used). About 99.57% of passengers use an electronic ticket to take buses, among 5.26 million electronic ticket cards, while only 0.43% of passengers pay using cash [10, 11].

As shown in Figure 3, based on the electronic ticket type use, the full-fare card utilization rate is about 89.17% of the total number used, which is equivalent to 73.85 million rides. It is interesting to note that the number of Taichung City Senior Cards are fewer than that of Other City or County Senior Cards, but the use of the Taichung City Senior Card is much higher than that of the Other City or County Senior Cards. This situation indicates that seniors who have established their household registration in Taichung have a greater number of transport opportunities than do other seniors [10, 11].

4.2 Monthly Passenger Carrying Capacity and Missing Data

Table 1 shows the monthly passenger carrying capacity and missing data of boarding and/or alighting at a bus stop. The missing data indicate that, in an electronic ticket transaction record, there is no bus stop boarding, alighting, or both boarding and alighting information that is available.

From Table 1, the highest passenger carrying capacity is in December, while the lowest carrying capacity is in June. Furthermore, of the four seasons, winter (November to January) and the middle of summer to the middle of fall (June to September) have the highest and lowest passenger carrying capacities, respectively. In fact, the carrying capacity in May is much higher than that in April or June. The weather may be a possible reason because, in Taiwan, May is a rainy season, while winter is colder than the other seasons.

The percentage of missing data is relatively small, so it is not likely to influence the results of the empirical analysis. For example, the highest missing data rate is in July, specifically 3.96%, 0.24%, and 0.06% for the missing alighting, boarding, and both boarding and alighting cases, respectively. For the total records, the missing data rates are about 1.75%, 0.10%, and 0.44% for the missing alighting, boarding, and both boarding and alighting, respectively.

4.3 Behaviour of Passengers with a Senior Card and a Non-Senior Card

The data in Table 2 show that the bus stops that passengers with senior cards and passengers with non-senior cards alight at are different, except for the Taichung Station stop, which is the highest for both groups of passengers. Otherwise, passengers with senior cards usually alight near traditional markets, such as Gancheng Station, Dongshi, and Yixin Market, while passengers with non-senior cards alight near universities, such as National Taichung University of Science and Technology, Overseas Chinese University, and Providence University. Similarly, passengers with senior cards alight near hospitals and department stores, while passengers with non-senior cards alight near shopping areas and transfer stations.

4.4 Passenger Special Patterns of 151 Route on Friday

According to [10], many passengers changed their behaviour to take route 151 on Fridays and the days before holidays, from Wufeng District (and/or Xitun District) to THSR Taichung Station. The reason was that the driver would pass the remaining bus stations unless passengers alighted from route 151 when route 151 reached the maximum passenger carrying capacity. Moreover, a passenger using an electronic ticket could take bus journeys below 10 kilometrs for free. Therefore, in order to increase the probability of boarding route 151 buses, many passengers would use another bus route to the station near the terminal station of route 151 buses.

Table 3 shows the numbers of passengers using the Top 10 hot bus stops of route 151 from CYUT to TCC, while Table 4 presents similar data from TCC to CYUT on weekdays. From the two tables, the following issues are clear:

(1) at some specific bus stops, such as T.P.C.C., Zhongzheng-Caohu Intersection, and Wufeng Post Office, the numbers of passengers on Fridays are much larger than those on Thursdays;

(2) more passengers are accessing route 151 when the station is nearer the terminal station. For example, the Zhongzheng-Caohu Intersection station and T.P.C.C. station have the highest rates of passengers accessing route 151 (at about 168% and 139%, respectively) in Tables 3 and 4.

4.5 Inter-County/City Bus Service and Routes

In the Taichung City Bus system [11], there are 8 inter-county and city bus services, namely:

(1) Taichung City ⟷ Miaoli County: routes 97, 181, 208, 253, and 258;
(2) Taichung City ⟷ Nantou County: route 108; and
(3) Taichung City ⟷ Changhua County: routes 101 and 180.

In Table 5, the monthly passenger carrying capacities of these 8 bus routes are described, from which it can be seen that every route omits some data, except for routes 97 and 180.

The possible reasons for such omission are as follows:

(1) In some month, such as August and October of route 181, March, June, July, August, and September of both routes 108 and 180, the bus companies forgot to upload the electronic ticket transaction records to the Bureau of Transportation, Taichung City Government.

(2) One party (either the bus company or the Bureau of Transportation) did not follow the changes after the format of records was modified. That resulted in data loss during the automatic data format conversion. For example, the passenger carrying capacity data of routes 208, 253, and 258 are missing after June 2015.

4.6 The Online Analysis Website Database

The electronic ticket transaction records were stored in a database which can be used to online analysis websites. For example, as shown in Figure 4, in the following website, a user can have a query with an input regarding any bus route and any two bus stops, which means the initial and final stops. Then the web system will provide output of the statistics of the number of passengers in that trip according to the different types of electronic tickets.

The website link is available at http://ttbd.asia.edu.tw/MRP/en/

ID / Password: guest / guest

5. Conclusion

In this paper, about 82 million electronic ticket transaction records in 2015 for the Taichung City Bus system have been analyzed. There are six important analytical results, which are discussed as follows:

(1) Given the Taichung City Government policy, more than 5 million passengers using an electronic ticket had some benefits, with cash used by fewer than 0.5% of users.

(2) The most popular type of five electronic ticket types in the Taichung City Bus system was the full-fare ticket type. This was because the ratios of the quantity and the transaction records for full-fare ticket types were the highest at 92.62% and 89.17%, respectively.

(3) Passengers with senior cards and those with non-senior cards alighted at different bus stops. For example, the former usually exited buses near hospitals, department stores, and traditional markets, while the latter usually alighted around shopping areas, transfer stations, and universities.

(4) No matter in which direction of route 151, passengers boarded and alighted at THSR Taichung Station. Wufeng Agr. Ind. Senior High School, T.P.C.C., Wufeng Post Office, and Wufeng, which were the bus stops that passengers accessed most frequently.

(5) The behaviour of many passengers for taking route 151 changed on the days before holidays and Fridays, especially in the direction from Wufeng District to the THSR Taichung Station. They took other bus routes to the station closest to the initial station of route 151 in order to increase the probability of being able to board route 151 buses.

(6) Among the routes managed by the Taichung City Government, routes 208, 108, and 101 were the major buses connecting Taichung City, and Miaoli, Nantou, and Changhua Counties, respectively.

In order to create more relevant applications and value in smart cities, analyzing electronic ticket transactions data for specific areas, districts, bus routes, and applications will be the focus of future analysis.

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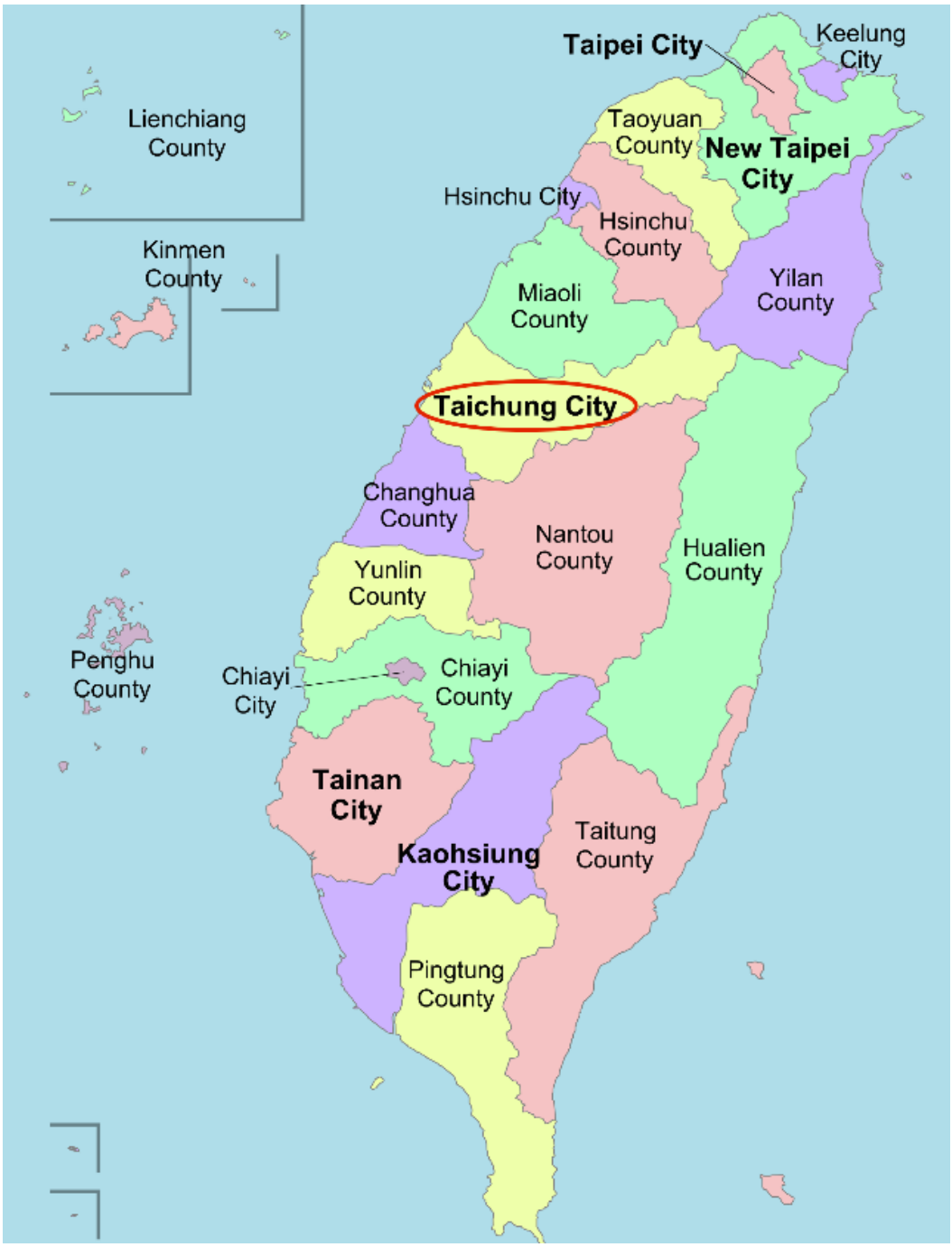

Figure 1

Taichung City's location and its adjacent counties in Taiwan

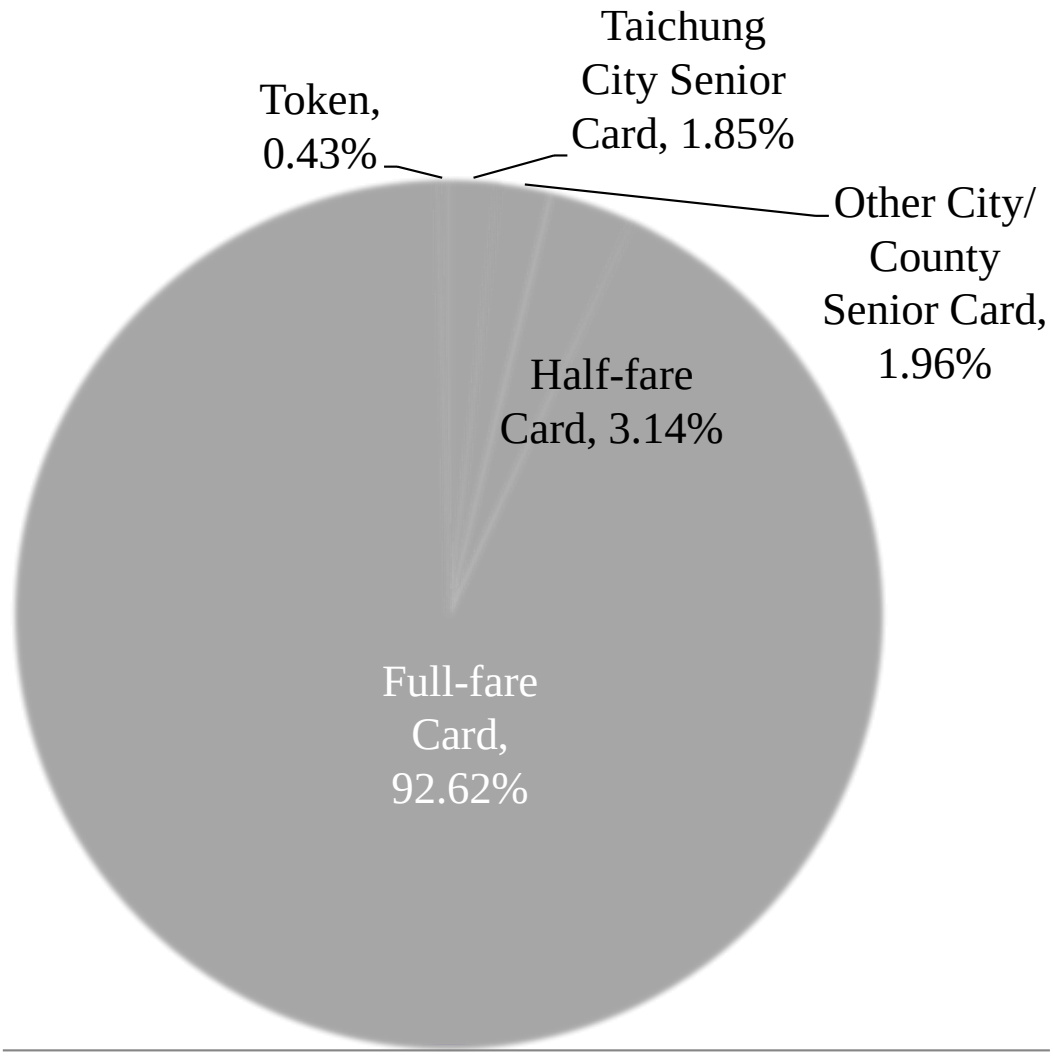

Figure 2

Number of electronic ticket type

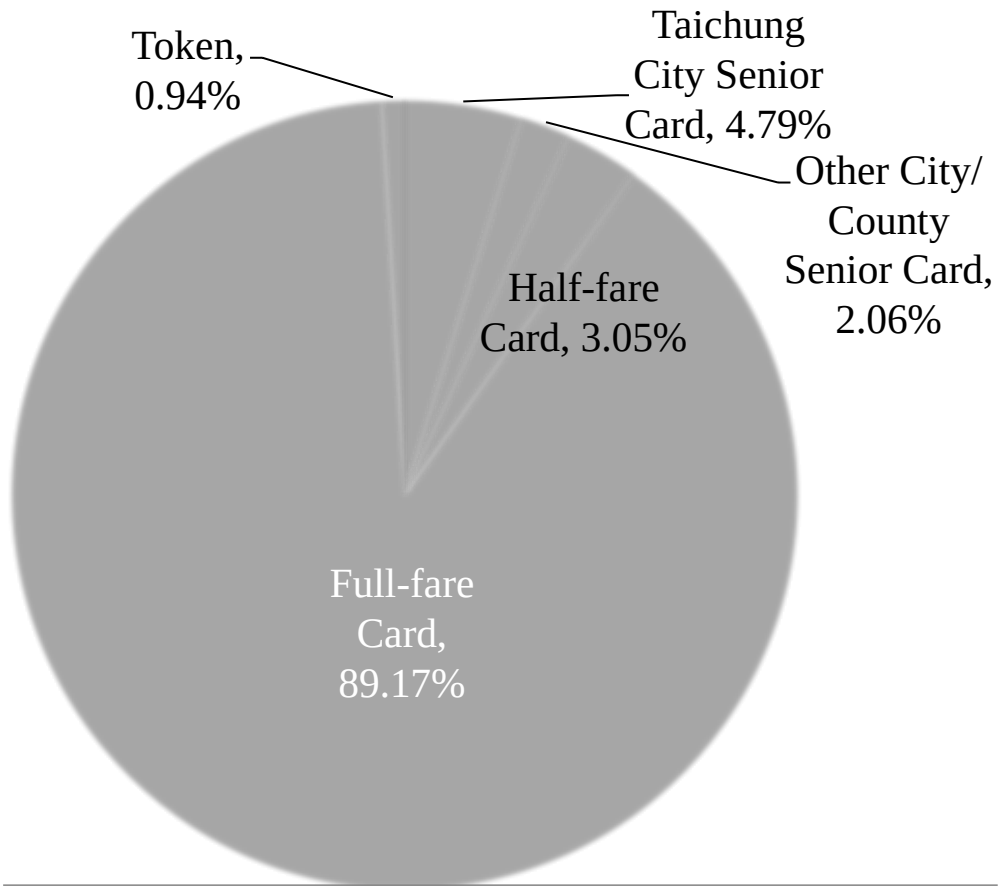

Figure 3

Electronic ticket type utilization

Table 1

Monthly passenger carrying capacity and missing data

Month	Carrying Capacity	Missing Alighting Bus Stop		Missing Boarding Bus Stop		Missing Boarding and Alighting Bus Stops	
		Count	Ratio	Count	Ratio	Count	Ratio
Jan.	9,276,813	63,222	6.82E-03	809	8.72E-05	8	8.62E-07
Feb.	6,483,469	54,411	8.39E-03	1,071	1.65E-04	3	4.63E-07
Mar.	5,542,962	49,089	8.86E-03	4,159	7.50E-04	41	7.40E-06
Apr.	7,725,663	53,986	6.99E-03	1,037	1.34E-04	2	2.59E-07
May	9,133,647	61,876	6.77E-03	10,884	1.19E-03	2,226	2.44E-04
Jun.	3,975,473	60,288	1.52E-02	5,792	1.46E-03	2,164	5.44E-04
Jul.	4,370,136	173,054	3.96E-02	10,445	2.39E-03	2,685	6.14E-04
Aug.	4,133,795	153,679	3.72E-02	4,975	1.20E-03	4,140	1.00E-03
Sep.	4,517,969	161,586	3.58E-02	8,249	1.803E-03	20,555	4.55E-03
Oct.	9,004,345	162,494	1.80E-02	8,682	9.64E-04	332,990	3.70E-02
Nov.	9,213,997	227,909	2.47E-02	14,751	1.60E-03	364	3.95E-05
Dec.	9,442,284	227,804	2.41E-02	11,133	1.18E-03	341	3.61E-05
Sum	**82,820,553**	**1,449,398**	**1.75E-02**	**81,987**	**9.90E-04**	**365,519**	**4.41E-03**

Table 2

Top 25 hop-off bus stops

Senior Card		Non-Senior Card	
Count	Hop-off bus stop	Count	Hop-off bus stop
244,567	Taichung Station	3,953,509	Taichung Station
69,434	Gancheng Station	2,362,017	National Taichung University of Science and Technology
58,920	Dongshi	1,247,107	Chungyo Department Store
55,147	Chungyo Department Store	1,114,733	Shin Kong Mitsukoshi/Top City Dept. Store
46,327	National Taichung University of Science and Technology	766,443	Overseas Chinese University
44,872	Yixin Market	743,824	Maple Garden
44,515	3rd Market	626,998	Gancheng Station
38,099	Taichung Veterans General Hospital/Tunghai University	595,454	Providence University
37,021	Fengyuan	589,174	Yixin Market
34,655	HSR Taichung Station	580,974	HSR Taichung Station
34,293	Fengyuan Post Office	557,072	National Museum of Natural Science
33,085	Wufong	555,686	Donghai Villa
32,832	China Medical University	529,322	Taichung Veterans General Hospital/Tunghai University
32,824	Shin Kong Mitsukoshi/Top City Dept. Store	513,909	Fuxing-Xian Intersection
32,344	Wuquan-Xueshi Intersection	434,022	Taichung 1st High School
29,084	Mazu Temple	413,922	Wuquan-Xueshi Intersection
25,149	Dajia Railway Station	355,201	Feng Chia University
23,232	Shuinan Market	350,153	3rd Market
21,944	Kuang Tien General Hospital	330,083	Chung Shan Meducal University
21,874	Chunghsing Hall	328,400	Taichung Industrial H.S. (Gaogong Rd)
20,553	Guang Fu El. School (Sanming Rd.)	321,984	Chiao Tai H.S. (Gaogong Rd.)
18,933	Motor Vehicles Office Stop	288,658	Chunghsing Hall
18,542	Taichung 2nd H.S.	274,901	Cheng Ching Hospital
17,898	Nanpingli	273,067	Taichung City Hall
17,133	Dakengkou	267,273	Wufong

Table 3

From CYUT to TCC by weekday, number of passengers

on the Top 10 hot bus stops of route 151

Bus stop name	Sun.	Mon.	Tue.	Wed.	Thur.	Fri.	Sat.
THSR Taichung Station	10,295	9,603	8,541	8,654	8,936	11,913	10,833
T.P.C.C.	3,654	3,779	3,902	4,300	4,918	7,559	4,142
Wufeng Post Office	2,301	2,372	2,210	2,180	2,508	3,494	2,483
Wufeng	2,688	2,504	2,187	2,056	2,266	3,040	2,455
Zhongzheng-Caohu Intersection	1,584	1,344	1,230	1,382	1,587	2,672	1,671
Wufeng Agr. Ind. Senior High School	624	1,800	1,919	1,840	1,824	1,828	928
Ministry of Education	677	1,247	1,290	1,196	1,399	1,724	652
Jiayin	1,032	994	774	955	1,013	1,262	986
Shin Kong Mitsukoshi Department Store	564	454	450	415	492	591	660
Wu Feng Elementary School	439	508	446	486	461	704	449

Table 4

From TCC to CYUT by weekday, number of passengers

on the Top 10 hot bus stops of route 151

Bus stop name	Sun.	Mon.	Tue.	Wed.	Thur.	Fri.	Sat.
THSR Taichung Station	10,655	10,794	7,846	7,200	8,054	10,397	8,093
Shin Kong Mitsukoshi Department Store	6,179	4,897	4,772	5,182	5,277	6,112	6,875
T.P.C.C.	5,211	5,211	3,817	3,536	3,485	4,853	3,762
Chaoma	1,877	2,888	2,620	2,569	2,925	2,980	1,779
Taichung City Police Bureau	2,176	2,871	2,958	2,747	2,713	3,368	2,436
Maple Garden (Chaoyang Bridge)	2,991	2,991	2,552	2,806	2,790	3,570	2,565
Wufeng Agr. Ind. Senior High School	196	1,361	1,473	1,367	1,406	1,193	300
Wufeng	592	1,145	1,159	1,153	1,172	1,145	778
Taichung City Hall	759	972	851	957	970	1,092	952
Wufeng Post Office	386	857	835	813	913	1,032	532

Table 5

In 2015, monthly passenger carrying capacities

for 8 inter-county/city bus routes

County	Route	Jan.	Feb.	Mar.	Apr.	May	Jun.
Miaoli	**97**	3,642	3,163	3,373	3,458	3,229	3,317
	181	14,426	8,926	15,473	14,770	15,388	13,884
	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	-----
Changhua	**101**	69,606	56,531	-----	74,484	79,726	-----
	180	7,474	4,588	8,729	8,104	8,130	7,522

County	Route	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Miaoli	**97**	3,532	3,065	3,483	4,069	3,909	3,979
	181	11,816	-----	13,876	-----	14,317	14,765
	208	-----	-----	-----	-----	-----	-----
	253	-----	-----	-----	-----	-----	-----
	258	-----	-----	-----	-----	-----	-----
Nantou	**108**	-----	-----	-----	93,302	89,298	93,793
Changhua	**101**	-----	-----	-----	78,718	80,801	84,938
	180	5,660	3,991	6,200	6,582	8,710	8,813

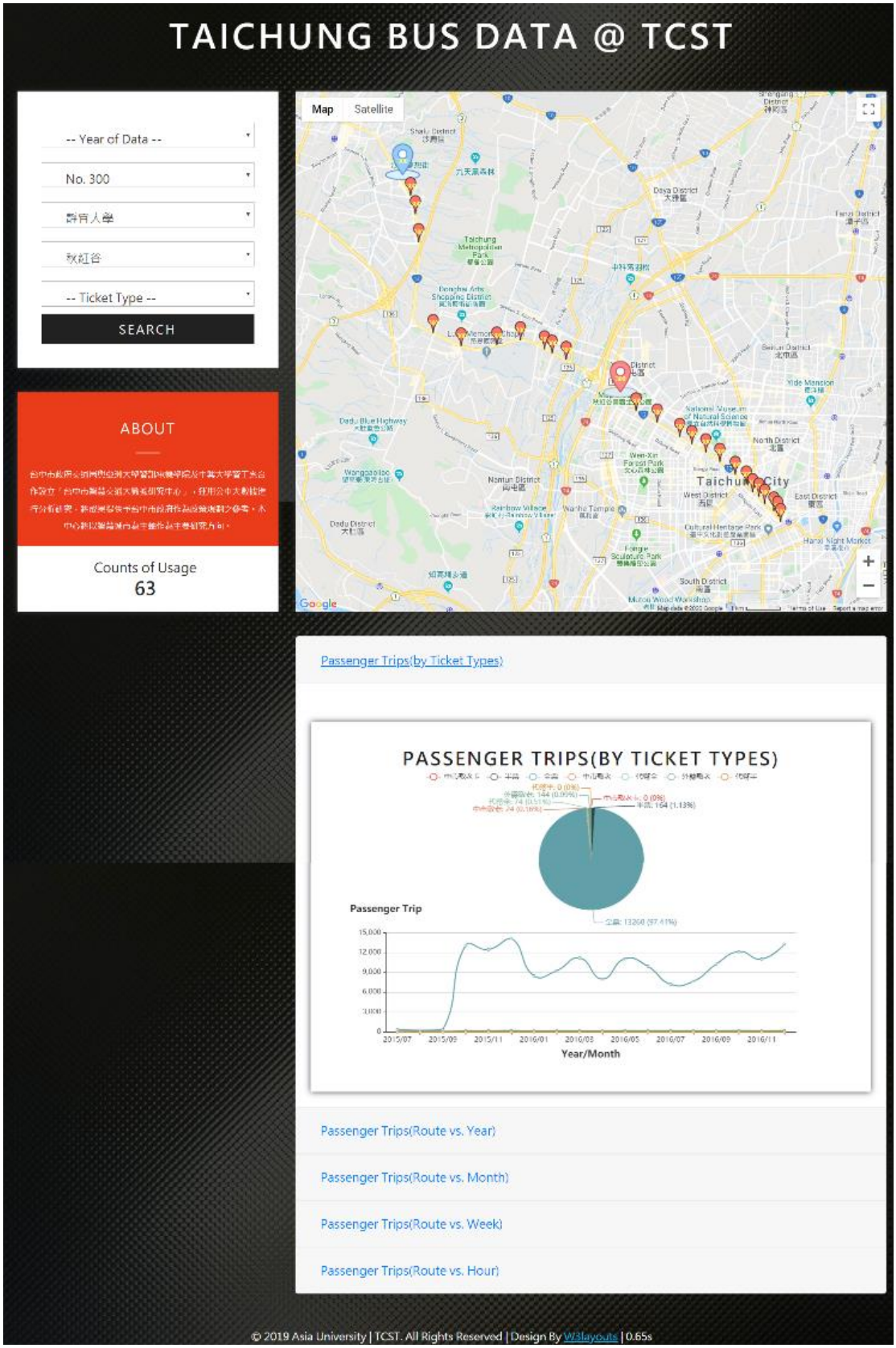

Figure 4

Online Analysis Website