Research on Passenger Carrying Capacity of Taichung City Bus with Big Data of Electronic Ticket Transactions: A Case Study of Route 151

Cheng-Yuan Ho[1,2,3(✉)] and I-Hsuan Chiu[4]

[1] Department of Computer Science and Information Engineering, Asia University, Taichung City, Taiwan
tommyho@asia.edu.tw
[2] Big Data Research Center, Asia University, Taichung City, Taiwan
[3] Taichung City Smart Transportation Big Data Research Center, Asia University, Taichung City, Taiwan
[4] Department of Civil Engineering, National Chiao Tung University, Hsinchu City, Taiwan
sherry52168@g2.nctu.edu.tw

Abstract. In order to find passengers' behaviors when the passengers take buses, 456 thousand and 82 million records of electronic ticket transactions of route 151 and Taichung City Bus in 2015 are respectively 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 for a free bus ride within 10 km with an electronic ticket; however, less than 0.5% users still used cash. Second, The passengers usually got on and off route 151 at THSR Taichung Station no matter which direction. Other bus stops for passengers usually getting on and off were T.P.C.C., Wufeng Agr. Ind. Senior High School, Wufeng, and Wufeng Post Office. Finally, on Friday and the day before holidays, many passengers changed their behaviors to take route 151 from Wufeng District to THSR Taichung Station. This change was that the passengers took another bus route to the station near the start station of route 151 to increase the probability to get on the route 151.

Keywords: Intelligent transport system · Smart Transportation · Passenger carrying capacity · Big Data · Electronic ticket transaction · Bus passenger · Taichung bus · Taiwan High Speed Rail · Hot spot distribution

1 Introduction

With the development of high-speed public transportation and the rapid economic development of Taiwan, in recent years, passengers for intercity travels, especially for business travels, are notably increased. In other words, a lot of passengers arrive, depart, and transfer in high-speed rail stations, railway stations, passenger transport stations, bus stations and so on [1]. The original designs of the connecting lines may

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not be appropriate for the new travel needs and the increasing traffic flow has triggered traffic jams around such external traffic hubs.

Furthermore, Developed countries not only develop public transportation systems (PTSs) but also integrate related transportation systems. This is because PTSs are also shared transport services; providing energy saving, reductions air pollution and traffic congestion, and enhanced convenience, while at the same time tackling the deteriorating traffic of private transportation. In order to make public transportation the major transport for people, PTSs have to be seamlessly integrated, and thus improve people's willingness to use them. Consequently, in order to establish a comprehensive public transport network and increase the service coverage ratio, Taichung City Government has aggressively enhanced its smart transport services and promoted the policy of a free bus ride within 10 km with an electronic ticket [2].

In the past, it was difficult to collect passengers' thoughts and feedback through telephone interviews, roadside interviews, simple surveys, or household visits. These methods were not only costly but also had biasing problems and there was a large gap between research and the real world. Fortunately, with the progress of science and technology, the charging system has been changed from coin-based to an electronic ticket-based system. In the future, the charging system may include third party payments and mobile payments. Currently, all buses in Taiwan are equipped with electronic ticket readers in support of electronic ticket payment. In addition, according to the statistics from EasyCard Corporation (2000–2016) [3], the number of EasyCards in March 2012 exceeded 30 million, and by April 2016, the number of EasyCards exceeded 60 million in Taiwan. Similarly, according to the statistics from iPASS Corporation (2008–2017) [4], the number of iPass in 2014 exceeded 5 million, and by 2017, the number of iPass had risen to over 12 million. The statistics from these two corporations show that the use of electronic tickets is gradually increasing 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 used for public transport implies the user's boarding record. The information may include the type of transportation used, route number, boarding or alighting station (depending on the charging method), etc. More information can be obtained through statistical analysis, such as the number of passengers getting on and off the bus/train, and the type of passengers in terms of electronic ticket used. These are valuable data for developing traffic and city management policies. Therefore, this has become an important focus of research in recent years.

Route 151 is a very important bus service for people living in Wufeng District because it is the only one bus service connecting to Taiwan High Speed Rail (abbreviated THSR) at Wuri District. In fact, as shown in Fig. 1, route 151 starts from Chaoyang University of Technology (labeled 1 and abbreviated CYUT) at Wufeng, passes through the THSR (labeled 17), and ends to Taichung City Council (labeled 25 and abbreviated TCC) at Xitun, and vice versa. Lots passengers, especially businessmen, travelers, and students, take route 151 for their major tools from THSR to Wufeng or Xitun, and vice versa. In this article, to understand the ridership of route 151 and the electronic ticket usages of Taichung City Bus, the electronic ticket transaction records of 2015 used in route 151 and Taichung City Bus, totaling 456,747 and 82,820,553 records, are analyzed, respectively.

The remainder of this article is organized as follows. Section 2 briefs the background of Wufeng District, Taiwan High Speed Rail, 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 passengers' patterns of route 151. Finally, Sect. 5 concludes the article with a brief summary.

Fig. 1. Route path and stops of route 151.

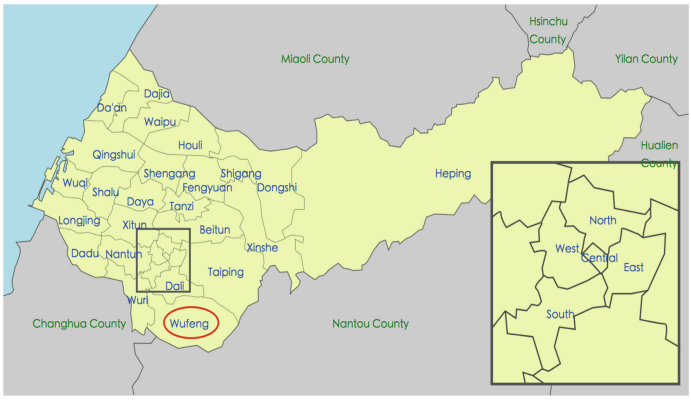

Fig. 2. Taichung City and its administrative regions.

2 Background

2.1 Wufeng District

Wufeng District is a suburban district in southernmost Taichung City, Taiwan, as shown in Fig. 2. It is an important traffic hub of Taichung City since it has the complete

highway system, like Freeway No. 3 and No. 6, and Provincial Highway 3, 63, and 74. Wufeng District is a mainly agricultural town, but it was a very early development zone in central Taiwan and Wufeng Lin Family, one of five major families of Taiwan under Japanese rule, located here. Moreover, Wufeng District is one of the birthplaces of democratization in Taiwan, is rich in many cultural and arts facilities, and has two major geographical features, (1) the Wu Xi (or Wu River), which forms the Wufeng's southern border, and (2) Xiangbi Shan (or Elephant Trunk Mountain), which lies in the eastern part of the township.

2.2 Taiwan High Speed Rail and Taichung Station

THSR is a high-speed rail line, approximately 349.5 km (217 mi) along the west coast of Taiwan, from the national capital Taipei to the southern city of Kaohsiung. The maximum speed of a train on the THSR can reach about 300 km/h (186 mph) and a passenger can only spend about 105 min taking the train from the northernmost station, Nangang, to the southernmost station, Zuoying.

THSR opened for service on January 5th, 2007. In the first few months of operation, the ridership was few, about 25,000 to 36,000 passengers per day. Today, after ten years, the ridership grows to about 152,000 to 175,000 passengers per day. This is because in the first two years of operation, THSR Corporation (THSRC) accumulated debt by high depreciation charges and interest. In 2009, THSRC negotiated with the government to vary the method of depreciation from depending on concessions on rights to ridership. At the same time, the government also started to help refinance THSRC's loans. With the government's help, THSR carried its first 100 million passengers by August 2010, and respectively over 200 and 400 million passengers by December 2012 and December 2016.

Most intermediate stations on the high-speed rail line locate outside the cities; however, the passengers can choose a variety of transfer options. For example, if the passengers have their own private transportations, they may take their cars, motorcycles, and electric vehicles. Otherwise, they will take the public transportations, such as shuttle buses, city buses, conventional rails, light rails, metros, subways, and ferries.

Taichung station, as labeled 17 in Fig. 1, is located in Wuri District of Taichung City and it has the biggest space of all THSR stations. It opened for service on October 24th, 2006. The architectural image of the Taichung Station integrates the regional transit through middle Taiwan and is a gateway to Taichung. Therefore, the development includes the High Speed Railway Station, Taiwan Railway Station, bus transit, parking lots, public squares, supporting facilities, and the road system for the adjacent areas. Unlike some of the other THSR stations, the surrounding areas of Taichung station are not as commercially vigorous. Instead, noted chain restaurants and souvenir stores stationed inside the station attract crowds who are actually not here to commute on their day-offs.

2.3 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% 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.

2.4 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 [5] used the origin and destination records in the electronic ticket data to adjust the transportation service and so increased the performance and improved the quality of the transportation service. Chapleau and Chu [6] used electronic ticket data to analyze variation in the number of passengers and thus determine changes in passenger carrying capacity on specific routes. Furthermore, Chu and Chapleau [7] conducted a study on smart card boarding transactions and revealed the transfer

patterns of travellers in their studies on transit demand modeling. Seaborn et al. [8] developed a method based on the maximum elapsed time to explain the transfer behaviors of passengers traveling on London public transport. This transfer behavior was divided into pure transfer, incidental activity transfer, and non-transfer. Wang et al. [9] used an Automatic Data Collection System (ADCS) to collect electronic ticket data to deduce passengers' destinations and analyze transfer service information, such as the transfer waiting time. Pelletier et al. [10] divided the use of electronic ticket data in public transport into three levels: (1) strategic 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. Alsger et al. [11] used 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. Agard et al. [12] divided the public transport users into four behavioral patterns according to the similar trip habits of travellers using K-mean clustering and Hierarchical Ascending Clustering (HAC) method on the boarding records. Medina [13] recognized the weekly mobility patterns by clustering a 14-dimension vector composed by start time and duration of mobility during 7 days in a week. Kieu et al. [14] proposed a new algorithm to detect the spatial travel pattern according to the number of repeated journeys from smart card data. Zhong et al. [15] measured the variability of mobility patterns using multiday smart card data and found out that mobility patterns varies from day to day.

4 Case Study

In this Section, 456,747 and 82,260,553 electronic ticket transaction records of route 151 and Taichung City Bus in 2015 are analyzed, respectively, and discussed by the number and utilization of electronic ticket type, the top 10 hot bus stops for passengers with different directions and the passengers' special patterns on Friday and the day before holidays.

4.1 Statistics of the Type of Electronic Ticket

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. 3, 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 major reasons: (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. 4, 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 have established their household registrations in Taichung have more locomotion abilities than other seniors.

Similar to 151, by classifying the number of tickets, it can be found that, as shown in Fig. 5, in 456,747 electronic ticket transactions, there are 115,069 electronic ticket cards and nearly 99.67% of passengers use electronic tickets to take buses and only 0.33% of passengers use cash. On the other hand, according to the electronic ticket type utilization, as shown in Fig. 6, it can be found that the utilization of the full-fare card is about 87.48% of the total number of utilizations, equaling to 399,573 rides.

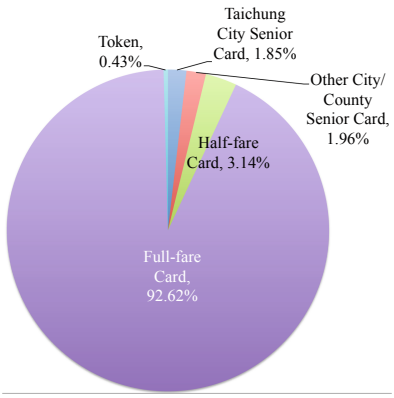

Fig. 3. Number of electronic ticket type.

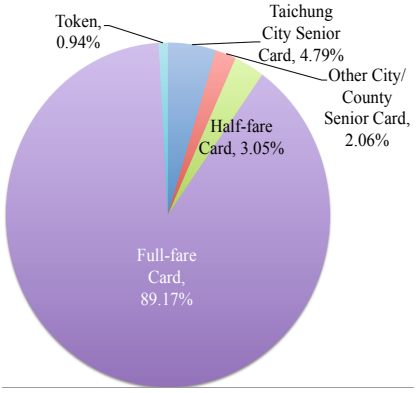

Fig. 4. Electronic ticket type utilization.

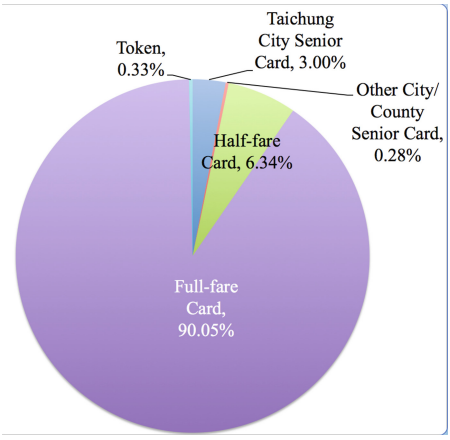

Fig. 5. Number of electronic ticket type of 151.

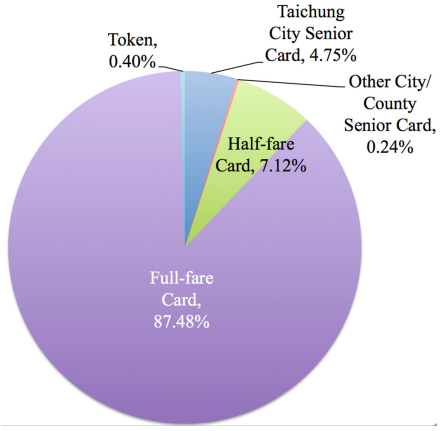

Fig. 6. Electronic ticket type utilization of 151.

4.2 Top 10 Hot Bus Stops

In this subsection, top 10 hot boarding and alighting bus stops of route 151 for different directions are discussed since route 151 only has 25 bus stops. From Tables 1 and 2, it can be found that THSR Taichung Station is the top one hot bus stop no matter which direction is and whether passengers board or alight the bus stop. Furthermore, the numbers of passengers of THSR Taichung Station are about 1.80, 1.19, 2.11, and 1.96 times greater than those of the top 2 hot bus stops (i.e., Shin Kong Mitsukoshi Department Store and T.P.C.C. in Table 1, and T.P.C.C. and Shin Kong Mitsukoshi Department Store in Table 2), respectively. In addition, four bus stops, T.P.C.C., Wufeng Agr. Ind. Senior High School, Wufeng, and Wufeng Post Office, come out on top in both two tables as THSR Taichung Station does. This means that, except THSR Taichung Station, the passengers who usually get route 151 on and off at these four bus stops may live, study, or work here or nearby. In the future, if a new route or service is created, these bus stops should be considered as the main bus stops.

Table 1. Top 10 hot bus stops of route 151 from TCC to CYUT.

Hop-on		Hop-off	
Count	Bus stop name	Count	Bus stop name
61,527	THSR Taichung Station	42,912	THSR Taichung Station
34,137	Shin Kong Mitsukoshi Department Store	36,096	T.P.C.C.
18,793	T.P.C.C.	15,662	Wufeng
17,638	Chaoma	13,342	Wufeng Post Office
16,838	Taichung City Police Bureau	11,406	Wu Feng Elementary School
16,752	Maple Garden (Chaoyang Bridge)	10,837	Zhongzheng-Caohu Intersection
7,129	Wufeng Agr. Ind. Senior High School	8,772	Wufeng Agr. Ind. Senior High School
6,783	Wufeng	7,943	Jiayin
5,552	Taichung City Hall	5,342	Ministry of Education
5,179	Wufeng Post Office	3,343	Maple Garden (Chaoyang Bridge)

Table 2. Top 10 hot bus stops of route 151 from CYUT to TCC.

Hop-on		Hop-off	
Count	Bus stop name	Count	Bus stop name
59,022	THSR Taichung Station	65,755	THSR Taichung Station
27,943	T.P.C.C.	33,618	Shin Kong Mitsukoshi Department Store
14,986	Wufeng Post Office	18,166	Maple Garden (Chaoyang Bridge)
14,384	Wufeng	16,257	Taichung City Police Bureau

(*continued*)

Table 2. (*continued*)

Hop-on		Hop-off	
9,706	Zhongzheng-Caohu Intersection	15,600	Wufeng Agr. Ind. Senior High School
9,354	Wufeng Agr. Ind. Senior High School	15,330	Chaoma
7,014	Ministry of Education	10,801	Wufeng Post Office
5,949	Jiayin	10,675	Wufeng
3,062	Shin Kong Mitsukoshi Department Store	9,853	Taichung City Hall
2,976	Wu Feng Elementary School	8,749	T.P.C.C.

4.3 Passengers' Special Patterns on Friday

On Friday and the day before holidays, many passengers changed their behaviors to take route 151 from Wufeng District (and/or Xitun District) to THSR Taichung Station. This was because when the route 151 arrived its maximum passenger carrying capacity, the driver would pass the remaining bus stations unless someone got off the route 151. Besides, a passenger with an electronic ticket can take bus journeys for free below 10 km. Hence, many passengers would take another bus route to the station near the start station of route 151 to increase the probability to get on the route 151. Tables 3 and 4 respectively show the numbers of passengers getting on the Top 10 hot bus stops of route 151 from CYUT to TCC and from TCC to CYUT by weekday. Two things can be found from tables. One is that the numbers of passengers on Friday are much larger

Table 3. Number of passengers getting on the Top 10 hot bus stops of route 151 from CYUT to TCC by weekday.

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

than those on Thursday at some specific bus stops, such as T.P.C.C., Zhongzheng-Caohu Intersection, Wufeng Post Office, and so on. The other is that when the station is nearer the start station, there are more passengers getting on the route 151. For example, Zhongzheng-Caohu Intersection station and T.P.C.C. station are the most increasing rate of passengers getting on the route 151 (about 168% and 139%, respectively) in Tables 3 and 4.

Table 4. Number of passengers getting on the Top 10 hot bus stops of route 151 from TCC to CYUT by weekday.

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

5 Conclusions

In this article, more than 456 thousand and 82 million records of electronic ticket transactions of route 151 and Taichung City Bus in 2015 are respectively 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 electronic ticket usage percentage of route 151 was similar to the whole case. (2) The passengers usually got on and off route 151 at THSR Taichung Station no matter which direction. Other bus stops for passengers usually getting on and off were T.P.C.C., Wufeng Agr. Ind. Senior High School, Wufeng, and Wufeng Post Office. (3) On Friday and the day before holidays, many passengers changed their behaviors to take route 151 from Wufeng District to THSR Taichung Station. This change was that the passengers took another bus route to the station near the start station of route 151 to increase the probability to get on the route 151. After Sep. 2016, the routing path of route 151 was changed to Fig. 7, so in the next step, it is necessary to compare the difference between two routing paths and use more electronic ticket transaction data of Taichung City Bus to create more value and relevant applications for smart city.

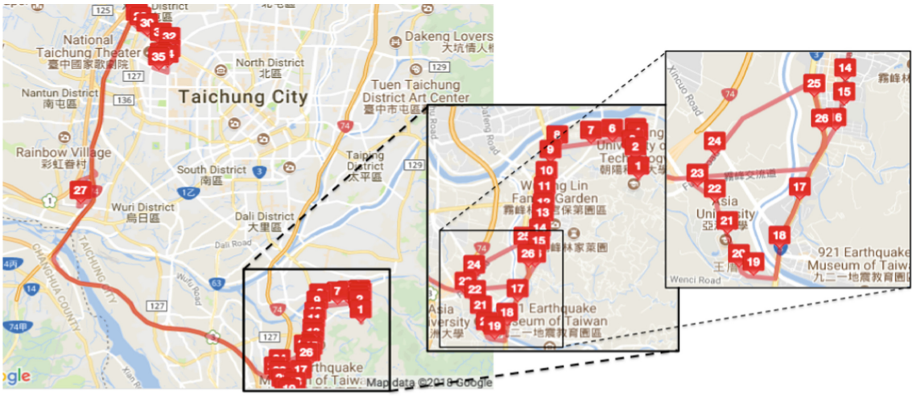

Fig. 7. New routing path of route 151.

References

1. Hai, X., Zhang, R., Zhao, C., Gao, B., Peng, J.: Hierarchical dividing of train station in passenger dedicated line based on self-organizing map. J. Convergence Inf. Technol. **7**(10), 265–271 (2012)
2. Official Website of the Bureau of Transportation, Taichung City Government. World Wide Web. http://www.traffic.taichung.gov.tw/index.asp. Accessed 28 Jan 2019
3. Official Website of EasyCard Corporation's Milestones. World Wide Web. https://www.easycard.com.tw/about/milestone.asp. Accessed 28 Jan 2019
4. Official Website of iPASS Corporation's Operations. World Wide Web. https://www.i-pass.com.tw/About/Operating. Accessed 28 Jan 2019
5. Bagchi, M., White, P.R.: The potential of public transport smart card data. Transp. Policy **12** (5), 464–474 (2005)
6. Chapleau, R., Chu, K.K.A.: Modeling transit travel patterns from location-stamped smart card data using a disaggregate approach. Presented at the 11th World Conference on Transportation Research, Berkeley, California (2007)
7. Chu, K.K.A., Chapleau, R.: Enriching archived smart card transaction data for transit demand modeling. Transp. Res. Rec. **2063**, 63–72 (2008)
8. Seaborn, C., Attanucci, J.P., Wilson, N.H.M.: Analyzing multimodal public transport journeys in London with smart card fare payment data. Transp. Res. Rec.: J. Transp. Res. Board **2121**, 55–62 (2009)
9. Wang, W., Attanucci, J.P., Wilson, N.H.M.: Bus passenger origin-destination estimation and related analyses using automated data collection systems. J. Public Transp. **14**(4), 131–150 (2011)
10. Pelletier, M.-P., Martin, T., Morency, C.: Smart card data use in public transit: a literature review. Transp. Res. Part C: Emerg. Technol. **19**(4), 557–568 (2011)
11. Alsger, A.M., Mesbah, M., Ferreira, L., Safi, H.: Public transport origin-destination estimation using smart card fare data. In: Transportation Research Board 94th Annual Meeting, no. 15–0801 (2015)
12. Agard, B., Morency, C., Trépanier, M.: Mining public transport user behaviour from smart card data. IFAC Proc. Volumes **39**(3), 399–404 (2006)

13. Medina, S.A.O.: Inferring weekly primary mobility patterns using public transport smart card data and a household travel survey. Travel Behav. Soc. **12**, 93–101 (2016)
14. Kieu, L.-M., Bhaskar, A., Chung, E.: A modified density-based scanning algorithm with noise for spatial travel pattern analysis from smart card AFC data. Transp. Res. C: Emerg. Technol. **58**, 193–207 (2015)
15. Zhong, C., Manley, E., Arisona, S.M., Batty, M., Schmitt, G.: Measuring variability of mobility patterns from multiday smart-card data. J. Comput. Sci. **9**, 125–130 (2015)