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Analysis of Bus Commuting Time of High School Students in Taichung City, Taiwan*

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Abstract

Most high school students in the metropolitan areas of Taiwan commute to school by public transportation. Due to the great pressure of academic workload, the time spent on commuting is an unbearable burden. In this study, by using both field study and the analysis based on the Taichung City Traffic Big Data database, we analyzed the bus journeying behavior of high school students of Taichung City on their school commuting. Our study results will be provided to the city government and high schools as a reference to support their transportation policy making. The results of the study show that, with the exception of a very small number of students, most students ridded less than one hour. It took less time to go to school in the morning and more time to get home in the afternoon. We also provided descriptive statistics on the commuting time of the main commuters of each school. The results of big data analysis was verified by the field observation without any obvious inconsistency, which lays an empirical basis for further use of big data analysis in the future.

Keywords: Smart Transportation, Big Data Analytics.
JEL: C46, I28, R40, R41.

1. Introduction

Most high school students in the metropolitan areas of Taiwan commute to school by public transportation. Due to the great pressure of academic workload aiming to enter a good college, the extra time spent on school commuting is an unbearable burden. The transportation departments of local governments have to rack their brain trying every possible mean to improve the service quality of public transportation in order to reduce students' commuting time. For example, a special type of bus lines, called Leapfrog bus, which was introduced by the Taichung City Government a few years ago and only operated in rush hours, only stops at some major stations and skips small ones on bus routes. Using both field study and big data analytics, this study aims to analyze the bus journeying behavior of high school students (including vocational school students) of Taichung City on their school commuting. Our study results will be provided to the city government and high schools as a reference to support their transportation policy making.

1.1 E-ticketing in Taiwan

In recent years, under the active promotion of the Taiwanese government and the advances of science and technology, mass transportation in Taiwan is becoming more and more convenient today. Many useful information services such as the on-bus stop-name announcement and various Apps for on-line access to bus/train schedules and real time bus status inquiry have been deployed [4, 5]. In addition to the cash based bus fare collecting method, an RFID based electronic ticketing system has been installed on every city bus. (Note that the paper based ticketing system had been abolished by all city bus systems many years ago.) Mobile payment for fare collection will be implemented in the near future. In fact, a handful of debit card style RFID cards, such as EasyCard [6], have been very popular in Taiwan. Some of them have been accepted by most public transportation systems as their access and fare payment means. As long as a user holds such a card, he/she can travel around the country by public transportation freely without carrying any cash.

The transaction records of electronic tickets in public transportation preserve many invaluable information for further analysis [1, 2, 3, 7]. Basic information consists of the transportation mean used, the bus/train/route taken, and the boarding/deboarding stations as well as their timestamps (depending on the fare collecting method, some bus systems may only take either boarding or deboarding details, but not both). With these information, big

data analytics will be able to cook out invaluable information for the future transportation network planning and operation management.

1.2 Public City Bus System in Taichung City

Taichung city, located in the middle part of Taiwan, became a metropolitan city with over two million residents after merging another county at 2010. The web site, named as "The public transportation information of Taichung" [5], has been providing digital information such as schedules and maps of bus routes to passengers since 2015. Today, there is more than one hundred bus routes in Taichung city operated by a handful of bus companies. To collect complete electronic records of all passengers' trips automatically, each passenger is encouraged to pay bus fare by an e-ticket, such as EasyCard mentioned in Section 1.1. Unlike other cities, Taichung City Bus system takes mileage based fare charging system demanding every e-ticketed passenger to check-in on boarding and check-out on deboarding. While some other bus systems may demand their passengers check only once either on boarding or on deboarding, the check-twice policy can record more comprehensive information for further analysis. After being aware of the great value of the check-twice policy, Taipei City Bus had changed their check-once policy to the check-twice policy in 2019.

At the initial stage of merging another county into the Taichung City, its bus system was quite out-of-date with almost all negative features such as low coverage, expensive bus fare, and long waiting time, etc. Low quality bus system scared away many potential passengers resulting an even desperate bus system due to incurred big financial loss. The situation had been turned around magically by the 8km-Free Policy, which will be explanted in next section, launched in 2012. Anticipating a big booming in business, every bus company has been taking all necessary steps to renovate its services trying to gain a bigger market share. Having more bus routes, higher coverage, denser bus schedules, and near free bus fare, Taichung City Bus system has turned itself around becoming one of the best bus systems in Taiwan and attracts much more passengers than before.

1.3 Class based Bus Fair Charging in Taichung City

The passengers of Taichung City Bus System are classified into several groups: Regular (or Full-Fare), Senior, Student, Minor, and Handicap. A passenger of each group other than

Full-Fare gets a 50% discount, and can be also called as a Half-Fare passenger.

Every senior citizen, who is older than 65, of Taichung city resident is entitled to take public buses of Taichung City up to 1000 NT dollar free. Every senior citizen is given a RFID senior citizen card, named "Taichung Senior", to which, the Taichung city government will deposit 1000 NT dollars credit every month and remove the balance at the end of month. This 1000 NT dollar credit can only be used to pay the fare of Taichung City buses, either inter-city buses, or city buses.

Senior citizens of other cities have similar cards for them to take public transportation system. Similarly, the credits granted by their own city governments are only applicable to their own public buses. Besides the senior cards issued by various city governments, some debit card companies, such as EasyCard, may also sell half-fare cards to half fare passengers. A half-fare passenger may have to show his/her real photo identification to claim his/her privilege to use a half-fare card. In summary, senior class passengers can be further classified into three sub-classes by the type of the card they used. .

The big data analysis would have been much easier and delicate if we could partition the bus riding transaction database according to the classes of passengers. Unfortunately, this advantage is ruined by the 8km-Free Policy, which will be described next.

1.4 8km-Free Policy in Taichung City

To promote public bus transportation systems, Taichung City government launched a special bus fare discount policy in 2012, called "8km-Free Policy" in short, that every full-fare bus trip is free for the first eight kilometers. (The policy was upgraded to 10 km free in 2015 plus 10 dollar maximum in 2020.) This special discount policy has greatly improved the service quality of Taichung City bus system and increased the population of bus passengers.

Based on our field study, passengers' journeying behavior may be influenced by this policy such that it is much more difficult to precisely classify a passenger from his/her riding records. Without this policy, most of half-fare passengers will use only one card since they do not have any incentive to use full-fare cards. On the other hand, with this 8km-Free policy, a half-fare passenger may use a full-fare card to take the advantage of this policy. For example,

a student who lives within 8km/10km away from his/her school will most likely use a full-fare card to enjoy free rides in their commuting trips. Even a city senior may use a full-fare card to take short bus trips in order to save the credit deposited in his/her senior card for long bus trips. This multi-card riding strategy will maximize his/her own senior benefit. Unfortunately, this phenomenon creates an extra challenge for our study in classifying student passengers from raw bus riding records.

The rest of this paper is organized as follows. Section 2 will describe the experiment environment, Section 3 and 4 will present our experimental results, field study and big data analytics, and finally, Section 5 will give a concluding remark.

2. Bus Riding Transaction Records

2.1 Available Data

The transaction records of bus ridings in all Taichung City buses are stored in the Taichung City Smart Transportation (TCST) Big Data database. Our research team is authorized by the Taichung City Government to use it for research purpose. It has 201,595,418 passenger trip records during a two year period from 2015 to 2016. We used only the data of 2015 in our study because it covers exactly one academic year and is sufficient to discover students' common journeying behavior of bus commuting.

2.2 Data Cleaning

It is a common practice that every set of raw data, either manually collected or automatically collected, requires a cleaning process to remove all possible errors, including incorrect data, inconsistent data, redundant data, etc. There are some unique errors occurred in the TCST database as follows:

- Inconsistent stop names

  A bus stop may have different names in different bus companies. Unfortunately, a unified stop identification is not available in the database. Thus, a labor-intensive stop

name unification process is an important task in the data cleaning process.

- Incorrect and missing timestamps

  A riding record may contains unreasonable timestamps such as (1) reversed timestamp in which the deboarding time is earlier than the boarding time; (2) short traveling time in which a bus moved from one stop to another in an extra high speed; (3) boarding/deboarding in an out-of-service time period; and (4) missing timestamp of either boarding or deboarding. Note that in this study, we skipped the long traveling time error removing at initial data cleaning stage since it requires an intensive cross check with other riding records to determine that an unusual long traveling time record is actually an error or just a traffic jam.

- Incorrect boarding/deboarding stops

  The boarding and deboarding stops must be on the bus route a trip took. It must also be in the order along the route. Unfortunately, there exists such erroneous riding records that do not meet this requirement.

- Missing boarding or deboarding stops and timestamps

  There exists such erroneous riding records that one or both stops of boarding/deboarding is missing. It is interesting to note the number of records with the deboarding stop missing is much higher than the other two types of erroneous riding records, that are most likely caused by machine errors. However, a missing deboarding stop error may actually be the result of a common human error that a passenger may fail to check-in or check-out. The card reader will take the single check as a check-in no matter it is a check-in or check-out.

3. Field Study

To carry out the field study, one of our team members had been taking various bus routes at student commuting time intervals almost every school day since February 2016. Due to the

time limit, only a few bus routes that were crowded with commuting high school students received intensive observation. The first important subject to study is to extract necessary features of student passengers from their journeying behavior. These features are critical for big data analytics due to the previously mentioned explanation that a student may use a full-fare card to take bus. For simplicity, the trip a student took to the school in the morning is called a *school trip* and the trip for going home in the afternoon is called a *home trip*. We have found the following features of student passengers.

1. The arrival times of the most students were concentrated between 7:00 and 7:30 in the morning because most of high schools have their classes begin at 7:30AM.
2. During the period of 7:00 to 7:30 AM, most stores and offices were closed such that non-student passengers only presented a nominal share in those buses that were full of students. In addition, because these student-full buses were often overly crowded during this period, many potential non-student passengers might be scared away. Therefore, with few exceptions, a large proportion of those who deboarded at a bus stop that is near a high school were commuting high school students.
3. High school students would not go to school regularly during winter and summer breaks.
4. Almost every student went to school every school day without absent.
5. Students of the same school might board and deboard the bus at several different stops. Possible reasons include (1) a school is located in the middle of two bus stops; (2) a student might have to buy his/her breakfasts at other stops; and (3) a student might take buses at another stop to avoid crowds.
6. A student tended to deboard a bus at the same stop every morning. Similarly, he/she tended to board a bus at the same stop every afternoon. However, the boarding stop and deboarding stop a student took might not be necessarily the same. The reasons are similar to Feature 5.
7. In order to arrive at the school by the designated time in the morning, a student might try to save time by taking a relatively simple and straightforward bus journey for his/her school trip. However, it is not the case for the home trip in the afternoon. A student might go to a tutorial class, go shopping, etc., before going home.
8. In addition to the well-known Taichung Railway Station, the hotspots for bus commuting by student commuters are the three major stops near Zhongyou Department Store, most likely for bus transfer.

4. Big Data Analytics

To analyze the bus journeying behavior of the students of a specific high school, we must identify the bus stops of most frequently boarding and deboarding by its students before we can analyze it. To save time and resources, we selected only 30 high schools whose names match to the stop names to analyze.

We selected the commuters of a school who deboard at the stops near that school between 6:30-7:30 in the morning to study. A student who took such journey more than 50 days during the period between March and June is called a *main commuter*. Other commuters are called *secondary commuters*. Our study focuses on the main commuters only. Note that, a secondary commuter may actually be a main commuter because he/she may use more than one card in his/her school commuting such that his/her riding frequency doesn't meet the selection criteria.

We calculated the average single trip bus riding time (AvgSTBR time, for short) each main commuter spent. A main commuter who takes more than one hour of AvgSTBR time is called a *super commuter*. The AvgSTBR time of a school is the total AvgSTBR time of all main commuters of that school divided by the total number of its main commuters. For the rest of the paper, we use "time" for AvgSTBR time unless specified.

4.1 Analysis of bus journeying behavior of main commuters

Out of 2384 main commuters, there were only a single digit number of super commuters. The super commuter who took the longest ride in her school trip was a card holder of Taichung Girls' High School, who regularly took Bus 55 from Fengyuan Cultural Village Stop to Taichung Girls' High School Stop for an average of 75 minutes per trip. This has an implication that students may be willing to bear a longer commuting time to enter a high rank school. Excluding super commuters as outliners, we can find that the upper limit of the time spent on a school trip is approximately one hour.

A home trip in the afternoon took more time than its school trip counterpart under the same condition. The longest home trip commuter is the passenger who spent 92 minutes in average

to take Bus 107 from Wufeng Agri. & Ind. High School Stop to Huiwen High School Stop. This is simply that school trips were all made before morning rush hours and home trips were made right in the afternoon rush hours. After a detailed data analysis, it is interesting to see that most super commuters took non-stop direct buses without any transfer in their home trips. For example, a student regularly took Bus 31 from NCHU Agriculture High School Stop directly to Chonghsingling Stop. If he/she made any transfer in his/her long home trip, the AvgSTBR time may approach or even exceed two hours. This is an unbearable waste of time. A high school student with extremely high time pressure might choose boarding rather than commuting.

The following summary excludes super commuters as outliners. For morning school trips, the shortest time is 13 minutes, deboarding at Lingtong High School Stop and the longest time is 30 minutes deboarding at Taichung First High School Stop. For afternoon home trips, the shortest time is 20 minutes boarding at Lingtong High School Stop and Dongshan High School Stop, and the longest time is 35 minutes boarding at Taichung First High School Stop. Unless it is close to the Taichung Train Station, a high school with a very short AvgSTBR time is likely to be a local high school.

Being consistent with our finding in the field study, students spent shortest time by taking relatively simple and straightforward bus journeys for their school trips. In his/her home trip, a student might deboard for other things in the middle of the trip. Except two high schools, Dajia High School and NCHU Agriculture High School, the mean home trip AvgSTBR time of every school is longer and with higher variant than its school trip counterpart. It shows that the traffic situation during home trip hours was more complicated and had more congestions than that of school trip hours.

For those schools that are near a train station, student commuters took buses for their school trips in a more stable and consistent manner than other situations. For example, Fengyuan Commercial High School's mean AvgSTBR time for school trips is 16 minutes with a standard deviation of 11.5, while the mean AvgSTBR time for home trips rose to 27 minutes with a standard deviation of 14.6. Furthermore, the number of home trip riders was also relatively smaller than that of school trips. In addition to the above reasons, students might get to Fengyuan Train Station by walk. It is a good social and shopping time on the way to the Fengyuan Train Station such that students prefer walking together to the train station

instead of taking free buses.

4.2 Bus journeying behavior of main commuters by school

The statistics of the selected 30 high schools is shown in Table 1. Out of these 30 high schools, we selected several high schools according to a variety of the distances away from Taichung Train Station to discuss the bus journeying behavior of their main commuters. Figures 1 to 6 are the distribution of AvgSTBR times of several sample schools. Figure 1 is Fengyuan Commercial High School, which is very close to Fengyuan Train Station. More than 60% of the main commuters took the train or inter-city bus to Fengyuan Bus Terminal and then took Bus 55 to Fengyuan Commercial High School Stop, which is only four short distance stops away from the Fengyuan Bus Terminal. This section of the road had never been congested in the early morning hours, and the bus traveling time remained stable at about 10 minutes. The AvgSTBR time to Fengyuan Commercial High School Stop from another direction was relatively longer with higher variant. The only super commuter of that school is the one who took bus 55 directly from Chonghsingtang Stop to the school.

We selected following three high schools along the route of Bus 100 from Taichung Train Station via Dali and Wufeng to Asia University to analyze: NCHU Agriculture High School (School 1), Youth High School (School 2), and Wufeng Agri. & Ind. High School (School 3) in the ascending order of the distance away from Taichung Train Station. As compared to other alternative routes, the route of Bus 100 is relatively simple and more representative since many bus routes share a common long segment on this route. This simplicity saved us a lot of time to do the field study in the determination of the stops boarded/deboarded by students. The AvgSTBR times for school trips were 20-40 minutes, 10-50 minutes, and 10-60 minutes, respectively. The standard deviations were also higher as the distance away from the train station became farther. However, the number of commuters of School 3 with an AvgSTBR time between 10-20 minutes is greater than that of the other two schools, indicating that School 3 has more flavor of local high school.

People may be interested in the bus journeying behaviors of the students of the two best high schools in the middle part of Taiwan, Taichung First High School and Taichung Girls' Senior High School. Taichung First High School Stop is located at Doubleten Road. The bus density of this section is much lower than that of Sanmin Road, which is just next to Doubleten Road

and is one of the busiest streets in Taichung city. A high percentage of student commuters of Taichung First High School chose to board and deboard at the stops on Sanmin Road. Unfortunately, there are many other types of passengers who chose to do so such that it is very difficult to classify student commuters from riding records. Therefore, we selected less representative commuters that took bus from the stops at Doubleten Road to analyze. Most commuters spend 20-40 minutes for their school and home trips. In contrast, Taichung Girls' High School Stop is about two stops away from the Taichung Train Station, and the traffic on the route is relatively smooth. Many commuters spend less than 10 minutes on the bus per trip, most likely after deboarding from the train station.

5. Concluding Remarks

The high school students in Taiwan are extremely stressful under the severe competition in the college entrance examination. Thus, extra time spent on school commuting is an unbearable burden. In this study, by using both an intensive field study and big data analysis based on the Taichung City Traffic Big Data database, we analyzed the bus journeying behavior of high school students of Taichung City on their commuting trips. The results of the study show that, with a few exceptions, most students ride less than one hour per bus trip. It took less time and more straightforward bus journey to go to school in the morning, while it took more time and transfers in the afternoon. The results of field study and big data analysis confirm each other. The results obtained by the two approaches are quite consistent, which lays an empirical basis for further big data analysis in the future. Due to the huge manpower required for empirical research, it is not possible to execute a full scale field study. In the future, more extensive research that takes more complicate journeys into account will be gradually incorporated to allow a more accurate analysis. Based on our research results, policy makers of the Taichung City government and bus companies could adjust their transportation policies, bus route design, and bus schedules to offer better bus services to the high school students of Taichung City. Our research results are a good reference for other cities of Taiwan and hopefully the cities of other countries.

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Table 1

AvgSTBR time of high school students by school (min.)

Stop Name	*Total Main Commuters*		*Max*		*Mean*		*SD*	
	AM	**PM**	**AM**	**PM**	**AM**	**PM**	**AM**	**PM**
Taichung First	105	109	63	66	30	35	10.8	12.4
Taichung Girls	109	109	75	49	21	25	11.3	10.3
Fengyuan Com	76	76	55	69	16	27	11.5	14.6
NCHU Argri	60	65	67	55	31	28	13.2	11.3
Shinmin	80	84	56	62	29	32	11.3	12.6
Wufeng Agri&Ind	116	116	58	70	29	32	11	12.5
Youth	29	29	59	66	27	31	13.7	13.6
Hongwen	59	59	27	70	15	22	5	8.8
Taichung Ind	103	103	57	55	29	32	9.3	9.2
Mingdao	63	65	61	65	27	31	11.6	11.5
Taichung Sec	73	73	51	54	26	30	11.1	11.1
MingDer	68	68	50	66	25	26	11.8	12.2
Chiayang	67	119	68	82	25	26	13.8	18.1
Dajia	78	83	44	50	25	25	9.7	10.4
Chiaotai	81	85	49	62	25	28	9.9	11.6
Fengyuan	79	85	45	50	24	26	10.7	11.5
Ining	48	48	54	61	24	33	10.5	11.1
Lizen	67	67	56	73	23	27	11.2	12.5
Dajia Ind	42	42	63	55	23	20	14.4	11.7
Cingshuei	84	84	49	65	23	25	10.6	11.8
Tzuming	61	61	50	57	22	27	10	11.7
Wenhua	144	132	42	57	22	27	7.7	9.8
Dali	72	72	50	53	22	26	12.3	11.4
Chungming	62	60	42	43	20	23	7.4	7.7

Changyi	48	48	37	47	19	23	8	9.9
Huiwen	106	137	52	92	18	20	11	11.6
Shalu Ind	105	116	57	38	17	17	9.5	8.5
Shiyuan	57	51	41	53	16	23	8.4	11.4
Dongshan	191	181	51	57	15	20	8.6	10.8
Lingtung	51	51	36	37	13	20	7.7	9.6

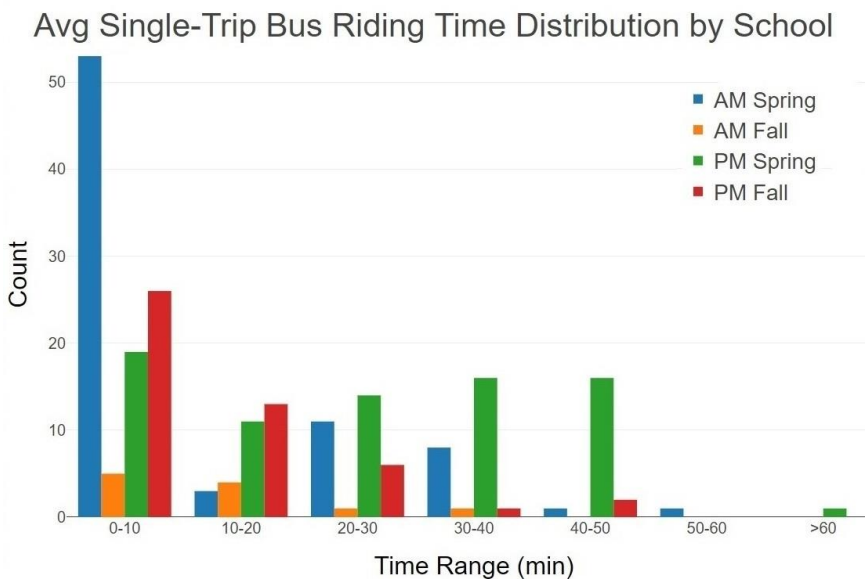

Figure 1

Distribution of AvgSTBR time of Fengyuan Commercial High School

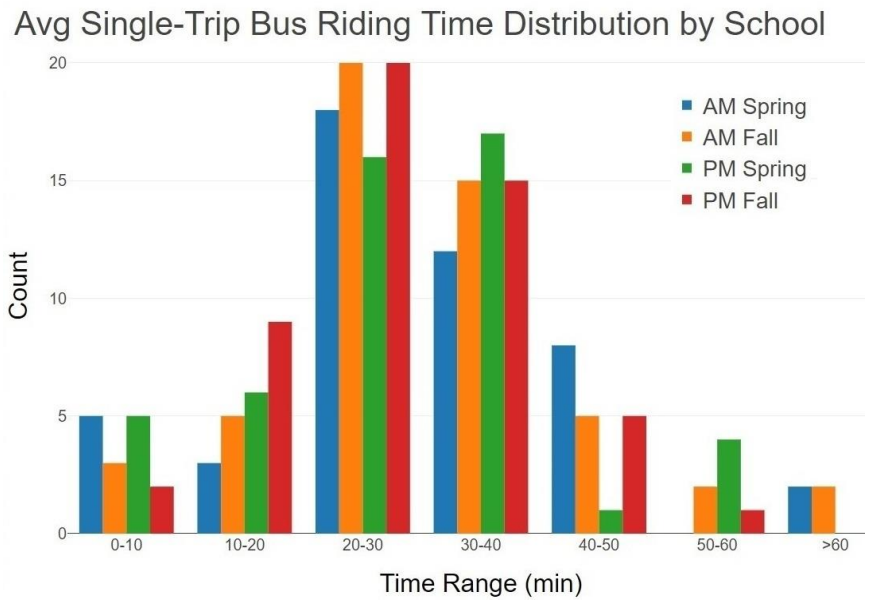

Figure 2

Distribution of AvgSTBR time of NCHU Argriculture High School

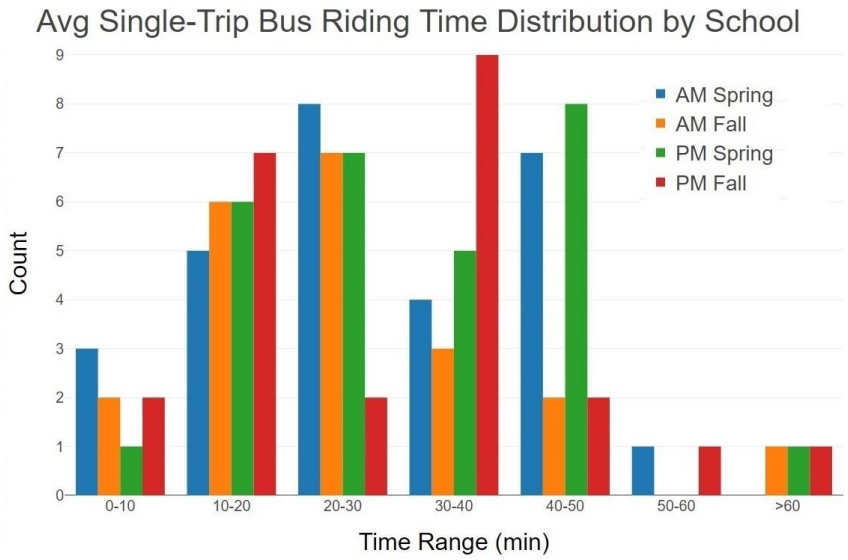

Figure 3

Distribution of AvgSTBR time of Youth High School

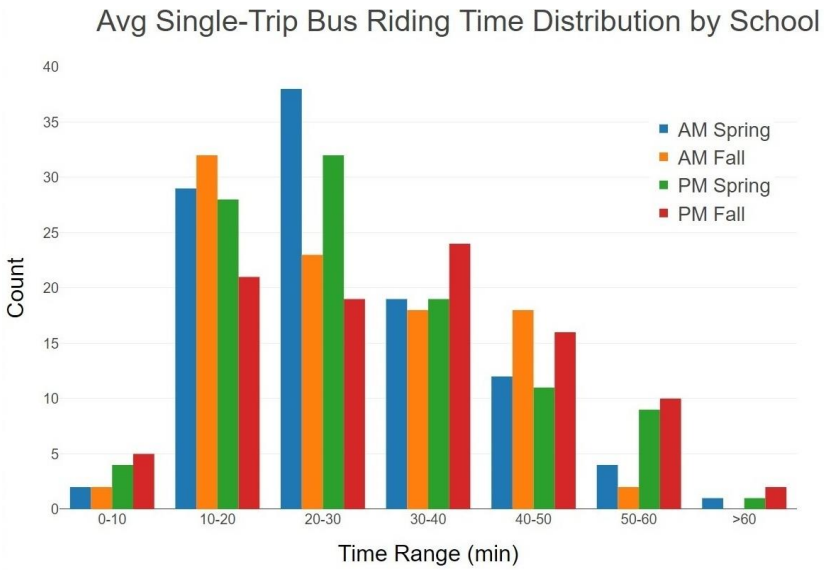

Figure 4

Distribution of AvgSTBR time of Youth High School

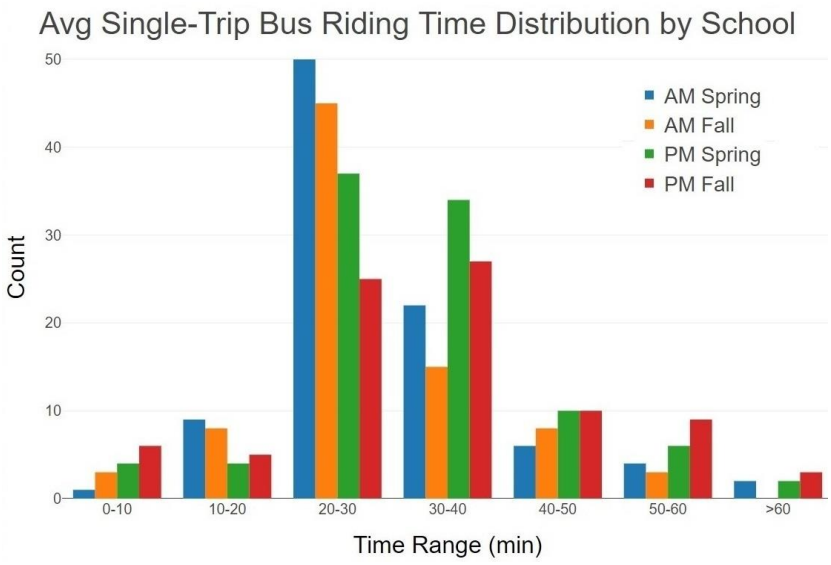

Figure 5

Distribution of AvgSTBR time of Taichung First High School

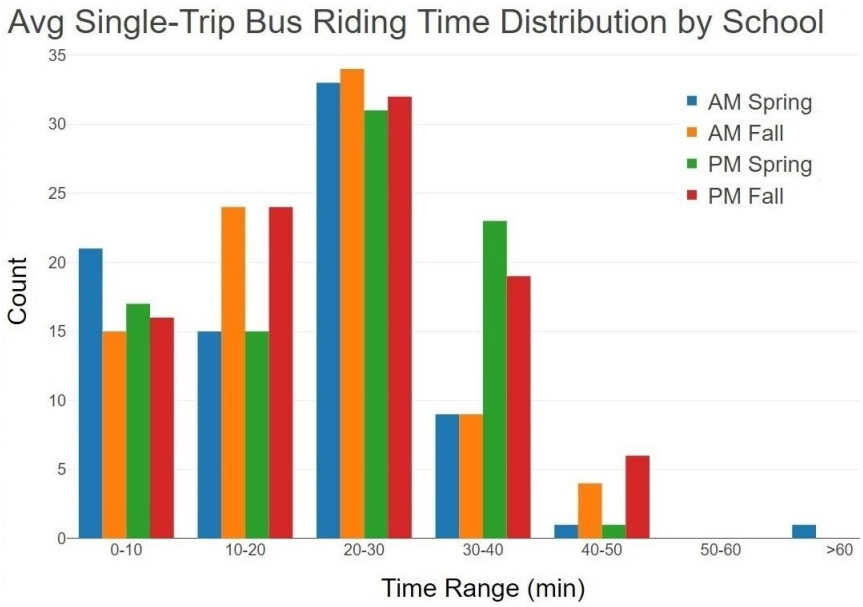

Figure 6

Distribution of AvgSTBR time of Taichung Girls' High School