Original research paper

How toll adjustment affects trip characteristics: big data analysis and experiences of Taipei's public bike system

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Abstract

The bikesharing program in Taiepi, YouBike, adjusted the rental fee from free of charge to NT$5 (about $0.15) for the first 30 min. To understand how the toll adjustment would have changed the trip characteristics, this research collected and processed big data of more than three million YouBike trips before and after the toll adjustment. By applying descriptive statistics and data mining methods, we found 1) The number of trips dropped about 43% on weekends and 14% on weekdays. This indicates that the price elasticity of weekend rentals

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was higher than that on weekday rentals. 2) The peak period, duration, and travel distance were approximately the same, regardless of the toll adjustment. 3) The turnover rate decreased from 9.6 to 7.3 times per day per bike, albeit it is still higher than many bikesharing programs. 4) Most trips had one end next to the MRT stations or schools. This study identified that minor toll adjustment could make a noticeable difference on the bike demand. The current practice of locating YouBike stations by the MRT lines and major trip generation spots had multi-faceted impacts. YouBike offered the first- and last-mile service of MRT, but also replaced some short MRT trips because of time and/or money savings. YouBike additionally provided a transport choice for trips without mass rapid transit (MRT) or bus services. As Taipei YouBike has long been subsidized by the government, it is suggested that 1) innovated business models be adopted for sustainable operation, and 2) more big data be released to the public for research purposes.

Keyword:

public bike, bikesharing, big data, toll adjustment, price elasticity

1 Introduction

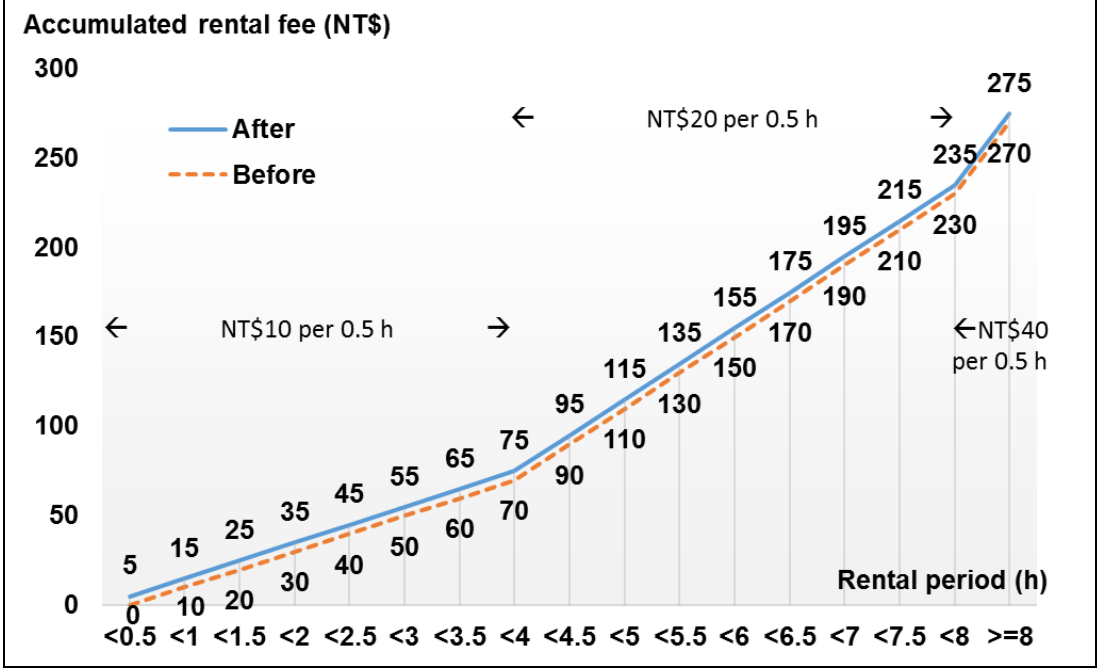
Bikesharing or public bike systems could be regarded as one of the most popular urban transportation initiatives in the last decade. According to the Bikesharing World Map (2017), 1,232 cities have bikesharing programs in operation. access. Heinen *et al*. (2010) indicated bike use affected by various factors from the natural environment (topography, attractive built environments, seasons and weather) to the built scheme (urban form, infrastructures, facilities at work, etc.), socio-economic and psychological conditions (attitudes and social norms, habits, ecological beliefs, etc.), and mode related attributes (cost, travel time, effort and safety). Taipei is of great potential developing urban biking given the flat terrain at the bottom of Taipei Basin, year-long nonfreezing subtropical weather, high population density, gradually completed bike route network, and the rising attitudes towards energy saving and carbon reduction as well as slow-paced life. Meanwhile, as the Taipei MRT network acts as the backbone with the support of extensive city bus services, many transport stations/stops are still too far by walking. The city government believed the public bike system as a possible medium for people to access MRT and buses. In an attempt to make the city more livable and sustainable, in 2009 the city government commissioned Giant, a world famous bike manufacturer headquartered in Taiwan, to run the public bike system—YouBike (Taipei City DOT, 2013a, 2013b).

As of mid-April 2017, there are 687 YouBike stations (320 in Taipei and 367 in New Taipei) in the metropolitan area and over 3.3 million trips per month (YouBike, 2017). The planned

55 amounts of stations/bikes are 400/13,138 in Taipei by December 2018 and 450/14,400 in New
56 Taipei by December 2017. Existing stations are primarily in the 243-km^2 flat bottom of Taipei
57 Basin with the population of 5.8 million. Like most bikesharing programs, Taipei City was free
58 of charge for the first 30 min. Users will be charged NT$10-40 for every additional 30 min
59 afterwards. In response to the user-pays principle, the authority started to charge NT$5 of the
60 start fee since April 2015, as shown in Table 1. It offers a great opportunity to examine the
61 effect of toll adjustment. Fishman *et al*. (2013) indicated that the value for money appears
62 paramount in the public bike members' motivation to use the programs. The new toll structure
63 seems not much different from the old one, but it did make a huge drop of YouBike trips. At the
64 same period, the tolls of the adjacent city, New Taipei, were unchanged (no start fee). Its
65 monthly ridership consistently grew, as shown in Fig. 1. Despite the impact of the start fee, the
66 success of bikesharing in Taipei has shaped biking into an urban fashion that soon spread out
67 to other places. Currently there are 10 public bike systems in operation and some under
68 planning in Taiwan. Local cities, including Changhua and Hsinchu, followed in Taipei's
69 footsteps to charge users NT$5 and NT$10 respectively after implementing a 30-min
70 complimentary period for months. Other cities, although struggling with the huge subsidies for
71 the complimentary 30 min, are hesitating to implement the start fee due to the unknown impact.
72 The study can fill the unanswered gap between the policies with and without start fees.
73

74 **Table 1** YouBike progressive toll structure

Rental Duration	Old policy: 2015.3.31 and before	New policy: 2015.4.1 and after
0.5 h	0	NT$5
0.5-4 h	NT$10 per 30 min	NT$10 per 30 min
4-8 h	NT$20 per 30 min	NT$20 per 30 min
> 8 h	NT$40 per 30 min	NT$40 per 30 min



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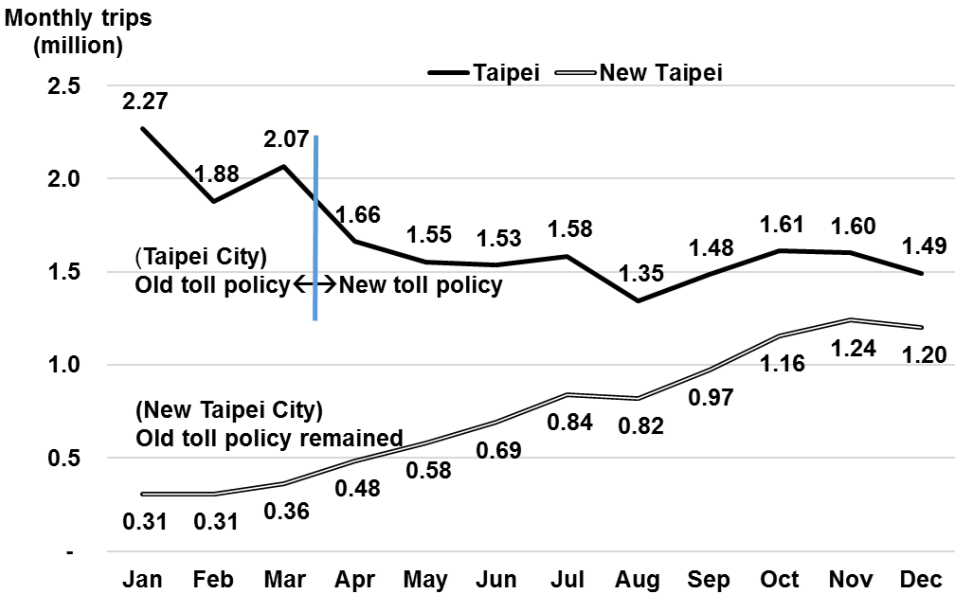


Fig. 1 Monthly YouBike trips in 2015

2 Data and methodology

Many cities periodically release their public bikes' operational data online, such as Divvy in Chicago, Citi Bike in New York, Bay Area Bike Share in San Francisco, and Hubway in Boston, etc. There are two types of operational data. One is station-based data that contain the number of bikes and vacant docks available at certain point of time (e.g., every five minutes). The other is trip-based data that contain the trip duration, start time, stop time, start station, stop station, and costs. Sometimes bike ID and user attributes (gender, membership, and ZIP code) are also available. Station-based data have been used to measure the service quality of bike systems, and spatiotemporal characteristics of bike stations (Chung & Huang, 2016; O'Brien *et al*., 2014; Chung & Chien, 2014; Kaltenbrunner *et al*., 2010; Froehlich *et al*., 2009). Trip-based data have been used to assess the spatiotemporal characteristics of bike trips and

related rental behaviors (Bordagaray *et al*., 2016; Corcorana *et al*., 2014; Berloco & Colonna, 2012; Borgnat *et al*., 2011; Vogel *et al*., 2011). Some research involved both data types, e.g., Zhou (2015) analyzed the station- and trip-based data of the public bike system in Chicago, Divvy. These two data types have strengths and weaknesses that could make a complement to each other. Trip-based data do not reveal the availability of bikes or vacant docks at bike stations. This may cause twisted rental behaviors if there is frequent lack of bikes or docks at certain stations, i.e., users would choose a station nearby or simply cancel the bike trip. On the other hand, station-based data could neither present the origins and destinations (OD) of bike trips, nor such items as the turnover rate, costs, and rental duration. It would be difficult to verify whether the public bikes fulfill the original intention of last- and first-mile service.

This study adopted trip-based data. The Department of Transportation (DOT) of Taipei City offered the two-month dataset with 3,315,691 YouBike trips before (in March 2015) and after (in June 2015) the toll adjustment. Like most trip-based open data of bikesharing programs, our raw data contain such columns as origins, destinations, and duration of each trip. We further associated each trip with two types of data: 1) trip-based rental fees, lengths, and speed; and 2) the corresponding hourly weather information such as temperature and raindrop. It should be noted that the real YouBike trip lengths are unknown. Given the grid network in Taipei, we assume the trip lengths be the summation of longitudinal and latitudinal distances between two ends. Some trips were found to have identical origin and destination

stations; the travel speed would be excluded in this case. Besides, YouBikers may take a break during a long rental period, leading to under-estimated speed. Fortunately, over 75% of the trips were within 30 min. According to our field observation, taking a break or running an enroute errand was not common for those short-time rentals.

This study has three major differences from the previous ones (Bordagaray *et al*., 2016; Corcorana *et al*., 2014, Berloco & Colonna, 2012; Borgnat et al., 2011; Vogel *et al*., 2011) that also used trip-based data. First, the rental fee is a key operational factor but has often been neglected previously. Second, this is unprecedented work to assess the impact of toll adjustment on the public bike operation. Third, our dataset (3.3 million trips) is greater than others (usually tens or hundreds of thousands of trips). Similar to the studies mentioned above, we applied descriptive statistics and data mining methods. Kantardzic (2011) defined that data mining is the search for new, valuable, and nontrivial information in large volumes of data. To verify the co-opetition relationship between YouBike and MRT, the bike trips were classified into distinct types based on their origin and destination stations. The K-means clustering was used to explore the characteristics of different trip groups (Kantardzic, 2011; Roiger & Geatz, 2003).

3 Results and discussion

3.1 Ridership and turnover rate

Given that YouBike was consistently at the scale of 196 stations and 6,406 bikes in Taipei City before and after the toll adjustment, the start fee of NT$5 reduced 43% of the trips and turnover rates on the weekends, 14% on the weekdays, and an average drop of 24% in total, as shown in Table 2. By contrast, the average daily ridership declined 28% in Changhwa when the start fee of NT$5 was applied, and 40% in Hsinchu when the start fee of NT$10 was applied. The declines comply with two principles: First, the greater the fees increase, the more the ridership drops (e.g., Hsinchu's case versus Taipei's or Changhwa's case). Second, the increased fee would cause less impact on the place with better socio-economic condition (e.g., Taipei's case versus Changhwa's case).

The impact of applying the start fee is long-lasting. As of February 2017, Taipei City had 304 stations and 9,970 bikes, the average daily trips were 53,100, higher than June 2015 as 46,923 daily trips, but lower than March 2015 as 61,549 daily trips. The daily turnover rate defined in Eq.(1) fell from 9.6 trips/bike in March 2015 to 7.3 in June 2015, and further to 5.3 in February 2017. Zhao *et al*. (2014) compiled the bike turnover rates of 69 Chinese cities; the rates ranged between 9.5 and 0.7 trips/day. Compared those cities with Taipei, the pre-, post-adjustment, and current turnover rates of YouBike respectively took the 1st, 6th, and 22nd places. Although having been in the leading group, the continuous drop of YouBike turnover rate is a warning sign. This shows that the impact of the start fee remains. Identical results were found in Changhwa and Hsinchu, where the current bike utilization has not yet resumed

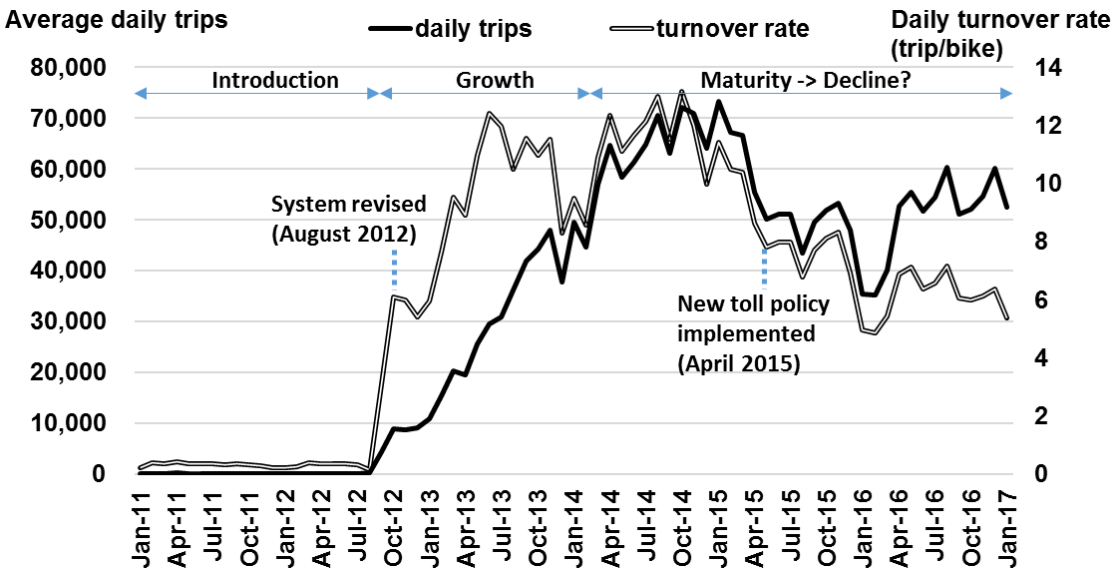
to the pre-adjustment level. Taipei YouBike is moving toward its 9th year of operation. It experienced the introduction and growth stages, and is now in the maturity stage, if not the decline stage, as shown in Fig. 2. More innovated strategies are needed to boost operation.

$$DTR = ADT/N_b \quad (1)$$

where DTR is the daily turnover rate (trips/bike), ADT is the average daily trip, and N_b is the number of bikes, which was 6,406 in March and June 2014, and 9,970 in February 2017.

Table 2 ADT and DTR before and after the toll adjustment

	Attribute	March 2015 a*	June 2015 b*	Drop=1-(b*/a*)
Weekend	Average daily trip (ADT)	72,672	41,414	43%
	Daily turnover rate (DTR)	11.3	6.5	43%
Weekday	Average daily trip (ADT)	56,998	48,926	14%
	Daily turnover rate (DTR)	8.9	7.6	14%
Total	Average daily trip (ADT)	61,549	46,923	24%
	Daily turnover rate (DTR)	9.6	7.3	24%



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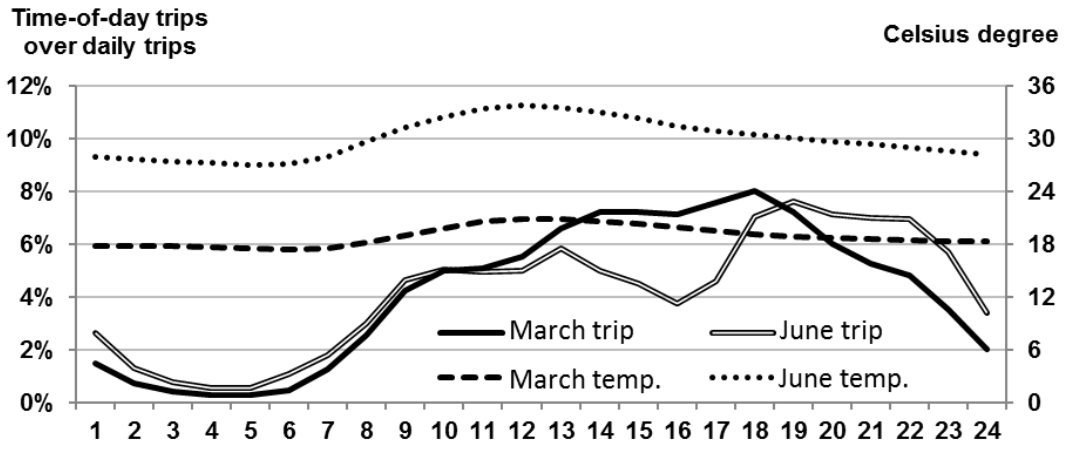
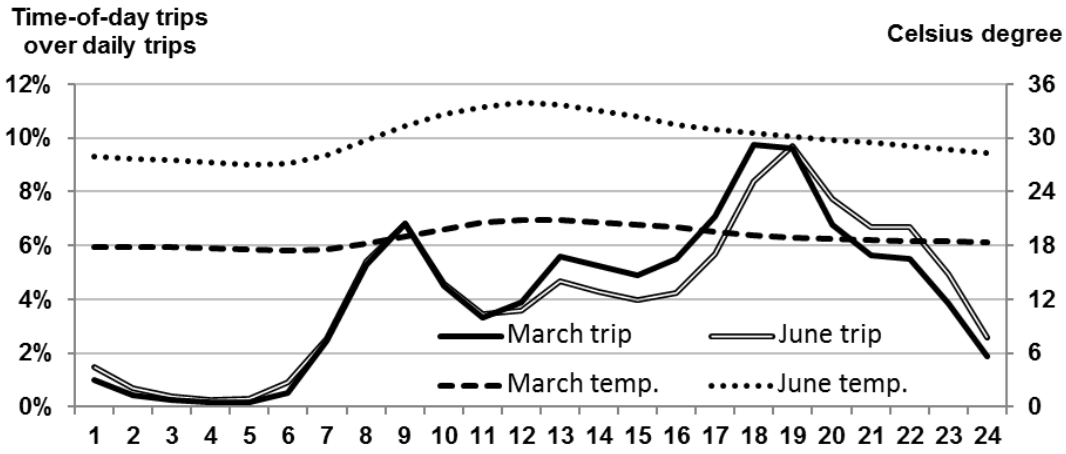
154 **Fig. 2** Daily trips and turnover rate by the month of year

155 *3.2 Trip pattern and price elasticity*

156 In addition to the drop of trips due to the start fee, the time-of-day patterns were different on
157 the weekends, but quite the same during the weekdays, as shown in Fig. 3. Such a result is
158 under expectation because the weekend trips are more flexible. Once the temperature rises
159 over 30 degrees and the daytime becomes longer, people try to prevent sunburns and thus
160 noticeably shift the weekend afternoon peak in March to the expanded evening peak in June.
161 In other words, it was not the start fee but the temperature that influenced the weekend trip
162 patterns. As for the weekday pattern, the working and school hours are relatively fixed, forming
163 the AM and PM peaks as well as a mini noon peak during the lunch break. Similar weekend
164 and weekday patterns were also found elsewhere (Zhou, 2014; Borgnat *et al.*, 2011). Due to
165 the short daytime, the weekday PM pattern in March was about 1 h earlier than that in June.



(a) Weekends



(b) Weekdays

Fig. 3 Time-of-day trip patterns and temperatures

Regardless of the toll adjustment, the majority (over 75%) of rental duration was within the first 30 min, as shown in Table 3. The duration medians of weekends and weekdays were respectively around 14 and 12 min, close to those of Divvy in Chicago (Zhou, 2015). The most popular YouBike sites were still those next to MRT stations or schools. The weekend trips reduced in every rental duration after the start fee took place, indicating that the start fee had kept YouBikers away from unnecessary trips. Some YouBike trips were cancelled or replaced

177 by walk. As YouBike was so popular, lack of bikes at certain stations was not uncommon
178 during the weekend peak hours. It became a concern of the authorities. The rental reduction
179 accidentally extricated the lack-of-bike situation (Taipei City DOT, 2016).

180 Interestingly, the weekdays presented another case. Over 80% of the weekday rental
181 duration was less than 30 min. The start fee reduced short trips, but longer trips surprisingly
182 increased. Again, the reduced weekday short trips might be replaced by walk, if not cancelled.
183 For any trip beyond a reasonable walking distance, as long as riding YouBike is cheaper than
184 taking a bus (with a fare ranging from NT$12 to 15) or MRT (with a start fee of NT$16), some
185 would still choose YouBike. Also, owing to the higher density of bike stations and literarily no
186 waiting time, YouBike stayed competitive. Even so, the YouBike ridership over 30 min should
187 not have grown, or at most remained at the same level in March. As the number of those trips
188 was quite small, any minor factor could cause its fluctuation. For instance, quite a few students
189 started their summer break in June, producing extra bike trips for outdoor activities. This would
190 lift the demand curve upwards that resulted in the growth of bike trips longer than 30 min.

191 Table 3 also shows that very little trips were longer than 1.5 h. Since the progressive toll
192 (see Table 1) will not take place until the fourth hour of rental, the progressive toll is nominally
193 existent but practically ineffective. The authority could consider a shorter time segment to
194 activate the progressive toll should the lack of bikes remain an issue. The price elasticity of
195 demand can be derived from Table 3 and Eq.(2). Regardless of weekends or weekdays, the

majority—the trips within 30 min—were inelastic, albeit the weekend price elasticity (0.3) was greater than the weekday (0.1), and the trips remarkably declined. The toll adjustment brought more impacts on the weekends. A closer look was taken to distinguish how the start fee affected different weekend trips. The bike OD pairs were set into three clusters based on the K-means method, namely A as high demand and short distances, B as median demand and distances, and C as low demand and long distances. Clusters A and B became elastic (1.4 and greater) if the rental duration was more than 30 min. For Cluster C to be elastic, it required the duration more than 1 h. The longer the duration was, the greater elastic each cluster was. Cluster C had the greatest price elasticity (4.0) of all when the duration was between 1.5 and 2 h. In other words, the impact of the start fee would increasingly extend to the period longer than 30 min.

Table 3 Number of daily trips by rental duration

Rental duration	Weekend		Weekday	
	March 2015 a*	June 2015 b*	March 2015 a*	June 2015 b*
< 0.5 h	56,726 (78%)	31,237 (75%)	49,434 (87%)	39,729 (81%)
0.5–1.0 h	8,321 (11%)	5,173 (13%)	4,960 (9%)	5,487 (11%)
1.0–1.5 h	3,079 (4%)	2,117 (5%)	1,324 (2%)	1,777 (4%)
> 1.5 h	4,536 (6%)	2,886 (7%)	1,280 (2%)	1,933 (4%)
Total	72,672 (100%)	41,414 (100%)	56,998 (100%)	48,926 (100%)

$$E = -\frac{(Q_2 - Q_1)/(Q_2 + Q_1)}{(P_2 - P_1)/(P_2 + P_1)} \quad (2)$$

where E is the price elasticity of demand, $Q_1(Q_2)$ is the number of trips before (after) the toll adjustment, and $P_1(P_2)$ refers to the old (new) toll policy.

The estimated bike trip length was on average 1.8-2.0 km, without noticeable differences between the weekends or weekdays, or before or after the toll adjustment. The weekend mean speed varied from 5.5 to 5.6 kph. The weekday mean speed was unsurprisingly higher, at the level between 6.4 and 7.1 kph. This matches the field observation that more people were in a hurry during the weekdays. Another issue comes out: typical bike speed can easily reach 12-15 kph under situations without any interruption. This is, however, not the case in Taipei or other populated city schemes. The dense signalized intersections are one of the reasons for the lower YouBike speed. Although the signals along major streets are synchronized for progressive movement, such green bandwidths are designed based on car speed, which is around 40-50 kph. The synchronized signals do not match the bike speed. Second, the bike lanes are not always exclusive and have to share the right-of-way with scooters or pedestrians, needless to say when the bike lanes are not available. Sometimes even the exclusive bike lanes might be occupied by pedestrians who do not recognize or simply neglect the bike signs or markings. Third, the field observation also found that back-home or weekend riders were more relaxed and enjoyed the “downshifting”. All these factors contribute to a lower speed.

3.3 Co-opetition relationship

228 The original purpose of bikesharing is to offer the last- and first-mile service for public transit.
229 Ideally, the use of scooters—a main concern in Taiwan—may reduce because of YouBike, but
230 unfortunately so may the transit ridership. According to the government statistics and research
231 projects, Fig. 4 shows the average travel distances and costs per trip of seven common urban
232 modes in Taipei. YouBike, buses, MRT, and scooters form a group that meets the short and
233 inexpensive travel demand. This group can be specifically demarcated as the travel distance
234 less than 10-15 km and travel cost less than NT$25-30 in the local transportation scheme. To
235 some extent the four modes within the group compete against and/or complement one another.
236 For example, when buses and MRT are not in operation in the midnight, YouBike becomes an
237 inexpensive alternative in comparison to taxi. During daytime, YouBike is a competitor against
238 MRT/buses on certain trips. YouBike can also be appealing to scooter riders because of such
239 reasons as the exclusive and less congested bike lanes, no need to wear helmets (so as no
240 bad hair days), easy parking, bi-directional movement in the one-way street system, and so on.
241 Fishman *et al*. (2013) pointed out that public bike users demonstrate a greater reluctance to
242 wear helmets that have acted as a deterrent of the programs if wearing helmets is mandatory.
243 On the other hand, as scooters can be as fast as cars, they more likely match the progressive
244 green lights, and riding a scooter requires less physical strength than riding a bike, especially
245 on the slopes. Scooters and YouBike can be day-of-week alternatives. Despite YouBike's
246 co-opetition relation to scooters/buses/MRT, it serves as an additional transport option for the

general public. The private cars and commuter rail are in another group with the travel distance over 15-20 km and cost from NT$30 to 80. Taxi alone forms a group for short but expensive (business) trips.

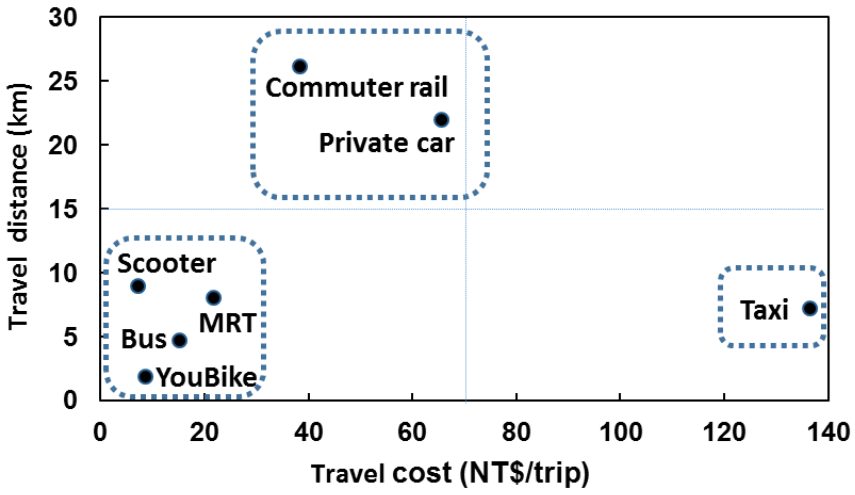


Fig. 4 Travel distances and costs of urban transportation modes

Note: The travel costs of private cars and scooters only include gas, tolls, and parking fees.

To further examine the intermodal relation between YouBike and MRT, the YouBike trips were classified into four types. Types 1 and 2 tend to complement (cooperate with) MRT, Type 3 possesses dual attributes, and Type 4 may be either irrelevant or a complement to MRT, as explained below.

Define that $\begin{cases} O_i^M: \text{origin station } i \text{ next to MRT} \\ O_i^N: \text{origin station } i \text{ not next to MRT} \\ D_j^M: \text{destination station } j \text{ next to MRT} \\ D_j^N: \text{destination station } j \text{ not next to MRT} \end{cases}$ (3)

Type 1: $O_i^M \rightarrow D_j^N$; $O_i^N \rightarrow D_j^M$

YouBike serves as the last- and first-mile mode of MRT.

Type 2: $O_i^N \rightarrow D_j^N, i \neq j$.

YouBike offers another choice of green transport in the area without MRT.

Type 3: $O_i^M \rightarrow D_j^M, i \neq j$.

This type has dual attributes. Depending on time of day (whether the MRT is open or not), YouBike may compete against or complement MRT.

Type 4: $O_i^N \rightarrow D_i^N$; $O_i^M \rightarrow D_i^M$.

YouBike has identical origins and destinations. They may be 1) newly created travel demand, 2) MRT extension service, or 3) originally walk trips that are now replaced by YouBike.

One of the keys to successful public bike systems is the location of bike stations and their relation to trip demand and the public transport system (García-Palomares, 2012; Lin & Yang, 2011). Among the 196 bike stations, 58 were next to the MRT stations, and the rest were close to either such trip attraction sites as public service/commercial buildings, schools, and parks, or such production sites as major communities and mixed land-use areas. Table 4 shows the shares of the four trip types with respect to the number of OD pairs (=196*196=38,416), as well as the weekend and weekday trips before and after the toll adjustment. The city DOT's policy that locates YouBike by MRT stations successfully sustained Type 1 to serve about half (47.4-50.2%) of the total trips, higher than its share of OD pairs (41.6%). In fact, Type 1 bike trips and MRT complement each other. Jäppinena *et al*. (2013) found that a hypothetical public

280 bike system in the Greater Helsinki area in Finland could reduce public transit travel times on
281 average by more than 10%, or some 6 min per each individual trip. They concluded that such
282 bikesharing potentially increases the competitiveness and attractiveness of sustainable modes
283 of urban transport and thus helps cities to promote sustainable daily mobility.

284 The second largest trips were Type 2 that accounted for 27-29% of the total trips, albeit
285 its share of OD pairs was up 49.2%, of which 55% were longer than 6 km. Since the average
286 bike speed was only around 6 kph, those long-distance OD pairs in Type 2 were not popular by
287 YouBikers. This presented that the first- and last-mile service of Type 1 was more significant
288 than the long-haul service of Type 2. No matter on the weekends or weekdays, the trip shares
289 of Types 1 and 2 were not noticeably affected by the toll adjustment. Lin *et al.* (2017)
290 conducted a stated preference survey on Taipei MRT passengers regarding their choice of
291 using YouBike as a transfer mode, i.e., the Type 1 trips here. They found that Type 1 was
292 highly dependent on the start fee and the its period (30 min in this study), not the variable fee
293 afterwards. Irregular Type 1 riders were more sensitive to the start fee and regular riders were
294 more sensitive to the start period. Although our data could not identify regular or irregular
295 riders, it is reasonable that the variable fee (after 30 min) was not a major concern since over
296 80% of the trips were within 30 min.

297 **Table 4** YouBike's share by different trip types

Trip type	No. of OD	Weekend trip share (%)	Weekday trip share (%)

	pairs (%)	March 2015	June 2015	March 2015	June 2015
Type 1	16,008 (41.6)	(47.7)	(47.4)	(50.2)	(49.4)
Type 2	18,906 (49.2)	(27.0)	(27.0)	(28.8)	(28.6)
Type 3	3,306 (8.6)	(12.7)	(10.8)	(11.4)	(10.2)
Type 4	196 (0.5)	(12.6)	(14.8)	(9.7)	(11.8)
Total	38,416 (100.0)	(100.0)	(100.0)	(100.0)	(100.0)

298

299 Fig. 2 has shown the relatively low ridership of YouBike during 0:00-6:00 am (when the
300 MRT was closed). Type 3 was thus more a competitor than a complement to MRT. The top 10
301 MRT trips replaced by YouBike are shown in Fig. 5; for those short and indirect MRT trips,
302 YouBike is a competitive alternative that saves money and time (no need to transfer, wait, and
303 go up or down when taking MRT). Some trips in Fig. 5 were bidirectional, indicating that people
304 may alternately take MRT and YouBike for a round trip. The competitiveness of YouBike over
305 MRT, however, was mitigated by the start fee of NT$5. The trip share of Type 3 on the
306 weekends dropped from 12.7% to 10.8%—a decline rate of 15.0%; that on the weekdays
307 dropped from 11.4% to 10.2%—a decline rate of 10.5%. Should the start fee be raised to a
308 higher level in the future (for example, the start fee in Hsinchu is NT$10), the decline rate of
309 Type 3 is expected to be greater than other types.

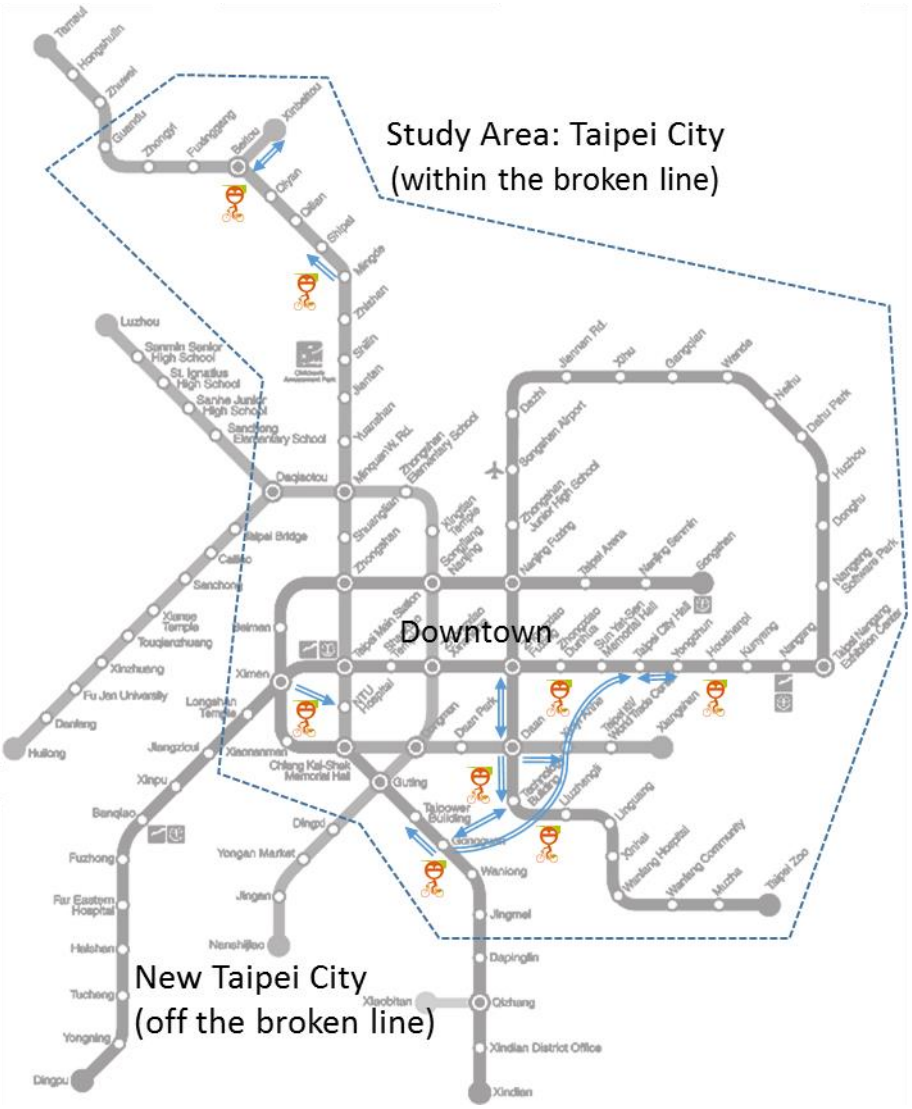


Fig. 5 Top 10 YouBike trips of Type 3: how YouBike competes against MRT

As for Type 4, the share of its OD pairs was only 0.5%, but the trip shares were as high as 9.7-14.8%. The city DOT defines the rentals completed within 5 min at the same station as failures due to a flawed bike being checked out. Such trips were excluded in Type 4. The top 10 stations of Type 4 were primarily by the universities (where YouBike was used to substitute some walk or even scooter trips when the students ran an errand nearby), or by the scenic spots (where the visitors had a choice of bike riding). Since some scenic spots were next to the MRT, it formed another cooperative model between MRT and YouBike, i.e., people take MRT

319 to a scenic spot that offers a bike tour. In addition, based on the field observation, it was also
320 popular for people who live by YouBike stations to have a short bike ride alone or with the
321 family members around their neighborhood. In this case, some of the Type 4 trips were newly
322 created as riding YouBike had become a way of life. The start fee did not stop the trip share of
323 Type 4 from growing.

324 4 Conclusions

325 As a follow-up research of bikesharing operations assessment (Chung and Huang, 2016), this
326 paper analyzed over three million of YouBike trips. We found that small adjustment on the
327 rental fee could make a huge drop on the bike ridership. It reminds the authorities that pricing
328 is a powerful tool in transportation management, albeit raising prices is politically unpopular.
329 The last- and first-mile service remains the most important function of YouBike, while special
330 attention is needed—YouBike could potentially compete against MRT, forming the co-opetition
331 relationship. Due to certain concerns of the authorities, the raw open data did not include the
332 whole trip chain. The upstream and downstream trips of YouBikers were thus unknown. Such
333 basic information as riding frequency cannot be retrieved either. It is suggested that more data
334 items be open to the public for research purposes. YouBike, MRT, buses, and scooters were
335 identified as an inexpensive mode properly for middle- to short-distance urban travel. This
336 study primarily targeted the relationship of YouBike and MRT. Future research can focus on

337 the intermodal relationship between bikesharing, buses, and even scooters.

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