A Study on the Improvement of Public Bicycle Services
Focused on South Korean Cases

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Abstract: This study analyzes public bicycle service trends in Korea. First, several cases of small Korean cities with the highest number of public bicycles were researched. The research results showed that bicycles were used 2,152 times a day with an average of 69 min spent on using the vehicle. Second, the public bicycle service in Daejeon, a metropolitan in Korea, was analyzed. Factors considered in the utilization rate of bicycles were neighboring schools, subway stations, and parks. When calculating the expected utilization rate, ten stations with low usage were assumed to be relocated. In this case, it was confirmed that the utilization rate increased by 34.00%.

1 INTRODUCTION

Korea introduced its first public bicycle service in October 2008 after benchmarking the 'Velib' system of France. The service was launched in Changwon, a regional city with 500,000 residents (S. W. Ha., 2011). Situated on a flatland with few hills, Changwon is Korea's first planned city where people live relatively close to their workplaces. First, the local government installed and operated public bicycle service; however, now a subordinate public entity is responsible for its maintenance and operation. As the city received credit for its successful public bicycle service, other local governments began to introduce such services in their own regions. Currently, 45 local governments provide 12,453 bicycles for the public through such services. Local governments can enjoy many benefits when their citizens use public bicycles often (D. J. Kim, et al., 2014), which include: fewer cars on the road resulting in improved traffic flow (C. R. Ye, 2011), significant reduction in CO2 emissions (H. J. Kwak, K. S. Jung, 2008), healthier citizens due to continual use of bicycles resulting in reduced public health expenditures, and many more. Comparing the number of patients visiting hospitals during the period of introducing public bicycle in each city provides an interesting result. In Changwon, the rate of patient increase decreased to 0.67% in 2009 from 1.79% in 2008 when public bicycle was introduced. In Ansan, the rate reduced to 0.98% in 2013 from 1.67% in 2012 (Korea Index website). If you look at the rate of Daejeon which is the object of this research, it is more reliable. In Daejeon, the rate was -3.73% in 2012 from 5.92% in 2011 (as shown in Fig. 1). It's improbable to conclude that public bicycles directly reduce the number of patients in cities. However, it is well known that regular exercise is good for health (Centers for Disease Control and Prevention website), and no one can deny that public bicycle service has positive effect in regular exercising.

Therefore, policies encouraging more citizens to use the service should be established. Public bicycles can replace short-distance transportation so long as the flow of human traffic is considered when installing and operating bicycle stations to optimize utilization. In Korea, public bicycle stations are mainly located in public sites or areas with large floating populations (J. Y. Lee, et al., 2012). When stations attract more users, more bicycle stands are installed to cope with the increase in usage. In consideration of the installation of a new station, citizens' demand is still a top priority, along with population flow and the feasibility of using a particular site. Today, existing public data can be used to compute an appropriate station location, including many studies on the improvement of the functioning public bicycle services (J. T. Wong, C. Y. Cheng, 2015; S. Wada, et al., 2013; C. Etienne, O. Latifa, 2014; M. B. Iderlina, 2015; S. Y. Han, et al., 2013). This allows the calculation of a proper station location by putting variables together. The purpose of

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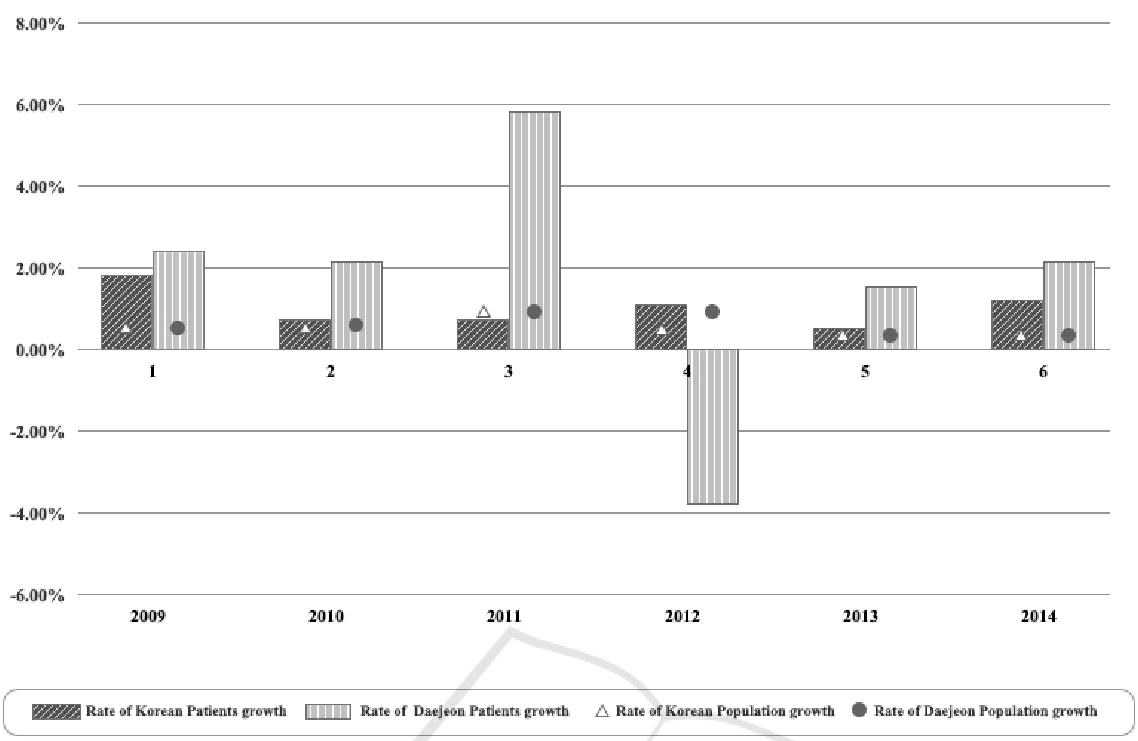

Figure 1: Rate of changes in patients in Daejeon.

this study is to determine where to locate new stations by using the existing public data and the way to change existing locations.

2 PUBLIC BICYCLE-SHARING IN KOREA

After the initial launch in Changwon in 2008, the public bicycle service is now being operated by 45 local governments with a constant increase in service adoption. As part of the central government's bicycle use promotion initiative launched in 2009, 45,675 km of cycle tracks have been constructed in South Korea (Bicycle Happy Sharing website). Today, bicycle lanes play an active role in providing roads for commuters in downtowns. Hiking and commuting courses have been built to connect cities. Bicycle paths now serve as arteries that allow bicycle users to travel to most of the cities in the country (as shown in Fig. 2).

Table 1: Public Bicycle Services of Several South Korean Cities.

City	Service Start Date	Number of Bicycles In Operation
Daejeon	OCT. 2011	2,615
Changwon	AUG. 2008	16,611
Ansan	SEP. 2012	5,646

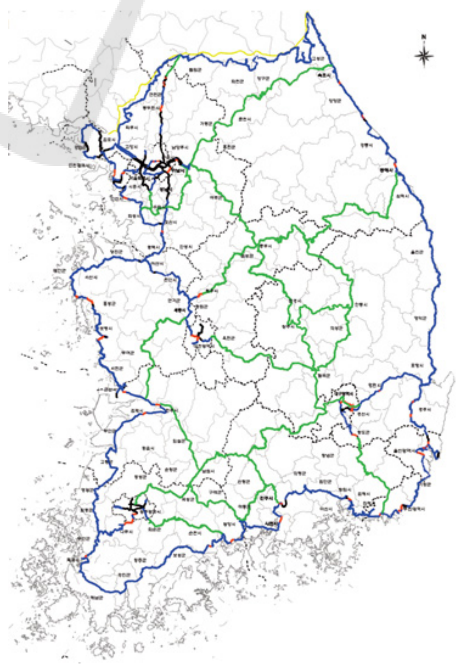

Figure 2: Bikeways of Korea.

Table 1 shows local governments that operate more than 200 public bicycles. In most of the cases, smart phones are used to rent and return the bicycles. Financial resources for operations are obtained from bicycle rental fees, advertising revenues and health management funds (J. Lee, et al., 2011). Since users are highly satisfied with the service in most of the cities, other local governments are considering the introduction of the service and establishing infrastructures required for cycle lanes (S. J. Choi, 2011).

3 DATA AND METHODOLOGY

Daejeon, a metropolitan in Korea, was chosen as a study subject. The city's public bicycle service called "Tashu" was analyzed. Data accumulated for three years from 2013 to 2014 were used for the analysis. Factors affecting the use of public bicycles were selected and structural equation modeling was used to forecast the influences of and demands for the bicycles. Neighboring schools, subway stations, and parks, and the population of residences were chosen as the factors, in consideration of the factors suggested in preceding research (M. G. Javier, et al., 2013; N. Gast, et al., 2015; J. T. Pai, S. Y. Pai, 2015; Y. C. Yoon, B. Y. Cho, 2014). This research calculates the expected rate of utilization by using methods below. Factors used for this research are subway stations, schools and parks. Select 8 local candidates to find new a' where the rate of Point a increases. Each point is named a1 to a8. Each local candidate is located 0, 45, 90, 135, 180, 225, 270 and 315 degrees from north-up direction of points where Point a to d moves (as shown in Fig. 3). At this point, Distance d is (station.average)/4 of station distance. This is due to opinions of public bicycle team of Daejeon city. The team didn't want moving too far from the original stations. Each expected rate of utilization was calculated from a1 to a8, and factors used are as follows.

distance.subway(d.su) : Distance to the nearest subway station from Point a
distance.school(d.sc) : Distance to the nearest school from Point a
distance.park(d.pa) : Distance to the nearest park from Point a
influence.subway(i.su) : Influence of subway
influence.school(i.sc) : Influence of school
influence.park(i.pa) : Influence of park
distance.average(d.av) : Average moving distance of users
station.average(s.av) : Average distance between stations
distance.subway1~8 : Distance to the nearest subway station from Point a1 to 8
distance.school1~8 : Distance to the nearest school from Point a1 to 8
distance.park1~8 : Distance to the nearest park from Point a1 to 8
Original.Number(o.nb) : Original Number of Bicycles Rented
New.Number(n.nb) : New Number of Bicycles Rented

((distance.average - distance.subway)influence.subway + (distance.average - distance.school) influence.school + (distance.average - distance.park) influence.park) : Original.Number = ((distance.average - distance.subway1) influence.subway + (distance.average - distance.school1) influence.school + (distance.average - distance.park1) influence.park) : New.Number *(f.1)*

Therefore,

n.nb1 = (((d.av- d.su) i.su + (d.av- d.sc) i.sc + (d.av- d.pa) i.pa) ((d.av- d.su1) i.su + (d.av- d.sc1) i.sc + (d.av- d.pa1) i.pa)) / o.nb (*f.2*)

However, when distance.subway, distance.school, distance.park are bigger than distance.average, use distance.subway, distance.school, distance.park for distance.average.

Figure 3: local candidates of stations.

4 RESULTS

Data related to the use of 202 stations provided by the Daejeon city were analyzed. On average, public bicycles were used 2,152 times a day with an average rental time of 69 min (Daejeon Public Bike website). The utilization rate during weekends was registered 14.85% while weekdays witnessed an increased rate of 85.15%. When the daily average was compared for weekends and weekdays, the daily average during weekdays was higher with 401 more occurrences of rental cases. By seasons, spring (April, May and June) recorded the highest rate with 34.40% whereas winter (December, January and February) had the lowest utilization rate of 10.58% (Table 2.). This means that different weather conditions in the two seasons affect the frequency of bicycle use (D. J. Kim, et al., 2012). The time of a day when public bicycles are used most frequently is 6 PM followed by 8 AM during weekdays (Table 3.). This suggests that weekday users use 'Tashu' for commuting to work or school, while weekend users use the service for leisure activities.

Table 4 shows the analysis of how often users return public bicycles to stations different from where they were rented. Bicycle traffic to schools, parks, and subway stations are as follows: traffic into and out of schools was 32.14% and 59.02% in the morning, respectively, while traffic into and out of subway stations was registered at 28.29% and 24.47%, respectively, in the morning. By contrast, in the afternoon, bicycle traffic into and out of schools was 67.86% and 40.98, respectively, and subway stations saw bicycle traffic flow in of 71.71% and flow out of 75.53%, respectively. It was confirmed that public bicycles are mostly used as a means to commute to work or schools. Public bicycles' traffic to and from parks was recorded to be 19.51% and 19.04% in the morning, respectively, while that in the afternoon was 80.49% and 80.96%, respectively, showing little difference between inflows and outflows.

To predict demand, factors affecting demand and the frequency of use should be compared. The three factors selected as shown above were set as independent variables and the frequency of use was adopted as dependent variables when structural equation modeling was used for analysis. When it comes to standardized path coefficients, 'frequency of use ← distances to neighboring schools' was 0.499, 'frequency of use ← distances to subway stations' 0.879, and 'frequency of use ← distances to

Table 2: Monthly Rental Frequency Average (2014-2015).

Month	JAN.	FEB.	MAR.	APR.	MAY	JUN.
Number of Bicycles Rented	23,156	29,460	57,101	80,005	100,877	89,332
Percentage Out of the Year	2.95%	3.75%	7.27%	10.18%	12.84%	11.37%
Month	**JUL.**	**AUG.**	**SEP.**	**OCT.**	**NOV.**	**DEC.**
Number of Bicycles Rented	87,778	61,071	80,225	88,044	58,013	30,526
Percentage Out of the Year	11.17%	7.77%	10.21%	11.21%	7.38%	3.89%

Table 3: Daily Rental Frequency Average by Time (2013-2014, unit: %).

Time	**12AM**	**1AM**	**2AM**	**3AM**	**4AM**	**5AM**	**6AM**	**7AM**	**8AM**	**9AM**	**10AM**	**11AM**
Weekday Percentage (per day)	0.80	0.07	0.01	0.00	0.00	0.88	1.52	4.61	8.99	4.55	3.33	3.25
Weekend Percentage (per day)	1.18	0.10	0.02	0.01	0.00	0.71	1.07	1.95	3.54	4.18	3.87	4.20
Time	**12PM**	**1PM**	**2PM**	**3PM**	**4PM**	**5PM**	**6PM**	**7PM**	**8PM**	**9PM**	**10PM**	**11PM**
Weekday Percentage (per day)	4.02	4.19	4.16	4.61	5.17	6.79	10.85	7.57	6.19	6.60	6.46	5.38
Weekend Percentage (per day)	5.43	6.01	6.39	6.70	6.93	7.90	7.97	6.83	6.52	6.53	6.24	5.70

Table 4: Rental Percentage of Bicycles per Major Area(unit: %).

Area	**Percentage of Bicycles being Returned**		**Percentage of Bicycles being Rented Out**	
	AM	**PM**	**AM**	**PM**
Stations Located Near Schools	32.14	67.86	59.02	40.98
Stations Located Near Subway Stations	28.29	71.71	24.47	75.53
Stations Located Near Parks	19.51	80.49	19.04	80.96

parks' was 0.572. 'The population of residences' was did not affect the frequency of use.

Many studies have proposed algorithms that can be applied to forecast frequency rates (Y. Seo, et al., 2015; L. Chen, et al., 2015; Y. Li, et al., 2015; Y. S. Noh, M. S. Do, 2014). This study, by contrast, adopts a verified standardized path coefficient to predict the usage frequency of new stations to be installed. It is possible to calculate projected frequency rates by using three independent variables that can affect the rates. The formula used here is f-2. The same method was applied to the calculation of the relocation of the five least used stations. The result is shown in Table 5. It was estimated that the relocation would increase the overall usage rate by 34.00%.

Table 5: Daily Simulation Results of Bicycles Usage Frequency Depending on Original and Moved Location (2013-2015).

Station ID	**Original Station Location**	**Moved Station Location**
027	28	39
059	32	45
129	58	93
007	63	75
157	69	83

5 DISCUSSION

Koreans relatively do more exercising, but when considering those in their 30s and 40s who are major participants of economic activities, it is problematic. As they are busy with their work and due to lack of time, 60% of them never exercise (Korea Index website). Bicycle commuting easily provides them time to exercise. This is the most positive effect of public bicycle service.

This research removes complex factors and uses methods to increase the rate of utilization in a simple way. However, the research to determine station location is not that simple. There are a lot of complex factors to be considered. The endless complexity can be calculated with the development of computers. Therefore, additional research to compare the method used in this research with methods with complex factors used is required. Simpler method can provide more certain results. That is why the method to increase the rate of utilizing public bicycle service confirmed in this research is very useful. We can search new stations where the rate of utilization is expected with analysis considering 3 factors. More accurate prediction is possible when adding factors including floating population, income levels, gender and ages. When measuring the actual utilization rate of stations with possibility of new installation or relocation and applying correction value to algorithm of this research, more effective results can be provided. Cities planning to introduce public bicycle service can use methods to determine station location suggested by this research. They can select points expected to have high rate of utilization after first installation and locate stations. positive effect of public bicycle service.

Mountainous areas account for more than 80% of Korea, and the favorite exercise for Koreans is hiking (Ministry of Culture, Sports and Tourism, 2013). The next popular exercise is walking. They do exercise that they can easily enjoy, and riding bicycle is also easy. However, there are many slopes in old cities, and the structure of roads are inconvinient to ride bicycles. Bicycle roads have been built in planning stages of new towns, and in old cities, the roads are mandatory for redevelopment. The Government is pushing forward with a national project to connect all cities with bicycle roads, and bicycle use will continue to increase in Korea (Ministry of Land, Infrastructure and Transport website).

6 CONCLUSIONS

This study suggested measures to relocate ten public bicycle stations currently being operated in the Daejeon city. The relocation is projected to increase the frequency from the current 250 to 335. In addition, if ten more stations are installed, 85 additional occurrences of bicycle use can be expected, which would increase the frequency by 34.00%. The values were statistically estimated without considering the operating workforce, budgets, or influences among stations. Field tests will be required for correct comparison and verification. Therefore, this study proposes, first, a preliminary analysis of new locations for the stations. Second, it is suggested that the relocation method proposed in this study be applied to the field to verify the results, and then a follow-up study be conducted to check if actual changes are made to the public bicycle service.

We make an inquiry to a public servant involved in public bicycle service. What are the standards of selecting stations? The answer was possible areas and places without complaints which are based on administrative convenience. As a result, stations are installed at places with low utilization rate and public resources are wasted. Basic simulation to determine installation points is required. In addition, algorithm to select station location by comparing the actual rate and expected rate of utilization after operation should be improved.

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