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# Relational Analysis Between Subway Ridership and Spatial Characteristics of Station Areas in Daejeon

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**Abstract:** The purpose of this study is to analyze the relationship between the number of users and land use of 22 subway stations of Daejeon city Urban Railway Line 1. The main results of the study are summarized as follows. First in Daejeon City subway station area, there is a large difference in the number of buildings and the number of floors per building and most of the total residential floor area is high. Second as a result of multiple regression analysis for all 22 stations, 'bus route number' and 'sales service, service (total floor area)' were analyzed as the main influencing factors on the number of users. Lastly, the influence of the number of bus routes on weekends was higher than that of weekdays. As the station area is an important space that can lead to new changes or revitalization in the city, it should be applied to urban maintenance and management strategies in the local cities.

**Key words:** Wireless subway station area, subway ridership, land use, building use, bus route number, station

## INTRODUCTION

**Background and purpose:** Recent urban planning and management is being promoted as an energy-saving urban spatial structure that responds to climate change, a strategic transformation centered on urban maintenance and management and a center for public transportation-oriented urban development. Among these, Transit-Oriented Development (TOD) is a development method that develops high-density and complex neighborhoods of public transportation nodes and creates a pedestrian-friendly environment to create space for public transportation and walking center (Kim and Lee, 2010; Lee and Yun, 2014).

It is also closely related to the energy-saving development method in terms of reducing energy consumption and minimizing environmental pollution by restricting the use of cars. In Korea, the construction of new cities and the expansion of newly developed cities have been actively carried out. Recently, however, urban management and regeneration focused management methods have become major issues and the contents of the comprehensive city plan and management plan established by local governments are actively reflected those issues. In this process, the space that is attracting attention in connection with Transit-Oriented Development (TOD) is the 'station area'. The station area can be a space for activating existing urban areas and providing more strategic maintenance effects.

This study aims to investigate the relationship between the number of users of Daejeon metropolitan railway station and the land use pattern of station area as a preliminary work to promote the station area. This study will explore the relationship between the demand for station area use and the spatial influencing factors to find ways to promote the utilization of public transport (urban railway) and the activation of subway station area in Daejeon city.

### Literature review

**Formation and importance of station area:** Urban railways (subways) are perceived as a major public transportation infrastructure because they run on time and are capable of mass transportation compared to other public transportation. In Korea, the urban railway (subway) was constructed only in some large cities such as Seoul and Busan until the 1990's. However, after the 2000s, urban railways were expanded in the metropolitan areas such as Gwangju and Daejeon.

The station area is the central space where the city activities are concentrated and the main nodal point. When the public transportation axes of the city are improved and the promotion of use is promoted, the

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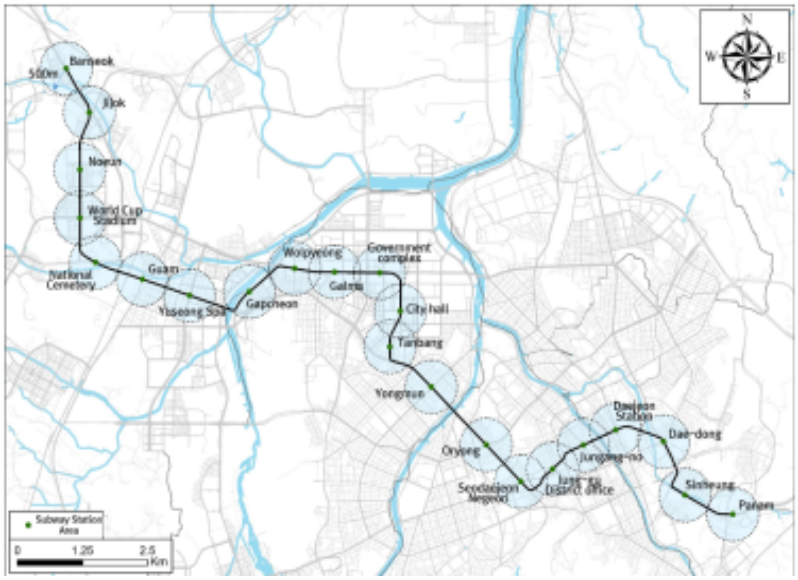


Fig. 1: Location map of Daejeon city Urban Railway Line

station area can be utilized as a space that can be linked with local revitalization. The station area plays a role as the center of the each living zone unit according to its location and function. It is known that the formation of the station area has a close influence on the change of the urban spatial structure and the promotion of the development of the surrounding area.

The station area is known to lead to the change or activation of existing commercial areas and also to the formation of new commercial areas. Ahn and Park (2011) showed that the opening of the railway affected the spatial change of the urban station area. Ji *et al*. (2013) showed that the probability of changing the use of the land located on wide roads after the opening of the urban railway was high. In the station area, there are various activity patterns according to the location or the space condition. There have been a lot of researches on the type of urban railway station in consideration of usage behavior, land use characteristics and network. These attempts to classify urban railway stations can provide an appropriate direction for effective management of public transportation and effective utilization of urban space.

**Relation between urban railway use and land use:** The recent development trend for the revitalization of the station area is to promote the revitalization of the surrounding area through the enhancement of public transportation use. In the meantime, many researches such as Kim and Lee (2010), Shon and Kim (2011), Lee and Yun (2014) showed that the increase of station area density and activation are highly correlated with the increase of urban railway usage. In particular, Shon and Kim (2011) showed that the high-density development pattern of the station area varies depending on the urban scale, mixed residential and non-residential patterns and also found that density, land use mix and urban design factors have some effects on inducing public transportation use. In order to effectively achieve the two objectives of improving public transport use and regional revitalization, it is necessary to closely examine characteristics of station area in consideration of the conditions of each city and to make customized urban maintenance strategies in accordance with the characteristics.

## MATERIALS AND METHODS

**Scope and method:** In order to conduct the research, it is necessary to set the extent of station area. In this study, the radius of 500 m is set as the analysis range based on the results of the previous studies. Figure 1 shows the 22 stations of Daejeon city Urban Railway Line 1 which is the subject of analysis.

The analysis data are divided into building related data and the number of urban railway users. The data related to the building are used to identify characteristics of the space in the station area and include usage area and density. The number of urban railway users is based on 2016 and the number of users is divided into week days and weekends. In addition, the road area, the number of bus routes and the resident population used in the analysis were investigated and arranged according to the

Table 1: Building status by station area

| Station name | Number of buildings | Average number of floors | Floor area ratio (%) | Floor area ($m^2$) Total | Floor area ($m^2$) Average |
|---|---|---|---|---|---|
| Panam | 335 | 2.7 | 43.9 | 345,198 | 1,030.4 |
| Sinheung | 1.576 | 1.8 | 52.7 | 413,346 | 262.3 |
| Dae-dong | 1.487 | 1.9 | 62.3 | 485,544 | 326.5 |
| Daejeon Station | 969 | 2.3 | 82.6 | 577,141 | 595.6 |
| Jungang-no | 1.117 | 3.2 | 148.9 | 961,240 | 860.6 |
| Jung-gu District Office | 1.001 | 2.6 | 103.1 | 655,073 | 654.4 |
| Seodaejeon Negeori | 639 | 4.0 | 175.4 | 1,211,167 | 1,895.4 |
| Oryong | 1.311 | 2.3 | 92.6 | 719,774 | 549.0 |
| Yongmun | **1.619** | 2.7 | 127.2 | 995,231 | 614.7 |
| Tanbang | 585 | 4.3 | 204.4 | 1,453,526 | 2,484.7 |
| City hall | 214 | 7.9 | 219.3 | 1,479,639 | 6,914.2 |
| Government Complex | 88 | **8.0** | 156.3 | 1,136,301 | **12,912.5** |
| Galma | 373 | 5.3 | 155.3 | 1,106,784 | 2,967.2 |
| Wolpyeong | 670 | 4.0 | 118.2 | 865,728 | 1,292.1 |
| Gapcheon | 585 | 3.4 | 84.4 | 661,188 | 1,130.2 |
| Yuseong Spa | 1.008 | 3.8 | **256.3** | **2,001,242** | 1,985.4 |
| Guam | 1.323 | 2.5 | 78.3 | 607,674 | 459.3 |
| National Cemetery | 292 | 1.3 | 5.5 | 41,956 | 143.7 |
| World Cup Stadium | 782 | 3.9 | 147.1 | 1,106,353 | 1,414.8 |
| Noeun | 655 | 6.7 | 250.6 | 1,934,436 | 2,953.3 |
| Jijok | 501 | 4.3 | 137.7 | 1,070,216 | 2,136.2 |
| Banseok | 465 | 6.4 | 135.4 | 1,052,667 | 2,263.8 |

Bold values are significant values

analysis purpose. The key process of this research is to identify the influencing factors affecting the number of users per station. Multiple regression analysis was performed and SPSS 18.0 statistical program was used in the process.

## Status review

**Land use status:** Table 1 shows the status of buildings by station in Daejeon city Urban Railway Line 1. The number of buildings, floor area, density (floor area ratio) and the average number of floors are summarized per station. Among the 22 stations, the number of buildings was the highest with 1.619 buildings in Yongmun Station and the average number of floors was 8.0 in the government office station. It can be seen that the number of buildings and the number of floors vary greatly depending on the station area. The station with the smallest number of buildings is the government office station with 88 buildings and the station with the lowest average number of floors was the National Cemetery Station and the average number of floors was 1.3. This shows that there is a significant difference in the number of buildings and the number of floors depending on the station area. As for the floor area by station area, Yuseong Spa station was the highest at 256.3% (floor area: 2,001, 242 $m^2$) and National Cemetery station (5.5%) and Panam station (43.9%) were low.

Table 2 shows the results of summarizing the use of buildings focused on the floor area per station area. In this case, the use of buildings is classified into five categories: 'residential', 'sales service', 'business', 'education, culture and medical service' and 'manufacturing industry'. Most of the station area has the largest residential floor area while Daejeon Station, Jungang-no and Yuseong Spa station have the largest sales service floor area and the city hall and government complex station have the largest business floor area.

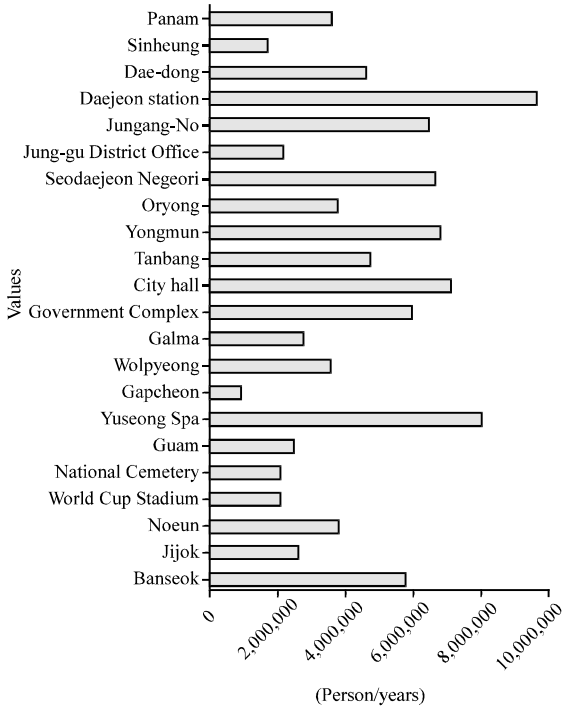


Fig. 2: The number of user per station

**Status of the number of users:** Figure 2 shows the number of user per station in Daejeon Urban Railway Line

Table 2: Floor area per the use of station area building

| | Floor area per the use of building | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Residential | | Sales service | | Business | | Education, culture and medical service | | Manufacturing industry | | Total | |
| Station name | 1,000 m$^2$ | Percentage | 1,000 m$^2$ | Percentage | 1,000 m$^2$ | Percentage | 1.000 m$^2$ | Percentage | 1.000 m$^2$ | Percentage | 1.000 m$^2$ | Percentage |
| Panam | **243.58** | **70.6** | 62.71 | 18.2 | - | 0.0 | 30.09 | 8.7 | 8.82 | 2.6 | 345.20 | 100.0 |
| Sinheung | **328.80** | **79.5** | 59.75 | 14.5 | 6.25 | 1.5 | 13.20 | 3.2 | 5.35 | 1.3 | 413.35 | 100.0 |
| Dae-dong | **292.29** | **60.2** | 104.25 | 21.5 | 3.53 | 0.7 | 62.65 | 12.9 | 22.82 | 4.7 | 485.54 | 100.0 |
| Daejeon Station | 55.68 | 9.6 | **274.71** | **47.6** | 141.99 | 24.6 | 42.27 | 7.3 | 62.50 | 10.8 | 577.14 | 100.0 |
| Jungang-no | 176.53 | 18.4 | **493.14** | **51.3** | 189.04 | 19.7 | 67.34 | 7 | 35.20 | 3.7 | 961.24 | 100.0 |
| Jung-gu District office | **232.06** | **35.4** | 106.51 | 16.3 | 162.86 | 24.9 | 125.92 | 19.2 | 27.72 | 4.2 | 655.07 | 100.0 |
| Seodaejeon Negeori | **664.40** | **54.9** | 403.48 | 33.3 | 50.54 | 4.2 | 63.92 | 5.3 | 28.83 | 2.4 | 1,211.17 | 100.0 |
| Oryong | **328.04** | **45.6** | 139.41 | 19.4 | 131.84 | 18.3 | 74.87 | 10.4 | 45.62 | 6.3 | 719.77 | 100.0 |
| Yongmun | **506.27** | **50.9** | 360.26 | 36.2 | 51.37 | 5.2 | 41.31 | 4.2 | 36.02 | 3.6 | 995.23 | 100.0 |
| Tanbang | **671.90** | **46.2** | 308.16 | 21.2 | 173.40 | 11.9 | 156.20 | 10.7 | 143.87 | 9.9 | 1,453.53 | 100.0 |
| City hall | 258.18 | 17.4 | 315.90 | 21.3 | **673.38** | **45.5** | 149.34 | 10.1 | 82.84 | 5.6 | 1,479.64 | 100.0 |
| Government complex | - | 0 | 138.42 | 12.2 | **745.88** | **65.6** | 182.64 | 16.1 | 69.37 | 6.1 | 1,136.30 | 100.0 |
| Galma | **946.96** | **85.6** | 69.78 | 6.3 | 9.97 | 0.9 | 80.08 | 7.2 | 0.00 | 0.0 | 1,106.78 | 100.0 |
| Wolpyeong | **614.40** | **71.0** | 183.34 | 21.2 | 5.27 | 0.6 | 53.07 | 6.1 | 9.64 | 1.1 | 865.73 | 100.0 |
| Gapcheon | **299.11** | **45.2** | 295.85 | 44.7 | 1.05 | 0.2 | 56.70 | 8.6 | 8.49 | 1.3 | 661.19 | 100.0 |
| Yuseong Spa | 602.06 | 30.1 | **960.24** | **48.0** | 378.95 | 18.9 | 53.08 | 2.7 | 6.9 | 0.3 | 2,001.24 | 100.0 |
| Guam | **367.25** | **60.4** | 180.55 | 29.7 | 43.02 | 7.1 | 5.30 | 0.9 | 11.57 | 1.9 | 607.67 | 100.0 |
| National Cemetery | **24.39** | **58.1** | 10.64 | 25.4 | - | 0.0 | 2.99 | 7.1 | 3.95 | 9.4 | 41.96 | 100.0 |
| World Cup Stadium | **757.61** | **68.5** | 196.75 | 17.8 | 12.34 | 1.1 | 95.45 | 8.6 | 44.2 | 4.0 | 1,106.35 | 100.0 |
| Noeun | **1,400.73** | **72.4** | 356.30 | 18.4 | 30.35 | 1.6 | 102.04 | 5.3 | 45.02 | 2.3 | 1,934.44 | 100.0 |
| Jijok | **595.64** | **55.7** | 231.23 | 21.6 | 102.12 | 9.5 | 118.08 | 11.0 | 23.15 | 2.2 | 1,070.22 | 100.0 |
| Banseok | **690.51** | **65.6** | 226.81 | 21.5 | - | 0.0 | 109.19 | 10.4 | 26.16 | 2.5 | 1,052.67 | 100.0 |

Bold values are significant values

Table 3: The change in the number of users per station

| | The number of users per year (person/year) | | Increase | |
|---|---|---|---|---|
| Station name | 2008 | 2016 | Person | Percentage |
| Panam | 2,752,550 | 2,952,903 | 200,353 | 7.3 |
| Sinheung | 1,131,275 | 1,383,132 | 251,857 | 22.3 |
| Dae-dong | 2,687,456 | 3,742,899 | 1,055,443 | 39.3 |
| Daejeon Station | **6,493,822** | **7,883,965** | 1,390,143 | 21.4 |
| Jungang-no | 4,597,963 | 5,329,002 | 731,039 | 15.9 |
| Jung-gu District office | 1,522,872 | 1,799,527 | 276,655 | 18.2 |
| Seodaejeon Negeori | 4,510,981 | 5,472,947 | 961,966 | 21.3 |
| Oryong | 2,201,703 | 3,117,428 | 915,725 | 41.6 |
| Yongmun | 4,196,668 | 5,563,827 | 1,367,159 | 32.6 |
| Tanbang | 2,729,195 | 3,883,414 | 1,154,219 | 42.3 |
| City hall | 4,619,423 | 5,830,048 | 1,210,625 | 26.2 |
| Government complex | 3,222,488 | 4,868,461 | 1,645,973 | 51.1 |
| Galma | 2,022,207 | 2,266,622 | 244,415 | 12.1 |
| Wolpyeong | 2,376,465 | 2,921,602 | 545,137 | 22.9 |
| Gapcheon | 682,272 | 760,462 | 78,190 | 11.5 |
| Yuseong Spa | 3,456,964 | 6,592,972 | **3,136,008** | 90.7 |
| Guam | 1,769,524 | 2,031,565 | 262,041 | 14.8 |
| National Cemetery | 775,666 | 1,697,551 | 921,885 | 118.9 |
| World Cup Stadium | 1,291,289 | 1,682,039 | 390,750 | 30.3 |
| Noeun | 2,049,773 | 3,118,374 | 1,068,601 | 52.1 |
| Jijok | 1,730,394 | 2,135,929 | 405,535 | 23.4 |
| Banseok | 1,713,820 | 4,726,659 | 3,012,839 | **175.8** |

Data: Daejeon metropolitan express transit corporation; Bold values are signficant values

The number of users in Daejeon Station was the highest and the number of users in Gapcheon station was the lowest.

Table 3 summarizes the changes in the number of users by of Daejeon city Urban Railway. The station with the largest increase in the number of users between 2008 and 2016 was Yuseong Spa Station which increased by 3.136 million. On the other hand, the user increase was relatively low in Gapcheon Station (0.078 million) Panam Station (0.20 million), Galma Station (0.24 million) and Sinheung Station (0.25 million). On the other hand, at the rate of increase, Banseok station was the heighest (175.8%) which is attributed to the increase of transit according to the launch of Sejong city and the enhancement of the transfer function.

**Relation between demand for use and spatial characteristic:** Multiple regression analysis was conducted to investigate the relationship between the spatial characteristic and the demand of users per station area. In this case, the number of users is used as a dependent variable and the 6 variables such as the resident population, land area, road area, residential floor area, sales-business floor area, the number of bus route are analyzed as independent variables. In this way, the influence factors on the number of users per station can be compared. The results of multiple regression analysis are shown in Table 4. Weekly and weekly analysis results

Table 4: The result of multiple regression analysis

| | Total | | Weekdays | | Weekend | |
|---|---|---|---|---|---|---|
| Model | B | t-values | B | t-values | B | t-values |
| (Constant) | | 0.975 | | 1.282 | - | 0.609 |
| Population | 0.128 | 0.641 | 0.141 | 0.606 | 0.031 | 0.163 |
| Site area | 0.022 | 0.178 | 0.030 | 0.214 | -0.020 | -0.173 |
| Road area | -0.141 | -0.916 | -0.176 | -0.984 | -0.119 | -0.807 |
| Residential Floor area | 0.062 | 0.312 | 0.039 | 0.167 | 0.152 | 0.795 |
| Sales*business Floor area | 0.536 | 3.036*** | 0.570 | 2.769** | 0.337 | 1.984* |
| Number of bus route | 0.628 | 4.139*** | 0.556 | 3.142*** | 0.771 | 5.277*** |

The result is meaningful in range of ****, ***, *, p<0.01, 0.05 and 0.1

are shown together with the total number of users. As a result of multiple regression analysis on the total number of users, two variables such as 'sales business floor area' and 'number of bus routes' were statistically significant among all 6 variables. Adj $R^2$ value of result was 0.734. Analyzing the influential factors centered on the significant variables, the 'number of bus routes' was the highest at 4.139 and 'sales-business floor area' 'was 3.036. The results of 'sales-business floor area' composed of city center functions are similar to those of previous researches such as Kim and Lee (2010) but there are some differences in the number of bus routes. It is interpreted as a result of the fact that the number of users is large in the center of the metropolitan area or in the center of the main node and these spaces are mostly concentrated in other public transportation such as buses. On the other hand, if the traffic link system such as bus-urban railway is constructed effectively, it can be expected that it will be possible to enhance the public transportation use and revitalize the area at the same time (Lim *et al*., 2011).

On the other hand as a result of multiple regression analysis by dividing the number of users into weekends and weekdays, 'sales business floor area' and 'number of bus routes' were derived as significant variables as in the results of the whole subjects. Analysis of influence on the variables of significance showed no significant difference in the number of bus routes (3.142) and sales business floor area (2.769) during week days while the difference between the number of bus routes (5.277) and sales business floor area (1.984) greatly increased for weekend users. In particular, the influence of the number of bus routes is higher in weekends (5.277) than in weekdays (3.142). It can be interpreted that the number of users on weekends is concentrated in the center of city or nodal points where bus routes are concentrated.

## RESULTS AND DISCUSSION

Recently, efforts are being made to construct urban spatial structures with an emphasis on public transportation systems and to induce diverse urban activities centered on major nodal points. In this type of urban maintenance and management strategy, station area is one of the most importantly recognized spaces. This study analyzed the relationship between demand and spatial characteristics of 22 subway stations (radius 500 m) of Daejeon city Urban Railway Line 1. The main results of the study are summarized as follows.

Firstly, in Daejeon city urban railway station area, the number of buildings and the number of floors vary greatly per stations. In most cases, the residential floor space occupies the highest proportion. Secondly, the total number of users of urban railways increased significantly compared to the initial period but peaked in 2014 and declined slightly. Thirdly, as a result of regression analysis for all 22 stations, 'number of bus route' and 'sales business floor area' were analyzed as the major influencing factors on the number of users. Lastly, the regression analysis of weekday and weekend users shows that the number of bus routes has increased significantly over the weekend.

The station area is an important space that can lead to new changes or revitalization within the urban space structure. Recent trends in urban or traffic paradigm shift show that it is recognized as a challenge for cities to strengthen the linkage between public transportation and land use, thereby promoting urban revitalization and function. In this process, the importance of station area is highlighted and it needs to be formed as a central space through aggressive activation strategy. If the status of station area is rearranged and appropriate function is given, it will be more effective in activating space such as old urban areas of local big cities.

## CONCLUSION

In the future, studies from various perspectives considering characteristics of station area should be actively continued.

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