Drawing Connections between Railway Station Ridership and Adjacent Urban Form

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April 1, 2022

Acknowledgements

I would like to thank everyone who helped me compose this paper, directly and indirectly. This includes the Georgia Tech School of City and Regional Planning's Faculty, especially my advisor for this paper, Dr. Paige Clayton. I also received significant help from several other students as they composed their papers, Hunter Abel, Gabrielle Oliverio, and Phillip Carnell.

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Abstract

This paper identifies and comparatively analyzes land use and urban design surrounding railway stations in the United States (US), United Kingdom (UK), and Japan. The objective is to identify land use and urban design patterns that are associated with higher railway ridership. The analysis first focuses on descriptively analyzing aspects of urban form and land use that correlate with stronger ridership. Following analysis of previous research, four potential design and land use factors potentially contributing to ridership are investigated using case studies selected from comparable urban and suburban areas in the three countries. Patterns that correspond with higher overall ridership are then recommended for consideration in future transit-oriented development.

Introduction

Railways are routes between or within cities that move passengers or freight in mass (Vassallo, 2007). The ridership of comparable railways around the world varies, sometimes to a high degree (Zuberi, 2016). There are many possible reasons for this, and with any given rail system, qualitative factors that increase or decrease a traveler's likelihood to use a given system can be difficult to determine. When choosing whether to use rail, considerations made by passengers include convenience, frequency of service, reliability, speed, and cost among other things. While rail companies can invest in improving their service, running more trains, and offering convenient connections to other means of transportation, there are some factors of railways that service providers cannot as effectively influence. These factors must be addressed by the governments responsible for urban design and land use near the stations operated by the railway companies, and there are many ideas for what the most impactful design of stations is. To provide insight into this, this paper investigates several urban design and land use factors associated with walkability, access to sources of ridership, population density, and other complexities of the urban environment.

Railways are often associated with vibrant cities. The increase in street activity that goes along with a strong railway system leads to demand for walkable urban spaces and improves access to other modes of transportation including local transit and cycling (Calimente, 2012). This connection is well documented and generally accepted by planners (Ewing, 2009). The creation of higher rail ridership using tools available to local planners can inspire rail companies to improve service, which induces demand for even more rail service (Taylor, 2003).

Finding the factors of urban design that have the greatest correlation with high rail ridership is important, and testing these common attributes between stations around the world can help provide greater understanding of ways to invest in order to promote this ridership. First, the designs of roadways surrounding rail stations have major effects on the urban form and pedestrian experience of a city. These designs can vary heavily by location and include several factors that impact pedestrian comfort and safety such as roadway width and either on- or off-street parking availability (Li, 2014). Stations with significant parking infrastructure and wider roadways are less pedestrian friendly, though some stations, known as park and rides, include vast parking lots to serve suburban commuters, and may have higher ridership despite their lack of pedestrian amenities (Brock, 2013).

In addition to automobile-based elements, land use is also necessary to analyze in order to fully understand how pedestrian activity and railway station usage interact. Land use analysis focuses on the density of development and the mixture of uses present. New transit stations are often built as part of Transit-Oriented Development (TOD) and include an intentional mixture of uses to promote increased ridership. This is often also seen with regional and intercity rail stations, especially with stations in previously existing activity centers (Jacobson, 2008).

The thesis analyzes development density, mixture of uses, and nearby automobile-oriented amenities in order to understand how walkable designs occur near stations, and how these designs correlate with ridership. The analysis is implemented using two methodologies. First, a quantitative study involving 75 stations randomly selected in three countries, the US, the UK, and Japan is completed. Second, six case studies are analyzed in detail to observe how urban design surrounding railway stations develops in practice.

The paper identifies the specific urban design and land use differences and indicates the ways in which they work with railway stations to potentially produce ridership. These differences are compared in order to drive future development near stations that encourages use of rail as opposed to private vehicles. By reducing the number of vehicles, safety and traffic in neighborhoods can be improved and areas around stations will be more inviting for non-motorists, who are more likely to make use of the stations (Bertaud, 2004). Identifying and adopting urban designs that correspond with higher ridership allows cities and regions to realize the greatest benefit from their railway infrastructure.

The paper proceeds as follows. The next section discusses the factors of urban design and land use present in station districts. In the following section, the research setting is outlined to provide understanding of what is being studied specifically. Finally, quantitative results and then case study results are provided.

Urban Design and Transit Ridership

Prior literature has found strong correlations between certain factors of urban design and transit ridership (Ewing, 2009). Intentional creation of environments that encourage the use of transit have been widely used to increase transit and railway ridership and to decrease dependence on private vehicles as a means of addressing traffic congestion. The points of contact between individuals and the railway system are stations, so the following section reviews the literature relating station design and their surrounding environments.

Railway Stations

This paper focuses on the effects of various factors of land use and urban design directly adjacent to railway stations. These factors vary by individual station and are important to note (Limtanakool, 2006). For this reason, stations must be selected based on several factors being held somewhat constant. Understanding the differences between types of stations is important to prevent outliers in data (Monsuur, 2017).

Train stations have been in the center of communities for over a century. In many older cities and towns, the development of the downtown area centered around the railway (Gopalakrishnan, 2019). With the rise of car culture, many of these stations, especially in rural areas have been closed to passenger service, but many of the buildings have been adaptively reused to make use of their convenient location and often historic nature. These buildings still stand as the centerpieces of their towns (Gopalakrishnan, 2019). The purpose of the passenger rail system has evolved since the early days of railroads and some successful systems have functioned more like local transit, with routes becoming shorter and long-distance services becoming more infrequent (Amtrak, 2019). Intercity rail has evolved much differently in the US than it has in other countries. For example, intercity routes serve primarily freight in the US, while they serve primarily passengers in the UK and Japan. Within metropolitan areas, services in all three countries focus on passengers, but in the US, only some very large, urbanized areas have heavily used passenger rail transit corridors (Shih, 2015).

There is significant research and precedent to indicate that high density development is a benefit to transit ridership (Taylor, 2003). It is more difficult to quantify the other factors related to development surrounding stations. In this paper, several potential factors have been identified based on connections that have been made between urban design and transit ridership. These include roadway design, land use, pedestrian amenities, parking, and building heights.

First, wider roads are less inviting to pedestrians, and tend to support higher vehicle speeds (Lewis-Evans, 2006). Second, mixed-use development is more common in many other countries than it is in the US due to Euclidean zoning, car dependent development patterns, and incentives from the government. The presence of mixed-use development tends to increase transit ridership. Planning walkable population centers near transit or railway stations is therefore a commonly used development tool to increase a municipality's tax base without straining roadway infrastructure with as much added traffic (Taylor, 2003). Third, parking is often included at railway stations to increase capacity for the system, especially in suburban areas. Parking around stations is not conducive to non-commuting related trips, however and does not support walkability (Shoup, 2021). Finally, surrounding station areas with larger buildings addresses both commercial and residential density as it relates to railway stations and potential ridership (Taylor, 2003).

Zoning and Land Use

The US is the home of very strict Euclidean zoning. This is not the case in all countries, resulting in the US having more car-oriented cities. With vast tracts of land dedicated only to single-family homes, most uses are very far apart (Shibata, 2002). This is an important reason for the difficulty transit has in providing service within areas not zoned for high density or mixed uses.

Some countries have no zoning, while others have very relaxed zoning or that handled by federal government, not local government. This does not mean there are no land use laws, and countries with no zoning can have significant suburbs and car-dependent areas. These countries typically still have more transit access and walkability than those with extremely strict zoning laws (Khan, 2011).

Urban Growth Boundaries and Geography

Urban growth boundaries aim to cluster growth in certain areas while limiting it in others. This leads to a sharp line between urban and rural land, if enforced effectively. Several cities in the US have adopted these boundaries, and three states require them by law. While the boundaries have the potential to increase density, zoning laws and land use policies that restrict density working in tandem with Urban Growth Boundaries can have an unintended consequence of limiting housing stock and driving up prices (James, 2013). In the some countries, urban growth boundaries are areas of protected farm or forestland.

Passenger railroads tend to thrive in locations where there are natural boundaries to growth, as this tends to lead to higher population density and less sprawl. San Francisco, New York City, and Seattle have growth limited by mountains or waterways and have developed differently from cities without geographic boundaries such as Atlanta, Dallas, and Phoenix (Google Earth). This is especially true when considering rail lines that run within metropolitan areas, but also applies to regional services (Chakraborty, 2013).

The Effects of Culture

With urban populations increasing around the world, transportation by private vehicle is getting increasingly difficult to manage. The answer to this problem in many cities has been to divert some car traffic to railroads by way of commuter rail, essentially a reverse of what happened fifty years prior (Suzuki, 2013). This can be difficult, however, as many metropolitan areas have developed such that lifestyles have become closely tied to vehicle ownership and usage (Shoup, 2021). Completely reworking urban design and land use regulations to combat this car culture is not a short-term endeavor.

Willingness to use transit may also be affected by other aspects of culture. This will not be heavily addressed in this paper but is worth noting. Driving alone and single-family housing are associated with the autonomy of the individual, while mass transportation and high-density housing have more collectivist implications. Depending on a nation’s culture, willingness to accept investment in certain aspects of urban design may vary (Zuberi, 2016).

Urban Design and Walkability

Strong urban design is that which provides mode options, even without explicitly indicating which options it is accommodating (Speck, 2013). Consider two local streets. The first street is 20 meters wide and includes two wide travel lanes, parking, bicycle lanes, and sidewalks. The second street is only 10 meters wide and has no markings, but is open to vehicles, bicycles, and pedestrians. Both can exist as a part of a pedestrian-friendly urban design, but pedestrians will most likely feel just as comfortable on the narrow street as on the wide one (Ewing, 2009). Identifying the factors of design that create spaces that attract street activity is the main goal of increasing walkability.

Ewing and Handy (2009) discuss walkability in situations like the one described above. Referred to as "Measuring the Unmeasurable," the authors clarify the designs that create these spaces. The conducted study utilized five specific details of urban design. The first aspect of the urban environment studied was imageability, which refers to the distinctiveness of an urban scene. Pedestrians are more likely to seek out areas with imageable features. These features serve as landmarks and keep pedestrians interested in the surrounding environment, making walking a more pleasurable experience (Ewing, 2009).

An important factor of urban design is the enclosure of a space. Despite what many zoning codes advocate or allow for, people do not seek out open spaces in an urban context. An enclosed street refers to one with walls of buildings creating an inviting "outdoor room." These spaces appeal to human nature's drive to seek protected locations, and these "rooms" can be ruined by just small sections of breakages in the enclosure, such as a surface parking lot (Speck, 2013).

Walkability is also associated with the scale of surrounding development, in connection with the enclosure factor previously suggested for pedestrian-friendly spaces, constructing development at the scale of a human is necessary to create a comfortable location (Ewing, 2009). This point is associated with both the height and width of buildings. Buildings higher than a certain number of stories, three according to Hans Blumenfeld, and six, according to Lennard are out of human scale and will subconsciously intimidate street users (Ewing, 2009). The width of buildings and size of signage also play into this factor of scale. Auto-centered development often includes the creation of large signs that can be seen at high speeds. On pedestrian-oriented streets, signs and storefronts are smaller and intended to attract those moving at slower speeds (Google Earth, 2021).

Transparency refers to the features of a building's street-fronting walls that make them appear to be associated with more street activity. Glass windows and frequent doors to the street give pedestrians the impression of more activity and tend to create more walkable spaces. Transparency is easier to quantitatively define than the previous factors as it refers to a specific feature of buildings (Ewing, 2009).

Finally, pedestrians enjoy a healthy dose of complexity on a walk. Not enough variation of scenery leads to boredom and low sensory input. Too much variation can lead to stress. This factor is related to imageability since it refers to the level of interest the pedestrian will be likely to have (Ewing, 2009). Especially in railway station districts, high complexity of the environment can be achieved, with more businesses, offices, and restaurants often located near these natural hubs of activity. Creating an interesting and sufficiently complex environment around stations can be used to increase pedestrian exposure to the stations (Speck, 2013), potentially driving higher ridership.

Research Setting: A Comparative Analysis of Railway Systems in the United States, United Kingdom, and Japan

When focusing on the US, UK, and Japan, it is noteworthy that rail networks in the UK and Japan tend to provide more distribution of coverage in cities. US networks are generally more focused on providing service to the central business district and are aimed at serving commuters traveling from the suburban areas (Brock, 2013). This network design is likely a result of the suburban nature of US cities and many railway stations being placed in these suburban areas around significant parking infrastructure (Brock, 2013).

The US has an unconventional mix of service types. Amtrak, the primary intercity passenger rail provider, invests much of its budget into operating unprofitable long-distance trains, while most revenue comes from regional services (Amtrak, 2019). In contrast, the UK and Japan are smaller countries and have less land to cover with a national rail system. These countries also have more high-speed rail line mileage, shortening the travel time between major cities. These high-speed lines overall replaced overnight trains, which are another common feature of American railroads and are inefficient and expensive, though they provide a unique experience (Amtrak, 2019).

Regarding infrastructure, the US and the UK use standard track gauge, which has 1,435 mm (4 ft 8.5 in) between the rails. Japan uses the smaller 1,067 mm (3 ft 6 in) gauge. Overall, this has little effect on offered services. Narrow-gauge railways are slightly cheaper to build, especially in mountainous areas, but they cannot handle as large of vehicles and therefore more frequent or longer trains are needed to provide the same service as a standard gauge line (Map of Gauges, 2021).

The US rail system was a pioneer in the development of a nationwide network and was built by private companies with incentives from the US government. Railroads were provided with land along their rights-of-way and towns formed around them (Swenson, 1956). In 1920, the US had over 250,000 miles of railroad tracks (IUR, 2021). Investment shifted gradually away from the railroads throughout the 20th century as infrastructure spending shifted to highways and airlines. Competing with new technologies, railroads began to declare bankruptcy. Tracks and equipment started falling into disrepair. Unprofitable passenger rail routes began being cut quickly until very few remained (Tobey, 1986). As a means of phasing out passenger rail in the US, Amtrak was founded in 1971 to assume public responsibility for intercity services. Amtrak was more successful than expected and continued to operate indefinitely (Tobey, 1986). While private railroads were no longer responsible for operating passenger trains, they were still having difficulty turning a profit on their freight business. To address this, the Staggers Act of 1980 was passed, which among other things, allowed railroads to set their own shipping rates, quickly turning the industry around (Caves, 2010).

Though railroads in the US are now profitable, they still do not generally support good passenger service. Amtrak still exists, but it operates mostly on tracks owned by freight railroads and suffers from delays caused by the freight trains operating on the same routes. Since there is no financial benefit for the freight railroads to improve quality of service for Amtrak, most routes see infrequent, unreliable trains (Caves, 2010). As a result of policy and other factors, American railroads have become almost completely associated with the movement of freight, and they do it very efficiently. Freight rail moves a significantly larger share of transported goods in the US than in the UK or Japan (Vassallo, 2007).

Passenger rail service not operated by Amtrak is mostly run by public transit agencies in certain large metropolitan areas. Sometimes, these systems operate on their own tracks, and sometimes they operate on tracks leased from freight companies, like Amtrak does (Tobey, 1986). There are also a small but growing number of freight railroads that offer for-profit passenger service, though most routes are still in planning or construction phases (Vock, 2018).

Railroads were invented in the UK and the first intercity railway was built from Liverpool to Manchester (Pollins, 1952). In 1948, the private railway companies operating in the UK were nationalized, similar to the formation of Amtrak in the US about 25 years later (Parry, 1996). Following nationalization, the new British Rail operated at a loss in most years and during the 1960s and 1970s, many lines were abandoned or had service reduced (Parry, 1996). Though the outlook was improving by the 1980s and 90s, the system was privatized, with rail service, maintenance, infrastructure work, and management all being handed over to several new private companies (Parry, 1996).

Though at first, customer satisfaction on the new private railways increased, and a rail link was built between the UK and France, the privatized railway model came into question as fares increased and safety incidents became more common. After several accidents due to poor management and maintenance, responsibility for tracks was handed back over to the Government through Network Rail, a public entity (Ison, 2012). At this point taxpayers were paying to maintain a system that private companies were then charging higher than market rate for them to use (Parry, 1996). As of 2020, the government determined that it would partially renationalize the system.

Unlike in the US and the UK, Japan's railway system was built almost entirely by the government. The Japanese National Railways (JNR) was founded to manage the network in 1949, after World War II (Mizutani, 1997). JNR dealt with similar issues to those faced by American and British railroads following the introduction of commercial airlines and highways. Coupled to this were a series of labor disputes, all which ended up putting the company in serious debt. In 1987, JNR privatized, forming seven for-profit companies, all within the Japan Railways (JR) group. Freight Service is secondary to passenger service in Japan and is handled by JR Freight, one of the seven JR companies (Mizutani, 1997).

Since the privatization, the seven companies have continued to operate in a way similar to how JNR had operated before, but as private enterprises, they had more control over how to manage the companies. JR East, the largest of the companies, makes a profit in most years (JR

East, 2019). Other smaller private rail companies provide service that complements JR. With higher demand for rail service in Japan than the US and the UK, quality of service is frequently considered among the highest for any rail system. This fact sets the Japanese system of railways apart from most others in the world (Yin, 2003).

Research Design

This paper employs a mixed-method design to investigate the relation of urban design and land use factors with railway ridership. First, the research question is approached quantitatively, using a random sample of 75 stations in three countries. All data, maps, images, and other materials used are publicly available, so no specific permissions were needed.

The analysis of land use employs a case study format in which two comparable stations (urban and suburban) from each of the three countries were selected and compared. Because certain American land use and urban design patterns have been compared with European and Asian ones, it is necessary to provide examples of various land uses traditionally found in areas surrounding stations.

To obtain a strong understanding of the correlation between urban design and railway usage, a dependent variable, ridership, was identified. Ridership data is not always available for railway stations, so only stations with data available were used. Data were then identified for four independent variables. The relationship between ridership and the four independent variables was then plotted, allowing conclusions to be drawn. The goal was to identify trends between the variables, and determine how various pedestrian-friendly factors of urban design and land use correlated with ridership at railway stations. Land uses and urban design factors that are correlated with high ridership are then recommended for future transit-oriented development studies near regional and intercity lines.

Data Analysis Procedure

Quantitative data points were selected randomly from rail systems in which ridership data was available in the three studied countries. The population in this research is all regional or intercity rail stations operated by companies with available data. The sample size is 25 stations per country for 75 total stations. Subways, light rail, trams, buses, and high-speed rail are not included. Selected stations with unusual characteristics (such as extremely high ridership) are removed as outliers. The stations were selected using a random number generator with combined lists of all eligible stations in the three countries. Land use and urban design at the station was only considered if it was directly adjacent to the station, such as the block across the street or next to the station building.

This research addresses four attributes of urban design as well as their connection with land use. The attributes are surrounding road width, surrounding land use mix, on-site parking, and overall density of development. Road width is a quantitative variable determined by counting the lanes of surrounding roadway and the parking variable is determined by counting the number of parking spaces provided by the station. Land use mix and overall density are qualitative data points and were first converted to categorical variables using the method described in the following paragraphs.

The land use mix variable was converted from a qualitative to categorical variable using the following approach. Areas with no development aside from parking surrounding the station are assigned the number 1, areas with a single land use are assigned the number 2, areas with multiple land uses are assigned 3. These assigned numbers are compared to ridership data to determine the correlation between land use mix and ridership. The results are useful to compare the popularity of park and ride stations to those in Transit-Oriented Developments.

Overall density is difficult to determine in a formulaic way between multiple countries, so apparent intensity of land use from Google Street View and satellite imagery is analyzed instead. Converting this qualitative variable to a categorical variable was completed by assigning stations surrounded by no buildings the number 1, while stations surrounded by low-rise structures (1-2 floors) were assigned 2, and stations surrounded by medium-high rise structures (3+ floors) were assigned the number 3. This variable represents commercial, residential, or other density and can be analyzed in a similar fashion to the land use mix variable.

Ridership data is available from the relevant railway companies and is available for most, but not all railway stations in the three focus countries. Since data comes from many railways, reporting is not always in the same year. All data used was collected between 2010 and 2019, before the COVID-19 pandemic affected ridership. Stations with no ridership data points will not be considered. US Amtrak station ridership is available from the Amtrak Fact Sheet, which lists ridership for all stations. Other systems within the US, generally regional and commuter systems, have similar data available. UK station ridership data is available from the UK office of Road and Rail (Gower, 2019). Japan station ridership data can be found on the JR company websites, as well as counterpart websites for other railroads. Major ridership outlier stations (Such as Penn Station in New York or Shinjuku Station in Tokyo) are not included in data. Stations selected for analysis are listed in the appendix. To determine statistical significance between the four dependent variables and station ridership, this paper uses the accepted threshold of a p-value less than or equal to 0.05. Table 1 provides a guide for how variables are used in the comparison.

Table 1: Measurements for Quantitative Comparison

Variable	Ridership	Land Use	Density	Road Width	Parking
Type	Dependent	Independent	Independent	Independent	Independent
Measurement	Number of Riders	Mixture of Uses (1-3)	Building Height (1-3)	Number of Lanes	Number of Spaces

Results: Cross-Country Quantitative Comparison

This section uses the data from Amtrak, commuter and regional rail systems, the UK Office of Road and Rail, JR, and other local railways to identify urban design and land use trends which correspond with higher ridership for a railway system. Twenty-five stations were selected at random from each of the three countries studied in this research, with the most significant outliers being removed, as described previously. The four tested factors were then plotted against ridership, combining the data collected from all three countries.

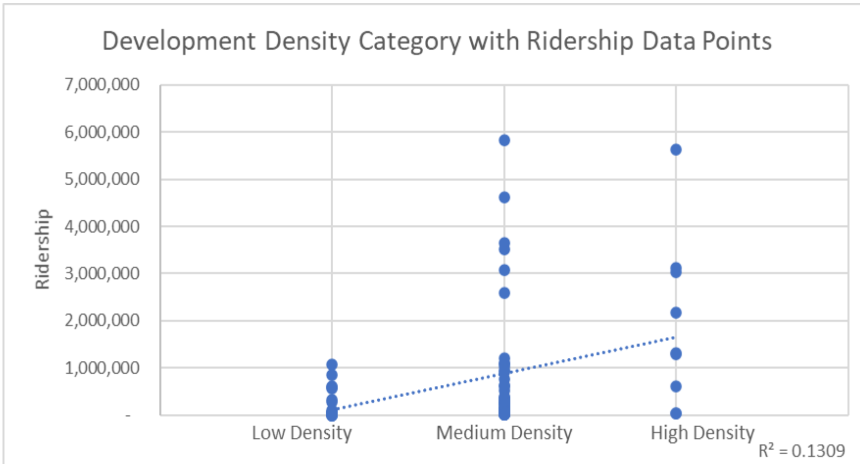

Figure 1: Railway ridership at 75 randomly selected stations with varying levels of development density

First, the density of development was compared with ridership for the 75 total stations studied (see Figure 1). Densities for each of the stations were manually converted to a category for comparison purposes. The categories are low, medium, and high density. As expected, there is an increasing trend observed between increasing density and increasing ridership. Though outliers are removed, there are many more stations with lower ridership than higher ridership. This will factor into each of the metrics analyzed.

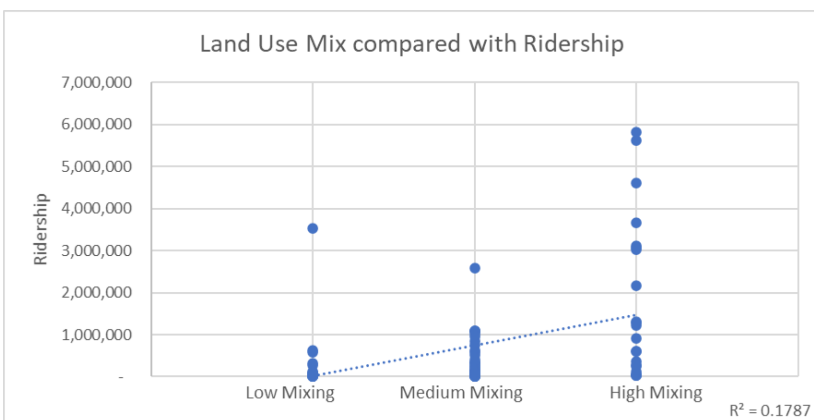

Figure 2: Railway ridership at 75 randomly selected stations organized by the level of mixed-use development

The second metric compared the mixture of uses in the station's surroundings with station ridership. The qualitative variable has been converted into a categorical one based on the observations of many station districts and careful consideration. The results are shown in Figure 2. Similar to the comparison of density and ridership, more uses is correlated with higher railway ridership in the sample of 75 stations selected from the three countries. This was expected, based on prior research. The R-squared value for the land use metric is higher than the value for density, indicating that there is a stronger correlation between land use mix and ridership than between density and ridership in the sample.

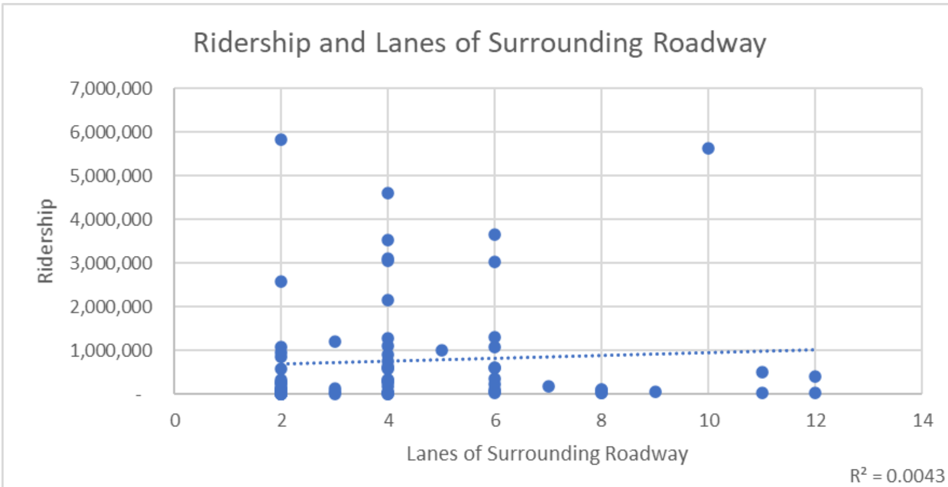

Figure 3: Railway ridership at 75 randomly selected stations sorted by the number of surrounding roadway lanes

Lanes of surrounding roadway are related to urban form in that wider roadways are more difficult to pedestrianize, but generally move more people on various modes (Lewis-Evans, 2006). Many core business districts are located on major arterial roadways and are likely to also have higher ridership (Google Earth, 2021). The relationship between ridership and lanes of surrounding roadway for the 75 stations is shown in Figure 3. There is a very weak positive correlation between lanes of surrounding roadway and ridership, with an R-squared value of 0.0043. It is difficult to draw any strong conclusions about the relationship between these factors.

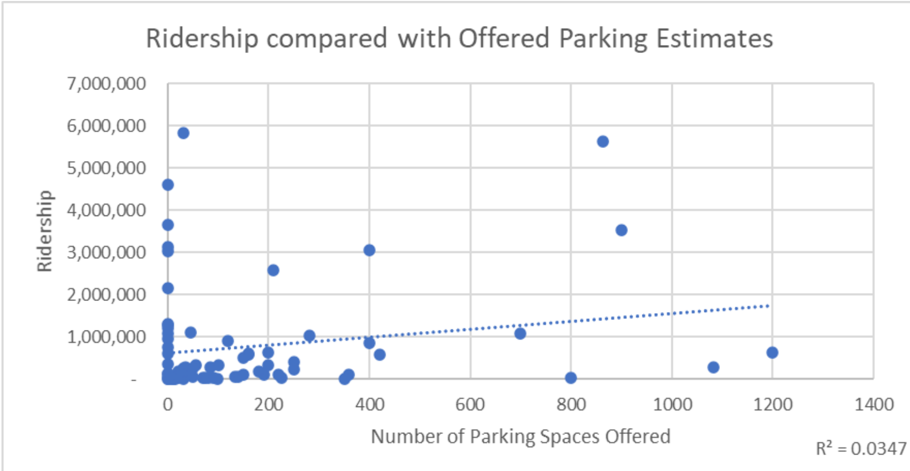

Figure 4: Railway ridership at 75 randomly selected stations compared with on-site parking offerings

The final quantitative variable studied was parking, and its relationship with ridership at railway stations. Parking was calculated by counting the number of offered spaces, so there was no need to convert the variable to a categorical form. Many stations had no parking and therefore were assigned a value of zero. The result of the comparison is shown in Figure 4. There is a moderately weak positive correlation between offered parking spaces and ridership, with an R-squared value of 0.0347. Though outliers were filtered out based on ridership, outliers were not filtered out based on parking spaces. This leads to a clustering of data points in the lower left portion of the scatterplot.

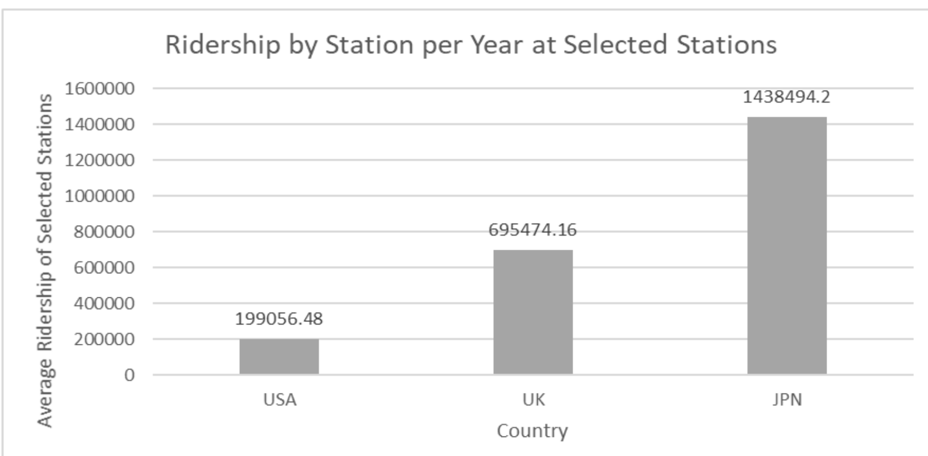

Figure 5: Average annual ridership per station within the 75-station selection, by country

In addition to these four comparisons, it is possible to compare the metrics by country as well. Taking the 25 data points from each country and determining the average, it is possible to observe the mean data value for stations in each country. First, average ridership is shown in Figure 5. Of the selected stations, the Japanese stations were much more heavily used than those in the US or UK. As the dataset was only 25 points per country, more data is needed to draw any conclusions about these results.

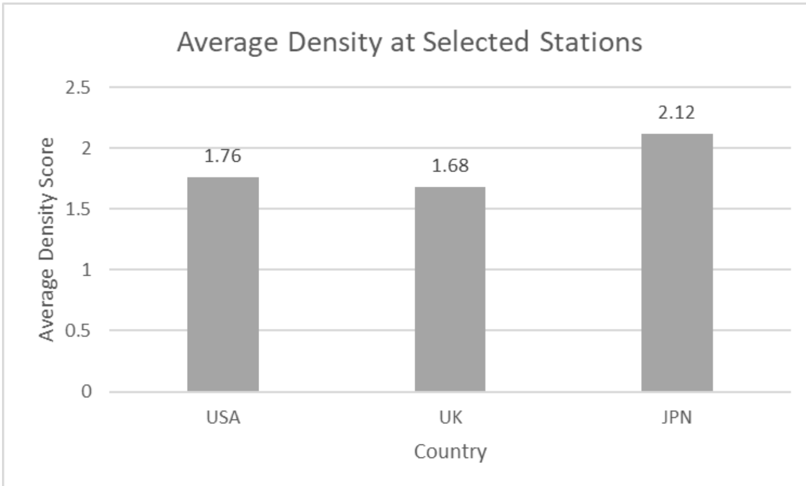

Figure 6: Average development density at stations within the 75-station selection, by country

While the difference observed in Figure 5 is quite significant, the difference in the other metrics is not as clear. Density, based on the categories created, is shown in Figure 6, compared by country. These values are different from each other, but not by enough to make any statements about station district density.

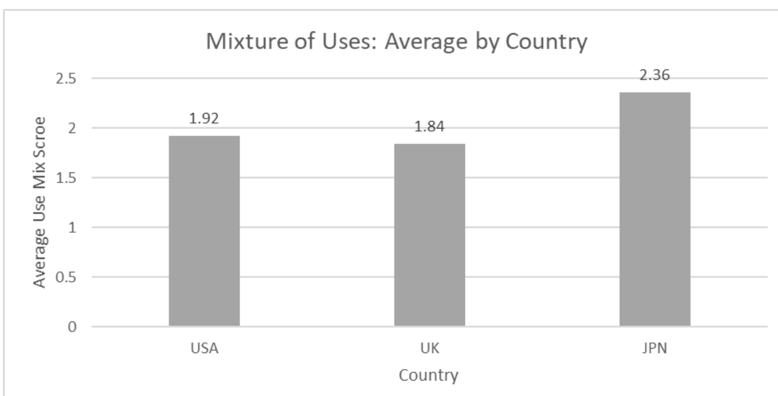

Figure 7: Average use mixing near stations within the 75-station selection, sorted by country

Stations tend to be in the center of communities, which usually have a higher mix of uses, so the values for all three countries are quite high. Twenty-five data points per country would need to be expanded to draw conclusions about these results.

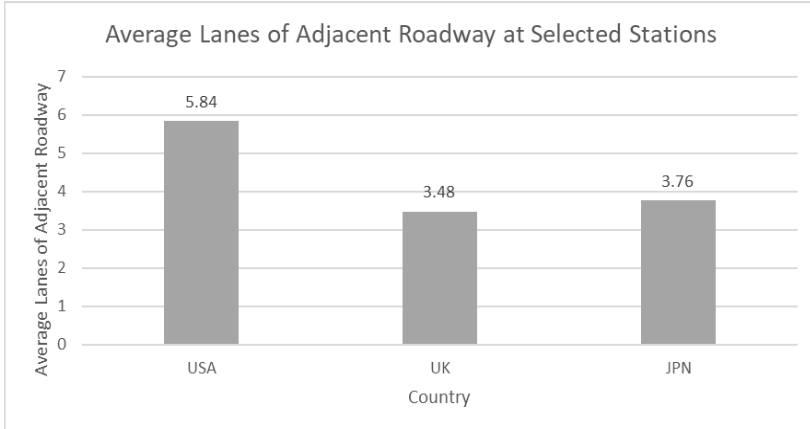

Figure 8: Average number of surrounding roadway lanes at stations within the 75-station selection, by country

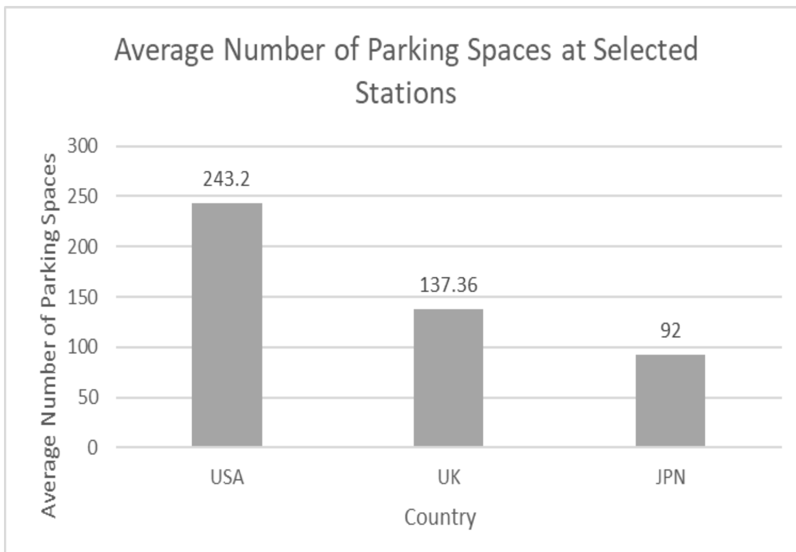

Figure 9: Average number of on-site parking spaces at stations within the 75-station selection, by country

Lanes of adjacent roadway (Figure 8) and parking (Figure 9) show more distinct trends. The US, with more stations in city centers and car-dependent suburbs, displays a higher number of lanes surrounding stations. The same result is found when investigating parking infrastructure at an average station in the sample. While Japan's stations have an average of 92 parking spaces provided, the US provides on average 243 spaces per station, according to the sample of 25 stations in each country. The UK displays a number of spaces at a midpoint between US and Japanese stations.

Figures 1-4 help develop answers to the research question of how pedestrian-focused elements of land use and urban design impact railway station ridership. Overall, higher density and more mixing of uses are associated with higher ridership, though more roadway lanes and parking are also associated with higher ridership. This is partially countered by Figures 5-9, which show that Japan has the highest overall ridership and the lowest average on-site parking.

The trend does show, however that urban designs and land use favoring pedestrians do correspond with more railway station usage. More specific research is needed to determine the true impacts of each of the four tested factors, however, including using only stations with similar ridership, and accounting for the number of stations within a certain distance of selected points.

Case Comparison Results

This section reviews the results of the comparative analysis of six stations and identifies elements of urban design and land use that encourage pedestrian activity and railway ridership. For the analysis, two stations were selected from each of the three countries. For each country, an urban and suburban station were included, with emphasis placed on similar station function and neighborhood land use. First each urban station is reviewed, followed by analysis of the suburban stations. The six case study stations were not included in the quantitative analysis, as they would have undermined the randomness of the sample. For completeness however, an idea of how the stations would have been used, had they been included is shown in Table 2.

Table 2: Setting the Stage for Case Comparison: Statistics for the Six Stations

Stations	Country / Type	Mixing of Uses	No. Parking Spaces	Surrounding roadway lanes	Density Category	Annual Ridership
Nostrand Avenue	US Urban	High	0	10	High	444,205
Deansgate	UK Urban	High	0	10	High	456,000
Sakou	Japan Urban	High	0	8	High	1,757,021
Midlothian	US Suburban	Medium	400	8	Low	342,370
Brimsdown	UK Suburban	Medium	0	5	Medium	988,000
Shin-Shiraoka	Japan Suburban	Medium	0	4	Medium	2,538,210

Note: This data was not included in the randomly selected group of 75 stations used for quantitative analysis.

Urban US Station

Urban rail stations serving regional riders are rare in the US, only being present in a few cities (Brock, 2013). Most regional rail systems in the US serve primarily suburban commuters and often serve very few urban riders (Brock, 2013). Since this function is very different from the usage pattern observed in the UK and Japan, a station in a city that functions more like a European or Asian city was needed for fair comparison. With a more diverse mode mix than other American cities, New York City was selected for this case study, as it is one of the few US cities with urban regional rail stations serving urban residents.

The station selected as the US urban case study is Nostrand Avenue Station in Brooklyn. The station serves seven branch lines of the Long Island Railroad on two tracks and two platforms. The station has impressive headways of about 15 minutes between trains, leading the station to a respectable ridership of 1,217 passengers per day (LIRR, 2014). The station is elevated above Atlantic Avenue, a major six-lane thoroughfare, and includes four entrances from the street level. The satellite image of the station is included in Figure 10.

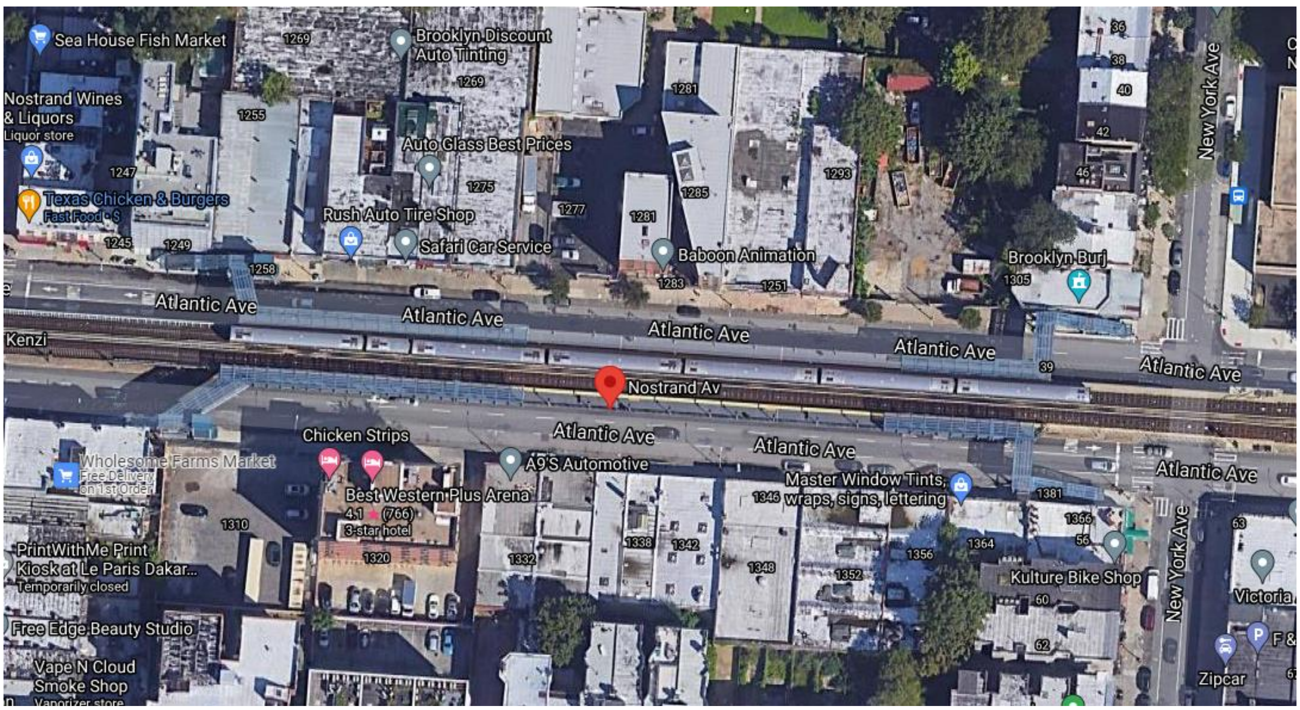

Figure 10: Satellite Imagery depicting the Nostrand Avenue station and its surroundings (Google Earth).

Notable is the high density of population and land use in the area surrounding the station. The elevated station is in the center of a major arterial, which is wide and encourages high speed traffic. Pedestrian experience is diminished as perception of safety is reduced along the roadway. Street parking creates a buffer between Atlantic Avenue and the sidewalk but reduces the corridor's viability for bicyclists. Figures 11 and 12 display the station district from street level.

Bicyclists are observed using sidewalks as the roadway is difficult to use for non-motorists due to width, one-way designation, and speed of traffic. Atlantic Avenue on both sides of the elevated railway has a similar design. Street trees are present along portions of the sidewalk, but there are areas where sidewalk space is lost to station components. Nostrand

Avenue Station has no designated parking, but parking is observed under the railway viaduct. It is unlikely that this parking serves the station.

Surrounding streets include medium to high density housing in a traditional New York style, with an inviting environment for pedestrians. Streets are tree-lined in most areas, and wide sidewalks and quiet streets encourage walking. These streets are within walking distance of the Nostrand Ave station as well as businesses and restaurants (Figure 13). On some streets, commercial development is present, though there is less mixing of uses than is observed in other areas of New York City (Google Earth, 2021). An example of a commercial street near the station is included in Figure 14.

Bicycle infrastructure here is more accessible and vehicle traffic is lower. The roadway on which the station is built, Atlantic Avenue, is much wider and more difficult to use than the surrounding streets, which include significant street activity and walkable urban design and land use. Nostrand Avenue's LIRR station is a good case study in American urban rail stations in that it is built along a major roadway corridor but serves areas of high population density and naturally occurring mixed-use development.

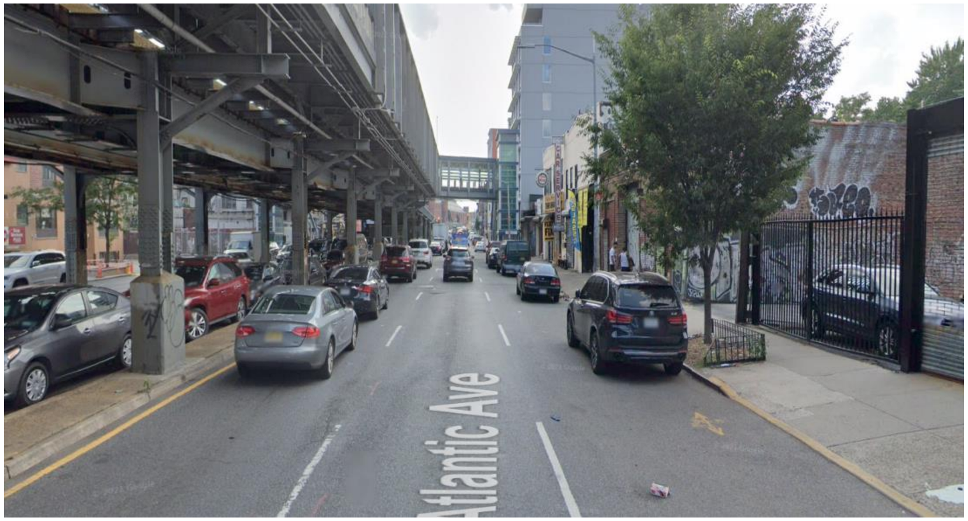

Figure 11: Atlantic Ave between Nostrand Ave and New York Ave, looking west on the north side of the station. Note the auto-oriented roadway design (Google Street View).

Figure 13: Herkimer St between Nostrand Ave and New York Ave, looking west. This is a typical residential street near the station, located one block to the north (Google Street View).

Figure 12: Atlantic Ave at Nostrand Ave, looking east on the north side of the station (Google Street View)

Figure 14: Nostrand Ave at Pacific St looking north. This is a typical commercial district on a collector street near the station, located one block to the southwest. The railway viaduct is visible in the background (Google Street View).

Urban UK Station

UK rail customers use urban railway stations at a higher rate compared with US customers (Gower, 2019). As a result, there is a larger pool of stations to draw from for an urban case study, despite the smaller physical size of the country. The station selected for this case study is Deansgate station in the city of Manchester. Like the Nostrand Avenue Station in New York, Deansgate is an old station, operating for over a century and a half (Butt, 1995). The station contains two tracks and two platforms, one for each track. The station serves about 1,095 passengers per day (Gower, 2019) and is built on a gentle curve near the center of Manchester. Deansgate is above grade and is on an embankment above Whitworth St and the A56 road, which it crosses on a bridge. Trains operate approximately every 5-10 minutes and primarily serve commuters (Northern Trains, 2022). The station is served by Northern Trains, one of the private rail companies serving the formerly nationalized railway system.

Deansgate station is very near the core business district of Manchester, but has a large stock of residential buildings nearby, which can help drive ridership. Land uses surrounding the station are mixed, however, with many restaurants and other businesses capitalizing on closeness of the station and housing. There is a tram stop nearby serving the station district as well. A satellite image of the station and its surroundings has been included in Figure 15.

Figure 15: Satellite Imagery depicting the Deansgate station and its surroundings (Google Earth).

The first clear urban design difference compared with Nostrand Ave is the irregular street pattern. Rather than a grid with a major east-west arterial (Atlantic Ave), Deansgate is surrounded by a more organic form of urban fabric. The station has no designated parking, though a sizable surface parking lot is present nearby. Similar to the station in New York, Deansgate is located on a major road, but pedestrians have access to both sides of the road, and infrastructure is at a more human scale. Figure 16 shows the front entrance to the Deansgate station. The back of the station also has street access, though it is located on a much lower-traffic street (see Figure 17). This quiet street includes the enclosed space discussed by Ewing, as it includes 3-4 story buildings along with windows and doors, which draws pedestrians in (Ewing, 2009). The street does not include every aspect of pedestrian-based design and includes some accessibility challenges, including sidewalk quality concerns, however. Unlike the US case study, this station is more closely integrated into the neighborhood it serves and is likely more inviting to riders.

There is a rough split in land uses at the Deansgate station. To the south, more residential development is present, though it is mixed with commercial, restaurant, and even some industrial uses. A residential street just south of the station is shown in Figure 18. The appealing sight lines, narrow street, and pedestrian amenities, including street trees and wide sidewalks make this street feel welcoming to non-motorists. Multiple pedestrians are present in the image, showing that they feel comfortable walking on this street.

North of the Deansgate station, there is a commercial street, which includes numerous restaurants, though there is not much residential use present (Figure 19). This street is wider and less inviting to pedestrians than the residential street shown previously. The wide sidewalks and street trees are not present here; it is possible that pedestrians will feel more vulnerable.

The area surrounding the Deansgate station displays a high degree of population density and natural mixing of uses, though residential and commercial frequency changes to the north and south of the station. With the non-grid urban design pattern, there is higher potential for an enjoyable pedestrian experience with more variability of designs than more intentionally planned areas (Jacobson, 2008). The relatively small number of parking lots present also enhances the urban room effect, as the enclosed streets are rarely broken by open spaces (Speck, 2013).

Figure 16: The intersection of Whitworth St and Deansgate in front of the station entrance, looking southeast (Google Street View).

Figure 18: Deansgate and Little Peter St on the south side of the station, looking north. Note the sight lines from this viewpoint (Google Street View).

Figure 17: Hewitt St at Gilbert St on the south side of the station, looking west. The station is the structure on the right side of the image (Google Street View).

Figure 19: Liverpool Rd near Barton St just north of the station, looking east. Note the pedestrian experience on this street compared with those in the previous two images (Google Street View).

Urban Japan Station

The Japanese city planning system is seemingly the most random of the three studied in this paper, though there is an effective method of zoning, and roadway planning has evolved over time (Shibata, 2002). The Japanese station used for the urban case study is Sakou station in Nagoya, Aichi Prefecture. The station is located on the Meitetsu Nagoya main line and like the other two urban case study stations, is an elevated station above a major roadway (Toriitori). The station is located just northwest of the city center and is surrounded by high-density mixed-use development. A hospital, elementary school, and museum are also within a short walking distance of the station. A satellite image is included in Figure 20.

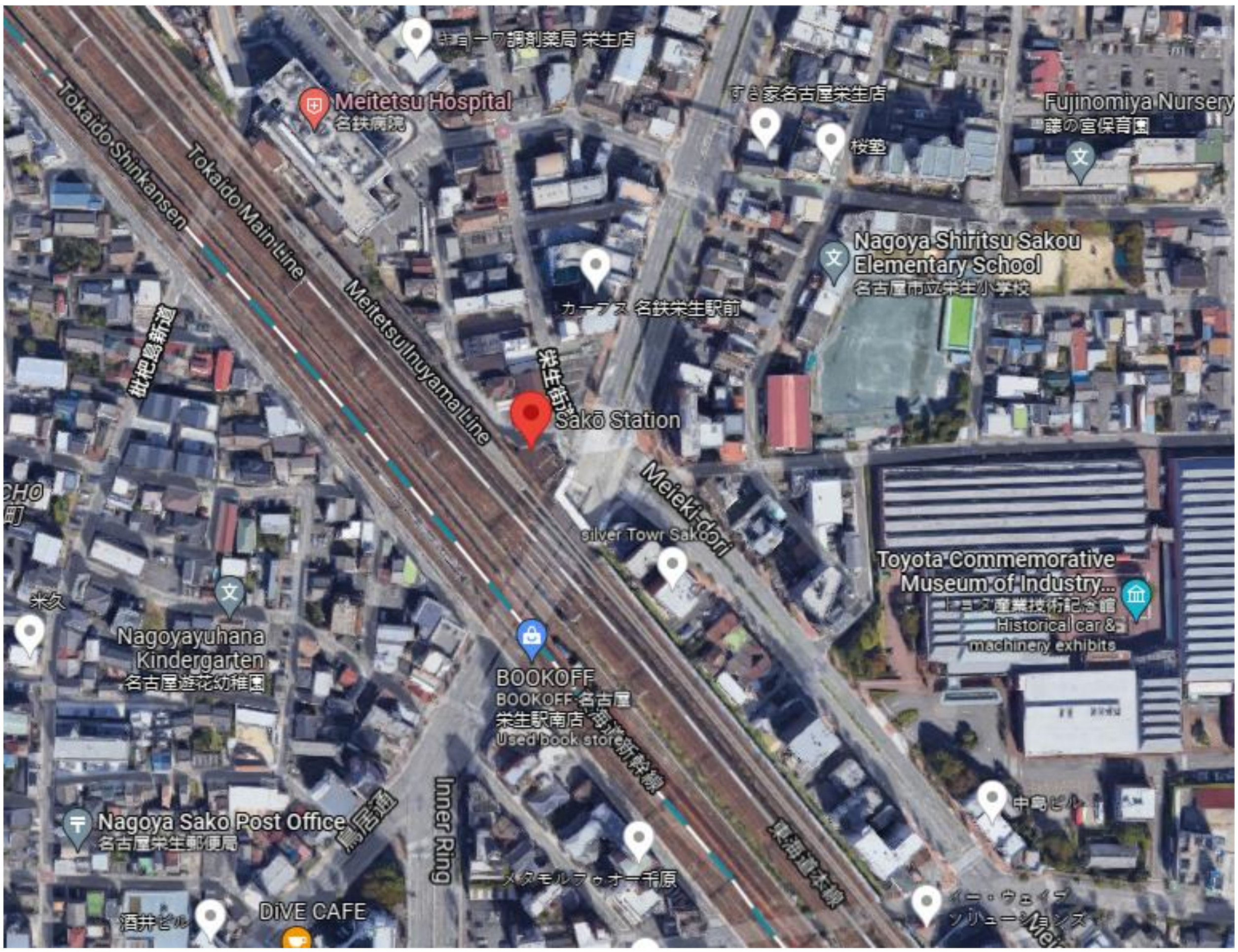

Figure 20: Satellite imagery of Sakou Station and the surrounding urban area (Google Earth).

Sakou station has only one entrance, and the platform is located on an embankment, which separates the neighborhoods on either side of the tracks. The platform serves two tracks, and approximately 4,800 passengers per day (Aichi Prefectural Government, 2010). The Tokaido Shinkansen (Bullet Train) tracks run parallel to the line served by the station, but trains do not stop at Sakou. The entrance to the station is next to a pedestrian scramble serving a very wide crossing between two large arterial roads. The six-lane, divided highway includes a planted median, street trees, and barriers preventing pedestrians from crossing outside of crosswalks, or motorists from entering sidewalks. The station entrance and the arterial roadway are shown in Figure 21.

The area behind the station can be accessed by walking under the railway overpass along the arterial roadway (Figure 22). The passage is used as a bicycle parking location for the station and is kept clean. There is no vehicle parking on site, though there are several small privately owned parking lots located on the back streets, along with a mixture of residential and commercial uses of varying intensity. Figure 23 shows an example of one of these parking lots.

Sidewalks are provided only on the arterials, though local streets are narrow and support only low-speed traffic. Pedestrians and bicyclists are quite common on these streets, which often have an unusual mixture of intensity, such as in the street in Figure 24, where single family homes are located directly beside apartment buildings and a small restaurant on a street of a width of less than ten meters. Though small businesses are frequently found on the back streets in the area near Sakou station, businesses are more focused on the main arterials, in a similar fashion to the US and UK stations. Sakou Station, like the other two case study urban stations, is not surrounded by large commercial centers, and is instead served by smaller local cores.

Like the other two stations used as urban case studies, Sakou station serves as a neighborhood station, not as a major transfer center or terminus. This station's location excels in the metric of serving pedestrians well. Aside from the main arterial roadway, most streets are reminiscent of a woonerf and are highly inviting to walkers. The lack of centralized station parking also encourages the station to serve the local community more effectively, as opposed to being used as a park-and-ride for people outside the community.

A concern with the area surrounding the Sakou station is accessibility for disabled people. Many pedestrian crossings are elevated and require stair-climbing to use. In some areas, there are very long distances between crosswalks. This issue is less pronounced in New York, where the rigid grid pattern allows crosswalks to be placed with more regular frequency. Bicycles can be used on sidewalks in Japan, but the arterials are not multimodal, and encourage very high vehicle speeds (Kobayashi, 2014). Despite this issue being present on arterials, overall, the walkability of the area near Sakou station is the highest of the three stations, and the high concentration of residences and other destinations within walking distance of the station create the demand necessary to support high ridership without the need to invest in parking or other infrastructure to boost it artificially.

Figure 21: Inner Ring and Meieki-dori, north of the Sakou station shown on the right side of the image (Google Street View).

Figure 23: Sakou Kaidou (a collector road north of the station) looking north, showing a typical parking lot near the station. Note the small lot sizes present (Google Street

Figure 22: Bicycle parking under the railway viaduct along Inner Ring (Google Street View).

Figure 24: A small street just to the east of the station displaying mixing of housing densities and uses. Note the road width and human scaling of the urban design (Google Street View).

Suburban US Station

As the country with possibly the world's most famous suburbs, the US has many suburban commuter rail stations in the largest metropolitan areas. These stations usually serve as a type of park-and-ride service, in which commuters from the wider region drive to stations and ride the system to the core business district in the mornings, and back in the evenings (Brock, 2013). Many of the stations in the US are set up to only serve inbound in the mornings and outbound in the evenings, though this is becoming less common as workplaces have migrated away from city centers in recent decades (Brock, 2013). As a case study subject, a medium/high ridership suburban station in Chicago has been selected. The Midlothian Station represents a very typical suburban US station in its parking offerings, surrounding land use, and density. A satellite image is provided in Figure 25:

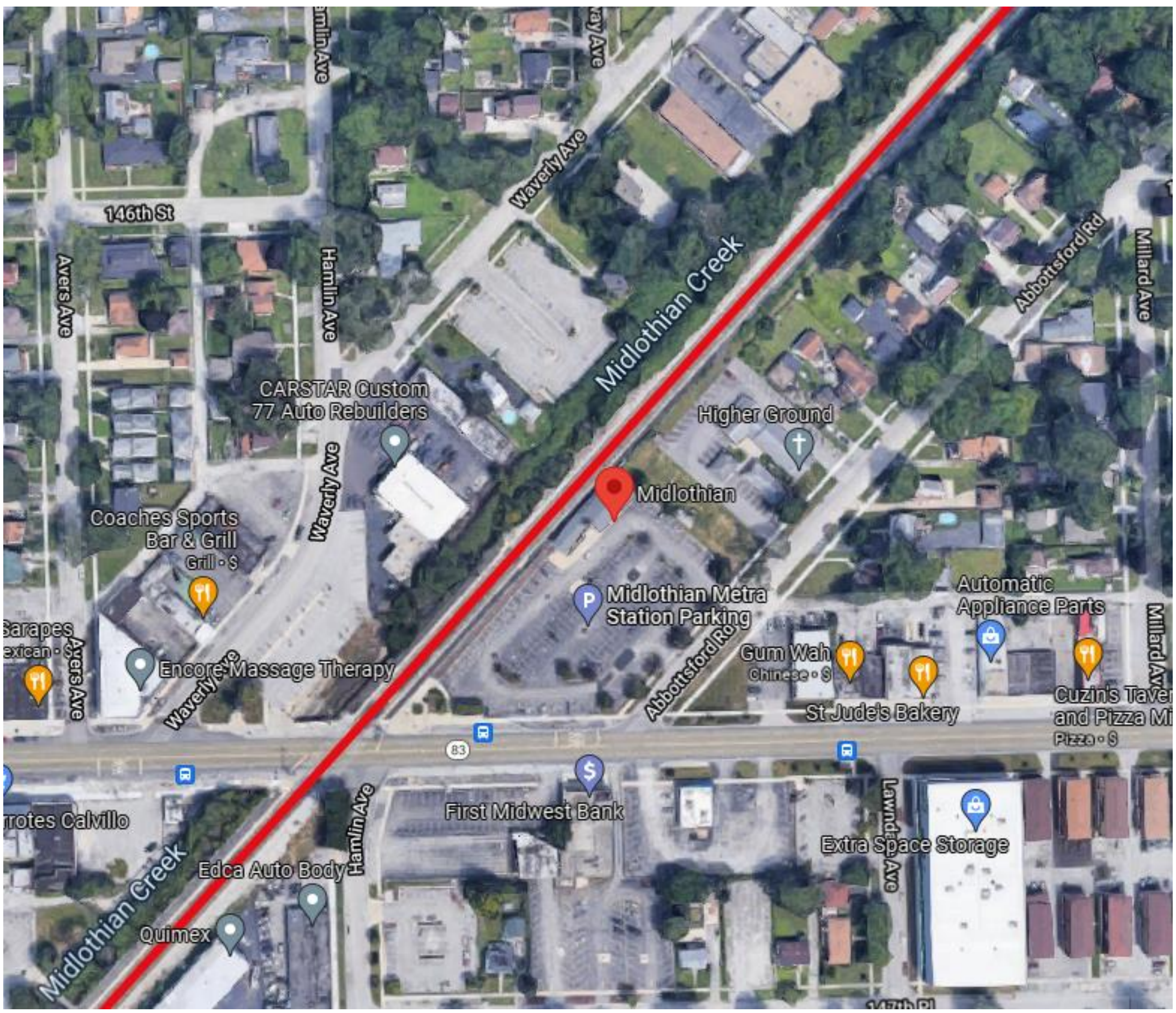

Figure 25: Satellite imagery of Midlothian Station and the surrounding urban area (Google Earth).

Unlike the urban stations previously covered as case studies, the Midlothian station is accessible without entering faregates and therefore is more open to the street. The station is also located at-grade and includes a railroad crossing just to the south of its location. The station serves Metra's Rock Island District, with service running slightly more than every hour in each direction. Midlothian has two tracks and two platforms, one serving each track and sees about 938 passengers per day (Metra, 2018).

The road crossing the tracks is 147th Street, a four-lane arterial roadway running from east to west. The station has parking provided on site and additional parking is present in the surrounding areas. Access to the station is possible by entering from the parking lots or from the sidewalk on 147th Street. A northward view of the station from the railroad crossing is provided in Figure 26. A second parking lot can be found to the south of the station, providing parking for peak traffic times. This parking lot is shown in Figure 28.

Based on the number of vehicles parked in the surface lots surrounding the Midlothian Station, this station is responsible for removing significant traffic from Chicago's core. While this helps make Chicago more pedestrian friendly, it has some negative impacts on the district surrounding the Midlothian station. Instead of businesses and homes capitalizing on the activity center of the station, the area is being used to store vehicles, and the urban design becomes car-oriented as a result. Considering the presence of transit, this could be a candidate for a future Transit-Oriented Development, though this would carry with it the risk of causing gentrification (Padeiro, 2019). Overall, the land use near the station displays a mix of multi-family residential and low-density commercial on the main arterials, while the density becomes lower and the use is only single-family residential on the nearby local roads (See figure 27).

Local roads around the station display very low density with few elements of walkable urban design. Most residents in these neighborhoods will be incentivized to use private vehicles, as this urban design encourages it with wide roadways, low density, and Euclidean zoning. A commercial area adjacent to the Midlothian station is shown in Figure 29. Pedestrians are few and far between in this commercial hub. With an intimidating wide arterial, businesses set back behind parking lots, and few street features, pedestrians and cyclists will feel vulnerable on this street. Street features that are present reinforce this as well. The intersection where this image was taken has no crosswalks across 147th Street and lighting features are very tall, widely spaced, and directed at the roadway lanes, with the poles placed in the sidewalks. Attempts at placemaking, including banners, help to make the neighborhood feel more welcoming to pedestrians, but they are overwhelmed by the car-centric urban design.

Figure 26: 147th St at the Midlothian Station location. There is a railroad crossing and at-grade entrance here (Google Street View).

Figure 27: A typical residential street near the station, 148th St near Hamlin Ave. Note the low-density development and large setbacks creating a very open-feeling environment (Google Street View).

Figure 28: The largest parking lot at the station, located adjacent to Waverly Ave south of the main station structure (Google Street View).

Figure 29: A commercial area near Midlothian station, 147th St at Pulaski Rd, looking east, toward the station (Google Street View).

Suburban UK Station

There is significant variation between different types of railway stations in the UK, and as with the previous case study stations, the one identified does not represent a standard followed by all stations, but rather a typical example of a suburban station. For the UK, this station is Brimsdown, a station in Enfield, a northern suburb of London. Brimsdown is similar to Midlothian station in Chicago in that it is at street level and is accessed from a major roadway. The station has two platforms serving two tracks, which run north to south. Rail service runs about every half hour in each direction and is designed to serve local commuters heading into downtown London. The station has a ridership of about 2,500 riders per day (Gower, 2019). The satellite imagery of the station is in Figure 30.

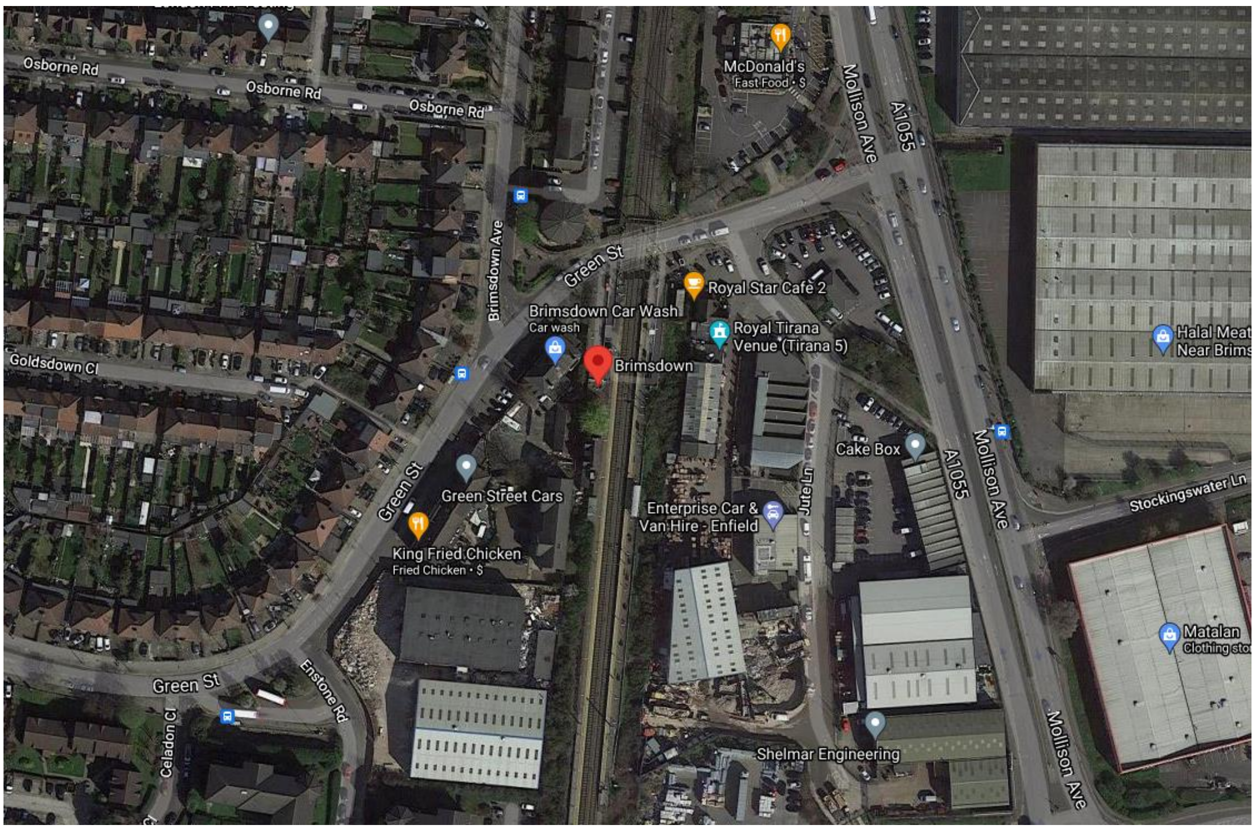

Figure 30: Satellite Imagery of the Brimsdown station and the surrounding development (Google Earth).

The road that crosses the railway is Green Street, a collector serving Mollison Avenue, which is visible on the right side of the image. Brimsdown station serves a medium density residential area as well as a large industrial and warehouse area just to the east. There is no parking on site, so unlike Midlothian, the station is not used to serve park and ride customers. This is a more typical station function in the UK, though park and ride stations are common as well (see Figure 9). The access point to the station is from Green Street and is shown in Figure 31.

The platform is only present on one side of the street. Though it is a busy collector serving many neighborhoods, Green Street is narrow at the station and encourages slower vehicle speeds, making pedestrians feel safer than they would on a wider roadway. The station is surrounded by car-oriented design on the east side with several parking lots and a fast food restaurant, though large sidewalks were added and are of high quality.

To the west of the station, the majority of the housing served by Brimsdown station is present. The design is typical of UK suburban development and includes mainly single-family homes with some multi-family structures present as well. Road width is dependent on traffic level and is narrower than the suburban US residential development in general. A busy residential street is shown in Figure 32, just west of the station. Compared with the Midlothian station, the Brimsdown station district has higher density, but much more irregular streets, some of which do not run through, and instead dead-end. The result of this is high traffic on some roads, and virtually no traffic on others. It also makes it more difficult to walk between two spatially close locations. Considering the fact that Brimsdown station has no on-site parking, this could encourage driving, despite otherwise high utility associated with using transit. The street system within the surrounding neighborhoods do not exhibit the loop and lollipop design of many modern US suburbs, but function in much the same way.

Although the UK does not formally use zoning, the Brimsdown area is very separated by use. The railway serves as the dividing line and is difficult to cross, with few roads connecting both sides of the tracks, adding traffic to Green St and the few other connections. A typical local street on the west side of the tracks, where residential land use predominates is shown in Figure 33. Note the car-oriented design of the street, despite the reasonably high density. Without mixtures of use, pedestrianization of local streets is difficult, as walking distances get stretched out. Due to the large distance between these homes and the railway station, commercial, and industrial areas, walking will be less common in this type of neighborhood.

There is a small commercial hub just to the west of the station, which is shown in Figure 34. This commercial area provides a place to purchase fruits and vegetables to local residents as well as parking for those coming from longer distances. The buildings have wide sidewalks and the road widens in this area to provide space for deliveries and drop-offs of customers and goods.

Although the urban design around the station includes significant car-oriented features, like the US example, the neighborhood developed that way during the age of the automobile (Larkham, 2003). Aside from the small area directly adjacent to the station, which was likely originally a town, most housing, commercial, and industrial land use was built around the roads and suburban sprawl that accompanied the development of suburbs everywhere. The overall urban design is much more pedestrian friendly than the US example, as the higher density and lower frequency of parking lots creates a more contiguous neighborhood, and the station serves the people who live and work around it, rather than those who drive to it as commuters.

Figure 31: The Brimsdown station is shown here, where it is accessed from Green St. View is to the south. Note how the road narrows when it crosses the railway (Google Street View).

Figure 33: Northward view at Carterhatch Rd and Leyland Ave north of the Brimsdown station (Google Street View).

Figure 32: The northward view on Brimsdown Ave near Green St displays a typical collector street near the station. Note the mixture of housing densities present (Google Street View).

Figure 34: Green St near the station, looking east. A local commercial node has developed in this location (Google Street View).

Suburban Japanese Station

The mixing of uses and organic design of Sakou station, used for the urban Japanese case study is not as prevalent in the suburban example. Like the US and the UK, suburbs come in many varieties in Japan and this case study aims to reflect a typical example. The case study is Shin-Shiraoka station in Saitama Prefecture, north of central Tokyo. The station serves the JR East Shonan-Shinjuku Line and the Utsunomiya Line and is a newer station compared with the other suburban case studies, opening in 1987 (JR East, 2019). Just like the other two studies, Shin-Shiraoka station includes two side platforms and two tracks, and service runs about every 20-30 minutes on either line. Average daily ridership is 6,954 (JR East, 2019). The station is surrounded by medium-density development which is very car-oriented in some areas, and more pedestrian-oriented in others. The satellite image is shown in Figure 35.

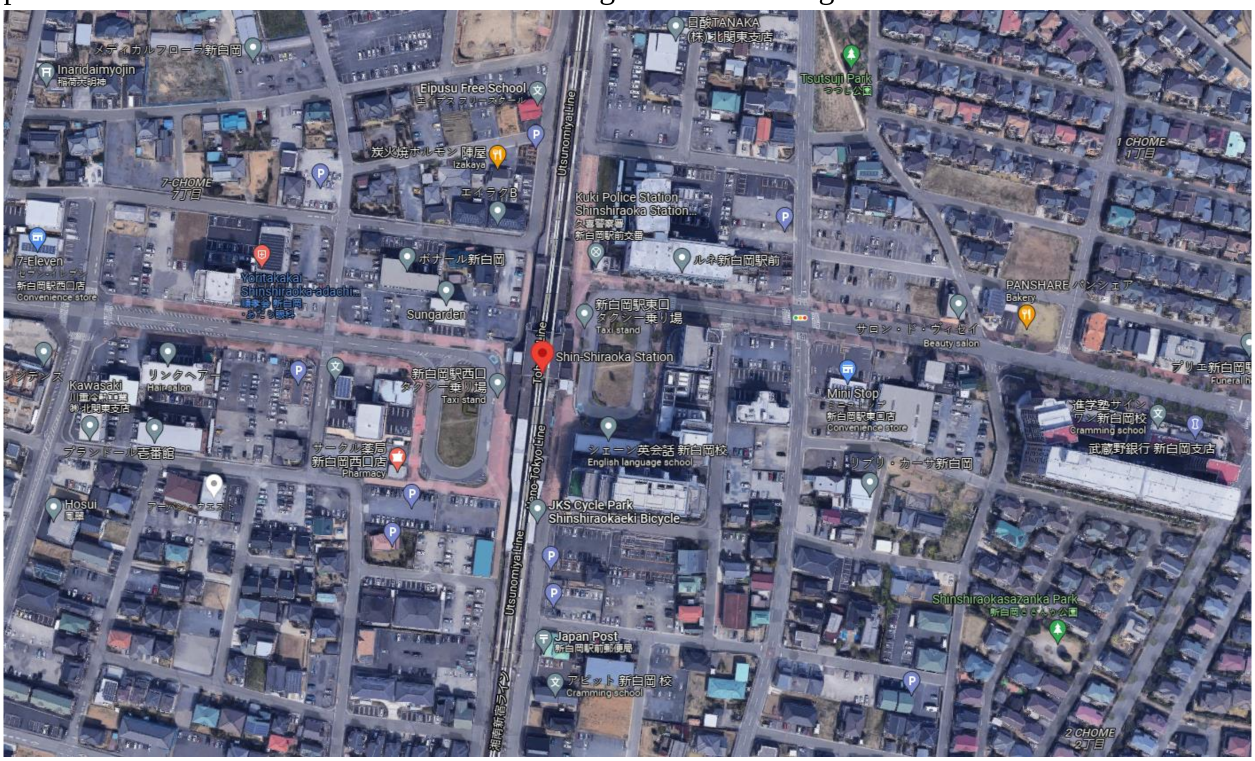

Figure 35: Satellite Imagery of Shin-Shiraoka Station and the surrounding development (Google Earth).

Shin-Shiraoka station has two entrances, on either side of the station structure, which sits over the railway. Access to the platform requires entering the station building, unlike the previous two suburban stations covered. There are large taxi hailing lanes at each entrance to the station, but there is no dedicated station parking. Parking is available in the surrounding neighborhood, offered by private landowners. The street design contains various collectors and local roads, though in this case, there are no wide arterials present. As a result, this station is not likely to be used as a park-and-ride location and more likely serves the residential and commercial uses present nearby. Development has occurred in a denser pattern than is typical of a suburban location as well; some taller structures are present along the taxi lane on the east side of the station.

The highest-intensity development is present near the station, as displayed by the large apartment buildings and commercial use adjacent to the taxi lane. Pedestrian access to the station is provided on both sides and dedicated walkways are present around the station providing access from behind the surrounding buildings. One of these walkways is shown in Figure 36. Note the bicycle parking, but lack of vehicle parking on site. Behind this image, a private parking lot is present, but is further from the station entrance than the pedestrian amenities and bicycle parking area, displaying that planners likely did not intend to use the station as a destination for motorists. Parking offered is for-profit and privately operated (Axhausen, 2015). Several of these private lots can be found on the south side of the station.

Similar to the Sakou station case study, Shin-Shiraoka station's sidewalk offerings are not nearly as complete as the US and UK case studies. This is justified by the narrow, low-speed streets, but raises questions about accessibility. On busier streets, pedestrians are protected from vehicles by raised curbs, but still walk at the level of the street. Mixing of uses is much more common near the station than farther from it, it can be assumed that the same trend is true for rail ridership with distance. For this reason, development becomes more car-based further from the station. Unlike the other two suburban stations discussed, Shin-Shiraoka station is surrounded by a ring of suburbs, followed by active farms. The edge of the developed area is quite easy to see (Figure 38).

The Shin-Shiraoka station also is near a large area of single-family homes, very similar to the other two suburban areas (Figure 37). Like the Brimsdown Station in the UK, the housing is medium density, but has little mixing of uses and supports car use more than other developments. Narrower streets present near the Shin-Shiraoka station make the neighborhood feel more human-scale for pedestrians, but a long walk is necessary to access businesses from this area. Finally, commercial areas are more car-oriented and lack many of the pedestrian amenities seen elsewhere. The streets are not nearly as welcoming to non-motorists and include parking in front of structures, wide lanes, and few street features. Despite being close to the station, there is a lack of capitalization on the convenience it provides (Figure 39).

Figure 36: View of the Shin-Shiraoka station from the north, showing the walkway and bicycle parking area (Google Street View).

Figure 37: An area exclusively made up of single-family homes, Shiraoka New Town, is shown here, within long walking distance of the station, which is located to the west (Google Street View).

Figure 38: A short walk from the station, the line between suburban and rural becomes very distinct (Google Street View).

Figure 39: View on the west side of the station. Development in this area is uneven, with many parking lots and high-rise structures (Google Street View).

Discussion of Case Comparison Findings

This study of three urban and three suburban stations provides important insight into the different ways that areas surrounding railway stations have developed, and how these developments have attracted pedestrians, or park-and-ride commuters. There is wide variation among different stations, and within each country, designs can be completely different. There were, however, some notable differences between stations that made them more accessible for more people, and more inviting for pedestrians and bicyclists. The differences in roadway design, presence or absence of mixed uses, parking, and density (including density of other railway stations) created a unique landscape at all six stations.

The first and most notable factor differentiating the stations was the roadway design. From the extremely car-centered urban form with straight, wide roads around the Midlothian station and park-and-ride lot to the narrow roads around the Sakou station, the experience of walking to the station is affected drastically. Pedestrians are comforted by enclosure and areas with fewer vehicles (Speck, 2013). Streets that support this subconscious desire are found in some of the case studies, such as many of the old streets around the Deansgate station, including the one shown in Figure 40.

Figure 40: View at Little Peter St and Jordan St in Manchester near the Deansgate station. Sign under 10a appropriately describes the urban design (Google Street View).

Another important observation was the differences in how uses were mixed in the case study districts. All three included significant residential and commercial areas, and places near the station where the two uses were close to each other. Notably, however, the areas within which a certain land use was present were much larger in the US than in the UK or Japan. Though the streets directly adjacent to the station included multiple uses, the districts were so large that walking between them becomes impractical. Even near Nostrand station in Brooklyn, most commercial development is present on arterial roads, while residential development is present within the interior of blocks. At Sakou station in Japan, commercial uses were more spread throughout blocks, and areas of concentrated commercial development were closer together. This is likely due to Japan's zoning code, which includes 12 distinct zones, which are assigned by the federal government defining the allowed intensity of use, but not the uses themselves, aside from industrial use (Hasegawa, 2009).

Addressing parking is difficult, as stations without parking were selected in each case other than Midlothian Station in the US, which has extensive parking lots. Studying parking infrastructure at the various stations goes hand in hand with the road width, as parking and wide roadways each encourage the use of private vehicles and discourage the use of the railways, walking, and cycling. Between the five stations studied that did not include onsite parking, the overall placement of parking in the neighborhoods was similar, though Japan's stations had more, but smaller parking lots compared with the UK and the US, which had fewer, larger parking lots. As the Nostrand Avenue station in the US and the Brimsdown Station in the UK are located in mainly residential areas, street parking is common in both locations. Street parking is uncommon in Japan as laws do not typically allow public streets to be used for parking (Axhausen, 2015).

A final important note about the case study stations is the density of stations. Though the stations were selected to be somewhat similar to each other, representing a typical urban or suburban station in each respective country, there are many more total stations in the UK and Japan compared with the US (Google Maps, 2021). For example, the urban US station, Nostrand Avenue, is one of quite a small number of urban railway stations in the country. American Cities tend to place more emphasis on bus, subway, metro and light rail services within urban areas, while using regional and intercity railways for suburban lines. Many US cities have one or two central stations, with all other rail stations in suburban locations; very large urban areas are an exception to this trend (Brock, 2013).

Conclusion and Policy Recommendations

Investigating six case study stations in three countries provided exposure to various types of urban design and stations that served differing purposes as part of the larger railway network. This is most useful after determining elements that are associated with higher ridership quantitatively. It was found that within the sample, there was a strong correlation between density and ridership, as well as land use mix and ridership, stations with more parking were shown to generally have higher ridership, and it was difficult to draw conclusions between lanes of surrounding roadway and ridership. This is most likely due to the factors other than urban design that influence ridership, such as level of service, reliability, and use of stations as park-and-ride locations.

With this information in hand, it was possible to perform detailed analysis and comparison of the pedestrian-friendly elements of design surrounding the case study stations, providing an in-depth and qualitative understanding of the different designs that exist and how they encourage use of the railway, use of private vehicles, or in some cases, both. Overall, ridership is not a perfect metric to compare to urban design, as it is influenced by many other factors. Still, given the results of the quantitative portion of this exercise, there are some key takeaways, and trends that were identified.

Each of the three studied countries have heavy variation of design and land use patterns between different cities and regions, so trends are based on the case studies. First, modern development in the US is favoring higher density development than it did previously, even in suburban areas, though uses are still not being mixed as much as in other countries (Delmelle, 2014). This could lead to more transit-oriented developments in the future. In the UK, a country that previously had no zoning, zoning is in the process of being implemented (Gallent, 2021). It is unclear how this will affect railway system usage or the design of areas surrounding stations, though the plan generally loosens current requirements on land use (Gallent, 2021). Japan is one of the most quickly depopulating countries in the world. As a result, density in many towns and rural areas will likely drop, though urban areas are not depopulating at the rates observed in rural areas, similar trends are likely to strike larger cities in the coming decades (Matanle, 2011). This will likely negatively impact railway ridership, though this depends on trends of where populations drop most rapidly.

With zoning laws varying heavily between countries, it is possible to use the observed urban form from the case study analysis to make some policy recommendations for zoning to increase railway ridership. As there is a positive correlation between the density and land use mix present near the sample of stations used in this exercise, promoting zoning which prioritizes high density development and mixture of uses will likely drive ridership and as a result, service quality on railways in all three countries.

Policy Recommendation 1: Allow neighborhoods to form around stations with an organic, human-scaled, and dense urban design. Any zoning that promotes the factors of density and use mixing will serve this purpose well. Consider eliminating maximum lot coverage and setback rules, adopting form-based and not use-based zoning, and allowing as-of-right development.

Parking is a more challenging point to draw conclusions about and needs to be approached differently from factors such as density. In the quantitative analysis, more parking corresponded with higher ridership, but the stations where this was true were usually not serving as local neighborhood stations, but rather as park-and-rides, or major destinations.

Approaching the parking issue from a different angle, it is possible to note that overall average railway ridership by country has a direct negative correlation with average number of parking spaces at stations by country within the sample. This indicates that at the individual station level, parking corresponds with higher ridership, though at the overall network level, it corresponds with lower ridership. This disconnect may be caused by the extreme variation between usage levels of stations. Large central stations in highly dense urban areas were not included in this research, but they account for much of a railway system's ridership. Omission of these stations may have significantly exaggerated the power of parking to drive ridership. More research would be needed on individual riders to draw conclusions about parking's effect on ridership, but policy relating to parking can still be made to benefit pedestrians using rail stations.

Policy Recommendation 2: Avoid permitting or building vast parking lots near stations. Allow parking to be offered only at the level and price at which it is demanded by the market. Disallow large surface parking facilities in favor of smaller lots and decks to open land for higher uses, generating more potential ridership sources.

Walkable streets were present in all three countries, and at every case comparison station, though the degree to how usable they were varied. There was no conclusive correlation between the number of lanes of surrounding roadway and the ridership at the selected stations, but design of roadways for walkability is recommended, as it works well with mixed-use and higher density development being proposed near railway stations.

Policy Recommendation 3: Design for walkability near stations by narrowing roadways to slow vehicles and making secondary walking routes along local roads as accessible and interesting as possible. Invest in sidewalks and increase mixed use zoning, particularly for the creation of residential development with street level retail. Promote biking by including bicycle parking and bikeable streets near stations.

Good urban design leads to more vibrant cities, with or without consideration of a highly used regional or intercity rail system. Planning cities that people want to visit or live in should be the goal of any city planner. These cities often embrace the urban design and land use elements that make it easy to move without needing a personal vehicle. Avoiding planning around the car will lead to more human-scaled cities where it is possible to look beyond driving and approach transportation in a more walking, biking, and transit-based format. The ridership of railway systems is one way to view the success of this goal, but an overall improvement of the quality of life of the people they serve goes beyond this and can be achieved. With the right investments into places served by existing railways, cities around the world have the potential to transform themselves in an exciting and future-oriented way.

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Appendix: List of Stations Used for Qualitative Comparison

US Stations

Schenectady, NY
Southampton, NY
Fullerton, CA
Olympia, WA
Cannondale, Wilton, CT
Cherry Hill, NJ
East Chicago, IN
Tucson, AZ
Temple University, Philadelphia, PA
Chatham, NJ
Harpers Ferry, WV
Anaheim, CA
Kissimee, FL
Winter Haven, FL
Kedzie, East Garfield Park, Chicago, IL
Valhalla, NY
Uphams Corner, Boston, MA
High Point, NC
Freeport, ME
Ravinia, Highland Park, IL
New Orleans, LA
Ramsey, NJ
Grand Junction, CO
Belmont, CA
Ramsey, MN

UK Stations

Crosshill, Glasgow
Park Street, St Albans
Garforth, Leeds
Fiskerton, Southwell
Stratford-upon-Avon, Stratford-upon-Avon
Wembley Stadium, Wembley
Horsforth, Leeds
New Pudsey, Pudsey
Wickford, Wickford
Loughborough Junction, London
Little Kimble, Aylesbury
Hildenborough, Tonbridge
Newstead, Nottingham

Dove Holes, Buxton
Gorton, Manchester
Hartford, Northwich
Woldingham, Caterham
Stonehouse, Stonehouse
Congleton, Congleton
Llandovery, Llandovery
Dalmally, Dalmally
Locheilside, Fort William
Berwick-upon-Tweed, Berwick-upon-Tweed
Birmingham Snow Hill, Birmingham
Newark Northgate, Newark

Japan Stations

Makuhari, Chiba
Keisei Owada, Chiba
Gochi, Mie
Taisanji, Aichi
Wakkanai, Hokkaido
Rifu, Miyagi
Chikura, Chiba
Beppu, Oita
Yagawa, Tokyo
Dentetsu-Kurobe, Toyama
Ginsui, Fukuoka
Chōjamachi, Chiba
Hama-Kawasaki, Kanagawa
Gakuden, Aichi
Umedoi, Mie
Egi, Gunma
Jōyō, Kyoto
Namioka, Aomori
Nagai, Yamagata
Miai, Aichi
Wakayamadaigakumae, Wakayama
Torahime, Shiga
Fukaya, Saitama
Shindaita, Tokyo
Aburatsu, Miyazaki