



Article

# Job Accessibility as a Lens for Understanding the Urban Structure of Colonial Cities: A Digital Humanities Study of the Colonial Seoul in the 1930s Using GIS

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**Abstract:** This study examined the urban structure of colonial Seoul in the 1930s, the capital city of Korea under the rule of the Japanese empire, by adopting quantitative geographical methods. We utilized a job accessibility index to operationalize the urban structure. We also used geographic information science (GIScience) analysis tools to digitize neighborhood-level sociodemographic and parcel-level business location information from historical materials. The results illustrated several findings that were not revealed by previous studies based on qualitative approaches. First, transit-based job accessibility (13.392) is significantly higher ( $p < 0.001$ ) than walk-based job accessibility (10.575). Second, there is a  $\Gamma$ -shaped area with higher job accessibility, including the central part of colonial Seoul. Third, Japanese-dominant neighborhoods had significantly ( $p < 0.001$ ) higher transit-based (27.156) job accessibility than Korean-dominant neighborhoods (9.319). Fourth, transit-based job accessibility is not significantly correlated with the unemployment rate overall. Although colonial Seoul was the seventh-largest city of the Japanese empire, few practical planning actions were taken to resolve urban issues, unlike the other large cities in mainland Japan.

**Keywords:** colonial urban planning; digital humanity; job accessibility; Korea; colonial Seoul; urban structure



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## 1. Introduction

In recent years, the urban structure of colonial cities in the period of New Imperialism has been widely studied by urban geographers and historians. Examining the urban structure of colonial cities provides insightful clues to understanding socio-spatial inequality (such as racial segregation, and disparity in economic opportunities) that might be historically rooted [1–4]. These studies have largely focused on colonial cities established by Europeans in South Asia [5–7], South America [8,9], and Africa [10–12]. Apart from a few exceptions [13,14], studies investigating the urban structure of colonial cities in East Asia, which were created and managed by the Japanese empire from the early 1900s to the 1940s, are less common. Thus, investigating the case of colonial cities in East Asia—where less attention has been paid—would significantly enrich our understanding of the urban spatial structure of colonial cities and its potential long-term impacts on the socio-spatial inequality in those cities presently.

In this light, examining 1930s colonial Seoul—which was one of the colonial cities in East Asia ruled by the Japanese empire—through the lens of urban structure would provide new insights into understanding the characteristics of colonial cities. From 1910 to 1945, the Japanese empire (colonists) made irreversible and substantial impacts on the urban structure of colonial Seoul (officially called Keijo in Japanese and Gyeongseong in Korean during the colonial period) [15]. Specifically, in the mid-1930s, the Japanese

Government-General of Korea first introduced modern urban planning practices that determined the land-use system of colonial Seoul, which is still a part of Seoul today [16–18]. For example, park plans established by the Keijo Municipal Government in 1940 were inherited by the Seoul Metropolitan Government during the mid-1960s [19]. Residential areas that were built through land readjustment projects in the late 1930s have been recognized as desirable residential areas. In the 1970s, the first Seoul subway line (Line 1) was built along the tram and suburban streetcar line that had been built in the colonial period.

Although previous studies on colonial Seoul provide useful ground, we argue that there are several critical research gaps. First, previous research largely adopted qualitative research methods such as document analysis [20–22]. Specifically, these studies revealed how the Japanese empire (colonists) changed Seoul from the capital of a kingdom (the Joseon dynasty) to the capital of a colony and how the urban lives of Koreans and Japanese were different in colonial Seoul. For instance, researchers traced the progress of how colonial Seoul became the logistic basement city of the Japanese empire by analyzing newspaper and magazine articles and official documents produced by the Japanese Governor-General of Korea [20]. Others revealed the historical context of how the western area of colonial Seoul became the industrial area by reviewing the document Keijo Urban Planning Report (1928) and the architecture magazine Joseon and Architecture, which was published between 1922 and 1945 [21]. Huh (2014) focused on the imaginary geography of colonial Seoul as a dual city by analyzing literary works that were written during the late colonial period to investigate how Koreans and Japanese perceived colonial Seoul differently [22].

These studies provide a meaningful ground for future studies, but their analyses might not provide a full, comprehensive picture of the urban structure of colonial Seoul and its relationship to ethnic disparities between Koreans (colonial subjects) and Japanese (colonists). This is because those studies did not utilize useful quantitative and geospatial datasets that pertain to measuring the urban structure (e.g., the spatial distribution of population and jobs and transportation networks). However, thanks to recent advances in open data governance, many historical materials (e.g., census data reports and maps) are now open to the public and researchers [19,23]. Additionally, the recent development of open-source geographic information science (GIScience) tools and methods facilitates quantitative geographical approaches in studies on colonial cities and historical geography broadly, which is in line with a recently growing number of studies in digital humanities [24–28].

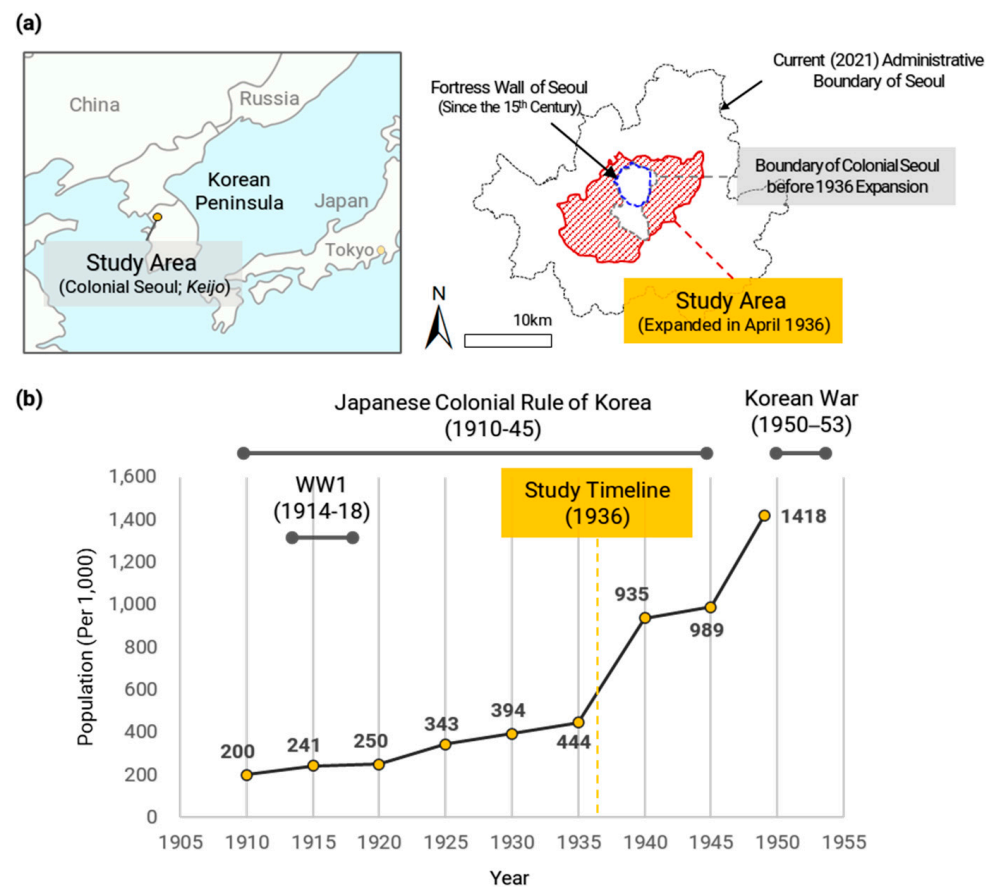
Second, many previous studies focused on limited geographic boundaries or periods of colonial Seoul, which may not capture the comprehensive picture of colonial Seoul at that time. For instance, researchers argued that the racial segregation of colonial Seoul between Koreans and Japanese should not be understood in a dichotomous way by analyzing the neighborhood population statistics based on the Japanese census from 1925 to 1935 [13]. Others found that there was significant segregation of industrial activities between Koreans and Japanese by using spatial analysis methods (e.g., Bivariate Local Moran's I) based on the document Index of Colonial Joseon Factories, published in 1932 [23]. Although these studies provide useful clues to understanding the urban structure of colonial Seoul, there is a critical limitation in the way that they only focused on partial areas of colonial Seoul. Moreover, many studies overlooked the time period after 1936 when the population of colonial Seoul increased exponentially, which resulted in many urban issues such as traffic congestion and the growth of the poor population.

To fill these significant research gaps, we aim to analyze the urban structure of colonial Seoul by using historical materials and open-source geographic information science (GIS) analysis toolkits. Specifically, we ask the following two research questions. RQ1. How can we describe the urban structure of colonial Seoul? RQ2. How does the urban structure of colonial Seoul relate to the disparity in economic opportunities between Koreans (colonial subjects) and Japanese (colonists)? To operationalize the urban structure, we focus on the job accessibility index, which has been proven to be a useful indicator [29,30] to measure

the urban structure that pertains to the land-use system (i.e., the spatial distribution of population and jobs) and the transportation system [31–36].

## 2. Background: Colonial Seoul under the Japanese Empire between 1910 and 1945

Seoul was the capital of the Joseon dynasty, which ruled the entire Korean Peninsula between 1394 and 1910. In August 1910, the Japanese Empire annexed the Joseon dynasty and began to govern the Korean Peninsula. Seoul, which had been the capital of the Joseon dynasty, continued to serve as the capital of colonial Korea. However, the city's name was officially changed to Keijo (京城) in Japanese and Gyeongseong (경성) in Korean. For 26 years after the Japanese annexation of Korea in 1910, the administrative boundary of colonial Seoul was almost constrained to the inner area of the old Seoul Fortress, which had been built in the 15th century (Figure 1a). Japanese had settled in the southern part of the old Seoul Fortress in the late 19th century. As the population of colonial Seoul was doubling at the time (Figure 1b), the Keijo Municipal Government prepared for an urban planning act and the expansion of the administrative boundary in the mid-1920s. Eventually, in April 1936, the administrative boundary of colonial Seoul was expanded fourfold. After the expansion, the population of colonial Seoul began to increase faster because more companies and factories were located there as the Japanese empire accelerated its preparations for World War II. In 1940, the population of colonial Seoul reached 935,000, making it the seventh-largest urban population of cities of the Japanese empire. Therefore, we focus on 1936, when colonial Seoul expanded its area (administrative boundary) and population in this study.



**Figure 1.** (a) Study area (colonial Seoul, the capital of Korea under the Japanese empire) and (b) study timeline (1936).

### 3. Data: Historical Materials of Colonial Seoul in the 1930s

This section describes historical materials of colonial Seoul in the 1930s.

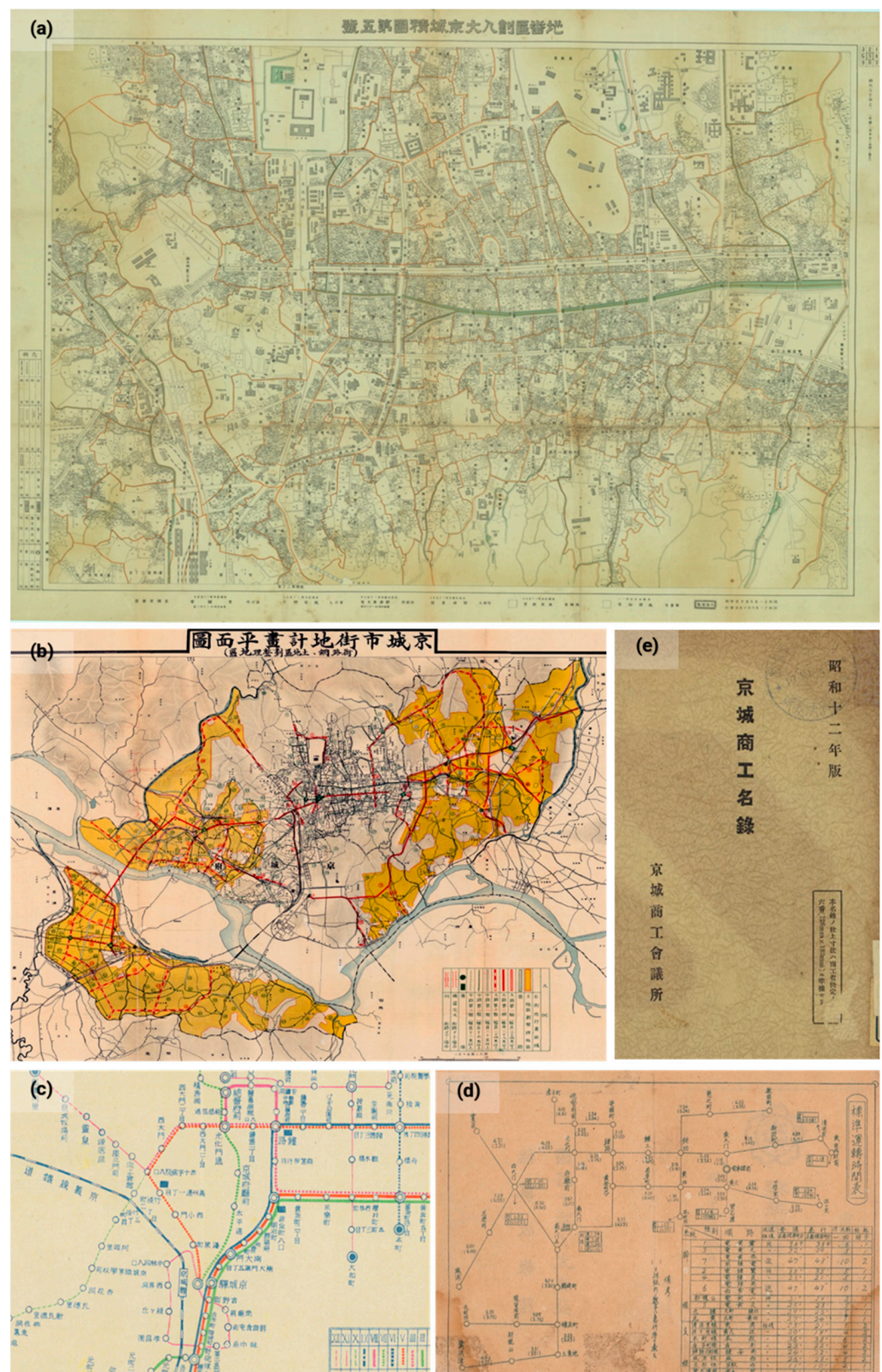
First, we utilized two historical maps: the Map of Greater Keijo (1936) and the Keijo Urban Planning Map (1938) (Figure 2a,b). The Map of Greater Keijo is a 1:5000 map produced by a map publishing company called Ji-seong-dang. This map is important historical material as it is the first official map that contains the new territory (mostly outskirt areas) that was incorporated into colonial Seoul in April 1936 [37]. In this light, this map allows us to investigate the urban structure. Moreover, the spatial resolution of this map is high as it clearly illustrates detailed road networks and individual parcels, which allows us to estimate the detailed spatial distribution of population and jobs in the 1930s. The Keijo Urban Planning Map (1938) is a 1:50,000 map that provides information on arterial roads and public transit routes, including 11 tram routes (including 1 suburban line) and 2 bus routes. These two historical maps are open to the public through the Seoul Museum of History (<https://museum.seoul.go.kr/eng/index.do>) (accessed on 1 September 2021).

Second, we obtained various historical materials to create detailed bus and tram networks that reflect how buses and trams were operated in the 1930s. We utilized the Keijo Tram and Bus Route Map of the mid-1930s produced by Keijo Electric Company (Figure 2c). This map provides the exact routes of trams and buses at the time. Moreover, we utilized the Keijo Tram Operation Timetable (1942) to estimate the travel time between two consecutive stations (Figure 2d). Note that although the Keijo Tram Operation Timetable was published in 1942, it still provides relatively accurate information on the tram operation timetable in 1936 (our study timeline), as tram routes and schedules had not substantially changed at the time.

Third, we utilized a historical government document, the Keijo Neighborhood Employment and Population Statistics (1936), produced in a report of the Keijo Municipal Government (Figure 2d). This document is used to create a database of sociodemographic information at the neighborhood level (called *dong* in Korean). This government document reports the official neighborhood-level statistics, including the number of people by gender (male and female), by ethnicity (Korean and Japanese), and by employment status (workers and non-workers). We created a database based on the scanned image of the document provided by the National Library of Korea.

Lastly, we utilized another historical government document, the Keijo Business Demography Index (1938), published by the Keijo Chamber of Commerce and Industry (Figure 2e). The document provides a list of 3598 companies that were surveyed by the government and includes each company's detailed business information, such as the company name, parcel-level address, owner, business type, and annual tax amount of each business. Note that the report includes businesses whose annual tax is 15 Japanese yen, which is approximately equivalent to \$85 in 2021 [38], indicating that the report does not include extremely small businesses. This document is important because it provides a comprehensive list of businesses with detailed location information, which is critical in measuring job accessibility.





**Figure 2.** Historical materials used for the study. (a) Map of Greater Keijo (1936); (b) Keijo Urban Planning Map (1938); (c) Keijo Tram and Bus Route Map (mid-1930s); (d) Keijo Tram Operation Timetable (1942); and (e) Keijo Business Demography Index (1938). (Note. Keijo indicates colonial Seoul, which is our study area).

#### 4. Methods

This section describes the overall methods by utilizing historical materials that we introduced in Section 3 and open-source geographic information science (GIScience) analysis tools and methods.

First, we georeferenced and created two ESRI shapefiles of the Map of Greater Keijo and the Keijo Urban Planning Map. The first shapefile contains the administrative boundaries of 258 neighborhoods in the study area. The second shapefile includes centroid points of 41,646 parcels in the study area. We also created a database of the Keijo Neighborhood Employment and Population Statistics and joined the database with the first shapefile. We also digitized the parcel-level location of the 3598 businesses listed in the Keijo Business Demography Index and created a point-based shapefile. To observe the spatial distribution of populations in general, we created a neighborhood-based map that illustrates the ratio of Korean populations (colonial subjects) to Japanese populations (colonists). We also created a kernel density estimation map of job locations to observe the overall spatial distribution of jobs.

Second, we digitized and built a high-resolution transportation network for our study area. We digitized the Keijo Tram and Bus Route Map to build an accurate public transit network of the study area in the 1930s. Specifically, we created a line-based shapefile that contains geometry information of 11 tram routes (including 1 suburban line) and 2 bus routes in the study area. We then established a General Transit Feed Specification (GTFS) dataset of the public transit network of our study area. The GTFS is a standardized data protocol that guides the structure and format of public transit datasets [39]. Many public transit agencies and researchers have recently adopted the GTFS and developed open-source public transit analysis tools [40]. By creating the GTFS format of public transit data from our historical materials (e.g., transit routes and schedules of colonial Seoul in the 1930s), we could utilize various modern open-source public transit analysis tools to analyze transportation-related issues of colonial Seoul in the 1930s. Specifically, we used the National Rural Transit Assistance Program (RTAP) GTFS Builder [41] to build a GTFS dataset for our study.

Third, we calculated two origin-destination (O-D) travel time matrices: walk-based and transit-based. Since walking and public transit were major modes of transportation for people living in colonial Seoul in the 1930s [42], we focused on these two modes of transportation. The list of origins contains 41,646 parcels' centroids (longitude and latitude), indicating the home locations of people living in the study area. The list of destinations contains 3598 parcels' centroids representing business locations in the study area. We calculated the walk-based and transit-based travel time for 149,842,308 origin-destination pairs obtained from the combination of 41,646 origins and 3598 destinations (i.e.,  $41,646 \times 3598$ ). To calculate the travel time, we used an open-source transport analysis tool, r5r R-package [40]. We assumed that trips were made at 6 a.m., representing morning commutes (i.e., home-based work trips) that pertain to job accessibility. For transit-based trips, we set 120 min as the maximum travel time and 3500 m as the maximum walking distance. Although several alternative routes might be present, we only considered the shortest travel time to define the travel time between two points. As a result, we obtained walk-based and transit-based travel time matrices consisting of 149,842,308 origin-destination pairs in the study area.

Lastly, we computed job accessibility for 41,646 parcels representing home locations in the study area. Among several accessibility measures, such as cumulative-opportunity types and gravity-types [34], we selected the inverse-distance type because of the lack of data (e.g., observed trips) that are needed for calibrating accessibility parameters (e.g.,  $\beta$  of gravity-type measures). Equation (1) indicates walk-based job accessibility, while Equation (2) indicates transit-based job accessibility.



$$A_i^{walk} = \sum_{j=1}^M walktime_{ij}^{-2} \quad (1)$$

$$A_i^{transit} = \sum_{j=1}^M transittime_{ij}^{-2} \quad (2)$$

where  $A_i^{walk}$  denotes walk-based job accessibility of parcel  $i$  ( $i = 1, 2, 3 \dots 41,646$ ) and  $A_i^{transit}$  denotes transit-based job accessibility of parcel  $i$ .  $j$  denotes the destination (job), and  $M$  indicates the number of destinations (i.e.,  $j = 1, 2, 3 \dots 3598$ ).  $walktime_{ij}$  and  $transittime_{ij}$  indicate travel time from parcel  $i$  (home) to parcel  $j$  (job) in a walk-based trip and a transit-based trip, respectively. As a result, we obtained walk-based and transit-based job accessibility values for 41,646 parcels in the study area. To examine the urban structure of the study area, which is our study objective, we mapped job accessibility results to observe their geographic patterns. Additionally, we aggregated parcel-level job accessibility results to the neighborhood level to investigate if there was a significant correlation between job accessibility and the unemployment rate surveyed at the neighborhood level. Specifically, we conducted a  $t$ -test to investigate whether there was a significant difference in job accessibility between Korean-dominant and Japanese-dominant neighborhoods. We also calculated the Person's correlation coefficient to identify if there was a significant association between job accessibility and unemployment at the neighborhood level. Additionally, we produced the Getis-Ord GI\* cluster map of the unemployment rate and observed the spatial patterns in terms of job accessibility and the unemployment rate.

## 5. Results

### 5.1. Spatial Distribution of Populations and Jobs

This subsection describes the overall spatial distribution of populations and jobs by observing maps. Figure 3a illustrates the ratio of Korean populations (colonial subjects) to Japanese populations (colonists) in 254 neighborhoods in the study area. A stronger blue color indicates that the population of Koreans is higher than that of Japanese. The figure illustrates that more Japanese lived in the southern part of central Seoul, indicating residential segregation between Koreans (colonial subjects) and Japanese (colonists). Additionally, it is interesting to observe that Korean-dominant neighborhoods and Japanese-dominant neighborhoods were split along the Cheonggyecheon stream that flows from east to west in colonial Seoul, indicating that the natural environment might act as a barrier between colonial subjects and rulers.

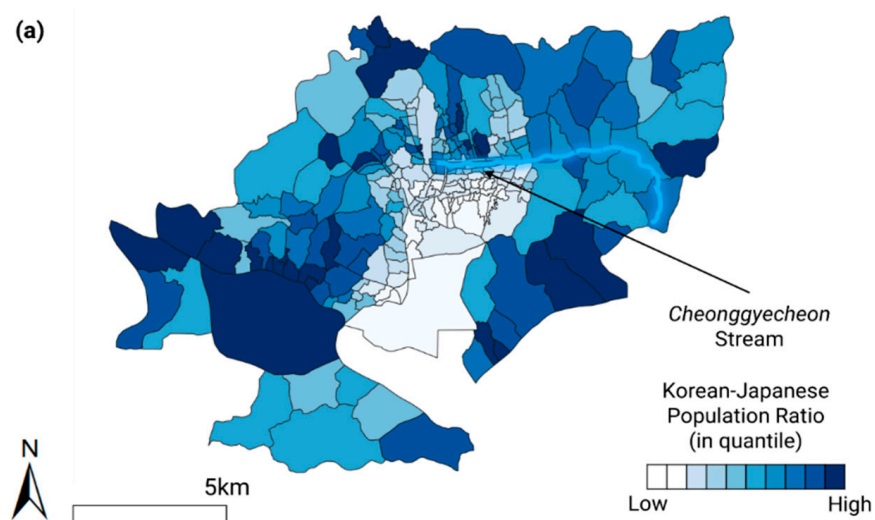
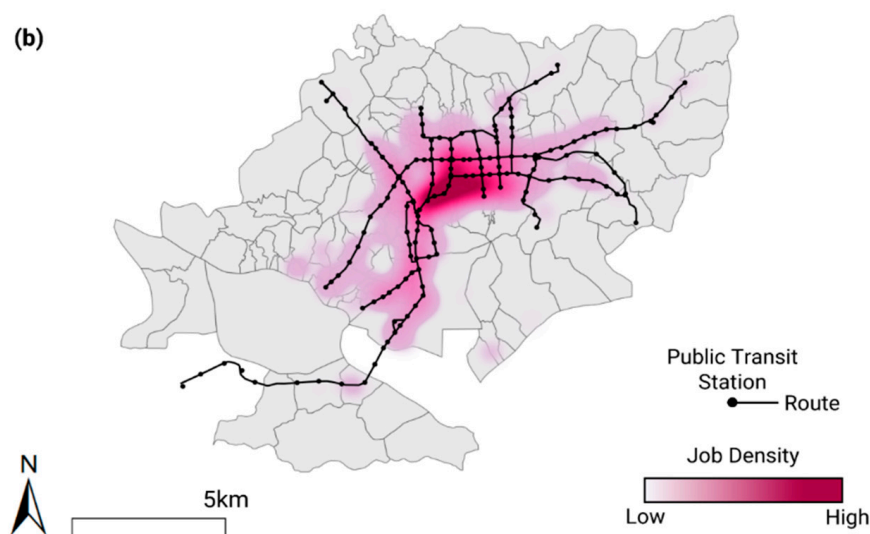


Figure 3. Cont.



**Figure 3.** (a) The ratio of Korean population to Japanese population at the neighborhood level; (b) A kernel density estimation map of 3598 jobs in the study area.

Figure 3b illustrates a kernel density estimation of job locations in colonial Seoul. The figure illustrates the geographic pattern of jobs. The central part of colonial Seoul had a higher job density than other areas. In other words, many jobs were concentrated in the center of colonial Seoul. This may reflect Seoul has been the capital of the Joseon dynasty (which was annexed by Japan in 1910) for over 500 years. By observing Figure 3a,b at the same time, we found that many businesses were concentrated in Japanese-dominant neighborhoods in the southern part of central Seoul. The government statistics report published at the time shows that the average annual tax amount of Japanese businesses was 23.3 Japanese yen, while that of Koreans was 4.7 Japanese yen [43], which may reflect our finding that many businesses were concentrated in Japanese-dominant neighborhoods.

### 5.2. Parcel-Level Job Accessibility Results

This subsection reports walk-based and transit-based job accessibility that was measured at the parcel level. Table 1 reports the descriptive statistics. The average transit-based job accessibility is approximately 32% higher than the average walk-based job accessibility. The *t*-test result indicates that transit-based accessibility is significantly ( $p < 0.001$ ) higher than walk-based accessibility. Given the fact that our study focuses on colonial Seoul in the 1930s (almost 90 years ago at the time of writing this manuscript), it is interesting to observe that the transit-based job accessibility was higher than the walk-based job accessibility, which is similar to what we can observe in cities nowadays. This means that public transportation was a travel option that was faster than walking in colonial Seoul in the 1930s.

**Table 1.** Descriptive statistics of walk-based and transit-based job accessibility measured at the parcel level.

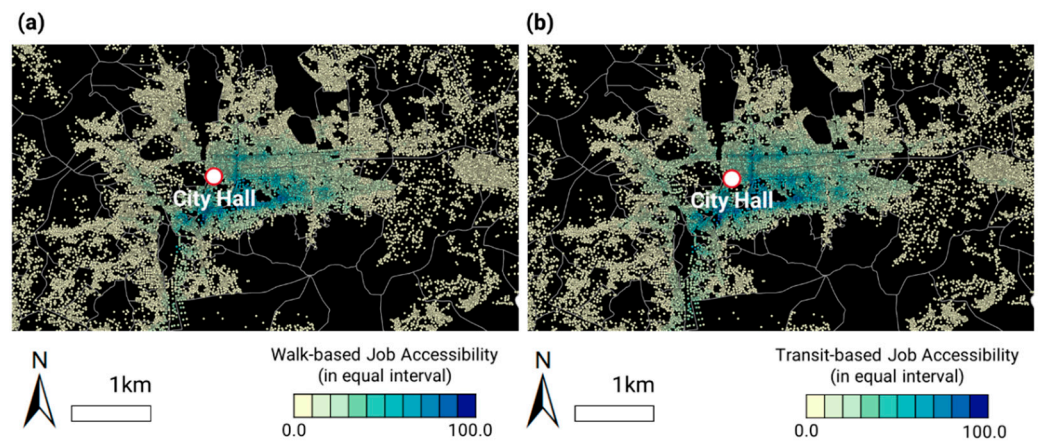
	Min	Max	Median	Standard Deviation	Mean
Walk-based job accessibility ( $A_i^{walk}$ )	0.000	93.343	2.334	11.038	7.074
Transit-based job accessibility ( $A_i^{transit}$ )	0.000	99.975	4.436	12.344	9.344
Welch's <i>t</i> -test					***

Note: \*\*\* denotes  $p < 0.001$ . *i* denotes the parcel number ( $i = 1, 2, 3 \dots 41,646$ ).

Moreover, Figure 4 illustrates the overall spatial pattern of walk-based and transit-based job accessibility at the parcel level. The figure shows that the central area of colo-



nial Seoul had higher walk-based and transit-based job accessibility than other areas. We also observed that areas with higher walk-based and transit-based job accessibility (i.e., blue color areas) have a “T” (uppercase Gamma) shape pattern. This can be explained by the many jobs in these areas, which are also covered by many tram and bus routes, as illustrated in Figure 3b. Moreover, we observed that the transit-based job accessibility map (Figure 4b) has wider blue or green areas than the walk-based job accessibility map (Figure 4a). This indicates that transit-based job accessibility was higher than walk-based job accessibility, corroborating our earlier observation in Table 1.



**Figure 4.** (a) Walk-based job accessibility and (b) transit-based job accessibility at the parcel level of the study area.

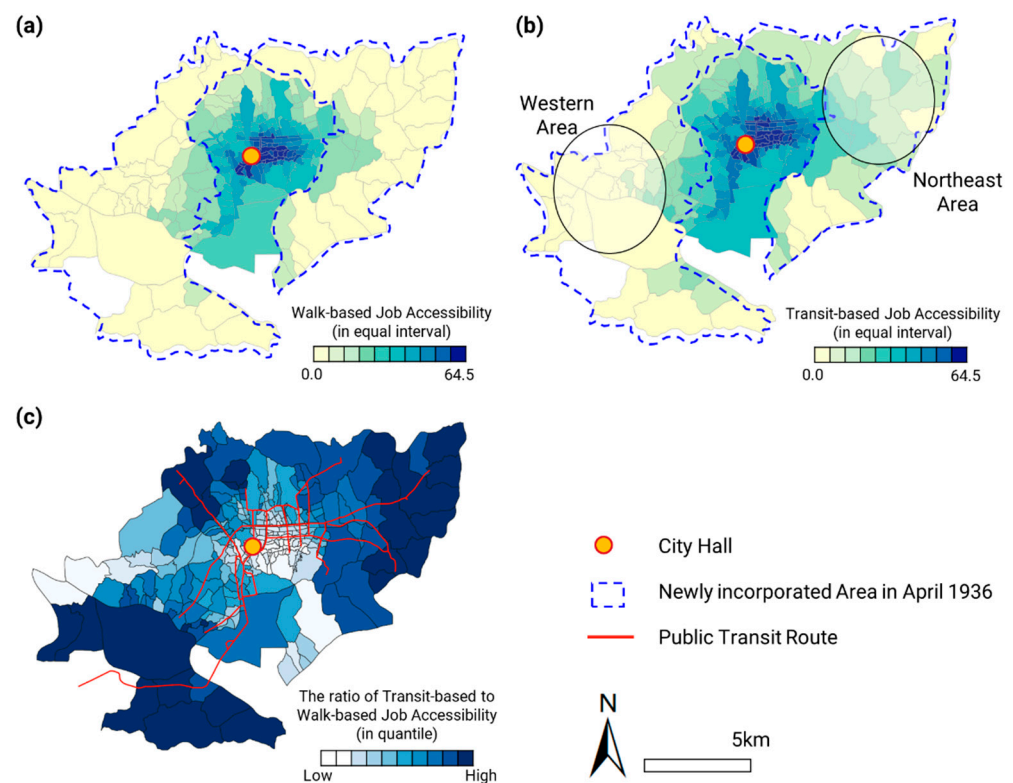
### 5.3. Neighborhood-Level Job Accessibility Results

This subsection illustrates the walk-based and transit-based job accessibility that was aggregated at the neighborhood level (Table 2 and Figure 5a,b). There are 254 neighborhoods in the study area. We aggregated the parcel-level job accessibility to the neighborhood-level by obtaining the average value. Overall, the results are highly consistent with what we observed in the results obtained from analyzing the parcel-level job accessibility in Section 5.2. For instance, the average transit-based job accessibility is 26.7% higher than the average walk-based job accessibility, which is also statistically significant ( $p < 0.001$ ). This is in line with Figure 5c, which illustrates the ratio of transit-based to walk-based job accessibility. Stronger blue color indicates the ratio is higher. We observed that the ratio of the peripheral areas is higher than other areas in colonial Seoul. Note that these peripheral areas had been incorporated into colonial Seoul because of the expansion of the administrative district of colonial Seoul in 1936 to handle the exponential population growth at the time [44]. Although these peripheral areas are distant from the urban center (where many jobs are concentrated), as some of those areas (especially northeast and western areas) are covered by adequate public transit services, they had relatively higher transit-based job accessibility. This finding highlights the important role of public transit as a means to access job opportunities for people living in colonial Seoul.

**Table 2.** Descriptive statistics of walk-based and transit-based job accessibility measured at the neighborhood level.

	Min	Max	Median	Standard Deviation	Mean
Walk-based job accessibility ( $A_i^{walk}$ )	0.021	60.641	6.742	13.743	10.575
Transit-based job accessibility ( $A_i^{transit}$ )	0.008	64.455	9.837	12.473	13.392
Welch's <i>t</i> -test					***

Note: \*\*\* denotes  $p < 0.001$ .  $n$ : 254 neighborhoods in the study area.



**Figure 5.** (a) Walk-based job accessibility, (b) transit-based job accessibility, and (c) the ratio of transit-based to walk-based job accessibility at the neighborhood level of the study area.

Table 2 reports the descriptive statistics at the neighborhood level. The average transit-based job accessibility is approximately 27% higher than the average walk-based job accessibility. The  $t$ -test result indicates that transit-based accessibility is significantly ( $p < 0.001$ ) higher than walk-based accessibility.

Moreover, we focused on comparing the transit-based accessibility of the northeast peripheral area with that of the western peripheral area. Overall, we observed that the transit-based job accessibility of the northeast areas was higher than that of the western areas. For example, in Figure 5b, there are more green color neighborhoods in the northeast areas than in the western areas. This may reflect the fact that transit lines had already been built for the northeast areas, which was not the case for the western areas. In addition to transit lines, more public facilities (e.g., schools), houses, and jobs were in the northeast areas than in the western areas [45,46].

#### 5.4. Job Accessibility between Koreans (Colonial Subjects) and Japanese (Colonists)

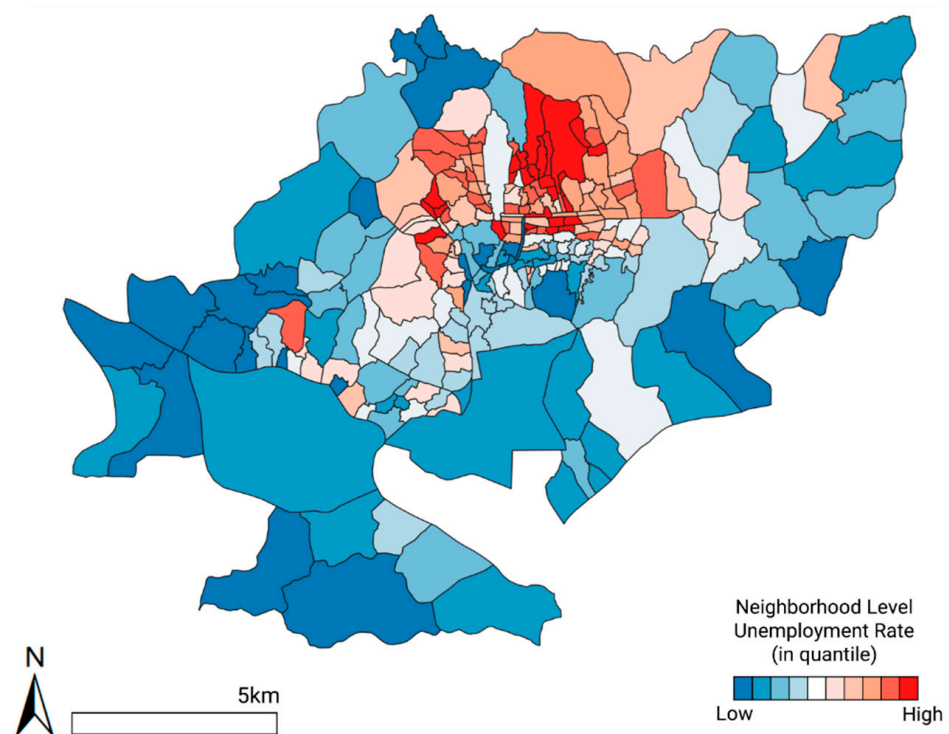
This subsection focuses on comparing the job accessibility of Koreans (colonial subjects) with that of Japanese (colonists). We classified 254 neighborhoods in our study area into two groups: (1) 58 Japanese-dominant neighborhoods where the Japanese population was higher than the Korean population and (2) 196 Korean-dominant neighborhoods. Table 3 illustrates that both walk-based and transit-based job accessibility of Japanese is higher than those of Koreans, and those differences are significant ( $p < 0.001$ ). The difference in the average job accessibility between the two groups is slightly higher in the transit-based approach than in the walk-based approach. This result implies that, in colonial Seoul, there was a disparity between job accessibility in Korean-dominant neighborhoods (colonial subjects) and in Japanese-dominant neighborhoods (colonists), which is in line with general expectations and findings from previous studies focusing on colonial Seoul and other colonial cities [47,48].

**Table 3.** The difference in job accessibility between Japanese-dominant neighborhoods and Korean-dominant neighborhoods.

	Walk-Based Job Accessibility	Transit-Based Job Accessibility
Japanese-dominant Neighborhood ( $n = 58$ )	23.501	27.156
Korean-dominant Neighborhood ( $n = 196$ )	6.745	9.319
Welch's $t$ -test	***	***

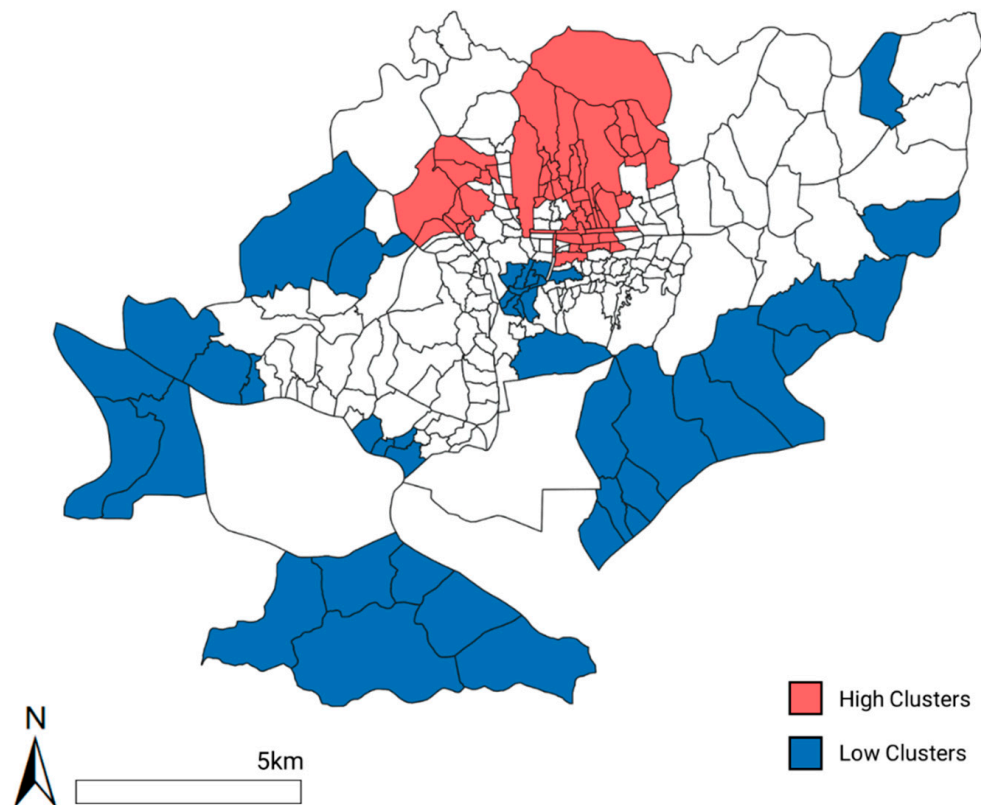
Note: \*\*\* denotes  $p < 0.001$ .

To better articulate the important role of transit-based job accessibility in people's economic activities in colonial Seoul in the 1930s, we focused on the relationship through Pearson's correlation coefficient result between job accessibility and unemployment rate regarding Koreans and Japanese. Figure 6 illustrates the neighborhood unemployment rate, demonstrating that some Korean-dominant neighborhoods in the northern areas of the city center (see Figure 3) had a higher unemployment rate. On the contrary, Japanese-dominant neighborhoods (e.g., the southern areas of the city center) and other Korean-dominant neighborhoods in the peripheral areas (see Figure 3) had a lower unemployment rate. However, Pearson's correlation coefficient result indicates that transit-based job accessibility and the unemployment rate have a weak correlation ( $\rho = 0.007$ ). In other words, there is no significant correlation between transit-based job accessibility and the unemployment rate in the overall study area.

**Figure 6.** Neighborhood level unemployment rate of the study area.

However, when we focused on certain specific local neighborhoods, we observed interesting findings. Figure 6 is a Getis-Ord  $GI^*$  cluster map of the unemployment rate. The red color indicates significant high clusters (i.e., clusters of higher unemployment rates), while the blue color indicates significant low clusters (i.e., clusters of lower unemployment rates).

First, the cluster of higher unemployment rates (57 neighborhoods, red color in Figure 7) was located in the city center's northern areas, where transit-based job accessibility was relatively higher than in other areas. Specifically, the average transit-based job accessibility of this cluster is 13.858, which is not considerably different from the average transit-based job accessibility of the study area (13.392). Neighborhoods in this cluster had a higher unemployment rate even though its transit-based job accessibility is similar to the average level of colonial Seoul. Considering that this cluster was largely occupied by Koreans (colonial subjects), there are some potential explanations for this finding, such as discrimination against colonial subjects, the disparity in education opportunities, mismatch in job skills, and so on, which has also been reported in studies adopting qualitative methods and studies on other colonial regions [49,50].



**Figure 7.** A cluster map (Getis-Ord  $G_i^*$ ) of the neighborhood-level unemployment rate. The red color indicates a significant high cluster of 57 neighborhoods with higher unemployment rates. The blue color indicates a significant low cluster of 43 neighborhoods with lower unemployment rates.

Second, the cluster of lower unemployment rates (43 neighborhoods, blue color in Figure 7) was located in the peripheral area of colonial Seoul, where transit-based job accessibility was relatively lower than in other areas. Specifically, the average transit-based job accessibility of this cluster is 12.186, which is lower than the average transit-based job accessibility of the study area (13.392). One possible explanation for this is the existence of the agriculture industry (e.g., small farms or tenant farming) in the peripheral areas. Since the outskirt areas had been incorporated into colonial Seoul at the study timeline (April 1936), many people living in those areas might have still been working in the agriculture industry. Thus, they might not have needed to access many jobs concentrated in the central area, which results in lower unemployment rates despite the lower transit-based job accessibility.

Our observation—the uneven development of colonial Seoul according to the expansion of the administrative boundary—is an interesting and important finding as it distinguishes colonial Seoul from the “six large cities” in the Japanese empire (called rokudai



toshi (六大都市) in Japanese): Tokyo, Osaka, Nagoya, Kobe, Kyoto, and Yokohama. These cities had been experiencing urban sprawl since the early 1900s [51]. For instance, in Tokyo, Osaka, and Nagoya, residential areas were largely formed along radial interurban railways. The expansion of the administrative district of the six large cities, which began in the mid-1920s, purposefully targeted two areas: (1) where sprawl had already occurred and (2) areas that were expected to be developed along railways [52]. Note that the modality of the urban expansion of the six large cities is considerably different from that of colonial Seoul in 1936: The expansion of colonial Seoul included areas that did not have public transit routes or did not experience urban sprawl. Moreover, urban policies that aimed at improving the accessibility of newly incorporated areas differed substantially between colonial Seoul and the six large cities. In 1920, the Tokyo Metropolitan Government and the Ministry of Railways of the Japanese Government agreed to build a comprehensive interurban commute network using existing state-owned railways and prepared a budget for the project, but a concrete budget execution plan did not exist for colonial Seoul [37,53].

In summary, although colonial Seoul achieved a scale (in terms of its population and size) equivalent to the scale of the six large cities, colonial Seoul experienced uneven urban expansion that was not experienced by the six large cities in mainland Japan due to the lack of practical actions for improving public transit. Moreover, our observation emphasizes the intrinsic limitations of colonial Seoul at the time as a colonial city, where most of the residents were colonial subjects who could not actively participate in the important decision-making process of land-use and transportation planning, which is also observed nowadays [54,55].

## 6. Conclusions and Discussion

This study examined the urban structure of colonial Seoul in the 1930s by adopting quantitative geographical methods. Seoul was the capital city of Korea under the rule of the Japanese empire, and it is one of the less-studied areas in studies on colonial cities. To operationalize the urban structure, we utilized a job accessibility index, which many researchers have utilized for this purpose [29,30]. We also used open-source geographic information science (GIScience) analysis tools (e.g., General Transit Feed Specification data builder and *r5r* R-programming package) to measure highly accurate walk-based and transit-based travel times based on actual public transit routes and schedules of colonial Seoul in the 1930s that were obtained from historical materials. Moreover, we obtained and digitized neighborhood-level sociodemographic and parcel-level business location information from historical materials (e.g., government reports). As a result, we measured walk-based and transit-based job accessibility at the parcel level and neighborhood level.

The results illustrated several interesting findings that were not revealed by previous studies that solely adopted qualitative approaches (e.g., document analysis). First, transit-based job accessibility is significantly higher than walk-based job accessibility. Second, geographic patterns in job accessibility exist. There is a  $\Gamma$ -shaped area with higher job accessibility, including the central part and the southern part of colonial Seoul. The geographic pattern of transit-based job accessibility was similar to that of walk-based job accessibility. Third, Japanese-dominant neighborhoods had significantly higher walk-based and transit-based job accessibility than Korean-dominant neighborhoods. Fourth, transit-based job accessibility is not significantly correlated with the unemployment rate overall. Fifth, we illustrated the uneven development issues of newly incorporated areas (e.g., peripheral areas of colonial Seoul) in 1936, which previous studies did not capture. We also discussed that although colonial Seoul was the seventh-largest city of the Japanese empire at the time, few practical planning actions were taken to resolve various urban planning issues, unlike the other six large cities in mainland Japan (e.g., Tokyo, Osaka, Nagoya, Kobe, Kyoto, and Yokohama), which were not colonial cities.

There are several limitations of our study. First, the study was conducted only at one point (1936) in a long colonial period, which was between 1910 and 1945. Thus, it may not capture dynamic changes in the urban structure of colonial Seoul that had been consid-

erably impacted by changes in the colonial policies of the Japanese empire. For example, despite the aggravating congestion problems of trams and buses in colonial Seoul in the late 1930s, historical documents (e.g., the Report of the Emergency Response Subcommittee that was published by the Keijo Urban Transportation Research Committee (published in 1942–44) witnessed that there were no effective urban transportation policy solutions. This might be due to the impacts of the second Sino-Japanese War (1937–1945) and the Pacific War (1941–1945) that were started by the Japanese empire. The research team will keep exploring historical materials to conduct a longitudinal analysis, which will benefit researchers by helping them to better understand how the urban structure of colonial cities has evolved in relation to colonists' policies. Second, the list of jobs (Keijo Business Demography Index) used in our study does not include several small firms and the informal economy, which might have played an important role in the economic activity of colonial subjects (Koreans). The research team will keep finding historical materials that might solve this issue and eventually provide a more comprehensive picture of our understanding of the urban structure of colonial cities.

Despite these limitations, our study significantly contributes to the literature on colonial cities. Specifically, our study provides useful insights into the socio-spatial inequality issues of modern-day Seoul that might be historically rooted in the colonial period. Although our study focused on one colonial city (Seoul) in East Asia, the overall methods and approaches adopted by our study can be applied to other colonial cities to enrich the existing discussion on those colonial cities. For example, in studies on colonial cities, there has recently been growing attention to comparing colonial cities in Korea, Taiwan, and mainland China, which were colonized by the same Japanese empire [14,56,57]. In this light, our methods and approaches can be useful for researchers who study those regions. Eventually, studies on colonial cities in East Asia will significantly expand the body of knowledge on colonial urban planning and decolonial approaches to urban geography, as these topics have been studied less compared to the existing studies on Western-ruled and African or South Asian subjects.

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