CALGARY LOCAL IMMIGRATION PARTNERSHIP

Mapping Newcomers' Commute in Calgary

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The Calgary Local Immigration Partnership (CLIP) is a multi-sector partnership designed to improve the integration of immigrants and newcomers in Calgary, and to strengthen the city's ability to better address the needs of newcomers. CLIP works towards the ultimate objective that immigrants in Calgary have a high quality of life that includes being economically well, enjoying physical and emotional well-being, being proficient in English / French and being fully engaged in all aspects of community life. CLIP is funded by Immigration, Refugees and Citizenship Canada (IRCC).

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CALGARY LOCAL IMMIGRATION PARTNERSHIP

UNIVERSITY OF CALGARY

Calgary

Abstract

The economies of Canada, including Calgary's, depend heavily on immigrants. However, new immigrants are often most vulnerable to joining the unemployed or working poor, which can make everyday life precarious. There are several reasons for this phenomenon, including their lack of Canadian experience, professional networks, and communication skills, but one crucial explanation is their limited travel options, coupled with socioeconomic factors such as not having a private vehicle, resulting in limited ability to travel to employment opportunities.

Accordingly, the objective of this study is to identify locations of newcomers and jobs in Calgary and analyze transit-based job accessibility from the locations of newcomers to their prospective jobs. The cumulative opportunity measure is used to compute job accessibility, which counts the number of job opportunities that can be reached from each Dissemination Area in Calgary within a given travel time. In addition, this study examines transit-based job accessibility based on various commute times and jobs in different employment sectors.

The results of the study show that newcomers in Calgary are distributed throughout the city, with a high concentration near the city's Northeast area. Also, it shows that the number of jobs is exceptionally high in industrial regions of the Northeast and Southeast, along with the city centre. In other words, there is geographic proximity between the newcomer clusters and the job clusters. However, major transit lines are not efficiently connected to most job clusters except for city centers, so job accessibility is inevitably low for those who use transit to commute to such areas. For example, newcomer clusters in the city's Northeast generally have low transit-based job accessibility despite their spatial proximity to job clusters in the Northeast industrial area. The locational relationship of newcomer clusters and job clusters has important implications from the perspective of transit planning. For instance, newcomers clustered in the Northwest and South end of the city are generally far from important job clusters and at the same time have limited access to transit services. In these cases, longer-term transit planning will need to examine ways to improve transit-based accessibility to the industrial areas. In contrast, newcomer and job clusters are spatially proximate in the Northeast, but additional transportation options that efficiently connect the short distances between them are needed to improve newcomers' job accessibility in this area. In both cases current

transit services, that have been geared toward commuters travelling from suburban areas to the centre or within the centre itself, need to be expanded to achieve better suburb-to-suburb service.

This study also identifies particular areas and time periods that need improvement in transit service by mapping transit-based job accessibility by the time of day and by industry. Since job accessibility significantly varies by the time of day, this study concludes that a different approach to transit planning is required depending on the time periods of commute. Specifically, the average transit-based job accessibility during the early morning commute time (04:30-06:00) is 38% lower than the morning peak hour (06:00-09:00). The lower frequency of transit service during non-peak hours makes it more difficult for shift workers to commute using transit. In addition, the significant differences in transit-based job accessibility by industry suggest that an industry-specific approach in transit planning will be a practical way to improve newcomers' job accessibility based on the current commute patterns of shift workers of each industry. For example, for mining, quarrying, and oil and gas extraction industry, where jobs are highly concentrated in the city center, the transit-based job accessibility is relatively high. On the contrary, for employment sectors where jobs are massively concentrated in industrial areas outskirts of the city (e.g., trade, manufacturing, construction, transportation and warehousing industries), the transit-based job accessibility is found to be generally low. It is important to note that the employment share of newcomers is exceptionally high in these industries. Furthermore, this study found that the accessibility to jobs in these industries during off-peak hours, compared to other sectors, was significantly lower than during the peak hours. Considering that the region's most significant number of newcomers are employed in these industries, and that there are many shift workers, improving transit services to these industrial areas is essential during off-peak hours.

In conclusion, the theoretical background combined with the empirical evidence found in this study leads to the broad conclusion that newcomers in Calgary need more efficient transit services to deliver them to their potential job opportunities. In addition, given that transit-based job accessibility varies considerably depending on the time of day and industry, time- and industry-specific approaches in transit planning will be helpful in efforts to improve newcomers' transit-based job accessibility and, in turn, their chances for stable employment and settlement.

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List of Acronyms & Abbreviations

BRT	Bus Rapid Transit
CMA	Census Metropolitan Area
CSD	Census Subdivision
DA	Dissemination area
GIS	Geographic Information Systems
GTFS	General Transit Feed Specification
LRT	Light Rail Transit
OSM	OpenStreetMap
OTP	OpenTripPlanner
PTN	Primary Transit Network

1. Introduction

Are there no jobs available or no means of transportation to get to the jobs? This question may not be relevant for the majority of people living in highly automobile-dependent cities in North America. Looking at Calgary, people own 1.76 vehicles per household, with 59 % of households with two or more cars and 17% of households with more than three, leaving only 6% with no automobile (The City of Calgary, 2018). Statistics also show that 77.9% of people in Calgary commute by automobile while 13.6% commute by transit that is served by two LRT (Light Rail Transit, CTrain) lines with 118.1 km track, four BRT (Bus Rapid Transit) lines, four MAX lines, and 169 regular bus lines (Statistics Canada, 2016; Calgary Transit 2019). Apparently, most people do not have a crucial problem with their commuting. However, having appropriate means of transportation to get to the worksites may be a critical concern for economically vulnerable populations in the city who readily need employment but do not have access to private cars. As examined in many previous studies, public transit is an essential mode of transportation for low-income workers (e.g., Blumenberg and Pierce, 2012; Fan, 2012; Johnson et al., 2017; Tyndall, 2017).

Meanwhile, Canada ranks among the most immigrant-receiving countries in the world, and Calgary is one of the top destination cities for immigrants and continues to attract people from a range of cultural and ethnic backgrounds. With a total number of about 400,000, the ever-increasing number of immigrants is the backbone of Calgary's economy (IRCC, 2019). However, new immigrants are often most vulnerable to joining the unemployed or working poor. According to the 2016 Canadian Census, the unemployment rate of newcomers in Calgary, who immigrated to Canada during the five years prior to a given census year, was 12.1%, higher than 9.3% of the total population. In the same year, their median individual income was 29,517 Canadian dollars, significantly lower than 43,908 Canadian dollars of the total population (Statistics Canada, 2016). This phenomenon could be a combined result of multiple factors, such as their lack of Canadian experience, professional network, and communication skills. However, there is rich empirical evidence that lack of appropriate transportation to access jobs is another important explanation for the lower opportunities of economically vulnerable groups, including newcomers (Sanchez, 1999; Yi, 2006; Blumenberg and Pierce, 2012; Fan, 2012; Tyndall, 2017).

Newcomers tend to settle in their respective ethnic clusters due to network effects or limited choices in housing markets, while their approachable low-skilled jobs are generally either located in the industrial areas in the city or moving to the outskirts as the city is sprawling (Cervero and Wu, 1998; Zavodny, 1999; Pamuk, 2004; Brown and Thompson, 2008; Blazquez et al., 2010). Thus, the spatial mismatch between newcomers and jobs increases, and it becomes more difficult for newcomers who cannot afford to own an automobile to access those jobs without an efficient transit system. Given the economic and social benefits that immigrants contribute to Calgary, it would be meaningful to look at the spatial mismatch between newcomers and their job opportunities and the limitations of current transit services in order to seek directions for improvement. In this study, we would like to identify the locations of newcomers and their job opportunities in the Calgary area and analyze newcomers' transit-based accessibility to their prospective worksites through Geographic Information Systems (GIS).

2. Literature Review

2.1 Spatial mismatch hypothesis

The spatial mismatch hypothesis argues that the geographic separation between jobs and housing has a negative effect on the employment outcomes of low-income minorities. The classic work of Kain (1968) investigated the spatial mismatch between African Americans concentrated in the central city and their job opportunities in suburban areas in Chicago and Detroit. In this study, Kain proposed that housing segregation had kept African Americans in areas of the city where access to employment had decreased due to the decentralization of low-skilled jobs to suburban regions. In the 50 years since Kain published his seminal work, the spatial mismatch hypothesis has been widely tested through a variety of disadvantaged groups, including low-income people (Blumenberg, 2004; Zhou et al., 2013), visible minorities (McLafferty and Preston, 1992; Stoll and Covington, 2012; Taylor and Ong, 1995), and immigrants

(Hellerstein et al., 2019; Liu and Painter, 2012; Painter et al., 2007). For example, McLafferty and Preston (1992) looked at the spatial mismatch between jobs and residences of black and Hispanic women in New Jersey. They found that minority women tend to have longer commutes and less-localized labour markets than white women, reflecting their heavy reliance on mass transit and poor spatial access to employment (McLafferty and Preston, 1992). Also, Liu and Painter (2011) pointed out that immigration and the decentralization of jobs have been notable in urban areas in the US in recent decades. They suggested that there is a spatial mismatch between immigrant settlement and employment by showing that immigrants tend to be more spatially mismatched with job opportunities than the white population in the 60 largest immigrant metropolitan areas in the US.

A detailed analysis of the factors driving racial and ethnic gaps in spatial mismatch conditions across US urban areas was conducted by Stroll and Covington (2012). They concluded that racial segregation in housing markets, among many other factors, is the most important factor explaining the spatial mismatch while employment decentralization (job sprawl) also matters. This study suggests that targeting policy towards reducing racial segregation is vital in eliminating spatial mismatch conditions.

The studies mentioned above revealed that the spatial mismatch between newcomers and jobs could be seen as a combined result of multiple urban processes, including residential segregation of minorities and decentralization of employment. Also, they suggested that social and economic minorities (mainly in the US) are likely to be more spatially mismatched with job opportunities than average populations. However, newcomers[1], despite the social and economic characteristics that differentiate them from established immigrants or low-income people as a whole, have not been addressed in previous studies.

2.2 Newcomers and spatial clustering

In many metropolitan regions of North America, including Canada's major cities, immigrant households have been the prime driver of demographic and economic growth

[1] Newcomers, or recent immigrants, refer to landed immigrants who came to Canada up to five years prior to a given census year (Statistics Canada, 2021).

(Government of Canada, 2021). Therefore, understanding the residential patterns of newcomers can help predict their impact on the labour market and the employment outcome of the host cities. In many urban areas, immigrant settlement patterns are largely characterized by spatial clustering (Donaldson, 2011; Blazquez et al., 2010). Numerous studies have revealed that the most relevant factor in determining residential location choice amongst new immigrants is proximity to more established immigrants who share similar ethnocultural backgrounds (Zavodny, 1999; Blazquez et al., 2010). This trend means that newcomers tend to settle around existing immigrant communities of familiar ethnic groups to benefit from access to information regarding housing and employment options (Donaldson, 2011). The formation of these ethnic enclaves has important social and economic implications from the perspective of the spatial mismatch hypothesis that residents of minority populations are more likely to suffer from job insecurity, lower wages, and longer commutes than residents living in more wealthy areas (Blazquez et al., 2010; Donaldson, 2011).

According to the theory of Chicago School sociologists based on the human ecology approach, newly arrived people are first expected to live in congested conditions in 'zones-in-transition' but move to working-class districts soon after their socioeconomic situation improves (Pamuk, 2004). Therefore, it would be meaningful to look at locations of newcomers as it is highly likely that they have different residential patterns than general citizens as well as more established immigrants.

2.3 Transportation and employment

There is considerable empirical literature on the relationship between transportation and employment (Blumenberg and Manville, 2004). Most studies consistently find that a lack of viable transportation options is a barrier to employment for minor individuals, including immigrants, and that reliable transportation leads to increased access to job opportunities, higher earnings, and increased employment stability (Ong and Blumenberg 1998; Cervero et al., 2002; Blumenberg 2004).

In urban areas, public transit plays an essential role in providing low-cost, environmentally friendly, and socially equitable means of accessibility (Pucher, 2004). Public transit is a particularly critical means of transportation for new immigrants whose automobile ownership is very low. However, using a private vehicle is generally a much faster and more convenient means of commuting than using public transit. For example, it is often the case that those who commute by car can find their commuting route much more manageable than those who rely on public transit, even when the travel distance by automobile is significantly longer (Donaldson, 2011). Several studies have concluded that automobile ownership is a more powerful determinant in both job seeking and job retention than public transit usage and that it also correlates positively with hours worked per week and average monthly earnings (Cervero et al., 2002; Blumenburg and Manville, 2004).

Conventional location theory suggests that many well-paid workers living in the city centre will eventually choose to live in the suburbs even if they are employed in the core because they can have more space with less budget in the outlying areas of metropolitan areas (Simpson, 1992; Donaldson, 2011). Also, higher income allows for greater access to a private vehicle that reduces much of the inherent cost and inconvenience of long-distance commutes. As a result, low-income workers tend to travel shorter distances to work, while those with higher earnings have longer commutes (Murakami and Young, 1997; Donaldson, 2011). However, a shorter commuting distance does not necessarily mean a shorter commute time. Travel times over short distances may still be quite long, especially when one is relying on inefficient public transit service. Even in cities with well-organized public transport, travel times tend to be much longer for transit riders than for automobile users when taking into account walking to and from stops, transferring routes and frequent vehicle stops along the way (McLafferty and Preston, 1997; Donaldson, 2011). Therefore, public transit often has difficulty in overcoming spatial barriers to employment.

Moreover, the most efficient transit services have been geared towards commuters travelling from suburban areas to the centre or within the centre itself and not outwards the suburbs or exclusively within suburban areas (Loveless, 1999). The mass suburbanization and decentralization of employment observed in North American cities have resulted in transit agencies struggling with decreased patronage, expanding services, and suburb-to-suburb commutes (Donaldson, 2011).

2.4 Measuring accessibility

Accessibility, or the ease of reaching destinations, is a comprehensive metric measuring the interaction between land use and transportation (Hansen, 1959). Accessibility is an essential characteristic of metropolitan areas and is often reflected in transportation and land-use planning goals (Handy and Niemeier, 1997). Also, it is a function of transport networks, land use characteristics as well as individual social and economic (Hanson, 1982; Geurs and Van Wee, 2004). It is important that the concept of accessibility be translated into performance measures as these can give planners and policymakers a powerful tool for determining the need for and the effectiveness of alternative land-use and transportation policies (Handy and Niemeier, 1997).

Measuring accessibility is concerned with evaluating how well a city's land use and transport networks allow people to go where they want in a reasonable amount of time (Allen and Farber, 2020). Accessibility also has a temporal dimension as the transportation and activity elements may differ throughout the day (Handy and Niemeier, 1997). For instance, shops have specific opening hours and the schedules of transit services change depending on the time of day and the day of the week (Delafontaine et al., 2001; Widener et al., 2017).

In the spatial mismatch literature, a group of researchers tried to quantify the spatial discrepancy by measuring the job accessibility of particular groups of people (Parks, 2004; Fan et al., 2014; Hu, 2015; Zhou et al., 2016; Haddad and Barufi, 2017). These studies typically introduce two different measures to calculate accessibility: cumulative opportunity and gravity-based measures. The most common form of accessibility measures used in previous studies is the cumulative opportunities measures that count the number of opportunities reachable from a certain point in space within a given travel time (Handy and Niemeier, 1997; Kwan, 1998). It is typically formulated as follows:

$$A_i = \sum_{j=1}^{j} O_j f\left(t_{i,j}\right) \tag{1}$$

Where Ai is the measure of accessibility for a location i, O_j is the number of opportunities at location j, and $f(t_{i,j})$ is a decreasing function of travel cost, t, from i to j. $f(t_{i,j})$ is based on one or more impedance factors like travel time or monetary cost. The simplest form of $f(t_{i,j})$ is a threshold indicator, which returns a 0 or 1 whether or not the travel time or monetary cost is less than the threshold. In this case, A_i is interpreted as the number of opportunities (e.g., jobs that can be reachable within a set travel time (e.g., within 30 minutes). For example, Fan et al. (2014) applied a cumulative opportunity approach to calculate the number of transit-accessible jobs based on a transit travel time threshold (60 min) and showed that Beijing offers highly centralized transit services that are not oriented towards actual low-wage jobs or worker distribution.

On the other hand, the gravity-based measures of accessibility discount the destinations or opportunities by distance; the further an opportunity is, the less it contributes to accessibility (Hansen, 1959; Koenig, 1980). The gravity model extends the cumulative measures by using a decay function to weigh nearby destinations more than destinations that are further away. Common decay functions used include exponential, Gaussian, and inverse-power (Handy and Niemeier, 1997; Kwan, 1998). Recent applications of this approach can be found in Parks (2004), Haddad and Barufi (2017), Liu and Kwan (2020), among others. A gravity-based approach is considered more robust because it relaxes the assumption made by the cumulative metric that all job opportunities are equally desirable for job seekers regardless of the distance. However, it is difficult to compute and communicate to varying audiences, reducing their chances to impact policy (Handy and Niemeier, 1997). For this reason, the cumulative opportunity measures have been preferably adopted in recent job accessibility studies and planning practices (Handy and Niemeier, 1997; Owen et al., 2016).

Measuring transit-based accessibility can be particularly complicated by the temporal variations inherent in transit services (Allen and Farber, 2020). Transit schedules vary by day of the week, time of day, and even minute-by-minute. To measure transit-based accessibility, the previous studies have combined transit schedules (usually in GTFS format) with walking network graphs to compute door-to-door trip durations pertaining to specific departure times, and to be inclusive of walking to and from stops, wait times, transfer times, and in-transit travel times (O'Sullivan et al., 2000; Lei and Church, 2010; Farber and Fu, 2017). The increased power of computation in recent years has allowed for computing large origin-destination matrices and accessibility measures for multiple departure times, allowing for averaging over set periods, such as the morning rush-hour commute (Owen and Levinson, 2015; Farber and Fu, 2017; Conway et al., 2017).

Several reviews on accessibility studies pointed out that accessibility measures used in practice should be theoretically and behaviourally sounds, be easily communicable, have available data sources to be measured by, and be able to be used in social and economic planning and policy (Handy and Niemeier, 1997; Geurs and Van Wee, 2004). The accessibility measures used in this study are determined based on these principles.

3. Research objectives and questions

Based on the literature review conducted in the previous section, this study aims to identify the locations of newcomers and their job opportunities in Calgary and analyze the transit-based accessibility between the two. Key research questions include:

1. Where do most newcomers live in Calgary?
2. Where are the jobs where newcomers generally work in the Calgary area?
3. How effectively do current transit services link newcomers to their worksites?
4. How does transit-based job accessibility vary by time of day and by industry?

4. Method

4.1 Study area

The geographical scope of this study is the Calgary CMA (Census Metropolitan Area). CMAs are urban agglomerations of municipalities with a population of over 100,000 where at least 50 % of the employed labour force works within the region's core (Statistics Canada, 2016). The Calgary CMA consists of nine census subdivisions, with a total area of 5,110.21 square kilometres and a population of 1,392,609 (Statistics Canada, 2016). Also, it is delineated into 1,759 census dissemination areas, which are the smallest areas in which socioeconomic data is available from the Canadian census. Figure 1 shows the boundaries of the Census subdivisions in the Calgary CMA.

Looking at the modes of transportation and travel behaviour of people in the Calgary CMA, people own 1.76 vehicles per household, with 59 % of households with two or more cars and 17% of households with more than three, leaving 6% with no car (The City of Calgary, 2018). Also, 78.8% of people in the Calgary CMA commute by automobile, while 13.6% commute by transit, which is currently served by two LRT (Light Rail Transit, CTrain) lines with 118.1 km track, four BRT (Bus Rapid Transit) lines, four MAX lines, and 169 regular bus lines (Statistics Canada, 2016; Calgary Transit 2019). The mean one-way commute duration in this area is 26 minutes; the mean commute time using transit is 41.6 minutes and using private cars is 24.1 minutes. Table 1 presents quick facts about this area, focusing on labour and commutes statistics.

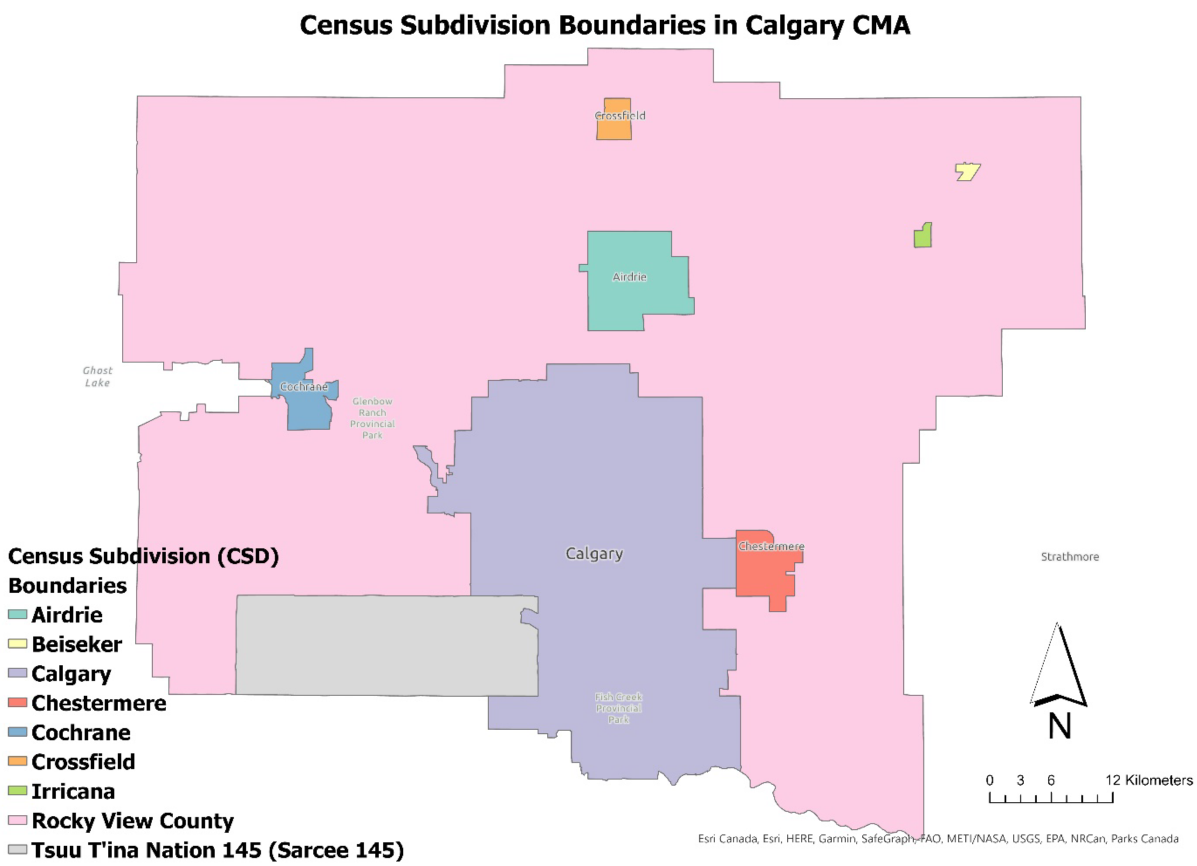


Figure 1. Boundaries of Census Subdivisions in Calgary CMA (Statistics Canada, 2021).

Table 1. Quick facts of the study area (Calgary CMA).

Area (Km2)	Population	Number of Newcomers*	Labour Force	Employed labour force	Transit mode share (%)	Mean commute time (min)	
						Transit	Car
						41.6	24.1
5,110.21	1,392,609	93,250	816,550	661,495	13.6	26	

**Landed immigrants who came to Canada prior to a given census year (2011-2016) (Statistics Canada, 2017).*

4.2 Datasets

Within the Calgary CMA, census Dissemination Areas (DAs) are used as the aggregation unit because they are the smallest geographic area in which Canadian census socioeconomic data is available, which minimizes error due to the MAUP (modifiable area unit problem). MAUP is one of the most critical problems in spatial analysis when spatially aggregated data are used. Data tabulated for different spatial scale levels or according to different zonal systems for the same region will not provide consistent analysis results (Wong, 2009). One way to deal with MAUP is to use the original point data rather than the aggregated ones, but this is usually not applicable due to legal privacy reasons. Alternatively, using smaller areal units (e.g., cities rather than provinces, census tracts rather than cities, or dissemination areas rather than census tracts) for data aggregation may decrease the MAUP effect (Su et al., 2011). A Dissemination Area is a small, relatively stable geographic unit composed of one or more adjacent dissemination blocks (Statistics Canada, 2016) and has been used in recent studies on transit accessibility in Canada (Widener et al., 2017; Wessel et al., 2017; Allen and Farber, 2020).

There are three types of input datasets needed to determine job accessibility in each DA: population, employment, and transit dataset. Table 2 Below is a list of the datasets used for this study, which will be discussed in more detail in the following sections. The long-form census, which we draw our data from, is a 25% representative sample of total households.

Table 2. Datasets used in the study

	Data Type	Descriptions	Data provider
1	Dissemination Area boundary	Shapefile that contains boundaries of a total of 1,759 DAs in Calgary CMA	Statistics Canada
2	Population data	Total number of residents, the number of newcomers in each DA, and their demographic characteristics	Statistics Canada
3	Employment data	Total number of jobs in each DA, broken by NAICS (North American Industry Classification System)	Statistics Canada
4	Transit data	GTFS (General Transit Feed Specification): Transit routes and schedules	City of Calgary

DA boundary

The Calgary CMA Dissemination Areas boundary shapefile (Figure 2) was obtained from Statistics Canada and will be used to visualize newcomers' residential patterns and job opportunities. The level of disaggregation is essential in measuring accessibility for smaller zones should result in more accurate estimates of accessibility in the zone, as accessibility can vary significantly across small distances (Handy and Niemeier, 1997). However, there is still a considerable variation in land size (0.017 to 45.416 km^2) and population (105 to 21,970 people) among DAs, which indicates that the MAUP will not be fully resolved.

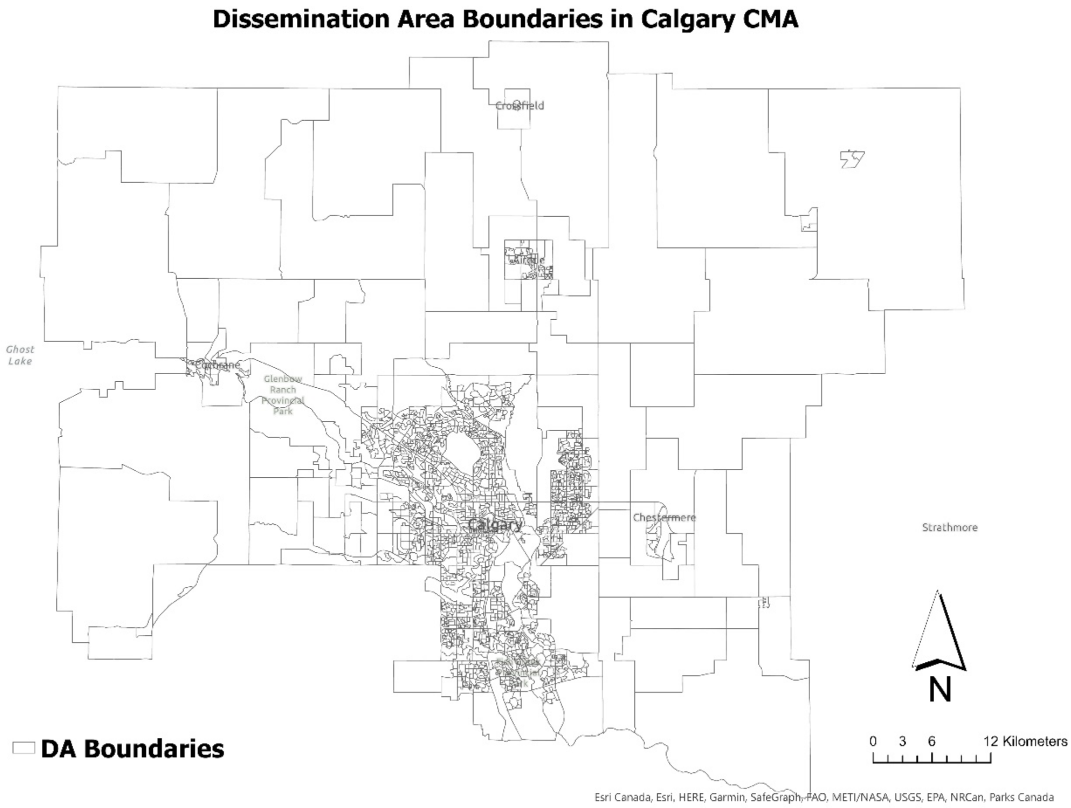


Figure 2. DA boundaries in Calgary CMA (Statistics Canada, 2017)

Population data

The population dataset provides various information on the population in each DA, including the total number of residents and the number of newcomers and their demographic characteristics. Although there are fewer than 1,000 people in most DAs, the number varies significantly from multiple thousands to more than 10,000. In particular, there are DAs in some new communities on the city's edges with more than 20,000 residents. Figure 3 shows the distribution of the population by DA in the Calgary CMA, and it is observed that the majority of the population is concentrated in Calgary CSD (89%), with some exceptions in some other urban centres such as Airdrie (4.4%) and Cochrane (1.9%).

Table 3. The distribution of population and newcomers in each Census subdivision (CSD) in Calgary CMA (Statistics Canada, 2017).

Census subdivision	Calgary	Airdrie	Rocky View County	Cochrane	Chestermere	Crossfield	Tsuu T'ina Nation 145	Irricana	Beiseker	Total
Population	1,239,220	61,581	39,407	25,853	19,887	2,983	1,643	1,216	819	1,392,609
The number of newcomers	89,660	1,775	455	710	600	20	20	0	10	93,250

Figures 5 and 6 show the distribution of the newcomers in Calgary CMA and CSD. There are less than 300 newcomers in most DAs in the Calgary CMA, but in some DAs at the northern edge of the city boundary of Calgary, where the total population is significantly high, there are more than 3,000 newcomers in each DA. However, these maps can be misleading because areas with a high number of newcomers generally coincide with large DAs. Figures 7 and 8 show the ratio of the number of newcomers in each DA in relation to the number of newcomers in the city and the total population of the DA. As can be seen, the ratio of the number of newcomers in each DA to the total number of newcomers in Calgary is significantly high in large DAs near the city limits, where the absolute number of newcomers is high. More than 15% of the city's total newcomers live in those areas on the city's edges. Additionally, the ratio of newcomers to the total population of each DA is generally very high in most DAs in the Northeast and some DAs in the inner city. The maps examined here show that although the absolute number of newcomers is generally high in the densely populated residential areas in general, looking at proportions, newcomers tend to be heavily concentrated in the Northeast along with some parts of the inner city.

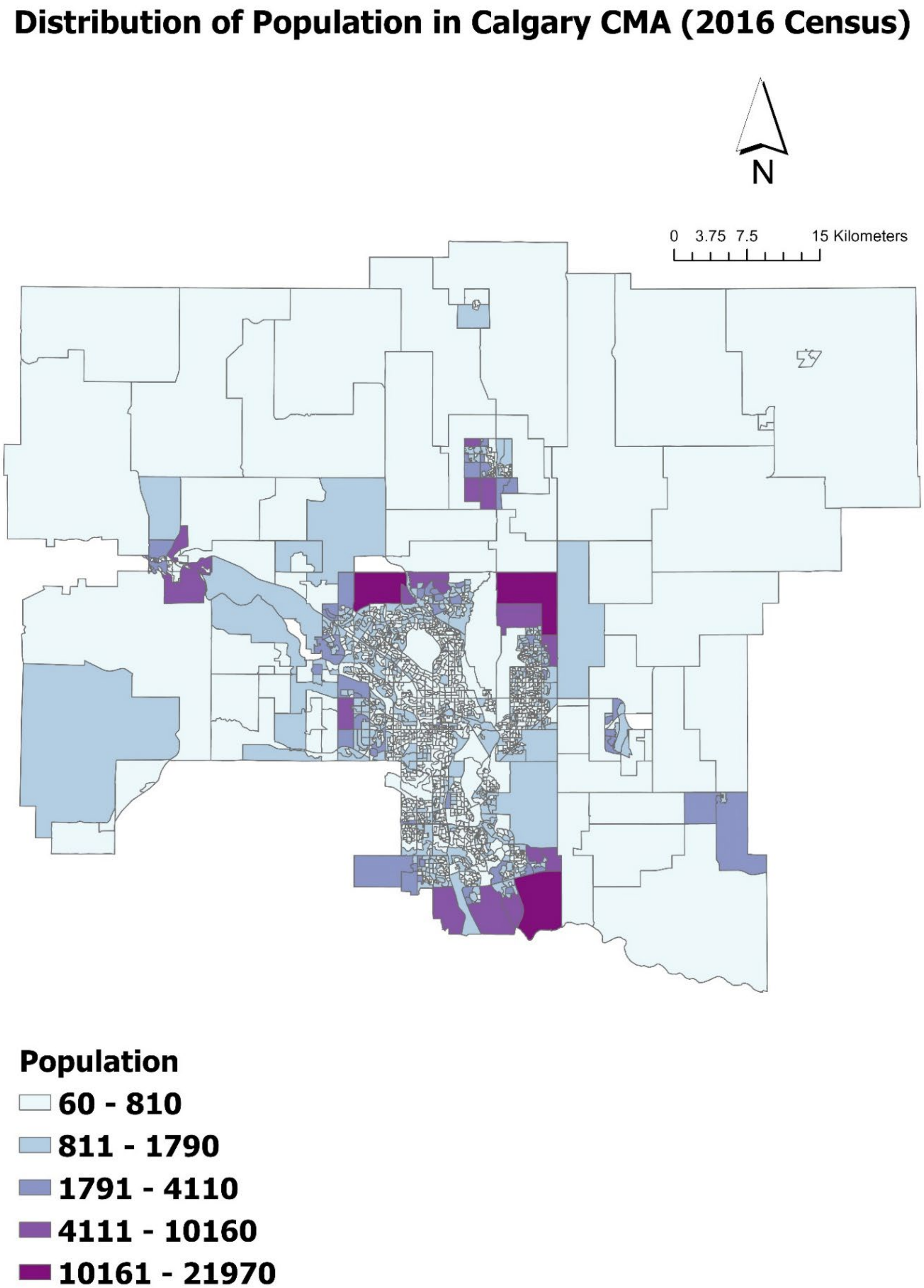


Figure 3. Distribution of the population in Calgary CMA (Statistics Canada, 2017).

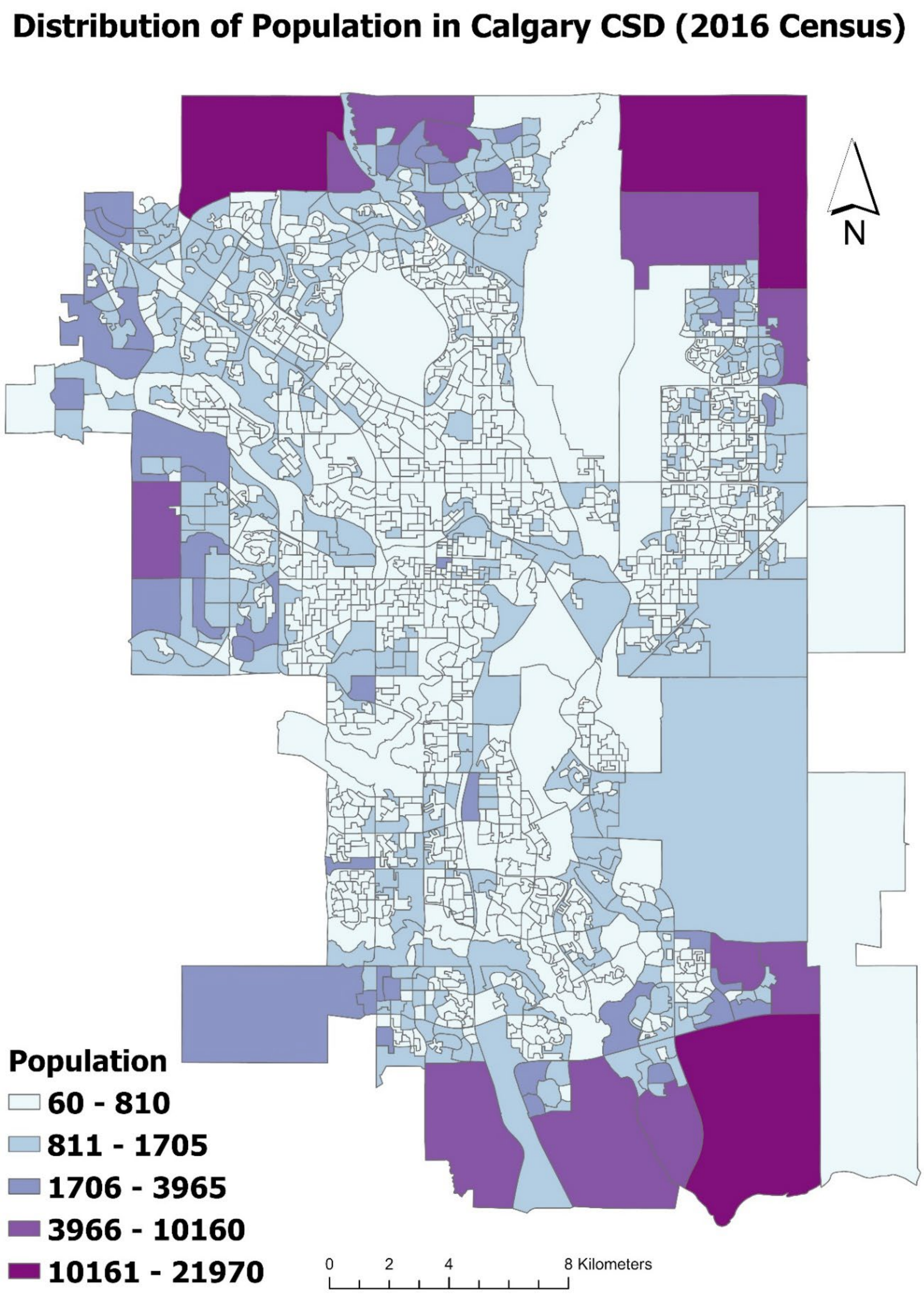


Figure 4. Distribution of the population in Calgary CSD (Statistics Canada, 2017).

Distribution of Newcomers in Calgary CMA (2016 Census)

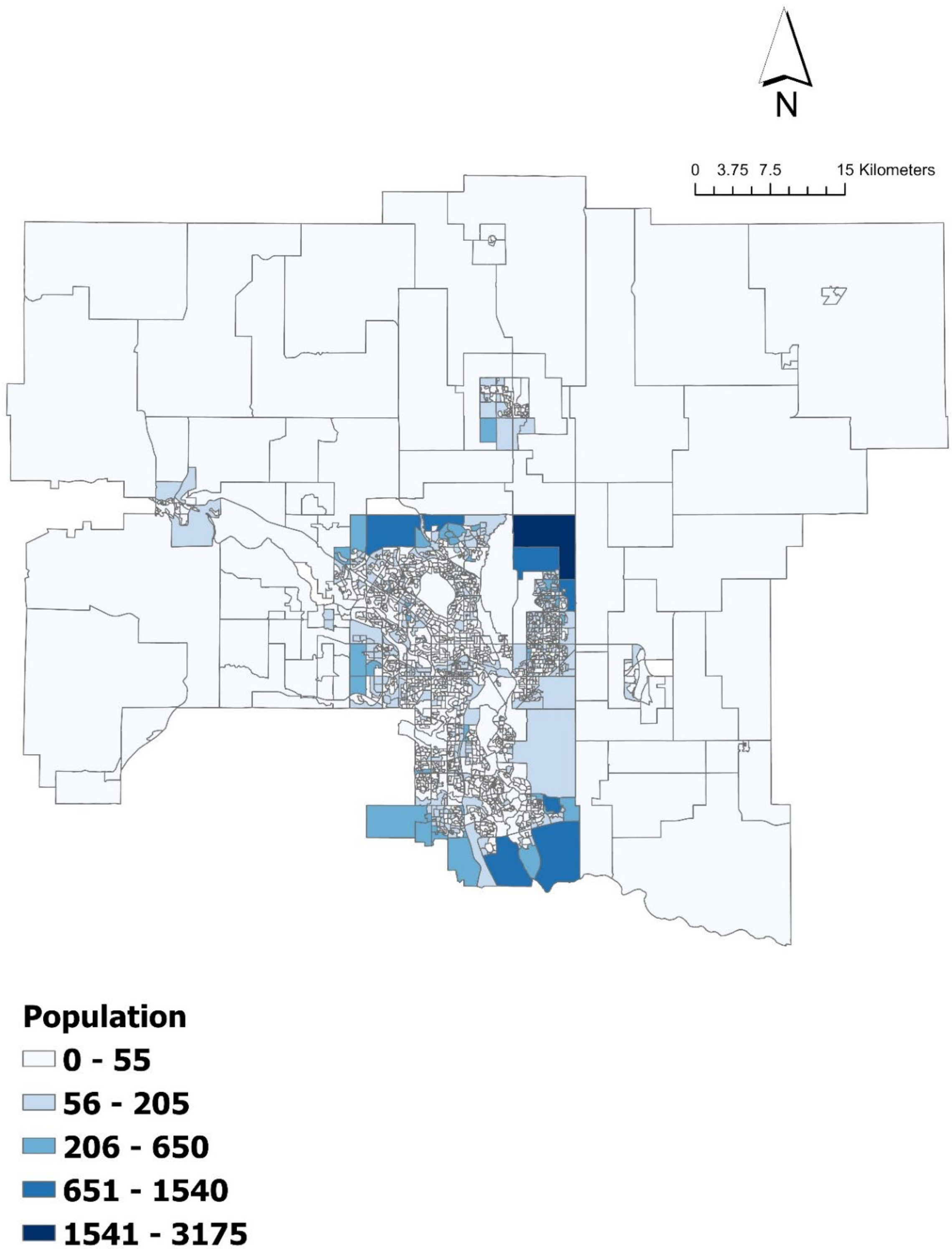


Figure 5. Distribution of newcomers in Calgary CMA (Statistics Canada, 2017).

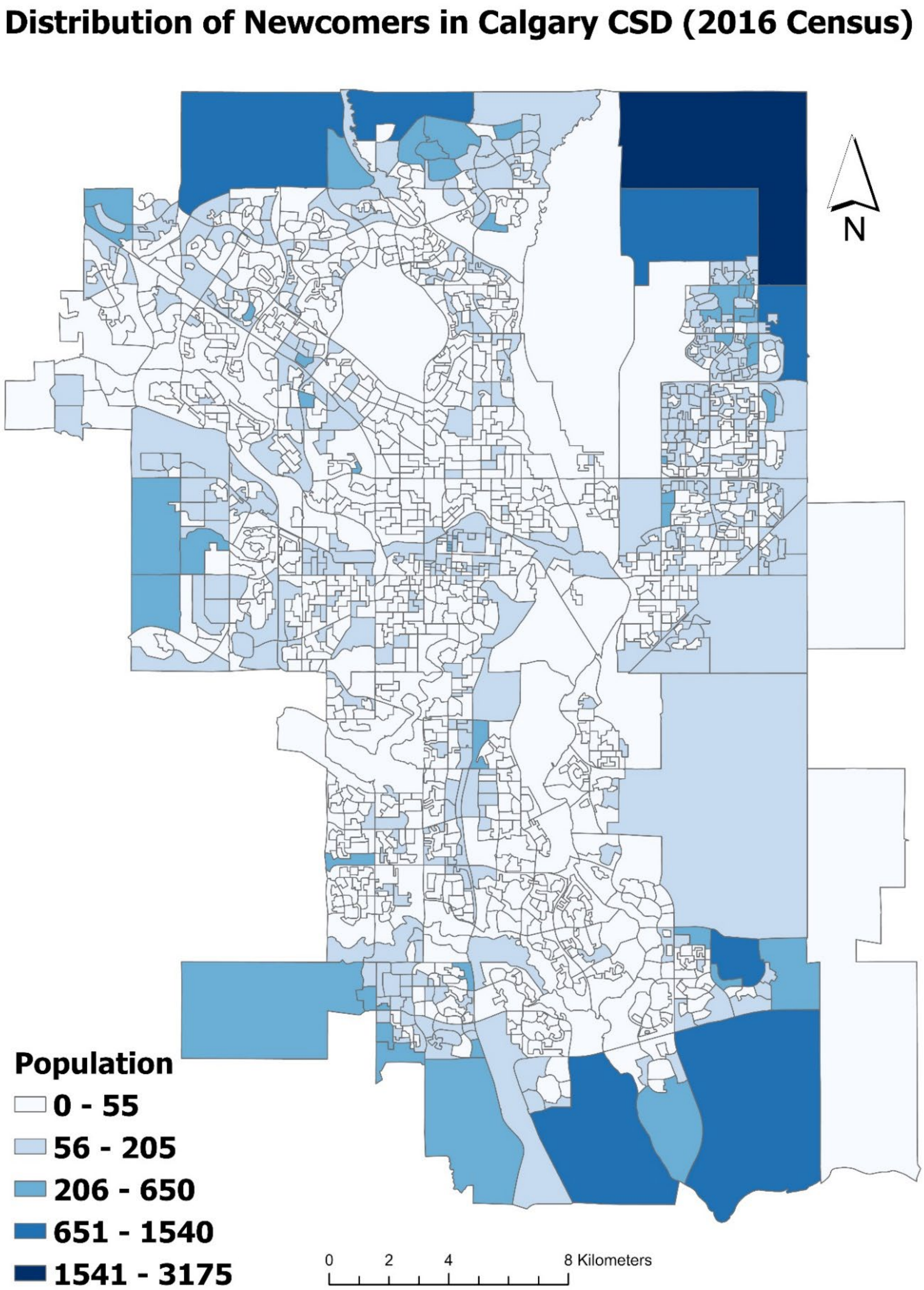


Figure 6. Distribution of newcomers in Calgary CSD (Statistics Canada, 2017).

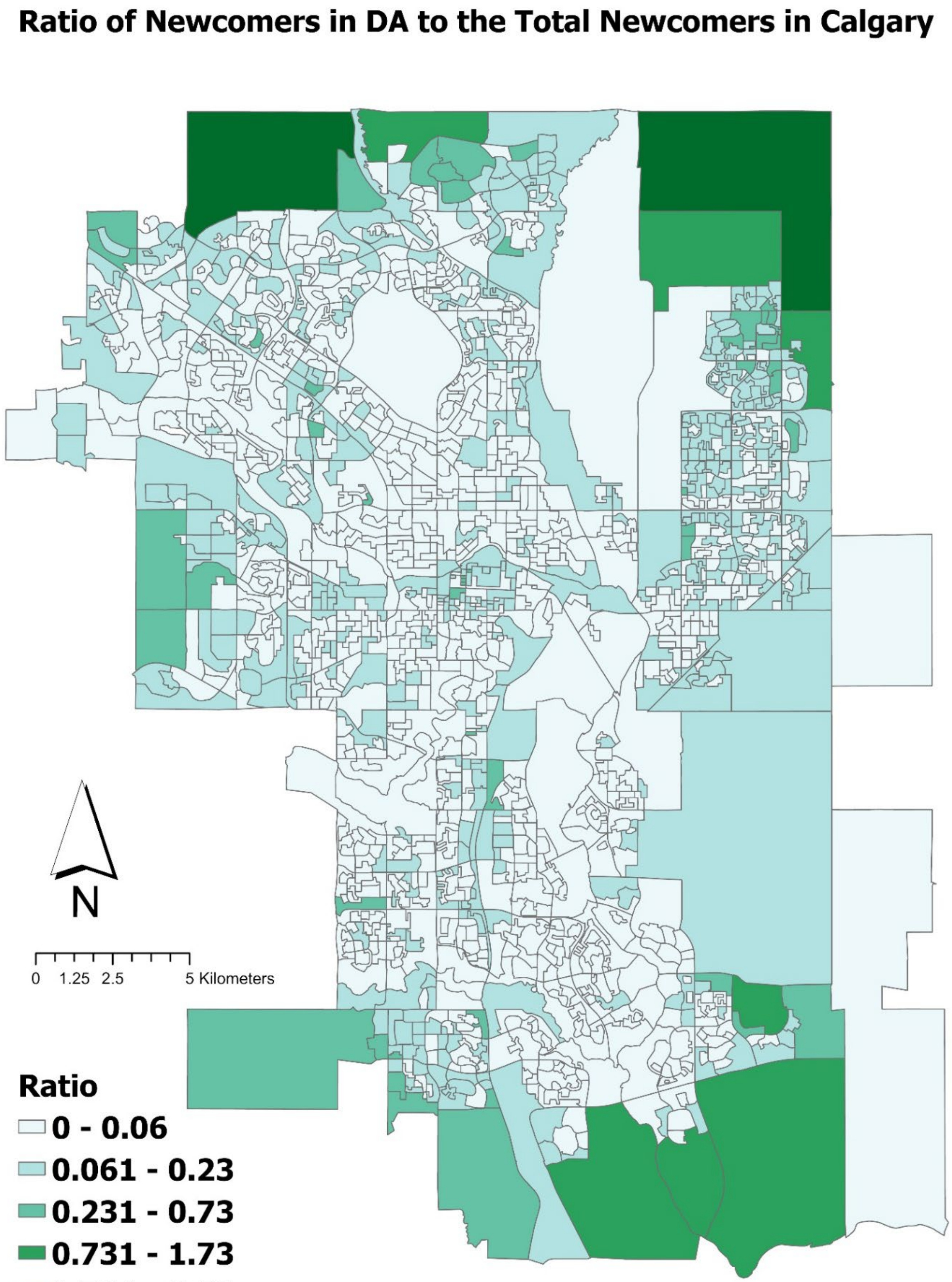


Figure 7. Ratio of newcomers in DA to the total newcomers in Calgary (Statistics Canada, 2017).

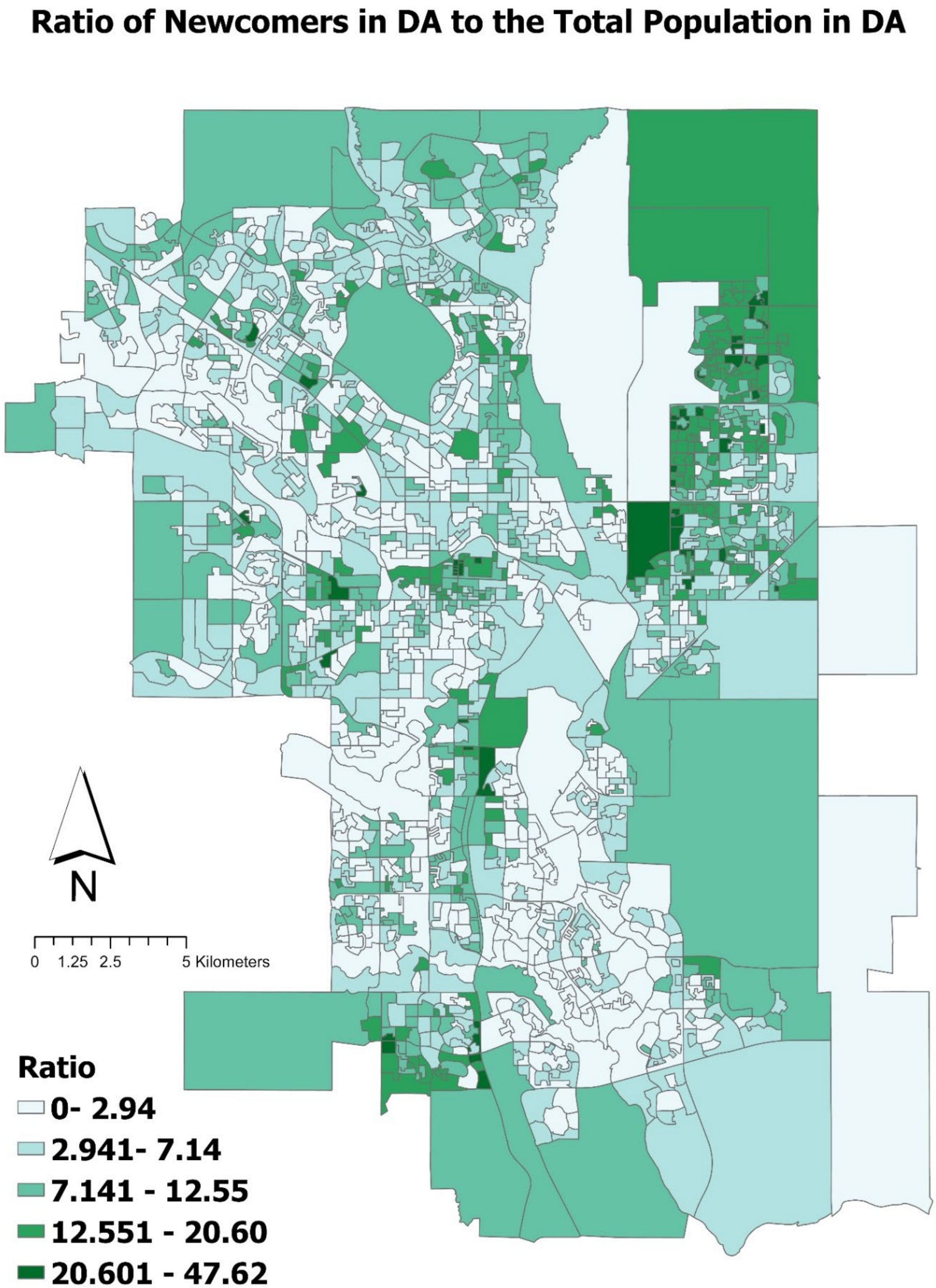


Figure 8. Ratio of newcomers in DA to the total population in DA (Statistics Canada, 2017).

In the latter part of this study, we will mainly look at the "Newcomers" group along with the "Citizens" group, which has dissimilar social and economic characteristics. According to Statistics Canada, the "Citizens" category includes persons who are citizens of Canada only and persons who are citizens of Canada and at least one other country. This group can represent “more established people” comprehensively by including not only persons born in Canada but also born abroad and settled in Canada for a certain period. The category of "Newcomers (or recent immigrants)" includes landed immigrants who came to Canada up to five years prior to a given census year. For the 2016 Census, which we use in this study, newcomers are defined as landed immigrants who arrived in Canada between January 1, 2011, and Census Day, May 10, 2016. Table 4 shows the distribution and definitions of the two groups.

Table 4. Distribution of the population of Citizens and Newcomers in Calgary CMA(Statistics Canada, 2017).

Residency status	Population	Percentage	Definition
Citizens	1,220,070	42.9 %	Persons who are citizens of Canada only and persons who are citizens of Canada and at least one other country. Persons who are Canadian citizens by birth and Immigrants who have obtained Canadian citizenship by naturalization are included in this group.
Newcomers	93,255	3.3 %	Landed immigrants who came to Canada up to five years prior to a given census year. For the 2016 Census, newcomers are landed immigrants who arrived in Canada between January 1, 2011, and Census Day, May 10, 2016

Employment data

The employment dataset acquired from Statistics Canada provides the number of employed labour force by place of work in DA level in 2016. As shown in Table 5 and Figure 9, more than 93% of the total employment in Calgary CMA is in Calgary CSD.

Table 5. The number of jobs in each CSD in Calgary CMA. Most of the employment (93.06%) is taken place in the Calgary CSD (Statistics Canada, 2017).

Census subdivision	Calgary	Airdrie	Rocky View County	Cochrane	Chestermere	Crossfield	Tsuu T'ina Nation 145	Irricana	Beiseker	Total
The number of jobs	615,555	15,055	18,545	7,295	2,640	1,210	860	110	225	661,495
Percentage (%)	93.06	2.28	2.80	1.10	0.40	0.18	0.13	0.02	0.03	100

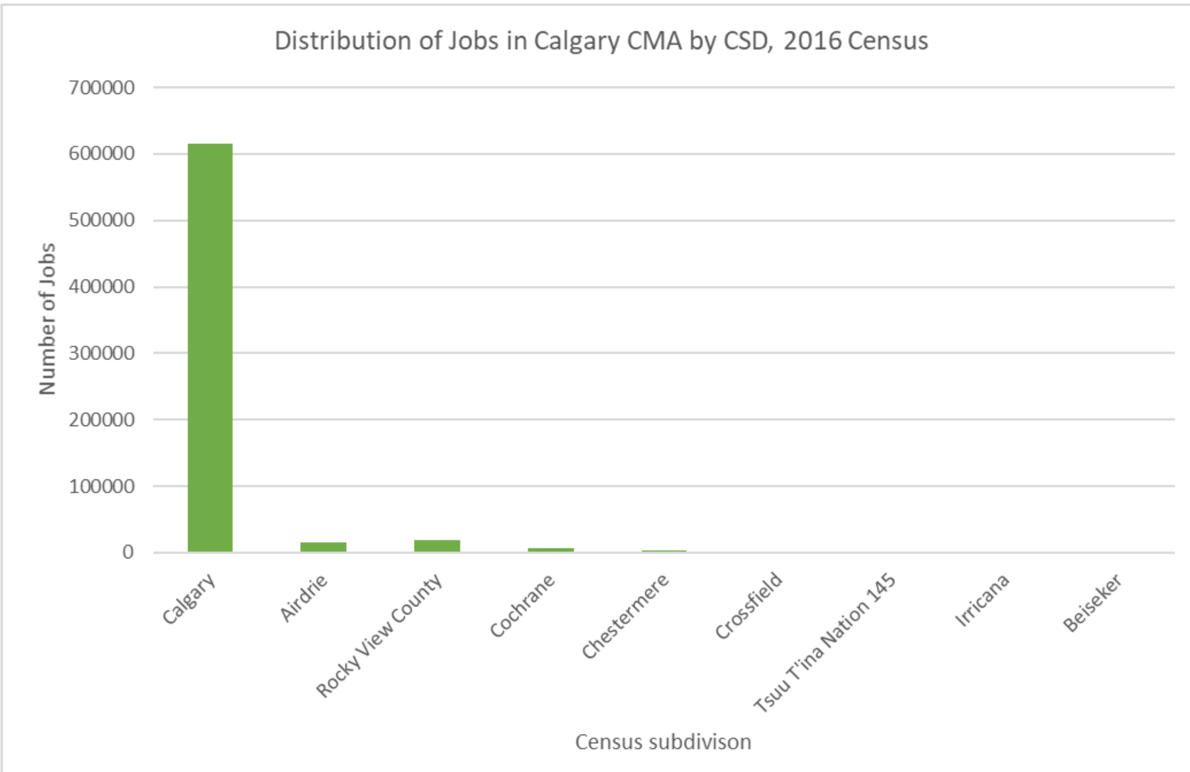


Figure 9. Distribution of employment in Calgary CMA by Census subdivision (Statistics Canada, 2017).

The employment dataset also has counts broken down by NAICS (North American Industry Classification System). Table 6 and Figure 10 show the number of employees in each industry and their share of total jobs in the region. Industry sectors such as retail trade (12.4%), health care and social assistance (12.0%), and professional, scientific and technical services (10.48%) lead employment in the region. In contrast, jobs in some other industries, including management of companies and enterprises (0.6%) and agriculture, forestry, fishing and hunting industries (1.0%), and utilities (1.2%), are minimal.

Table 6. The number of jobs in Calgary CMA by industry based on the North American Industry Classification System (NAICS) (Statistics Canada, 2017).

Industry	Number of Jobs	Percentage (%)
Agriculture, forestry, fishing and hunting	6,435	1.0
Mining, quarrying, and oil and gas extraction	40,605	6.1
Utilities	8,025	1.2
Construction	32,555	4.9
Manufacturing	36,850	5.6
Wholesale trade	25,990	3.9
Retail trade	81,885	12.4
Transportation and warehousing	33,330	5.0
Information and cultural industries	13,500	2.0
Finance and insurance	27,600	4.2
Real estate and rental and leasing	13,790	2.1
Professional, scientific and technical services	69,320	10.5
Management of companies and enterprises	3,660	0.6
Administrative and support, waste management and remediation services	20,710	3.1
Educational services	46,185	7.0
Health care and social assistance	79,290	12.0
Arts, entertainment and recreation	15,450	2.3
Accommodation and food services	49,425	7.5
Other services (except public administration)	29,335	4.4
Public administration	27,780	4.2
Total	661,495	100.00

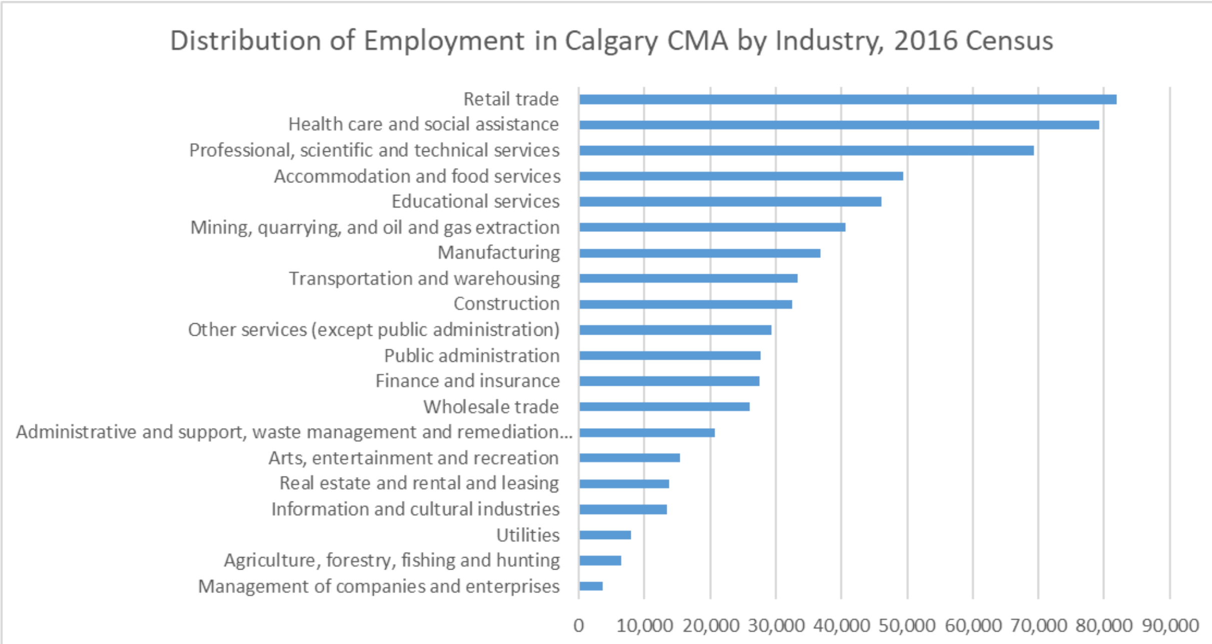


Figure 10. Distribution of employment in Calgary CMA by Industry (Statistics Canada, 2017).

Meanwhile, newcomers tend to work in specific industries. According to 2017 Alberta Labour Force Profiles, the majority of newcomers in Alberta are employed in three sectors: accommodation and food services (20.4%); trade (wholesale and retail trade, total 16.0%); health care and social assistance (14.7%), followed by manufacturing (7.9%), construction (6.0%), and transportation and warehousing (5.5%), professional, scientific and technical services (5.2%), as shown in Figure 11 (Government of Alberta, 2017). Since more than three-quarters of newcomers work in these eight industries, the latter part of this study will focus mainly on these industries. However, we will additionally include two more industries, 'educational services' and 'mining, quarrying, and oil and gas extraction.' This is due to the fact that there are a relatively high number of job opportunities (7.0% and 6.1% of the total jobs) in the Calgary CMA in these two particular industries, despite their generally low employment shares of newcomers in Alberta (3.4% and 1.9%). Table 7 shows the number of jobs in Calgary CMA and newcomers' employment shares in Alberta by industry. The ten major industry sectors identified for this study account for 74.9 % of jobs in Calgary CMA and 80.8% of employment for newcomers in Alberta.

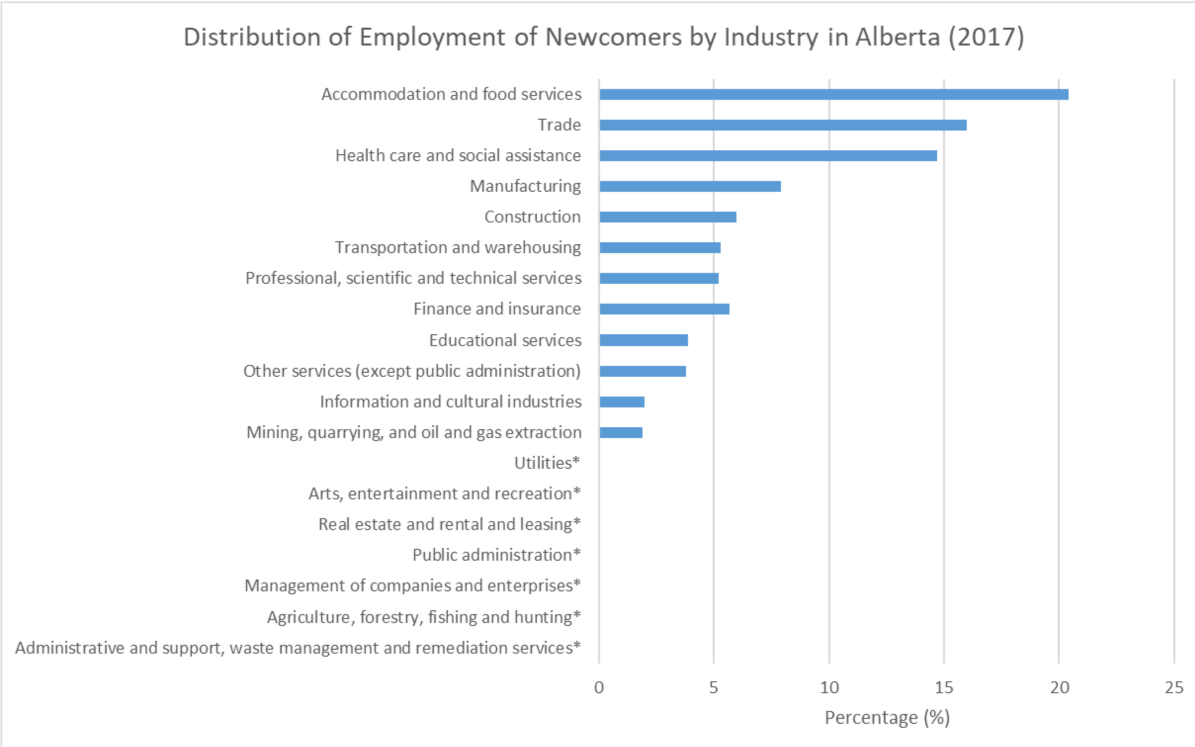


*Figure 11. Distribution of employment of newcomers by industry (Government of Alberta, 2017). *Insufficient data*

Table 7. The number of jobs in Calgary CMA and newcomers' employment share of the ten relevant industries in Alberta (Statistics Canada 2017; Government of Alberta, 2017).

Industry	The number of jobs in Calgary CMA		Newcomers' employment share in Alberta
accommodation and food services	49,425	7.5%	20.4%
wholesale trade	25,990	3.9%	16.0%
retail trade	81,885	12.4%	
health care and social assistance	79,290	12.0%	14.7%
manufacturing	36,850	5.6%	7.9%
construction	32,555	4.9%	6.0%
transportation and warehousing	33,330	5.0%	5.3%
professional, scientific and technical services	69,320	10.5%	5.2%
educational services	46,185	7.0%	3.4%
mining, quarrying, and oil and gas extraction	40,605	6.1%	1.9%
major 10 industries	**495,435**	**74.9%**	**80.8%**

Figures 12 and 13 show the spatial distribution of jobs in Calgary. Many employment opportunities are concentrated in the city center and some specific areas near the city's boundaries, including the industrial zones located in the Northeast and Southeast of Calgary. Figures 14 and 15 show the spatial distribution of jobs in the ten major industries defined for this study. The distribution of jobs in these industries, which account for approximately 75 percent of all jobs in the region, is naturally similar to the distribution of total jobs in the region. However, Jobs are distributed differently depending on the industry. See Appendix A for the distribution of jobs by industry. For example, many jobs in the retail trade industry are located not only within but also outside the Northwest city boundary (Figure 43, Appendix A), and many jobs in the construction industry exist outside the Southeast's city limit. (Figure 46, Appendix A). Also, there are more jobs in education services and mining, quarrying, and oil and gas extraction industries in the inner city than in industrial areas of the city (Figure 49 and 50, Appendix A). Based on this locational information of jobs, transit-based job accessibility will be calculated by sector to help identify which job sectors are more (or less) spatially mismatched with newcomers.

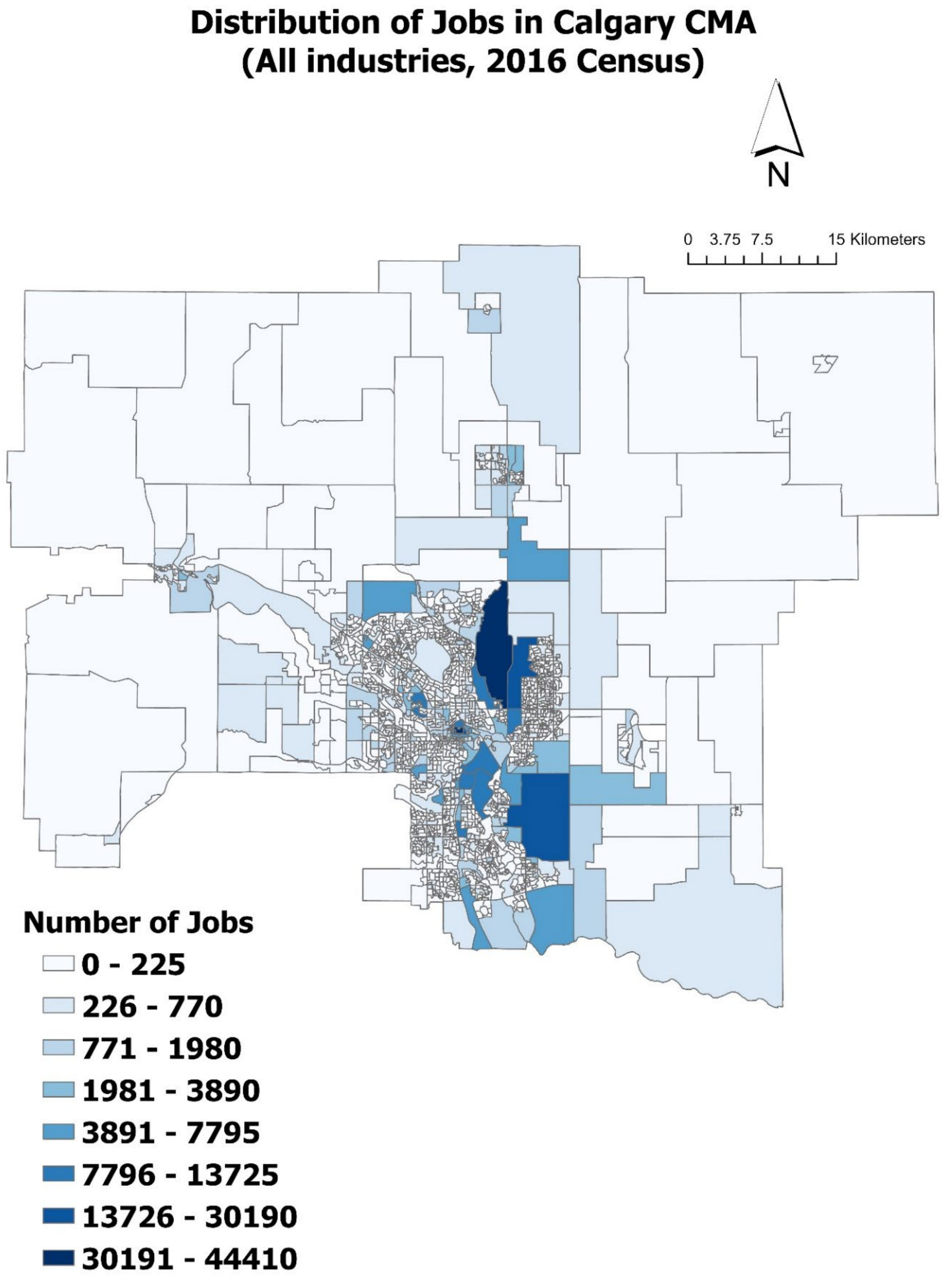


Figure 12. Distribution of jobs in Calgary CMA (Statistics Canada, 2017).

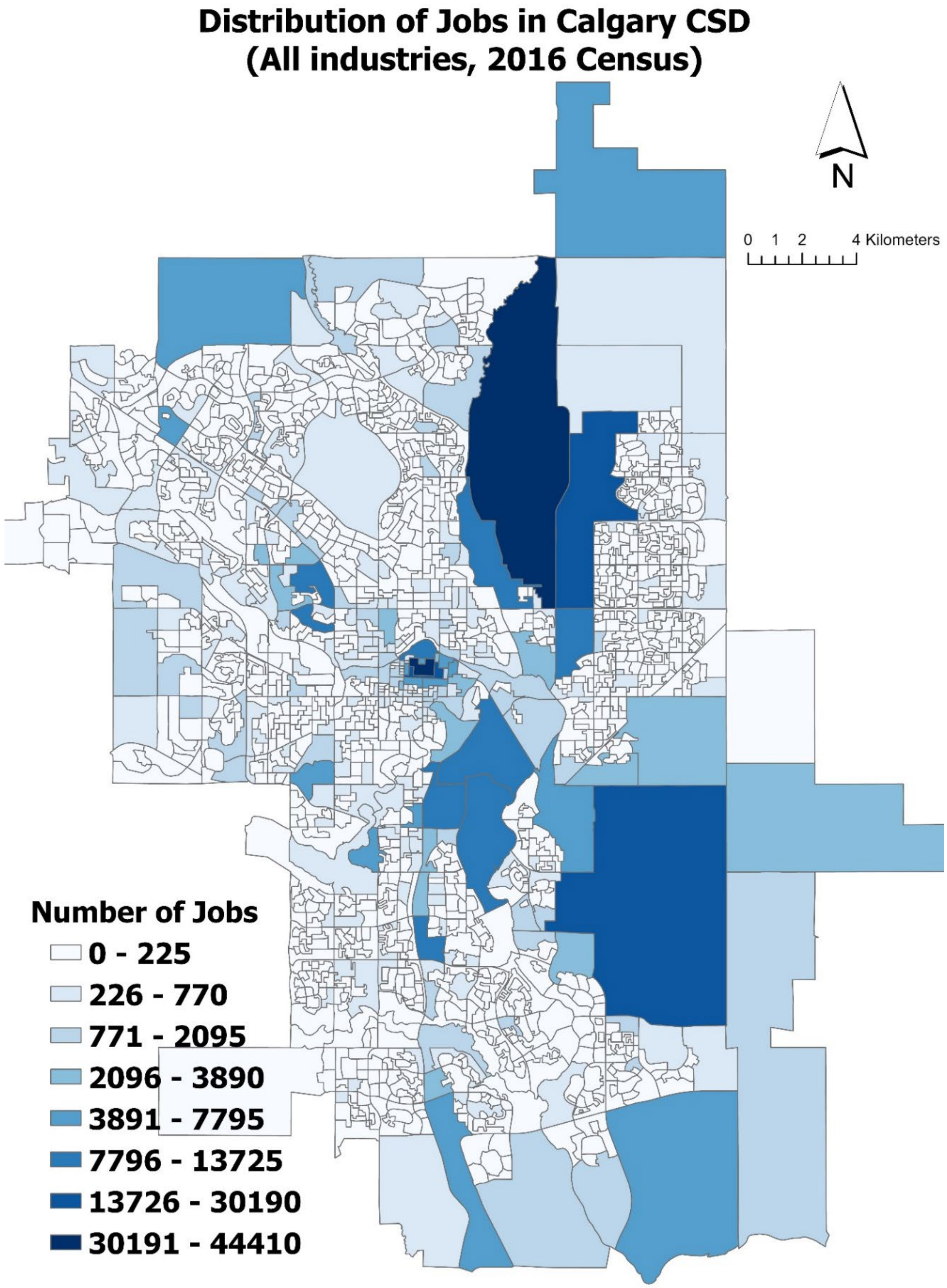


Figure 13. Distribution of jobs in Calgary CSD (Statistics Canada, 2017).

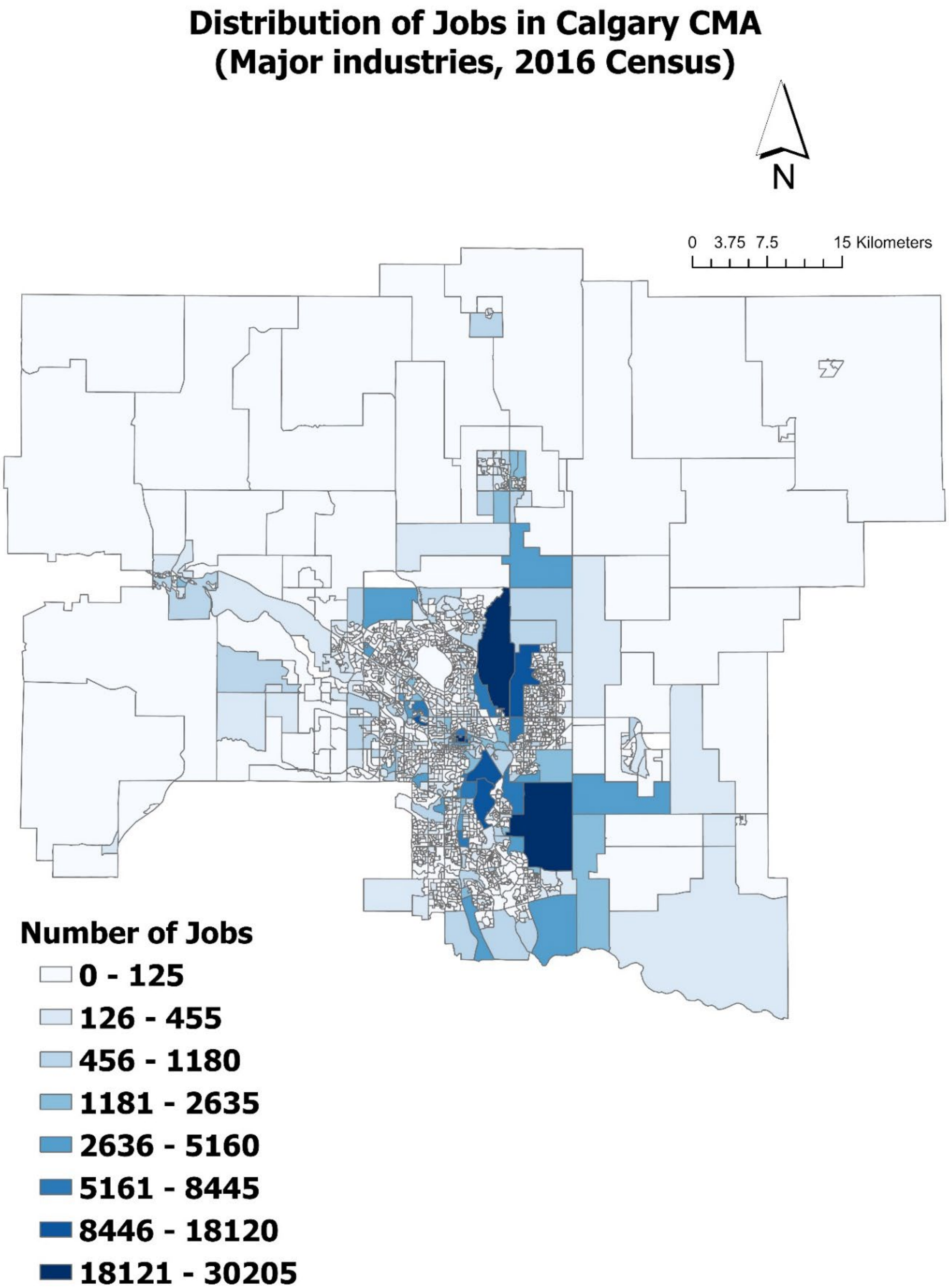


Figure 14. Distribution of jobs in major industries in Calgary CMA (Statistics Canada, 2017).

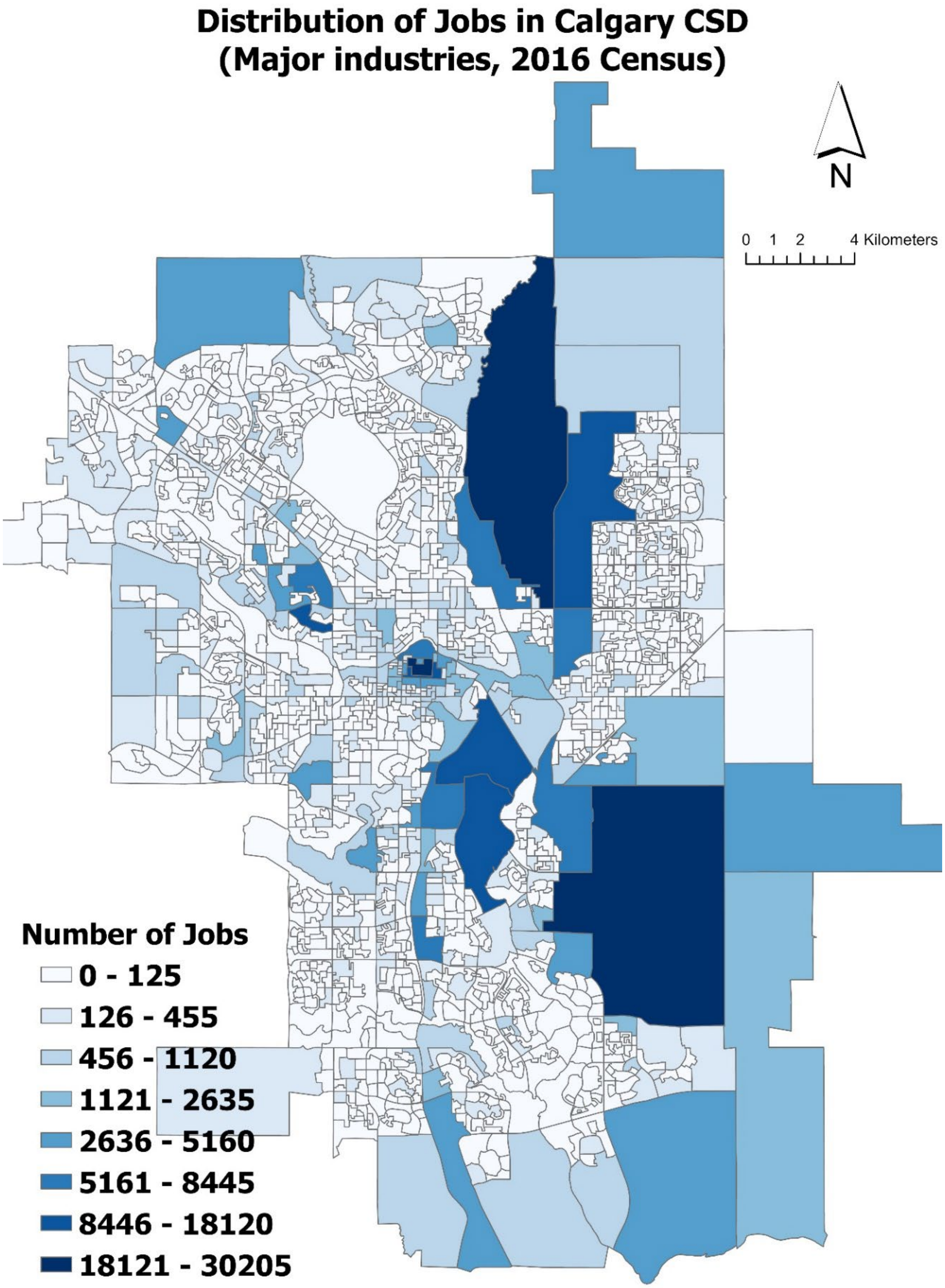


Figure 15. Distribution of jobs in major industries in Calgary CSD (Statistics Canada, 2017).

Transit data

The transit dataset used in this study is provided in the form of the GTFS (General Transit Feed Specification). The GTFS is a data specification that allows public transit agencies to publish their transit data in a format that can be used by a wide variety of software applications (GTFS, 2021). A GTFS feed comprises a series of text files: each file models a particular aspect of transit information, including stops, routes, trips, and other schedule data. This dataset will be used to compute travel times between DAs combined with the pedestrian network from OpenStreetMap (OSM) and the open-source routing engine OpenTripPlanner (OTP). OSM is an initiative to create and provide free geographic data, such as street maps. OSM data can be used in many ways, such as routing or navigation, planning or logistics, utilities, government, etc. (OpenStreetMap, 2021). OTP is open-source software that provides passenger information and transportation network analysis services. Java component of the software finds itineraries combining transit, pedestrian, bicycle, and car segments through networks built from OpenStreetMap and GTFS data (OpenTripPlanner, 2021).

Primary transit network

Even though all the existing transit routes will be included in computing travel times between DAs and transit-based job accessibility for each DA, it is critical to identify the Primary Transit Network to determine the proximity of newcomers to major transit routes. According to Calgary Transportation Plan 2020, the Primary Transit Network is defined as "a permanent network of high-frequency transit services that will operate every 10 minutes or less at least 15 hours a day, seven days a week." (The City of Calgary, 2021). Presently, however, only two LRT lines and a few BRT and MAX lines barely meet this standard. Therefore, we will define the Primary Transit Network slightly more generously for this study: the LRT, BRT, and MAX lines as well as regular bus lines operating every 18 minutes or less during the morning peak hours (06:00 to 09:00) and 30 minutes or less during off-peak hours. As a result, the Primary Transit Network in this study includes regular bus routes 3, 9, 23, 37, 43, 145, and 159 in addition to the LRT, BRT, and MAX lines, as shown in Figure 17. Table 8 shows the frequency of the high-frequency regular bus routes.

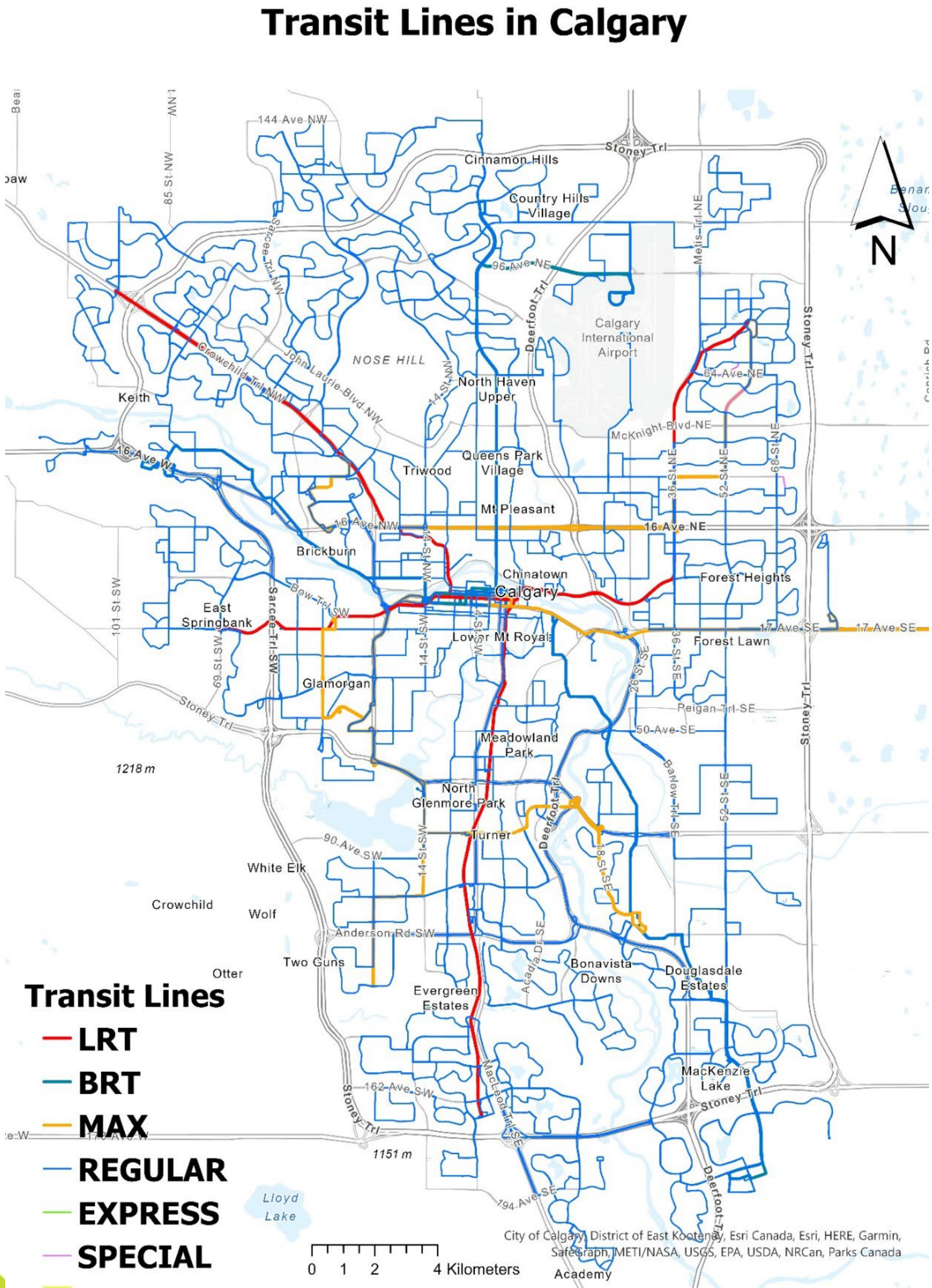


Figure 16. Transit lines in Calgary (The City of Calgary, 2021)

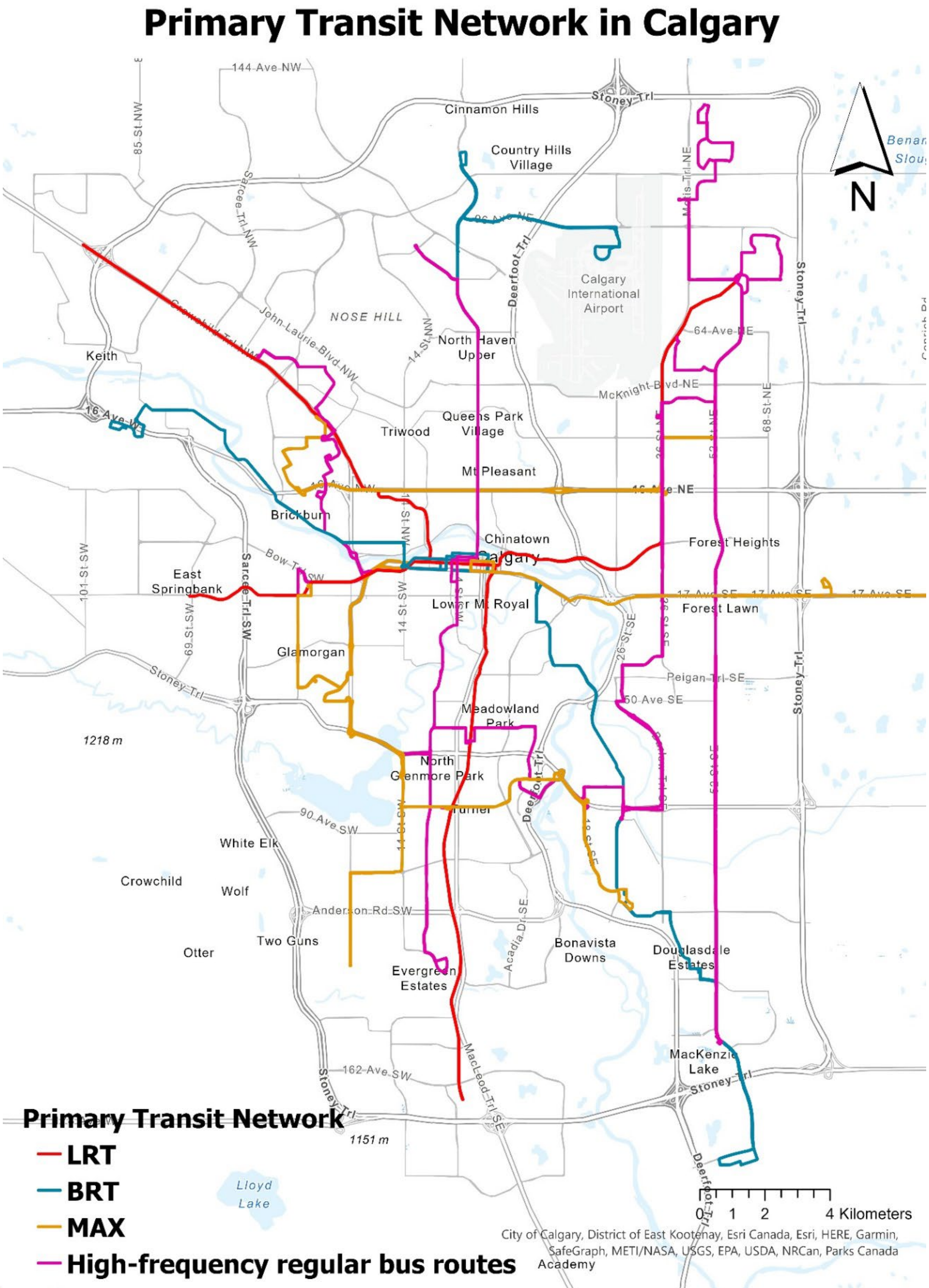


Figure 17. Primary Transit Network in Calgary (The City of Calgary, 2021)

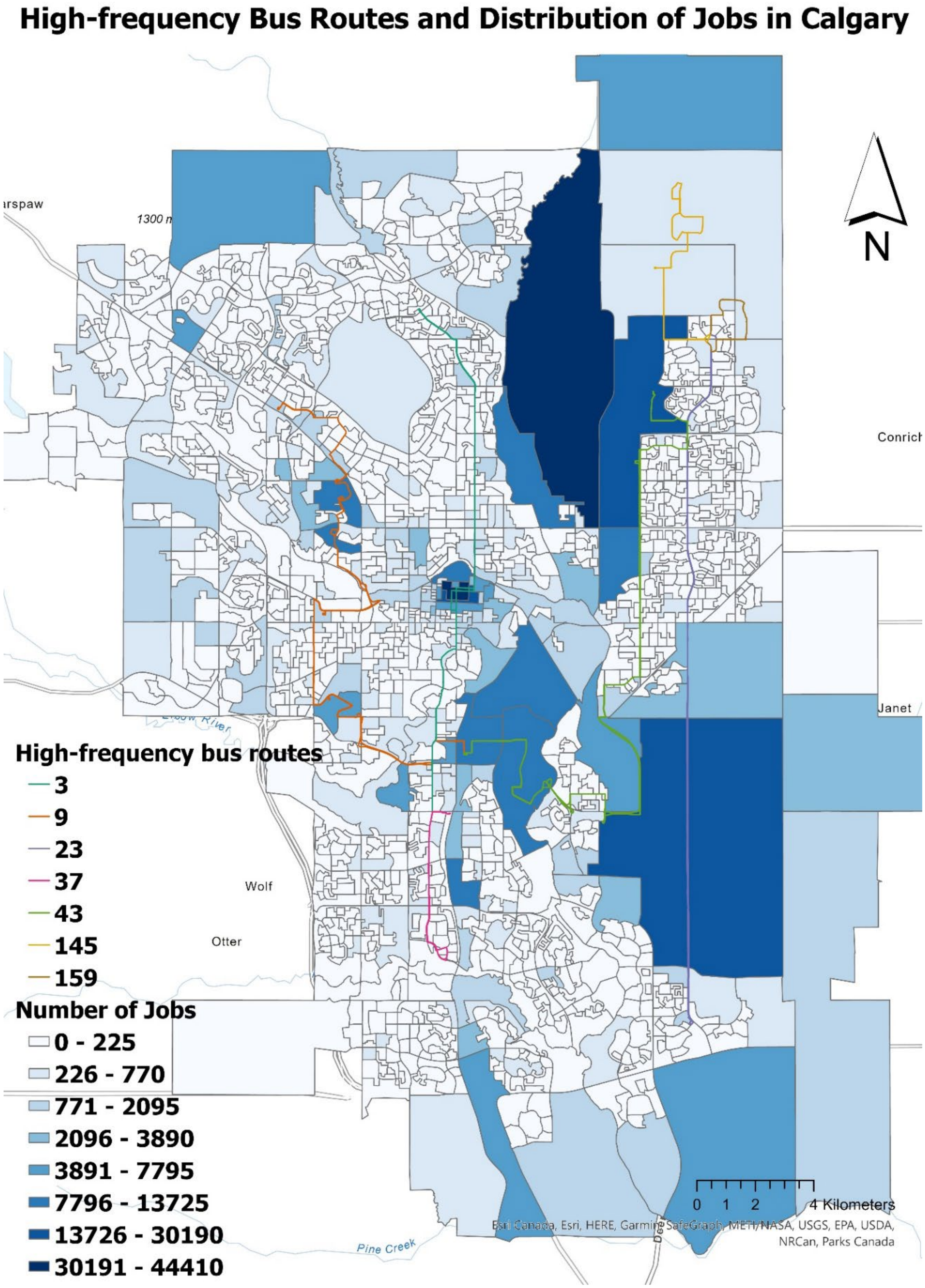


Figure 18. High-frequency bus routes and the distribution of jobs in Calgary (The City of Calgary, 2021).

Table 8. Frequency (minutes) of the high-frequency regular bus routes. (Calgary Transit, 2021)

		Weekday				Saturday		Sunday
Route No.	Route Name	AM Peak	Mid Day	PM Peak	Eve	Day	Eve	All Day
3	Sandstone/Elbow Dr	13/6/7	15	6/7/13	15/20	20	20	20
9	Dalhousie.Chinook	10/20	20	10/20	20/30	31	31	31
23	52 Street East	12/17	20	17	28	29	28/29	28/29
37	Heritage / Canyon Meadows	18	18	18	30	18/30	18/30	18/30
43	McKnight / Chinook	9/15	20	9/15	30	27/30	30	27/30
145	Skyview Ranch/ Redstone	7/15	25	6/15	25	25	25	25
159	Saddlebrook	11	22	11	22	32	32	32

High-frequency bus routes can play an essential role in commutes by directly linking the residential areas with the job clusters. They allow commuters to make fewer transfers and get right to their final destinations. Therefore, the development and improvement of bus routes that play this role can significantly improve job accessibility for newcomers. Figure 18 shows how high-frequency bus routes are linked to important job clusters. Routes 23 and 43, for example, connect the newcomer cluster in the Northeast with the industrial area in the Southeast.

4.3 Analytical steps

Identify locations of newcomers and jobs

The analysis part of this study begins by identifying the locations of newcomers and the jobs in the study area. The locations of newcomers and jobs will be mapped using ArcGIS Pro (version 2.7.1), and the Primary Transit Network will be overlayed on the maps to illustrate how the locations of newcomers and jobs relate to major transit routes. Additionally, we will evaluate how the proportion of newcomers and commute patterns such as mode of commute and travel duration are related in the study area via Pearson correlation analysis. Lastly, we will map the distribution of jobs across various industry sectors as a starting point for analyzing transit-based job accessibility by industry.

Calculate travel times by transit

To measure transit-based accessibility to jobs, we will first compute transit-based travel times between all dissemination areas in the region. The public transit travel time cube devised by Farber and Fu (2017) will be used to compute travel times. The public transit travel time cube is a three-dimensional array, $T = [t_{i,j,m}]$, estimated transit travel times, where i indexes departure location and j indexes destination location, and m indexes trip departure times (Farber and Fu, 2017). Due to the inherent temporal variations in transit schedules, computing accessibility for only a single departure time could potentially overestimate or underestimate travel times, thus accessibility scores for a particular area (Allen, 2018). Therefore, we follow the precedent in the literature to compute transit travel times for every minute of the morning commute period (Owen and Levinson, 2015; Farber and Fu, 2017; Allen and Farber, 2020) to be subsequently averaged when computing accessibility metrics. However, it is also important to note that people do not only travel to work during the morning rush hour. In particular, there are many shift jobs in industries where many newcomers are engaged (e.g., accommodation and food services, health care and social assistance, retail trade, etc.). Therefore, in this study, we consider multiple time periods of the day in which many shift workers are generally considered to commute: 04:00-06:00, 06:00-09:00, 10:00-12:00, 15:00-18:00, 19:00-21:00, and 22:30-00:30.

To compute travel times, we will build custom multi-modal network graphs for each time period. These graphs are inclusive of the time walking to and from stops, wait times, in-vehicle travels times and transfers. These were built using the open-source routing engine OpenTripPlanner. This computation has two sets of inputs. The first is the walking networks via the topological edges from OpenStreetMap. The second is transit schedules in the form of GTFS (General Transit Feed Specification) data. OpenTripPlanner uses the algorithm to find shortest-path transit itineraries between each origin and destination and can be parameterized to set limits on overall travel time, walk distances, number of transfers, and wait times (OpenTripPlanner, 2017). The algorithm returns a matrix of origin-destination shortest path travel times that may include "walk-only" routes if walking is faster than using transit. Travel times are zero for intra-DA trips because they have the same Origin-Destination pairs with the same centroid.

Calculate transit-based job accessibility

We use the cumulative opportunities measure to calculate accessibility, which is one of the most common accessibility measures. It counts the number of opportunities reachable from a certain point in space within a given travel time (Handy and Niemeier, 1997; Kwan, 1998). We choose this approach over gravity-based measures that discount the opportunities by distance, mainly because the differences in opportunities by distance between jobs that can be accessed within the same time frame can be neglectable in this study. Furthermore, a cumulative opportunity approach is much easier to communicate to decision-makers and highly correlated with the gravity-based measures (El-Geneidy and Levinson, 2006; Owen et al., 2016). The cumulative opportunities measure is typically formulated as follows:

$$A_i = \sum_{j=1}^{j} O_j f(t_{i,j}) \quad (1)$$

Where A_i is the measure of accessibility for a location i, O_j is the number of opportunities at location j, and $f(t_{i,j})$ is a decreasing function of travel cost, t, from i to j. $f(t_{i,j})$ is based on travel times computed in the previous step. We use $f(t_{i,j})$ as a threshold indicator, which returns a 0 or 1 whether or less the travel time is less than a threshold. Based on the fact that the mean travel time to work in Calgary is 26 minutes and that the mean transit travel time is 41.6 minutes (City of Calgary, 2018), we decided to set five thresholds at 15-minute intervals, starting at 30 minutes. As a result, A_i is interpreted as the number of job opportunities that can be reached from the location i within a set travel time by transit. This study examines not only accessibility to jobs as a whole but also to jobs in the specific industries in which newcomers are typically employed or have relatively high employment opportunities in the region.

Finally, this study calculates the “Newcomer spatial mismatch index” by the community level to provide a more tangible picture of newcomers’ transit-based job accessibility in Calgary. This index is calculated by dividing the number of newcomers in the community by the number of jobs in major industries that can be reached 45 minutes from the centroid of the community.

5. Summary of research design

So far in this report, we have focused on the comprehensive review of the relevant literature, datasets and methods that will be used in the next part of the study. As a result of reviewing the previous studies, we reviewed the background of the research and identified the research gaps in the literature. This study is based on the spatial mismatch hypothesis, which suggests that social and economic minorities are likely to be more spatially mismatched with job opportunities, and that they are more likely to experience difficulties commuting than the average population. In particular, this study focuses on newcomers (or recent immigrants) in Calgary. This group of people is a critical research subject considering the impact of immigrants on the population and the economic growth in Calgary.

Spatial mismatch literature has been focused on cities in the United States, and most of them are looking at visible minorities and low-income populations. Although some recent studies are looking at Canadian cities, they focused on comparing job accessibility among cities and commute problems of low-income people in general (Deboosere and El-Geneidy, 2018; Allen and Farber, 2020), and yet there is no study intensively analyzing the job accessibility of a particular group within a particular city. Also, one of the limitations in previous studies is that they do not consider specific job sectors that are more approachable for recent immigrants; instead, they consider all jobs equally as prospective job opportunities for newly arrived people. This study is different from previous studies in that it looks at how job accessibility varies by industry sector where newcomers have relatively good employment prospects rather than looking at jobs in general. In doing so, we would be able to gain a better understanding of newcomers' access to their potential employment opportunities.

Using population, employment, and transit datasets, this study identifies the locations of newcomers in Calgary and their job opportunities and analyzes the transit-based accessibility of newcomers to jobs. The aggregate level of the population and employment datasets obtained from Statistics Canada is the census Dissemination Area, which is the most granular level of data available.

The cumulative opportunity measure is chosen as a method to measure job accessibility based on the literature suggesting that accessibility measures used in practice should be theoretically and behaviourally sounds, be easily communicable, have available data sources to be measured by, and be able to be used in social and economic planning and policy (Handy and Niemeier, 1997; Geurs and Van Wee, 2004). The cumulative opportunity measure counts the number of opportunities reachable from a certain point in space within a given travel time (Handy and Niemeier, 1997; Kwan, 1998). The choice of this method over gravity-based measures that discount the opportunities based on distance has been made since it is possible to neglectable differences in opportunities based on the distance between accessible jobs within the same period. Moreover, the cumulative opportunity approach is much easier to compute and communicate to decision-makers because it involves much fewer assumptions (El-Geneidy and Levinson, 2006; Owen et al., 2016).

Finally, analytical steps are composed of identifying locations of newcomers and jobs, computing travel times between DAs and calculating the job accessibility for each area, based on the pedestrian network from OpenStreetMap and the routing engine OpenTripPlanner. Data analysis will be carried out using Rstudio (version 4.0.2) and Esri ArcGIS pro (version 2.7.1).

6. Results

6.1 Location of newcomers relative to major transit routes

A large number of newcomers in Calgary live near major transit routes such as LRT, MAX, BRT, and high-frequency bus lines, as shown in Figure 19. On the other hand, the locations of people with Canadian citizenship are less related to major transit routes (Figure 20). By creating 100-, 300-, 500- and 1,000-meter buffers around the Primary Transit Network, we calculated the ratio of newcomers and citizens living in the buffer areas to the total number of newcomers and citizens in the entire city (Figure 21). The proportion of newcomers residing within a 300-metre radius of major transit routes is 50%, within a 1,000-metre radius is 68% to the total number of newcomers in the city, higher than 37% and 55% of the proportion of citizens to the total number of citizens of the entire city. This result shows that the newcomers tend to live closer to major transit routes than the citizens and are likely to have better access to transit services.

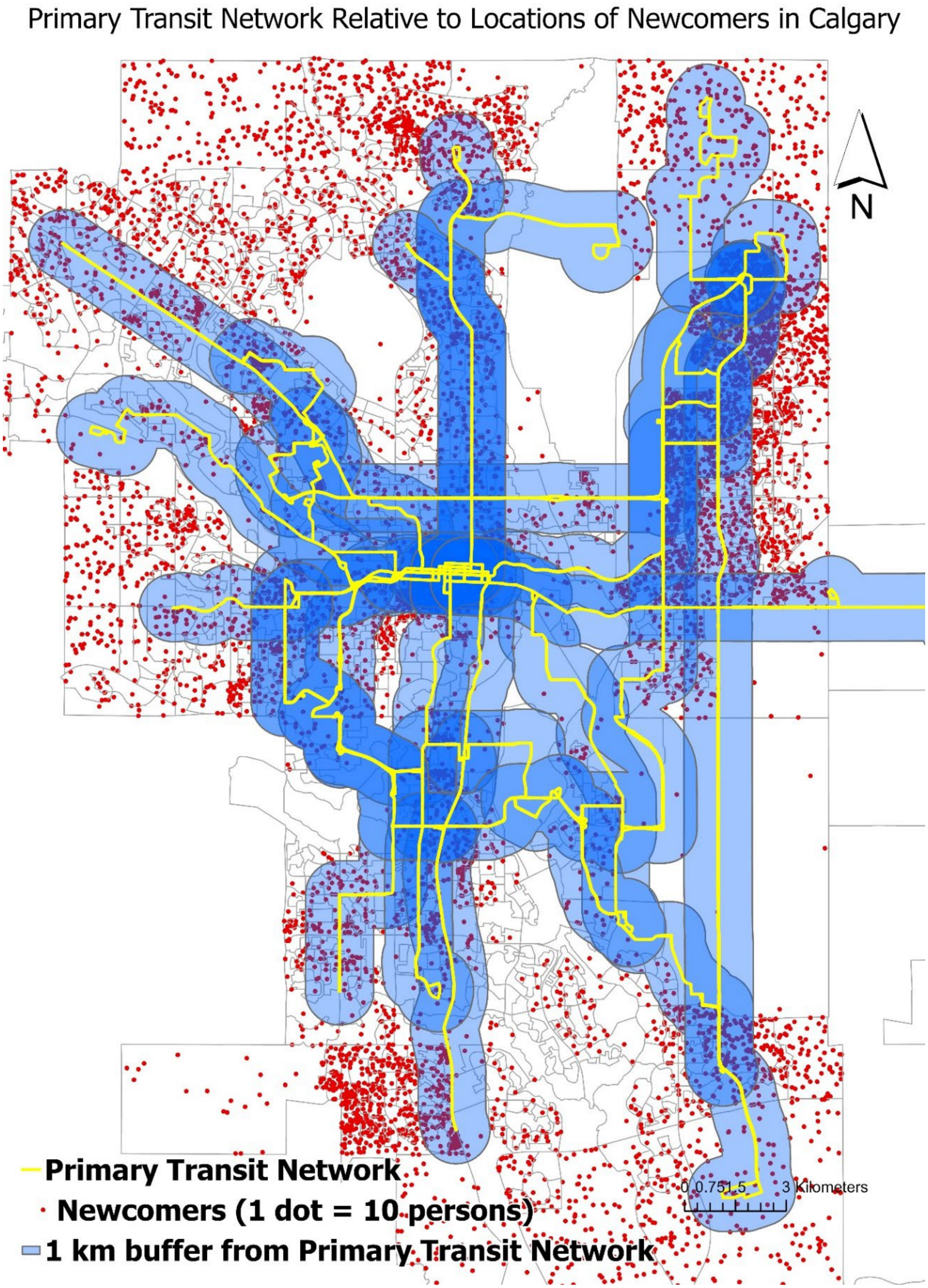


Figure 19. Primary Transit Network and locations of newcomers in Calgary, with the 1km buffer from Primary Transit Network. Note: The Primary Transit Network consists of LRT, BRT, MAX lines, and high-frequency bus lines (3, 9, 23, 37, 43, 145, 159).

Primary Transit Network Relative to Locations of Citizens in Calgary

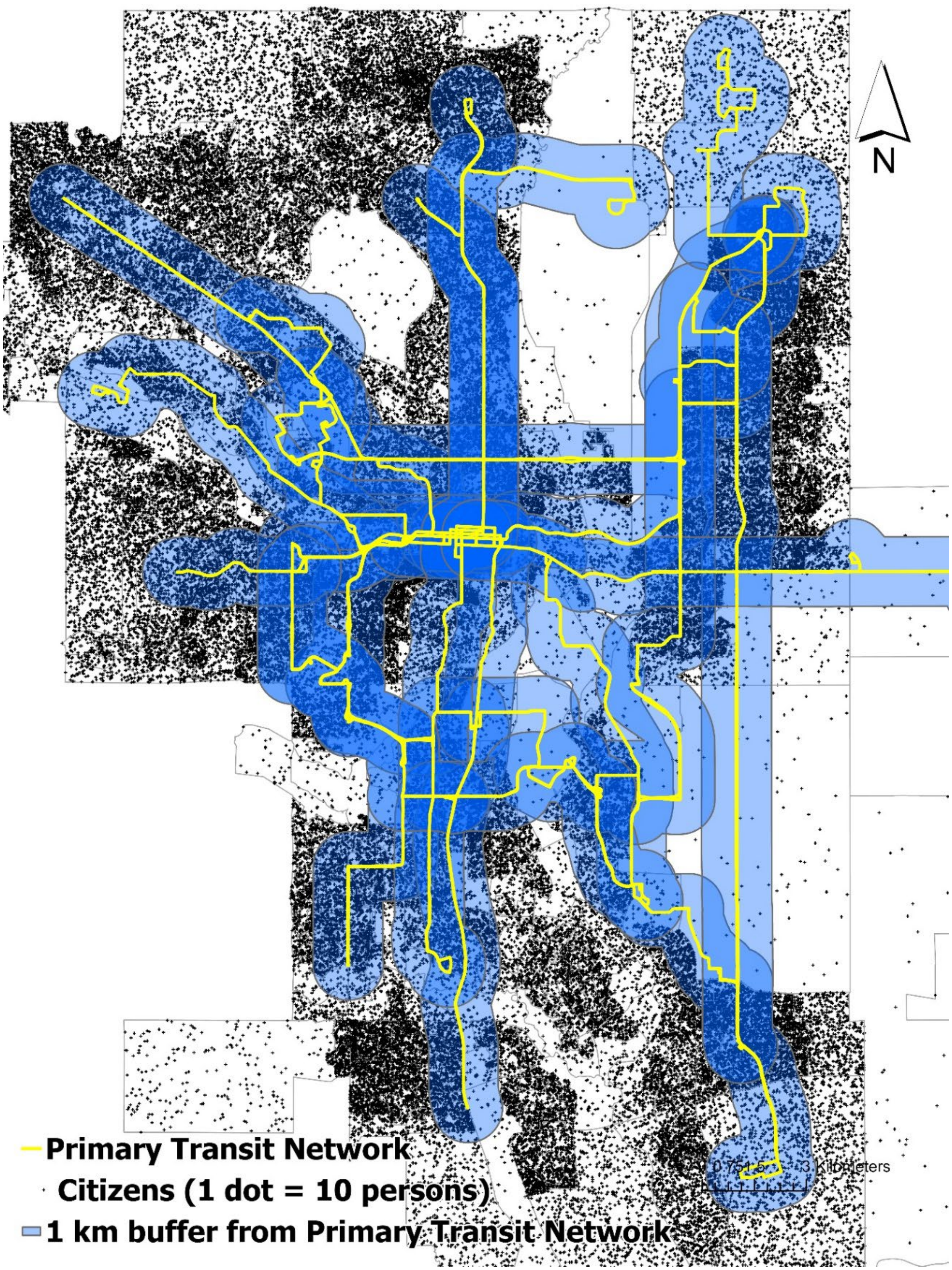


Figure 20. Primary Transit Network and locations of citizens in Calgary, with the 1km buffer from Primary Transit Network. Note: The Primary Transit Network consists of LRT, BRT, MAX lines, and high-frequency bus lines (3, 9, 23, 37, 43, 145, 159).

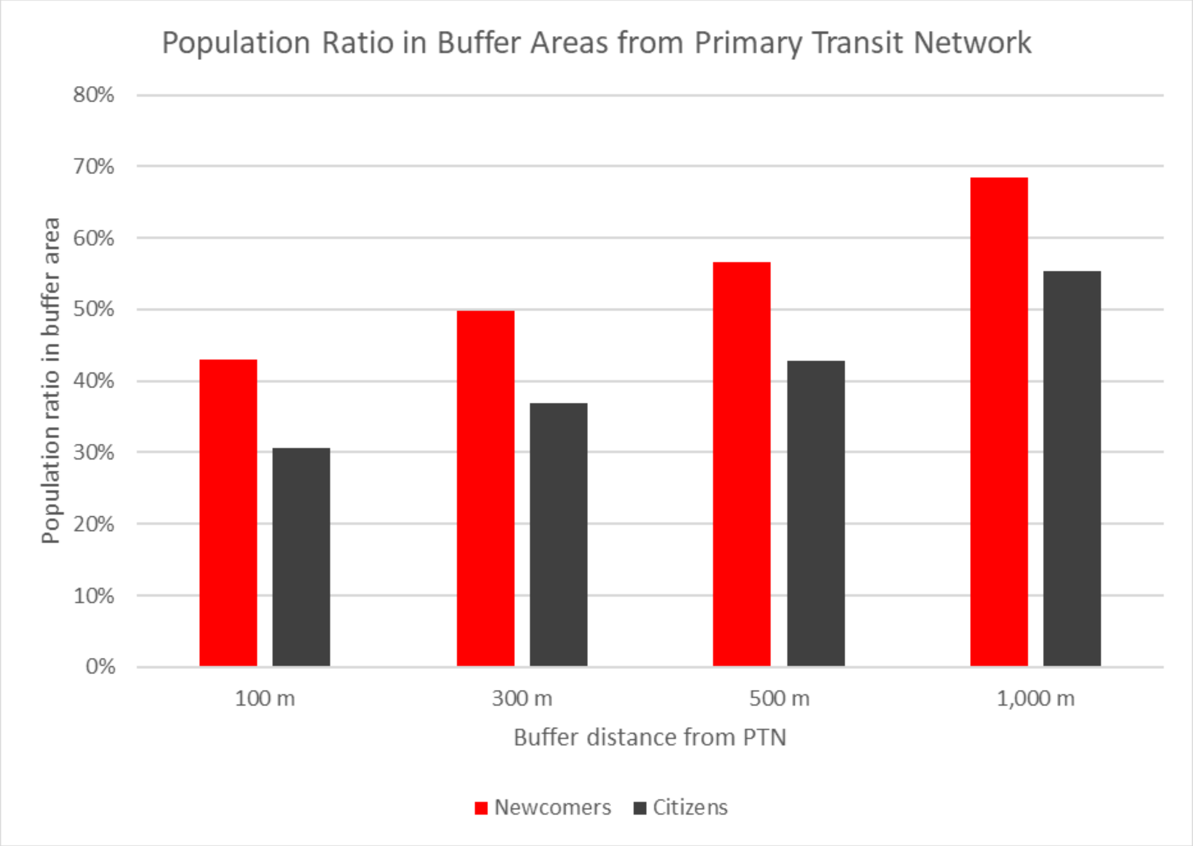


Figure 21. Population ratio of newcomers and citizens in buffer areas from Primary Transit Network. Note: The newcomers' ratio represents the number of newcomers in a buffer area to the total number of newcomers in Calgary. The ciitizens' ratio represents the number of citizens in a buffer area to the total number of citizens in Calgary.

6.2 Commute behaviour of newcomers

A significant number of commuters (78.8%) in the Calgary CMA commute by automobile, and the proportion of commuters who commute by transit is 13.6%. The commuters within the city boundary of Calgary, where transit services are relatively well established, do not differ significantly. In the Calgary CSD, 77% of commuters use automobiles to commute, and 14% take public transportation (Table 9).

Table 9. Distribution of modes of commute in Calgary CMA and Calgary CSD.

	car,truck,van as a driver	car,truck,van as a passenger	transit	walk	bicycle	others
Calgary CMA	73.7%	5.1%	13.6%	4.7%	1.5%	1.5%
Calgary CSD	71.9%	5.1%	14.0%	5.5%	1.7%	1.8%

As for commuting duration, the average duration of Calgary CMA is 26 minutes; the average duration using transit is 41.6 minutes, and using automobiles is 24.1 minutes. Figure 22 shows the distribution of one-way commuting duration in Calgary CMA and CSD. About 58% of commuters in Calgary CMA reach work within 30 minutes, while 6.4% of commuters spend more than 60 minutes to get to work. The commuting duration of commuters residing within the Calgary city boundary is slightly shorter, with 60% arriving at work within 30 minutes and 6% of people spending more than 60 minutes getting to work.

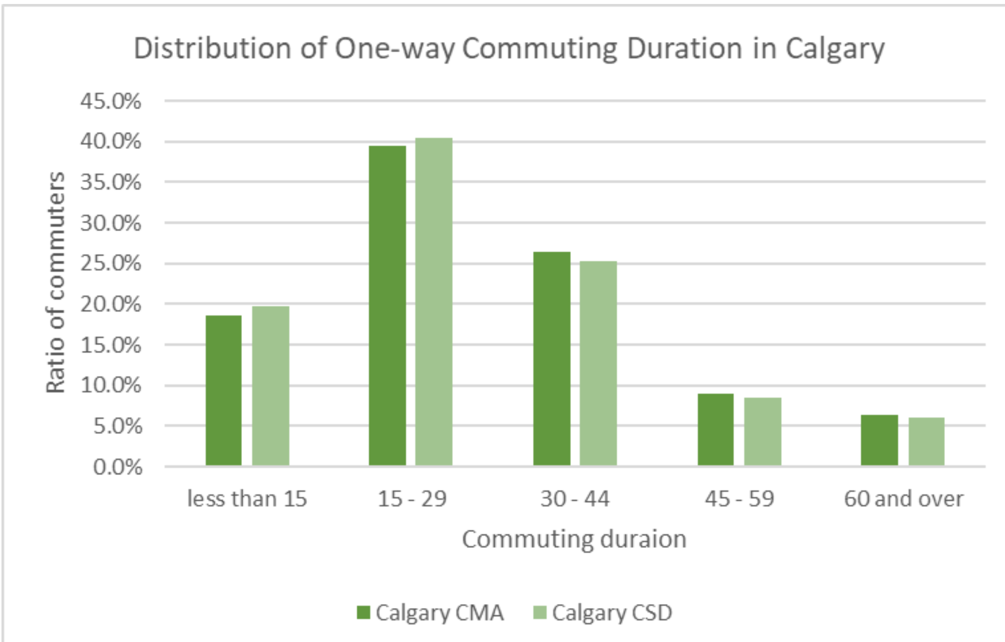


Figure 22. Distribution of one-way commuting duration in Calgary CMA and CSD (Statistics Canada, 2017).

Despite the lack of data on the commute patterns of newcomers, such as the means and time duration of their commute, it is possible to see the correlation between the composition of the population and the commute patterns of each DA of the city. We synthesized the demographic information possessed by DAs and the commute patterns such as the average commute duration and share of commute modes and then conducted Pearson correlation analyses between commute patterns and composition of the residency status of people of DAs. Table 10 shows the results of the Pearson correlation analyses.

Table 10. Correlation between commute patterns and residency status in Calgary (Newcomers vs. Citizens).

	newcomers		citizens	
	correlation coefficient	p-value	correlation coefficient	p-value
mode of commute (car)	-0.38	< .001	**0.47**	< .001
mode of commute (transit)	**0.52**	< .001	-0.55	< .001
one-way commute (29 min or less)	-0.15	< .001	**0.09**	< .001
one-way commute (60 min or more)	**0.24**	< .001	-0.08	< .001

In Calgary's DAs, the results show that the newcomers' ratio has a statistically significant positive correlation with the percentage of commuters who use public transportation to commute and those who spend more than 60 minutes commuting. In contrast, the citizens' ratio shows a statistically significant positive correlation with the percentage of people using an automobile to commute and those who spend 29 minutes or less commuting. In short, newcomers are more likely to use transit more and automobiles less to commute and spend more time on the road for commuting. There are a number of disadvantages long transit commute times pose for newcomers with low social and economic stability. In addition to significantly reducing their quality of life, long commute times make it challenging to find and retain employment, resulting in difficulty settling in.

6.3 Location of jobs

As confirmed in chapter 4, while most jobs exist within the Calgary city boundary, there are job clusters in part of the Rocky view County outside the Northeast and Southeast boundaries. Therefore, those areas along with the Calgary city boundary will be included in the employment distribution maps. Maps in Figures 23 and 24 show the distribution of all jobs and jobs in the major ten industries, combined with the distribution of newcomers and the Primary Transit Network overlay. Jobs in major industries, like all jobs, are concentrated in the city centre and industrial areas of Northeast and Southeast, with the concentration in the Southeast industrial area more pronounced. However, distribution patterns significantly vary by industry. For example, jobs in the retail trade industry are highly concentrated inside and outside the city boundary of the industrial area in the Northeast, and manufacturing jobs are concentrated around the Southeast industrial area. On the other hand, jobs in educational services and mining, quarrying, and oil and gas extraction industries are more concentrated in the inner city rather than in industrial zones. See the maps in Appendix A for the distributions of jobs by industry sector.

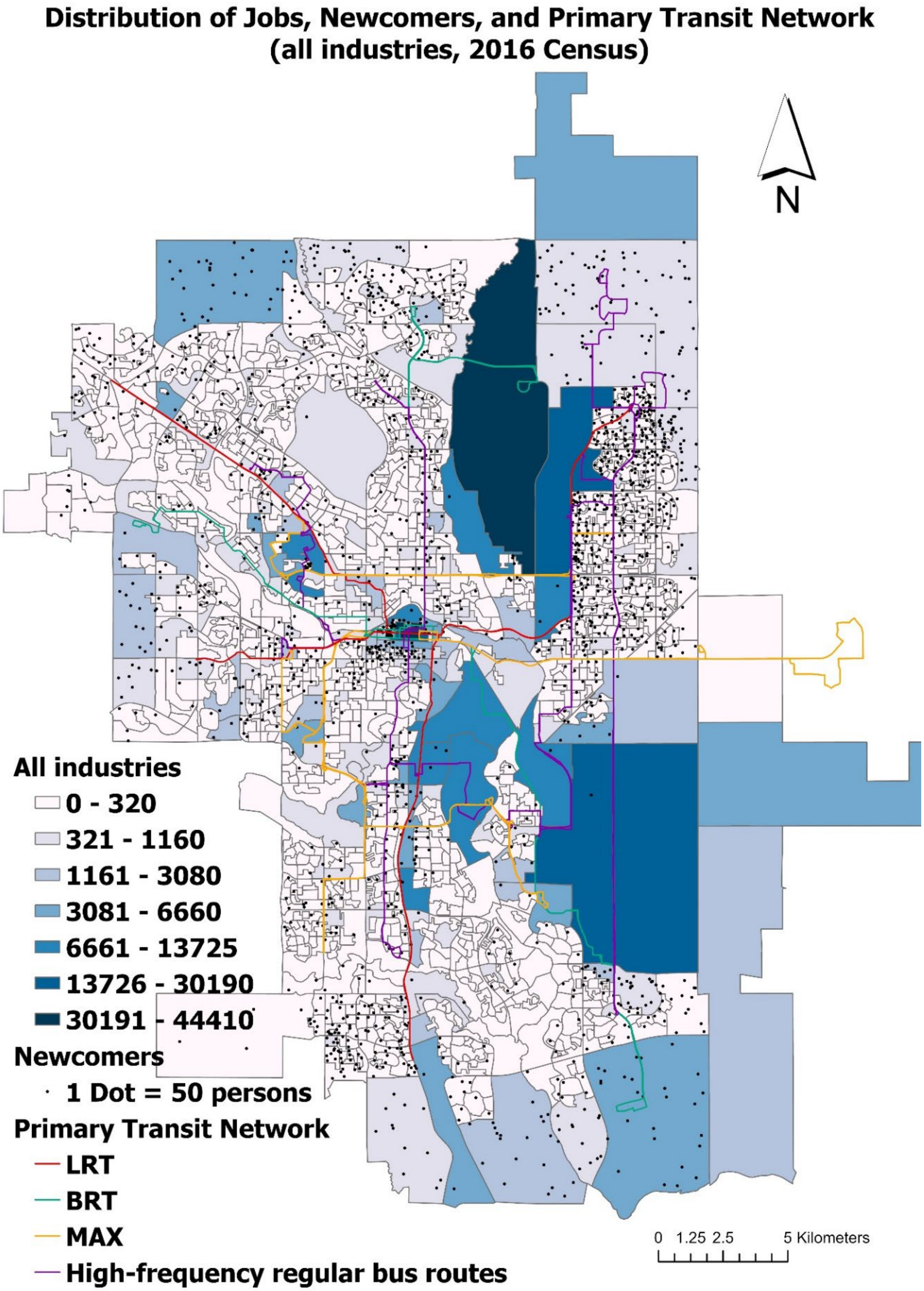


Figure 23. Distribution of all jobs with the distribution of newcomers and Primary Transit Network overlay.

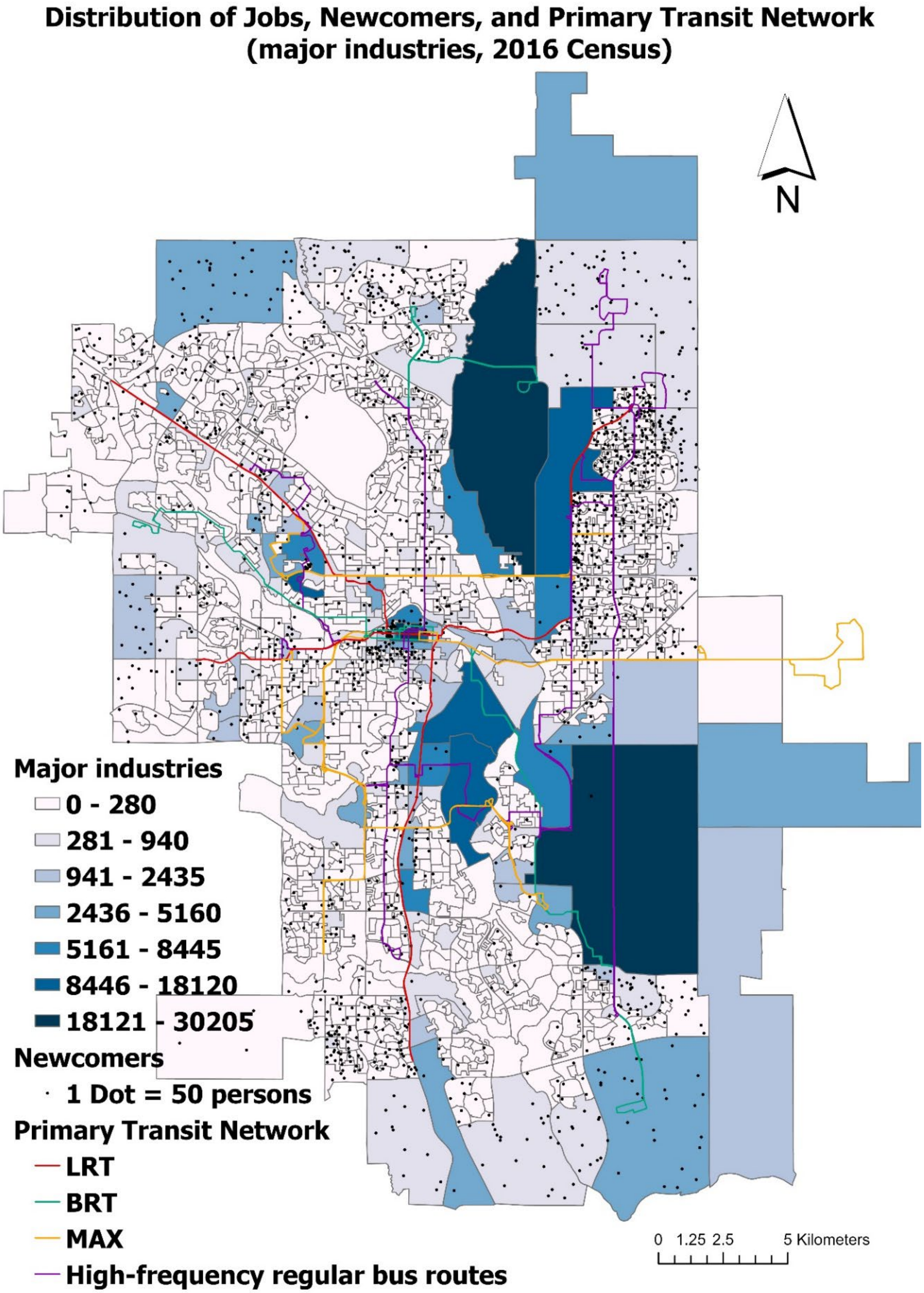


Figure 24. Distribution of jobs in major industries with the distribution of newcomers and the Primary Transit Network overlay.

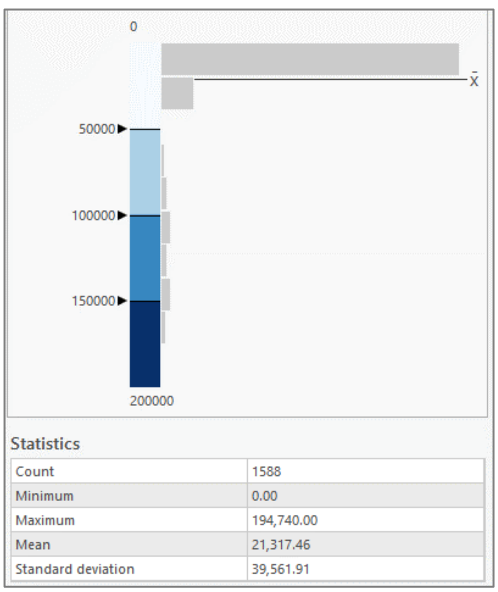
6.4 Transit-based job accessibility by the time of day

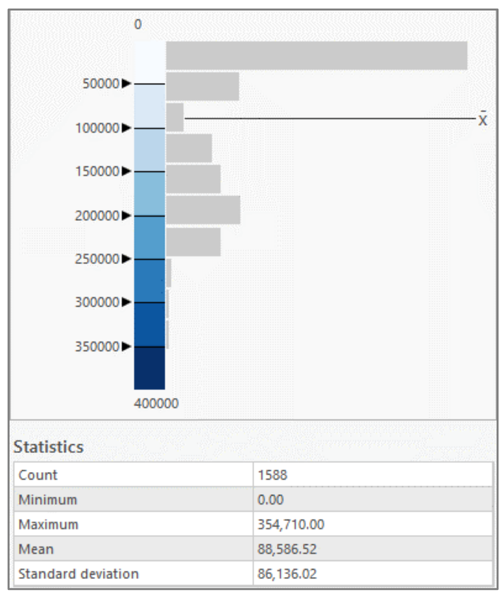
Transit-based job accessibility[2] was calculated in six important commute time periods in Calgary. Although existing studies on job accessibility generally consider only the morning rush hour, but in reality, not everyone goes to work during the regular morning commute hours. 62.8% of workers in Calgary commute to work during the regular commute hours (06:00-09:00), while the remaining 37.2% commute outside of those hours (Statistics Canada, 2017). Many shift workers even go to work very late at night. It is estimated that approximately 12% of working people in Alberta work shifts between midnight and 5 am (Carex Canada, 2021). It is important to note that the industries with the most workers at night include trades, health care and social assistance, manufacturing, and accommodation and food services (Carex Canada, 2021), which corresponds to the major employment sectors for newcomers. Accordingly, the time periods selected in this study consisted of four additional times (04:30-06:00, 10:30-12:00, 19:00-21:00, and 22:30-00:30) during which many shift workers commute, on top of morning and afternoon rush hours (06:00-09:00 and 15:00-18:00).

Figure 25 shows summary statistics and histograms of the distribution of job accessibility at each time threshold. Also, Figures 26 ~29 show transit-based job accessibility maps during the morning rush hour (06:00 to 09:00) with different time thresholds (30, 45, 60, 75 minutes). Figure 26 shows that the number of jobs that can be reached within 30 minutes using transit from most DA is very limited, although the average commute duration in Calgary is 26 minutes. The number of reachable jobs within 30 minutes using transit from most areas in Calgary except the city center area is less than 50,000, that is, about 7.5% of the total number of jobs (Figures 25 and 26). The average transit-based 30-minute job accessibility in Calgary is 21,317, which accounts for only 3.2 percent of the total number of jobs. Looking at the 45-minute job accessibility, which is closest to the average transit commute duration of 41.6 minutes, the average transit-based job accessibility is 88,586, 13.5 percent of the total number of jobs (Figure 25). Some DAs with the accessibility of around 200,000, which is about 30

[2] It refers to the number of reachable from a point in space within a certain time using transit.

percent of the total number of jobs, can be found in areas around the Primary Transit Network outside the city centre. However, the job accessibility in areas near the city boundaries, where there is a high concentration of newcomers, is generally still very low (Figure 27). Almost one-third of jobs can be reached within 60 minutes on average. The average number of reachable jobs in 60 minutes from DAs is 217,623, accounting for about 33% of all jobs (Figures 25 and 28). The 75-minute average transit-based job accessibility is 349,723, which is more than half (53%) of all jobs. As shown in Figure 29, although the 75-minute job accessibility is relatively high in most areas of the city, the job accessibility in outskirt areas that are not connected to the primary transit lines is still low. Similar patterns are observed in other time periods, although overall accessibility is significantly lower compared to the morning rush hour (see the maps in Appendix B).





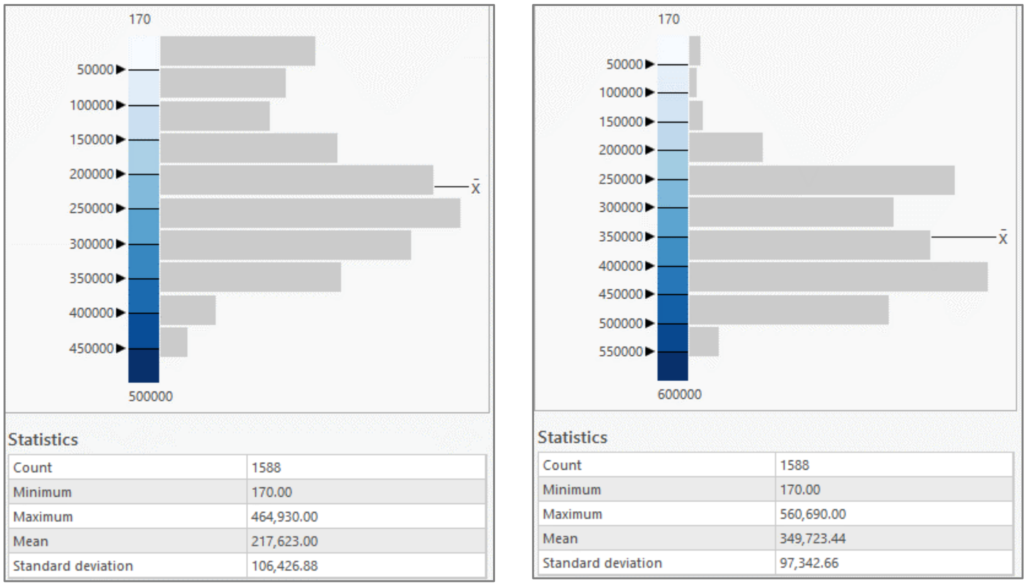


Figure 25. Summary statistics and histograms, showing the distribution of job accessibility in the morning rush hour (6:00 to 09:00) at each time threshold. Clockwise from top-left: 30, 45, 60, 75 min.

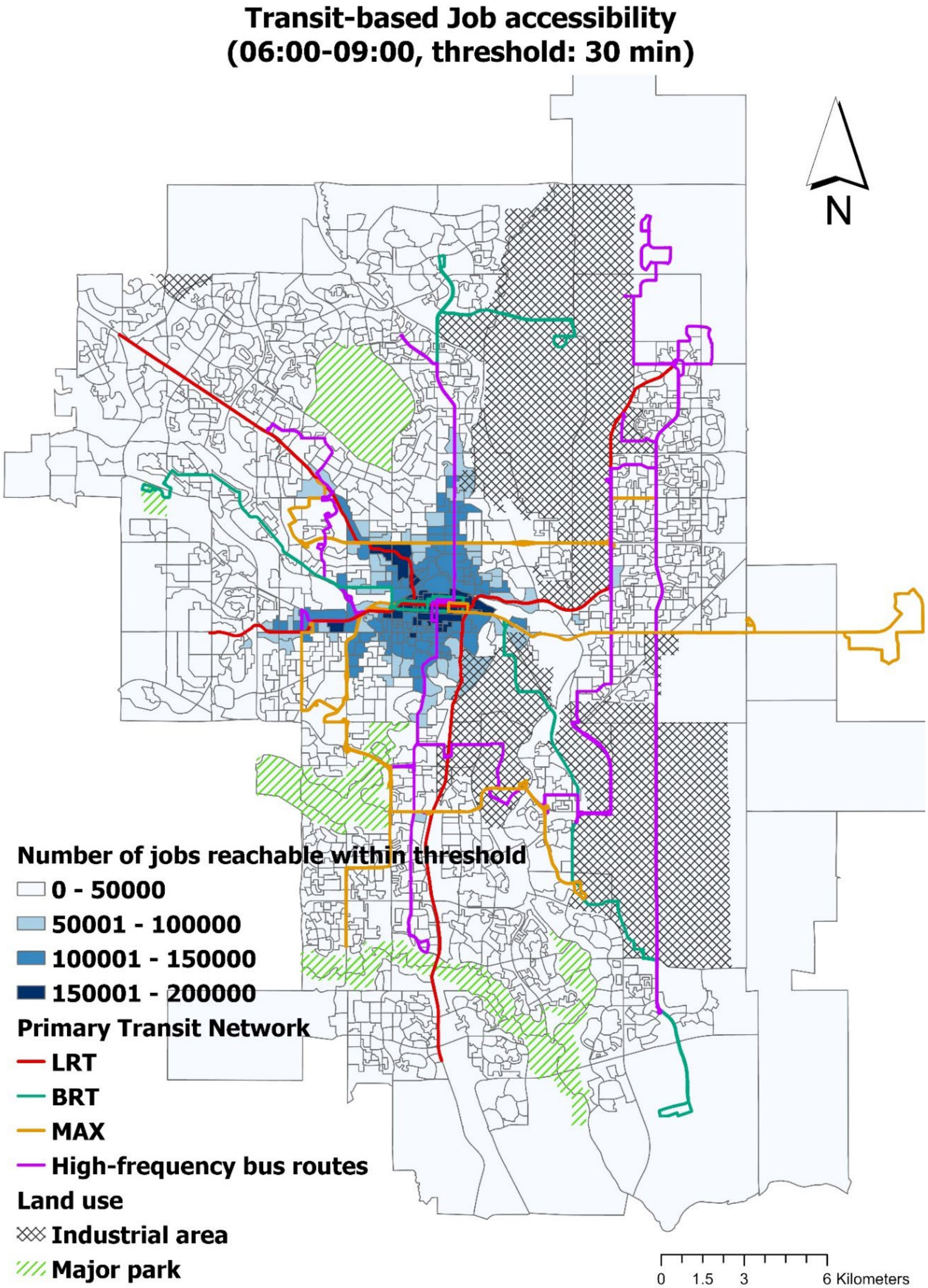


Figure 26. Transit-based job accessibility during 06:00-09:00 with different time thresholds: 30 min.

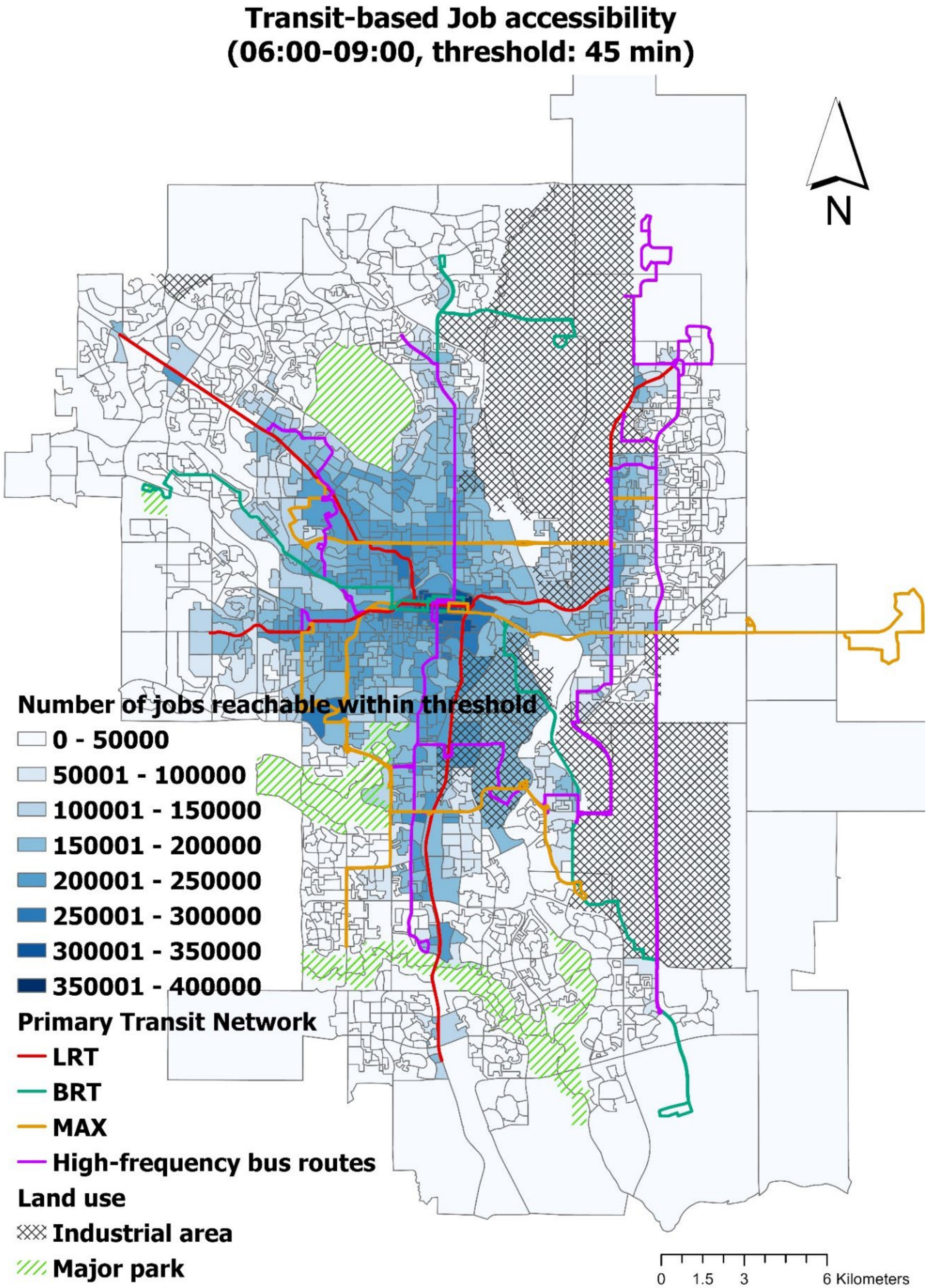


Figure 27. Transit-based job accessibility of during 06:00-09:00 with different time thresholds: 45 min.

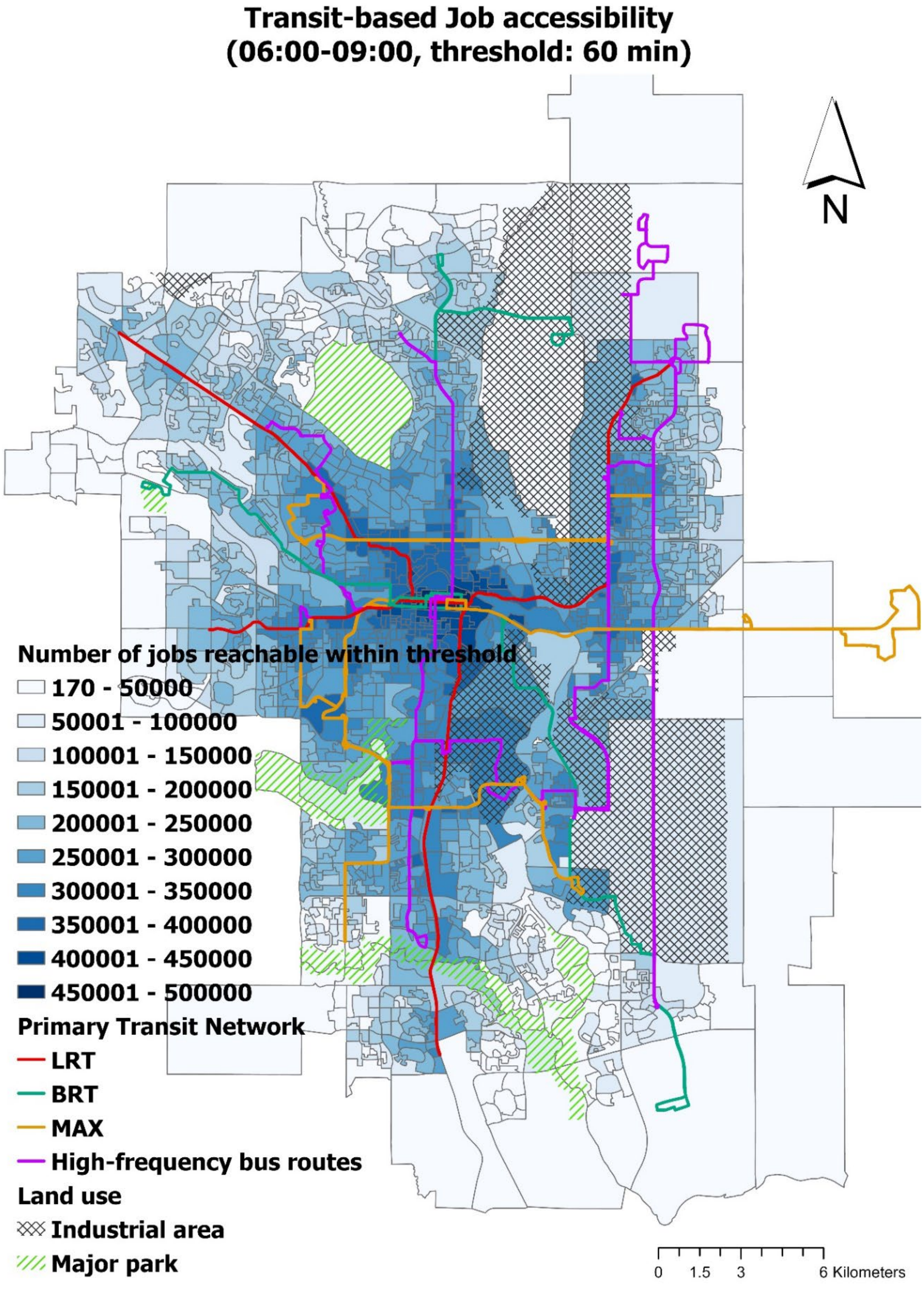


Figure 28. Transit-based job accessibility during 06:00 to 09:00 with different time thresholds: 60 min.

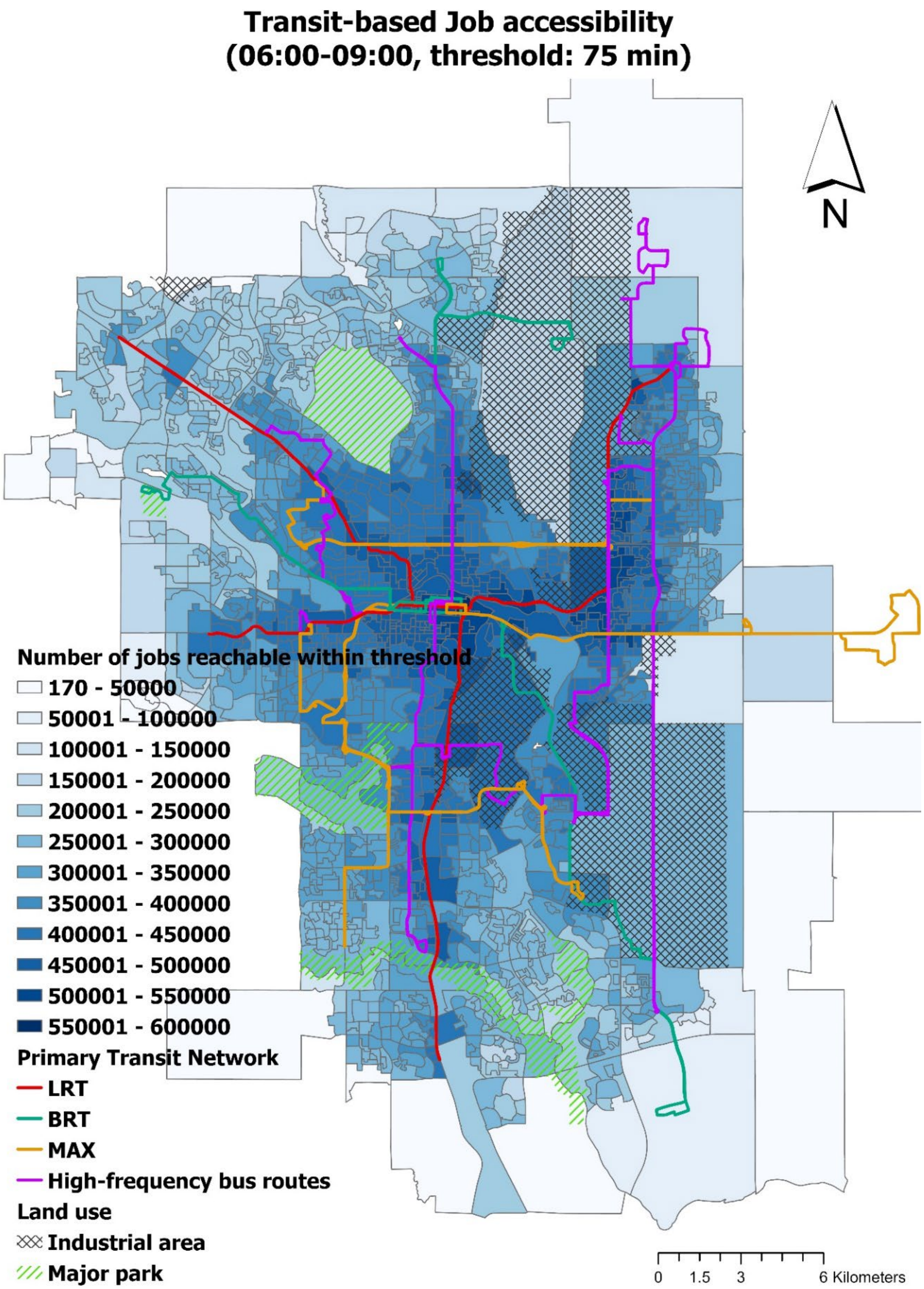


Figure 29. Transit-based job accessibility during 06:00 to 09:00 with different time thresholds: 75 min.

Transit-based job accessibility varies by time of day because the frequency of transit services changes over the day. Figure 30 and Table 11 show the average job accessibility at various times of the day with different time thresholds.

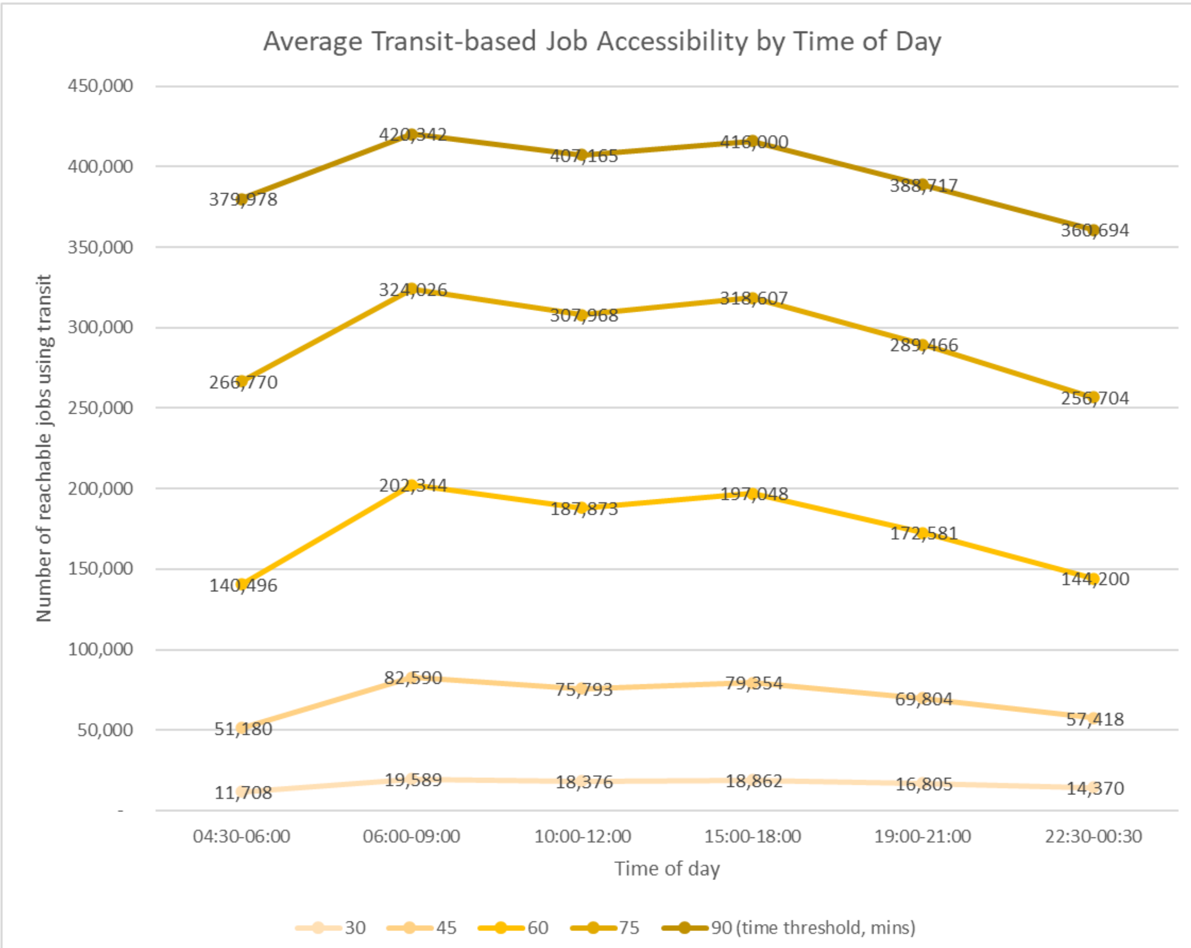


Figure 30. Average transit-based job accessibility by the time of day

Table 11. Average job accessibility with different time thresholds over time of day

		Time of day					
		04:30-06:00	06:00-09:00	10:00-12:00	15:00-18:00	19:00-21:00	22:30-00:30
Threshold	30 min	11,708	19,589	18,376	18,862	16,805	14,370
	45 min	**51,180**	**82,590**	**75,793**	**79,354**	**69,804**	**57,418**
	60 min	140,496	202,344	187,873	197,048	172,581	144,200
	75 min	266,770	324,026	307,968	318,607	289,466	256,704
	90 min	379,978	420,342	407,165	416,000	388,717	360,694

On average, transit-based job accessibility is highest in the morning rush hour (06:00-09:00), the period with the highest transit frequency, and it is lowest in the early morning (04:30-06:00), the period with low transit frequency. In the afternoon rush hour (15:00-18:00), the average accessibility is slightly (3.9%) lower than during the morning rush hour (06:00-09:00). In off-peak hours, the accessibility is still moderate between 10:00 and 12:00, but it sharply decreases as the night progresses (Figure 30). The average transit-based job accessibility during 19:00-21:00 is 15.5% lower than during the morning peak hour and 30.5% lower during 22:00-00:30.

Throughout the rest of this report, we will focus on the 45-minute transit-based job accessibility of each time of the day. This is because it is closest to the average transit-based commuting duration in Calgary CMA, which is 41.6 minutes. Table 12 shows the summary statistics on the 45-minute transit-based job accessibility for each commute time period. In Figure 31, it is shown that the transit-based job accessibility based on the 45-minute commute for early morning shift workers (04:30-06:00) was found to be 38% lower on average than during the morning peak period (06:00-09:00), when the average accessibility is the highest. Figure 32 indicates, however, that the standard deviation is greatest during the morning peak hour (06:00-09:00), which means that the regional gap in job accessibility is also largest during the morning peak hour.

Table 12. Summary statistics of 45 min job accessibility over time of day

	mininum	1st quartile	median	3rd quartile	maximum	mean	SD
04:30-06:00	0	6,183	15,160	95,745	291,110	51,180	65,397
06:00-09:00	0	11,020	36,095	162,503	354,390	82,590	85,301
10:00-12:00	0	9,853	31,230	150,533	335,690	75,793	82,323
15:00-18:00	0	10,583	34,578	154,848	379,145	79,460	84,470
19:00-21:00	0	3,215	23,995	137,455	322,455	69,804	79,743
22:30-00:30	0	5,983	16,100	114,393	302,000	57,418	72,887

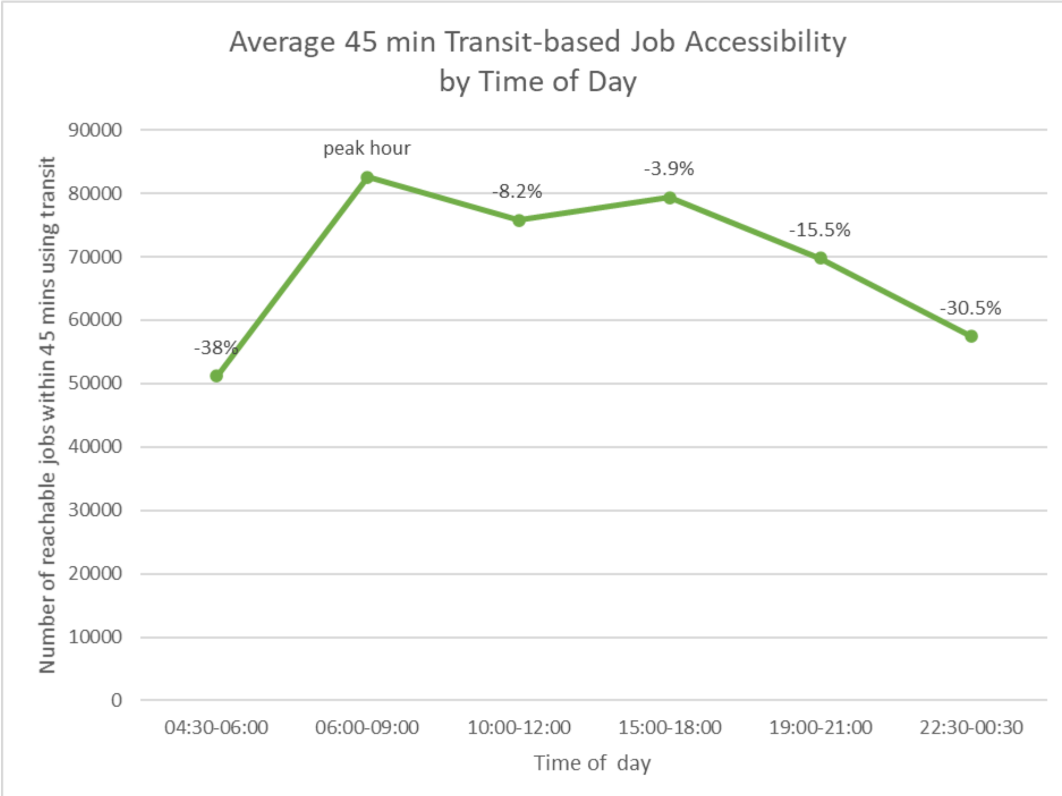


Figure 31. Average 45 min transit-based job accessibility by the time of day.

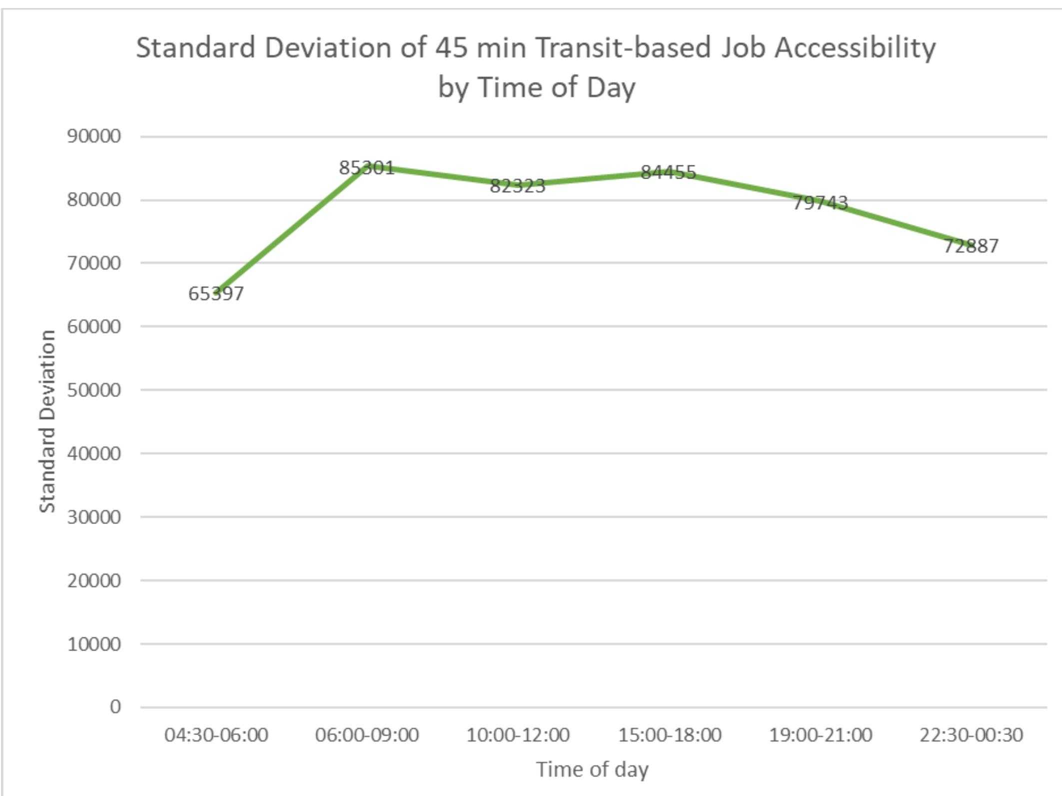


Figure 32. The standard deviation of 45 min transit-based job accessibility by the time of day.

6.5 Transit-based job accessibility by industry

In this section, we analyze and map the 45-minute transit-based job accessibility by the industry sector. By overlaying the distribution of newcomers and jobs on accessibility maps, it will help identify areas where accessibility needs to be improved to allow newcomers to access their prospective jobs.

Figures 33 and 34 illustrate that newcomers residing in the inner city have relatively good access to jobs in major industries during the morning peak hour (06:00-09:00), thanks to the many jobs available and various transit services that exist nearby. However, despite the fact that many jobs in major industries are concentrated near areas where there are many newcomers, job accessibility for some industrial areas, for instance in parts of the Northeast, have low accessibility unless located along a major transit route. This underscores the fact that absolute distance between job clusters from residences does not significantly affect local transit-based job accessibility, while proximity to the major transit routes notably increases accessibility. The locational relationship between newcomer clusters and job clusters has meaningful implications from the perspective of transit planning. For instance, considering the proximity of the newcomers' cluster to the major employment cluster in the Northeast, alternative transportation options that can effectively connect the short distance between the two would be practical to improve newcomers' accessibility to jobs via transit. On the other hand, newcomers who live in the Northwest and South end of the city are generally located a long way away from important employment clusters and have limited public transportation options. In this case, long-term transit planning should consider changes needed to improve their transit-based job accessibility.

Figures 35 and 36 show that transit-based accessibility to jobs in major industries in the early morning (04:30-06:00) is generally very low when transit frequency is lowest among the newcomers' major commute hours. When compared with the morning rush hour (06:00-09:00, Figures 33 and 24), it is clear that the accessibility is significantly lower during 04:30-06:00, except for some areas along the Primary Transit Network. The lower transit frequency during off-peak hours makes it even more difficult for shift workers to commute using transit during these hours.

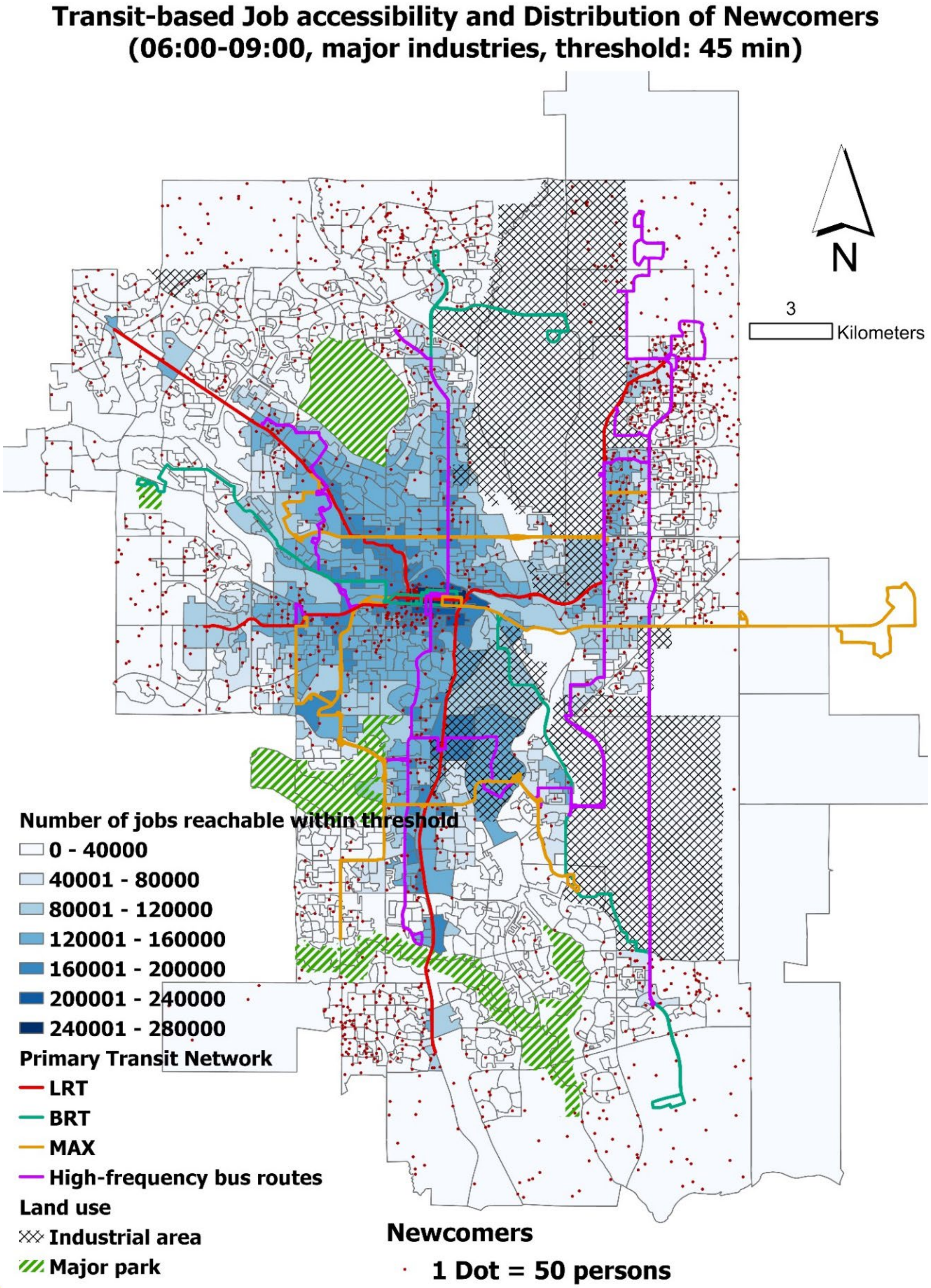


Figure 33. Transit-based job accessibility to major industries during 6:00-9:00 and distribution of newcomers.

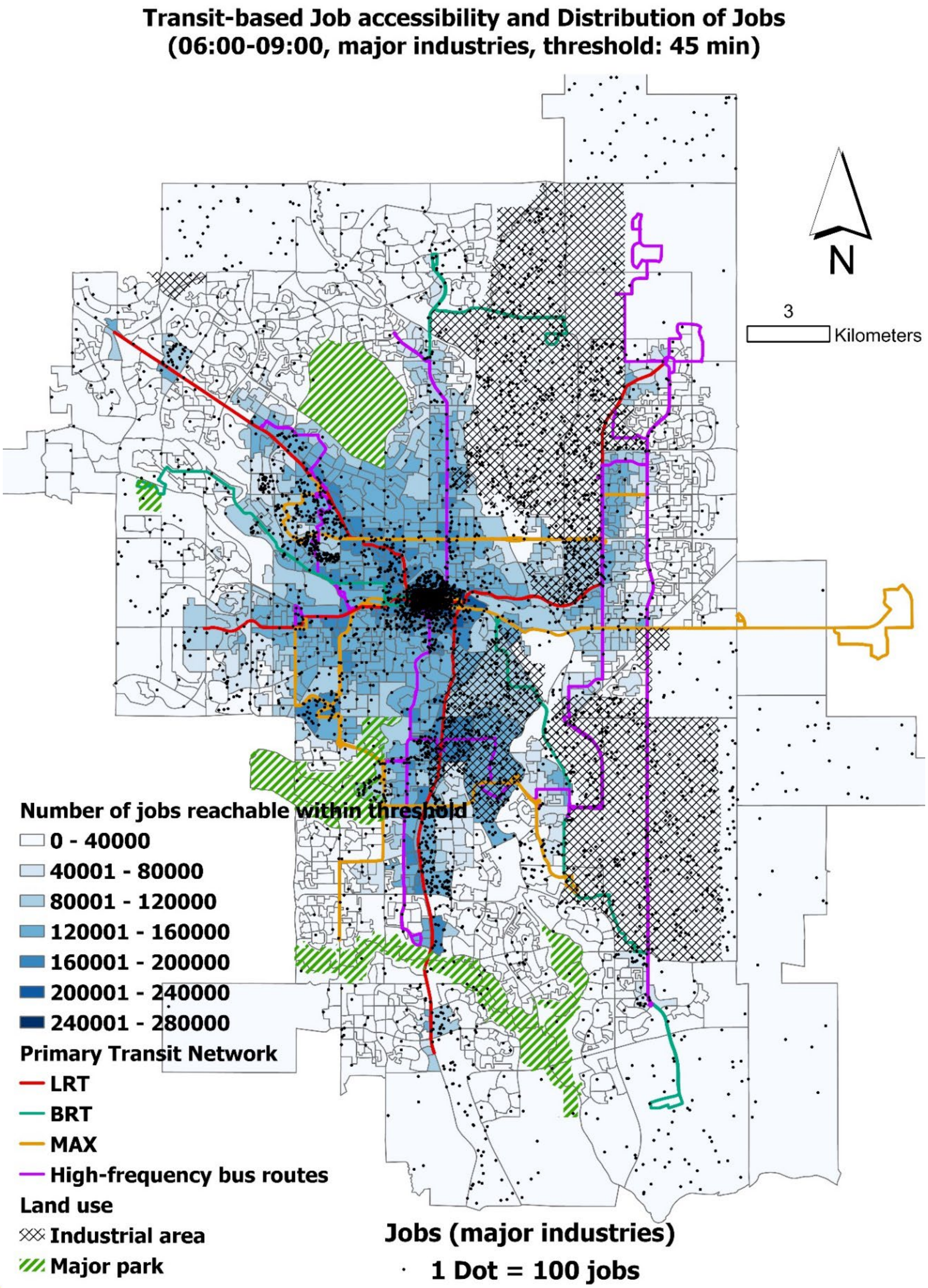


Figure 34. Transit-based job accessibility to major industries during 6:00-9:00 and distribution of jobs.

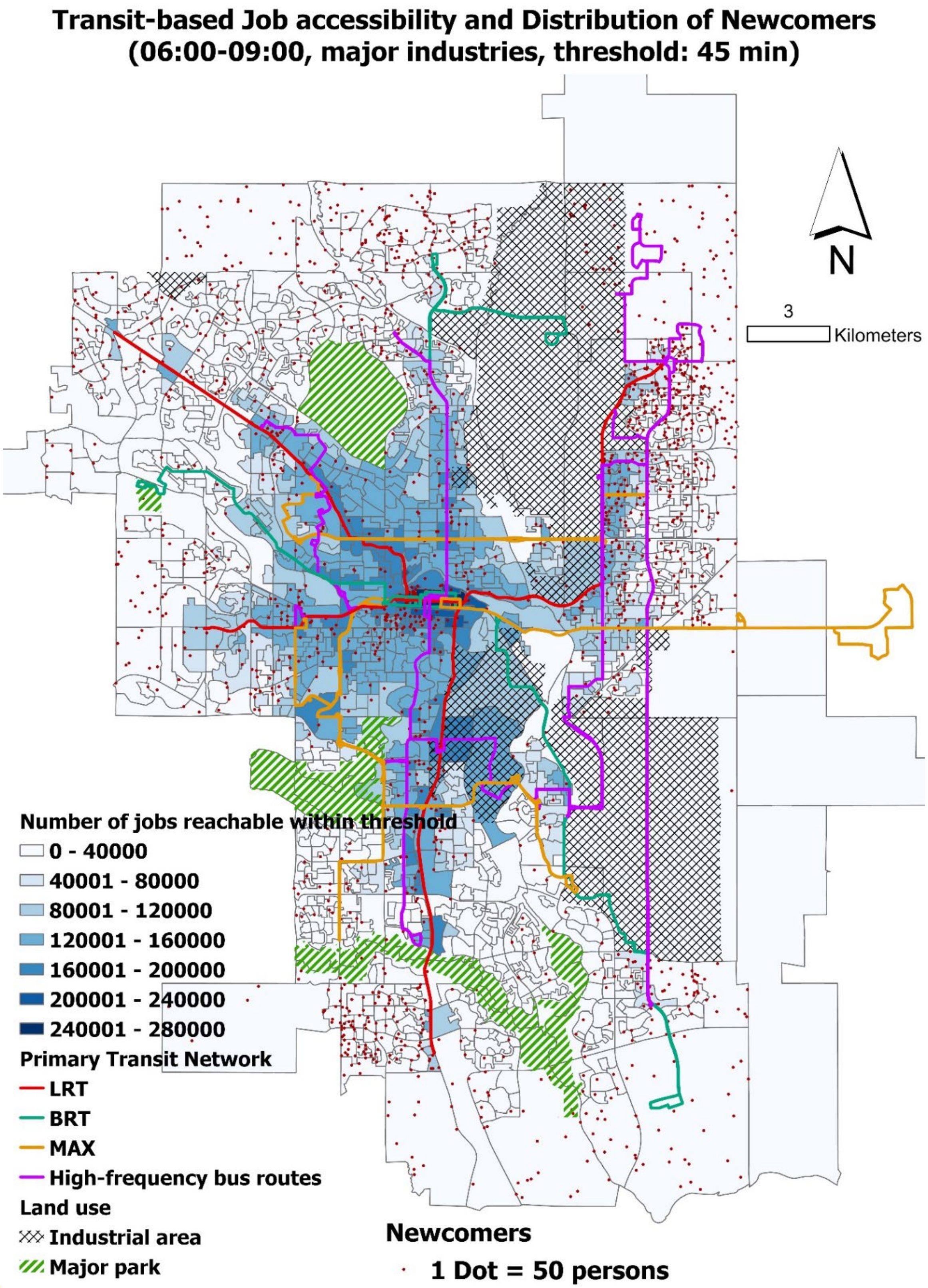


Figure 35. Transit-based job accessibility to major industries during 4:30-6:00 and distribution of newcomers.

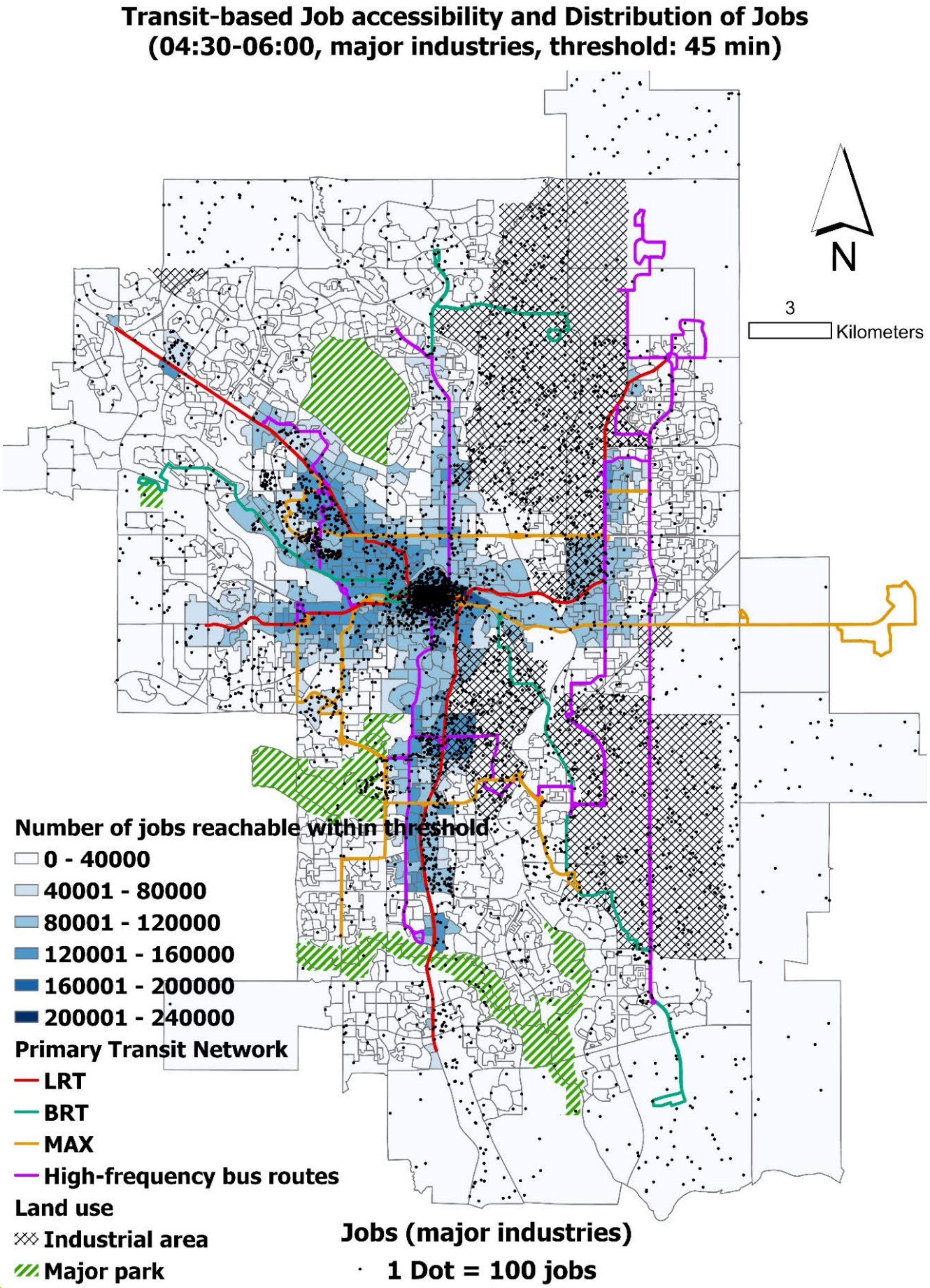


Figure 36. Transit-based job accessibility to major industries during 4:30-6:00 and distribution of jobs.

There are differences in transit-based job accessibility by industry. See the Industry-specific accessibility maps in Appendix C. As shown in Figure 37, the average 45-minute transit-based job accessibility in Calgary's morning rush hour (06:00-09:00) is 13.1% of total jobs. Similarly, the number of reachable jobs in major industries by transit within 45 minutes is 12.5 percent of the total number.

The gaps in job accessibility by industry are large. For example, the average accessibility in the mining, quarrying, and oil and gas extraction industries is 28.2% of the number of jobs in the sector, significantly higher compared to other industries. This is because many jobs in this industry are located in the city center with relatively good access using public transportation (See Figure 108 in Appendix C). The average transit-based accessibility to the professional, scientific and technical services industry, where a large number of jobs are located in the city centre, is 16.7% of the total jobs in the sector, also higher than the average (Figure 100 in Appendix C). It suggests that the current transit system is relatively effective at transporting commuters to the city centre.

On the other hand, the average accessibility of jobs in the wholesale and retail trade, manufacturing, construction, transportation and warehousing industries is very low. Jobs in these industry sectors are massively concentrated in industrial areas in the Northeast and Southeast rather than the inner city. Also, many jobs in these sectors are located even outside the north and east of the city boundary, with few transit services (Figures 76, 80, 88, 92, and 96 in Appendix C). It is important to note that the employment share of newcomers is especially high in these industries (see Table 7 in section 4.2). Therefore, improving transit-based accessibility to these areas is crucial in order to increase newcomers' accessibility to their workplaces.

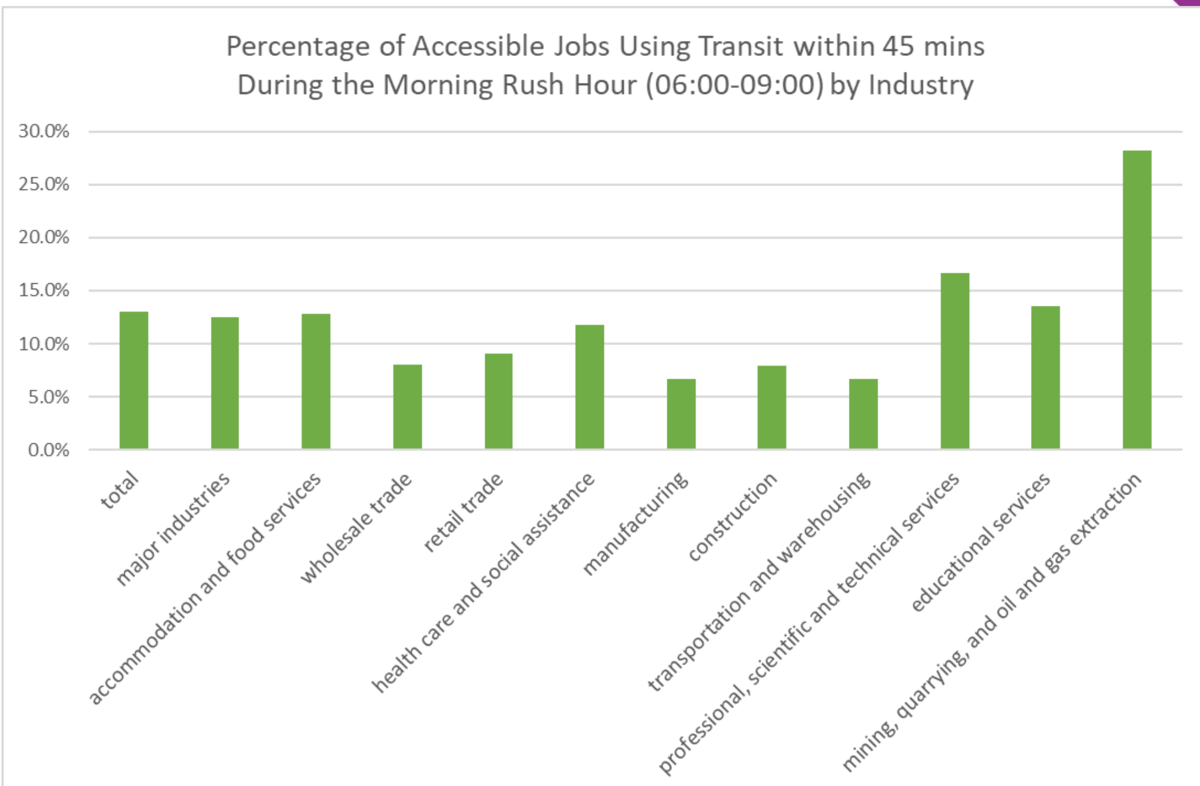


Figure 37. Percentage of accessible jobs, within 45 minutes, using transit during the morning rush hour (6:00-09:00), by industry.

Figure 38 shows the gap in transit-based job accessibility between the morning peak hours (06:00-09:00) and other commute times, by industry. The gaps in accessibility vary greatly from time to time and from industry to industry. For example, during 04:30-06:00 and 22:00-00:30, when many early morning and midnight shift workers go to work, the gap in transit-based job accessibility with the morning peak hours is the largest in general. In particular, the accessibility to health care and social assistance jobs is 45.2% lower at 04:30-06:00 than peak hours, 06:00-09:00. This is because many jobs in the health care and social assistance industry are located at the Southeast edge of the city with little connection to the major transit routes (See Figures 86 in Appendix C), and the frequency of transit to this area becomes notably low during off-peak hours. Also, there is a large gap (42.3%) between the morning peak hours and during 04:30-06:00 in the transit-based accessibility to educational services jobs. Jobs in the educational services sector are scattered in many residential areas rather than concentrated in city centers (Figure 106 in Appendix C), and irregular transit schedules to those areas affect this large gap. Lastly, Figure 38 also shows during most off-peak hours of transit services, compared to other industries, transit-based accessibility to wholesale trade, manufacturing, construction, and transportation and warehousing jobs is significantly lower than peak hours. The jobs in these industry sectors tend to be more concentrated in the industrial areas of the Northeast and Southeast compared to other industries, and it can be inferred that the transit frequency to these areas during off-peak hours is particularly low (Figures 112, 124, 128, and 132). Considering the large number of newcomers are employed in these industries, and that many are shift workers, it is essential to improve transit services to these areas during off-peak hours.

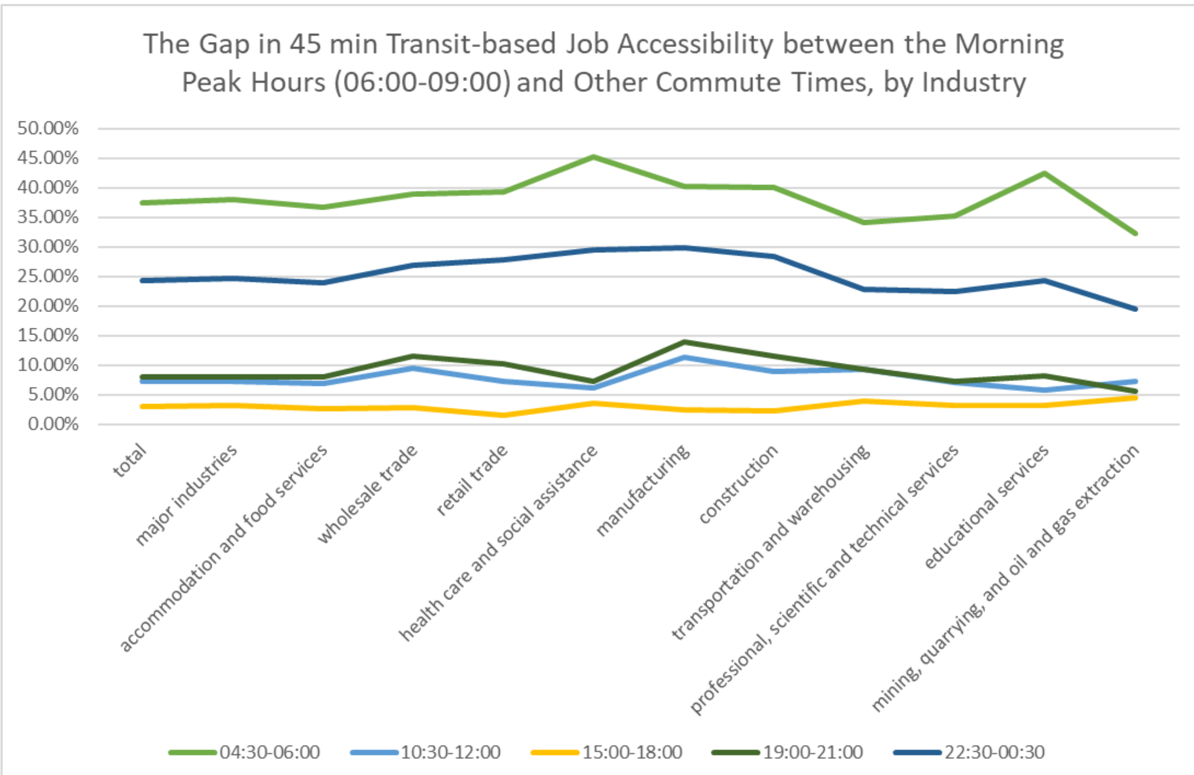


Figure 38. The gap in 45 min transit-based job accessibility between the morning peak hours (06:00-09:00) and other commute times, by industry

6.6 Newcomer spatial mismatch index by community

By using the Dissemination Area as aggregation level, which is the smallest geographic analytical unit in the study area, this study has attempted to minimize MAUP (Modifiable Areal Unit Problem) while at the same time addressing regional job accessibility issues in Calgary in detail. This section provides a more tangible picture of newcomers' transit-based job accessibility in Calgary by integrating transit-based job accessibilities at the community level. Based on the number of newcomers and job accessibility at the community level, we want to identify the communities where newcomers tend to cluster and at the same time, transit-based accessibility to jobs in industries newcomers are primarily employed is particularly challenged. A community's "Newcomer spatial mismatch index" is calculated by dividing the number of newcomers by jobs in major industries accessible within 45 minutes from the community. The higher the number of newcomers in the community and the lower the transit-based job accessibility, the higher this index.

Figures 39 and 40 show the "Newcomer Spatial Mismatch Index" by the community for the peak transit hours of 06:00-09:00 and the off-peak hours of 04:30-06:00, respectively. It can be once again confirmed that newcomers in communities at city edges are particularly mismatched with the locations of jobs in major industries based on transit-based accessibility. The average index for the peak hour (06:00-09:00) is 0.058, and the indexes of communities such as Taradale (1.03) and Skyview ranch (0.729) in the Northeast and Discovery ridge (0.847) and Valley ridge (0.646) in the West are particularly high. The average index of the off-peak hour (04:30-06:00) is 0.094, which is much higher than the peak hour. In particular, communities including Copperfield (1.197) in the Southeast, Taradale (1.135) and Skyview Ranch (1.085) in the Northeast, and Bridlewood (0.92%) in the South had exceptionally high indexes. It is evident that the newcomer spatial mismatch indexes of most communities in the Northwest and South end, which are far from important job clusters and at the same time have limited access to transit services, tend to be high. Also, it is confirmed again that the transit-based job accessibility is generally very low in the newcomer cluster in the Northeast communities that are not far from industrial areas but lack efficient transit services. See Appendix D for the “Newcomer Spatial Mismatch Indexes” for 196 residential communities in Calgary.

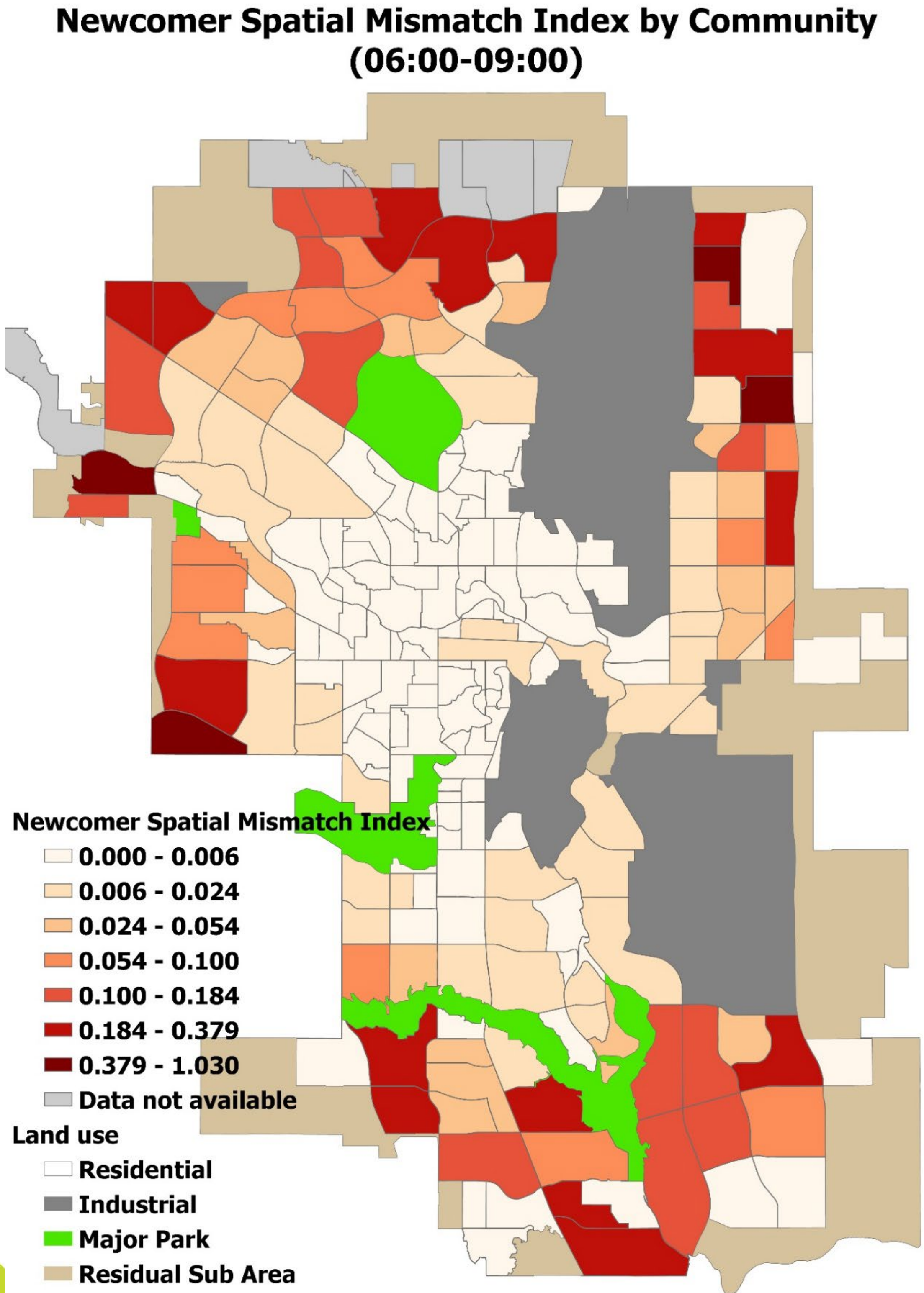


Figure 39. Newcomer spatial mismatch index by community (06:00-09:00)

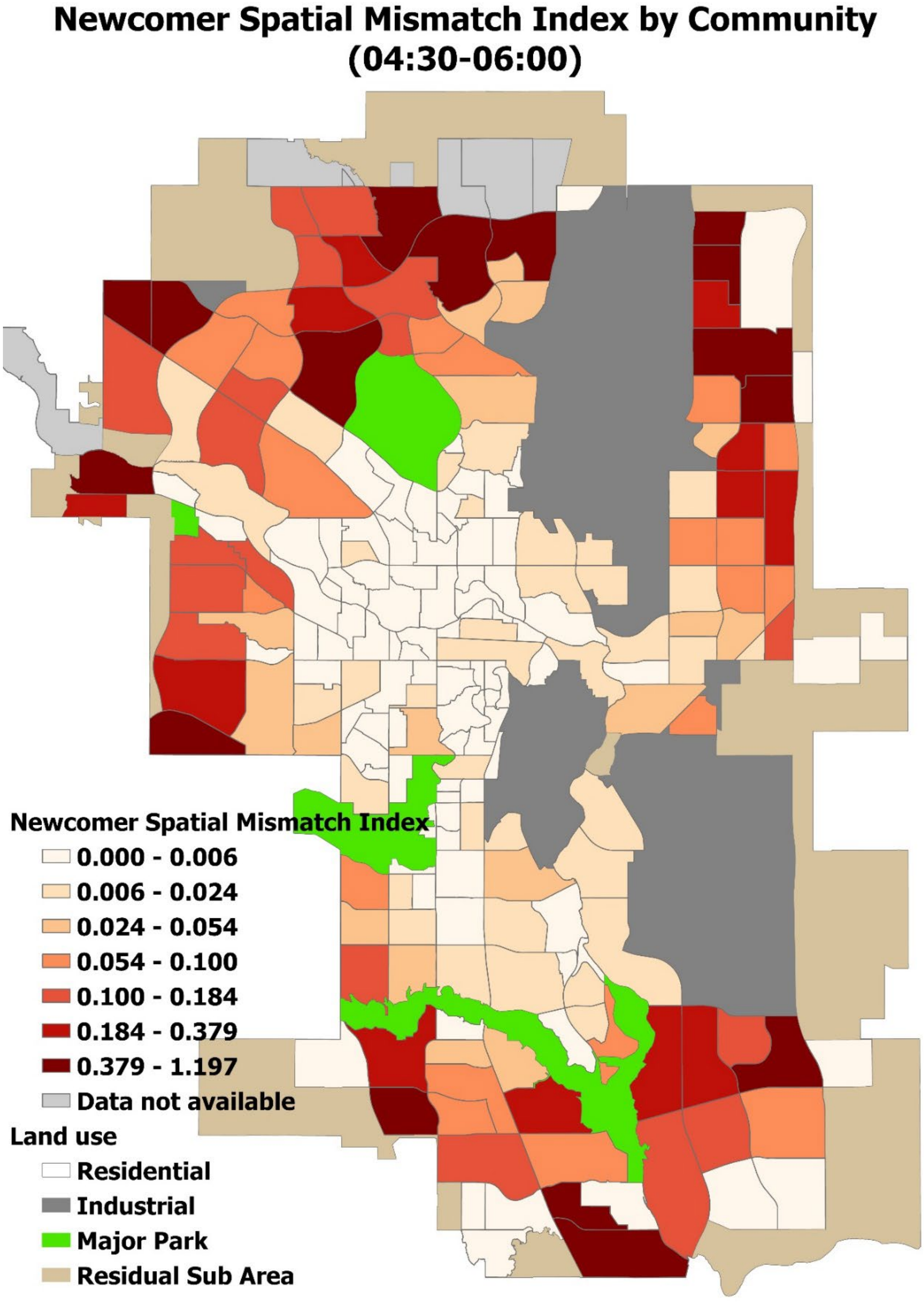


Figure 40. Newcomer spatial mismatch index by community (04:30-06:00)

7. Discussion

This study started from the spatial mismatch hypothesis that economically and socially disadvantaged groups of people tend to be more spatially mismatched with job opportunities and that they have more trouble commuting than average populations. However, this study revealed that newcomers in Calgary are technically not mismatched "spatially" with job opportunities, but rather they have difficulties accessing jobs due to the lack of appropriate means of transportation. This study shows that many newcomers in Calgary reside near major transit routes and that newcomers who live near major transit routes enjoy relatively easy access to transit services. However, due to the low and irregular frequency and limited routes of transit services, those who use transit to commute are suffering from commutes that take much longer than car users, limiting their ability to find and retain employment. Newcomers are one of the population groups that have difficulties with commutes. Newcomers' ratio in DAs of Calgary has a positive correlation with the percentage of people who use transit to commute and those who spend more than 60 minutes commuting (c.f., the citizens' ratio has a positive correlation with the percentage of people using an automobile to commute and spend 29 minutes or less commuting). The theoretical background combined with the empirical evidence found in this study leads to the broad conclusion that newcomers in Calgary need more efficient transit services to deliver them to their potential job opportunities for stable economic activity and settlement.

Newcomers in Calgary are distributed throughout the city, with a high concentration near the city's Northeast and South edges. Also, the distribution of jobs in important industries is exceptionally high in industrial areas of the Northeast and Southeast along with the city centre. In other words, there is geographic proximity rather than a significant spatial mismatch between the newcomer clusters and the job clusters. This is in line with previous studies claiming that low-income workers travel shorter distances to work while those with higher earnings have longer commutes (Murakami and Young, 1997; Donaldson, 2011). However, major transit lines are not efficiently connected to most job clusters except for city centers, so job accessibility for those who have to use transit to commute is inevitably low. For example, the DAs of the newcomer cluster in the city's Northeast edge generally have low transit-based job accessibility despite their spatial proximity to the job cluster in the Northeast industrial area. The locational relationship of newcomer clusters and job clusters has important implications from the perspective of transit planning. For instance, given the proximity of the newcomer cluster and the job cluster in the Northeast, alternative transportation options that effectively connect the short distance between them would be practical to improve newcomers' transit-based job accessibility in this area. On the contrary, newcomers living at the Northwest and South ends of the city are generally far from important job clusters and have limited transit service options too. In this case, long-term transit planning will be required to improve their transit-based job accessibility. Also, in both cases, current transit services that have been geared towards commuters travelling from suburban areas to the centre or within the centre itself need to be expanded to suburb-to-suburb services. For example, Calgary's LRT and BRT lines serve as a means of connecting every corner of the city to the city centre, while some regular bus lines and MAX lines can directly link residential and industrial areas. In particular, some regular bus routes, such as routes 23 and 43, connect the newcomer cluster in the Northeast with the industrial area in the Southeast, with high frequency, so that newcomers can be transported to work without having to transfer multiple times or go through the city centre. Development and improvement of bus routes that play this role can significantly improve job accessibility for newcomers.

This study tried to identify areas and time periods that need improvements in transit services in detail by mapping transit-based job accessibility by the time of day as well as by industry. Since job accessibility significantly varies according to the time of day, a different approach to transit planning is required depending on the time periods of commute. The results of this study indicate that an industry-specific approach in transit planning will be practical to improve newcomers' transit-based job accessibility based on the current commute patterns of shift workers of each industry. For instance, the average transit-based job accessibility during the early morning commute time at 04:30-06:00 is 38% lower than the morning peak hour at 06:00-09:00. The lower transit frequency of non-peak hours makes it more difficult for shift workers to commute using transit. In addition, transit-based job accessibility largely differs from industry to industry. In industries such as mining, quarrying, and oil and gas extraction, and professional, scientific and technical services where jobs are highly concentrated in city centers, the average ratio of jobs that can be reached within 45 minutes during morning rush hour is relatively high, indicating that the current transit system is relatively effective at transporting commuters to the city centre. On the contrary, for employment sectors where jobs are massively concentrated in industrial areas on the outskirts of the city (e.g., trade, manufacturing, construction, transportation and warehousing industries), the average percentage of jobs that can be reached within 45 minutes during the morning rush hour is significantly lower, less than 10%. It is important to note that the employment share of newcomers is particularly high in these industries. In addition, this study found that the accessibility to jobs in these industries during off-peak hours, compared to other industries, was significantly lower than during the morning rush hours. Considering that the largest number of newcomers are employed in these industries, and that many are shift workers, it is essential to improve transit services to these areas during off-peak hours as well.

8. Limitations

There are several limitations to this work, which suggests directions for improvement and future work. First, although this study used the smallest aggregation unit available (Dissemination Area) in population and employment data to minimize the MAUP (modifiable area unit problem), it still did not use original point data, so it is not possible to resolve the MAUP completely. For example, there is a considerable variation in land size (0.017 to 45.416 km^2) and population (105 to 21,970 people) among DAs, which may cause misunderstandings in visualizing the distribution of population and jobs by DA. As well, in the part of the study, we visualized the employment distribution using dots, and 500 jobs were expressed as one dot. The problem is that one DA with 1,000 jobs is expressed as 2 dots, but if there are 250 jobs in each of 4 neighbouring DAs, not a single dot is expressed. This problem is the same when visualizing population distribution using dots. We tried to minimize misunderstandings related to representation by making the number of jobs and population expressed per dot as low as possible. Second, this study considered only one-way travel from residence to work.

However, in finding and retaining a job, the existence of appropriate transportation to return from work is also important, so it will be necessary to look into the ease of travel of this reverse journey as well. Third, this study did not consider differences in job accessibility of subgroups within the larger newcomer group, such as different gender and age groups, mainly because the dissemination area level census data was used instead of individual data. However, the literature suggests that women (especially working mothers) have complexity in residential and work location decisions, which causes labour characteristics that differentiate them from men in terms of wage, occupation, and commute mode (Hanson and Pratt, 1995). In the literature on the travel patterns of low-income women, it is shown that they are more likely to stop on the way to and from work than men, and they are more likely to work nights and weekends when transit frequency is lower (Blumenberg, 2004). Also, spatial mismatch is a particular challenge for youth because young people have more limited means of transportation (Brandtner et al., 2017). Providing efficient public transit may serve as a critical factor in reducing youth unemployment among newcomer households. Accordingly, future research will need to look into variations in job accessibility within the newcomer group using in-depth qualitative approaches such as questionnaires or interviews. Lastly, the study area was limited to Calgary CMA due to data limitations, and jobs outside of Calgary CMA were not considered. However, it is known that some people live within the Calgary city boundary and commute outside the Calgary CMA (e.g., meat packing companies in High River, Alberta). Thus, it will be necessary to look at the accessibility issues to jobs outside the Calgary CMA boundary as well.

9. Conclusion

In this study, we identified the distribution of newcomers and jobs in the Calgary CMA and analyzed newcomers' transit-based job accessibility by industry sector during various commute times. Specifically, we used the cumulative opportunity measure to compute accessibility, which counts the number of jobs that can be reached from a given point in space within a certain travel time threshold.

This study found that newcomers’ residential clusters are often not far away from important job clusters in the region. However, it also shows that low and inconsistent frequency and limited transit service routes mean that those who commute by transit often endure long journeys to work, limiting their ability to find and retain employment. The results of this study also indicate that job accessibility largely varies depending on the time of day and industry sector; therefore, future transit planning should take into account time of day and type of industry in order to meet the needs of shift workers in the various employment sectors.

This study contributes to the literature on spatial mismatch and job accessibility by focusing on the job accessibility of a specific Canadian city and the newcomer group, a group that has not previously been addressed. Previous spatial mismatch studies have largely focused on cities in the United States and considered visible minorities and low-income populations. One of the limitations of these studies is that they did not take into account the specific job sectors that represent likely skill set matches; instead, all jobs were treated equally as potential job opportunities for any group of individuals. This study differs from previous ones in that it identified industry sectors where recent immigrants have relatively high chances of employment and analyzed transit-based job accessibility by industry sector. This approach provides a more plausible representation of newcomers' accessibility to potential workplaces. In addition, while previous studies have mainly approached job accessibility by focusing on the morning rush hour, this study looks at six different commute times at which shift workers may travel to work. Taking into account multiple time periods is important given that many newcomers are employed in shift work in industries such as retail trade, accommodation and food services, health care and social assistance, etc.

As mentioned in the previous section, this study has some limitations, many of which can be attributed to the fact that it was purely quantitative, based on census data. As well, the census data were insufficient to answer all of our research questions. Future qualitative research will be able to illuminate more detailed issues of job accessibility in the Calgary region. For example, in-depth interviews with individual newcomers may provide insight into job accessibility issues, by age and gender subgroups, and address job accessibility issues of those people commuting outside the Calgary CMA.

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