Urban Connectivity Dynamics: Analyzing Free Public WiFi Distribution in Toronto*

By Building Typology, Population, and Socioeconomic Indicators

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In the era of increasing digital dependence, understanding the intricacies of urban internet connectivity is pivotal for fostering an effective and technologically equitable society. Public WiFi is a vital tool in modern society, offering internet access and supporting economic development, education, and social connections. In response to the increasing importance of internet connectivity in contemporary urban life, I investigate the distribution of free public WiFi in Toronto. This paper aims to provide key statistics on the distribution of public WiFi in Toronto and analyze the impact of building types, demographics, and economic influences on its distribution to gain as comprehensive a picture as possible of the role and impact of public WiFi in our lives.

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*Code and data are available at: https://github.com/BerniceBao/Free-Public-WiFi-Distribution-in-Toronto.

1 Introduction

In an era characterized by an ever-deepening reliance on digital technologies, the intricate tapestry of urban internet connectivity is emerging as a pivotal force in the transformation of our societal fabric. Countries globally are acknowledging internet access as an indispensable tool for active participation in contemporary democratic societies. In Canada, the Canadian Radio-television and Telecommunications Commission (CRTC) has recognized that "broadband internet access services are crucial to Canada's economic, social, democratic, and cultural fabric."("Datasharing - Toronto - Free Wi-Fi" (2019)) As a university student navigating the complexities of contemporary living, the significance of understanding these dynamics cannot be overstated. We are acutely aware of the transformative potential that connectivity holds.

Public WiFi, often taken for granted in our daily lives, emerges as a vital tool shaping the contours of a technologically inclusive society. It plays a pivotal role in modern society, offering a myriad of benefits to individuals. Beyond providing a cost-effective alternative to cellular data, it fosters internet accessibility, enabling people to stay connected without constraints. This flexibility and mobility are particularly advantageous for students, travelers, and those on a budget, allowing them to work, study, or communicate from diverse locations. Moreover, public WiFi contributes to social inclusion, bridging the digital divide and ensuring that even those without home internet access can engage in online activities. Access to information, job searching, and remote work opportunities are further facilitated, enhancing the overall quality of life. In emergencies, public WiFi serves as a crucial communication lifeline, demonstrating its indispensable role in connecting people and providing access to vital services.(Broadbandsearch (2023))

Beyond the conveniences of internet access, it serves as a linchpin fostering economic development, facilitating education, and fortifying social connections. The present study, anchored in the evolving landscape of Toronto, endeavors to unravel the mysteries surrounding the distribution of public WiFi. This paper embarks on a compelling exploration of the distribution of free public WiFi in Toronto, recognizing it as not merely a technological amenity but a cornerstone of our modern existence. By examining the impact of various factors, such as building types, demographic patterns, and economic influences, this research seeks to paint a comprehensive portrait of the role and impact of public WiFi in our lives, providing readers with a lens to comprehend the symbiotic relationship between technology and urban living.

This research is divided into three main parts: `Introduction`(Section 1), `Data`(Section 2), `Model` (Section 3), `Results` (Section 4), and `Discussion` (Section 5). Commencing with the Data section, a meticulous exposition ensues, delineating the origin of datasets garnered from the OpenDataToronto Library and expounding upon the procedural rigors applied for data refinement and analysis. The conclusion part shows what I found during the analysis, while goes deeper into those findings, and finally wraps up the main discoveries from this paper about public free WiFi in Toronto.

2 Data

In this section, I will explore the diverse modes of `R`-based data collection and generation within the `RStudio` environment (R Core Team 2022; RStudio Team 2021). The data under scrutiny in this paper originates from the `opendatatoronto` R package (Gelfand 2022), specifically drawing from theLocation and description data of Toronto free public WiFi dataset, as well as the 2021 Ward Profiles based on the 25-Ward model dataset. The analysis benefits from additional functionalities harnessed from various R packages such as `tidyverse` (Wickham et al. 2019) installed to gain access to other important R packages, `here` (Müller 2020) created a path to specific saved files, `readr` (Wickham, Hester, and Bryan 2024) read and imported data, `ggplot2` (Wickham 2016) made the data visualizations, `knitr` (Xie 2023) and `dplyr` (Wickham et al. 2023) manipulated and cleaned data, and `modelsummary` (Arel-Bundock 2022) to create summary tables. Further insights into the deployment of these packages will be expounded upon in the ensuing subsections.

2.1 First Dataset: Location and description data of Toronto free public WiFi

The data I mainly used to generate the visualizations in this paper is City of Toronto Free Public WiFi from Open Data Toronto (Gelfand 2022) that is an open source tool designed to be publicly available and encourage the development of valuable insights. The dataset, released by Toronto's Department of Information & Technology, captures information on location and description data free public WiFi locations in the City of Toronto and is updated monthly.

The data used for analysis in this article is as of January 3, 2024. According to the data characteristics described on the portal, this data should include information such as address, building type, building name, postal code, whether there is public wifi, etc. Through systematic analysis, it is found that only building type is the main subject variable that can be used to study the influencing factors of distribution. In order to quickly extract available data, only columns with reasonable data are retained during the data cleaning process (see Table 1). Basic data cleaning of column values to shorten the description of different types of clinics and improve readability. I create a statistic on the basis of monthly groups, using kable() from knitr to create Table 1.

Table 1: Sample of cleaned Free Public WiFi data

Building type	Ward	Ward Number
Arena	Etobicoke North	1
Arena	Don Valley East	16
Arena	Willowdale	18
Arena	Humber River-Black Creek	7
Arena	Humber River-Black Creek	7
Arena	Humber River-Black Creek	7
Arena	Parkdale-High Park	4
Arena	Etobicoke-Lakeshore	3
Arena	Etobicoke-Lakeshore	3
Arena	Don Valley East	16

From the Location and description data of Toronto free public WiFi, as of January 3, 2024, there are 194 free public WiFi location in the City of Toronto. Further breakdown shows that there are 27 free public WiFi location that are set in Arena, 74 free public WiFi location that are set in Community Recreation Centre, 17 free public WiFi location that are set in Outdoor Pool Building clinics, and 100 free public WiFi location that are set in library. Since the same wifi may cover multiple buildings, the sum of the number of public wifi corresponding to each building type is greater than the total number of public wifi in Toronto. The four building types mentioned above have the largest number of public wifi, covering almost 90% of total.

Library has the highest number of free public WiFi, which means that, in comparison to other types of buildings in Toronto, libraries offer the highest availability or coverage of free public WiFi services. This suggests that libraries prioritize or invest in providing accessible and free internet connectivity to the public within Toronto. Besides, Community Recreation Centre has the second most amount of free public WiFi. This information is indicative of the efforts or infrastructure investments made by Community Recreation Centres to offer accessible and free internet connectivity to the public.

2.2 Second Dataset: 2021 Ward Profiles based on the 25-Ward model

In order to deeply understand the factors affecting the distribution of public wifi in Toronto, I will study the population and income of each ward in Toronto on this basis. Therefore, the regional profile dataset (Data 2021), based on the 2021 Census data, was also included in the analysis. The dataset, published by City Planning, was last updated on January 3, 2024. The dataset contains demographic, social and economic information such as income and population for each ward.("Toronto Ward Profiles" 2023)

Ward profile data is stored in an Excel file with multiple tabs. The relevant data used for this analysis is included as a variable in the first TAB, the 2021 Census. Therefore, only the data from this TAB is downloaded for analysis. Further data cleansing was done to transform the data, retaining only information related to income and population levels in each ward (see Table 2). Based on the Toronto Open Data Portal, the package has a CSV file, 25 ward names and numbers, which contains the mapping between ward codes and ward names. I create statistic to visualize these data, using kable() from knitr to create Table 2.

Table 2: Sample of cleaned Ward of Toronto data

Population	Income	Ward Number
115120	38135	1
117200	45345	2
139920	65575	3
104715	49440	4
115675	45055	5
107355	41265	6
111200	37675	7
114820	45915	8
104730	45670	9
135400	80730	10

There are 25 wards in the City of Toronto. Based 2021 census data, the wards with the highest population are: Etobicoke-Lakeshore (Ward 3) at 139920, Spadina-Fort York (Ward 10) at 135400, and Etobicoke Centre (Ward 2) at 117200. The wards with the lowest population are: Scarborough North (Ward 23) at 94025, Don Valley East (Ward 16) at 94335, and Don Valley West (Ward 15) at 101025.

The wards with the highest household income are: Spadina-Fort York (Ward 10) at $ 80730, Toronto Centre (Ward 13) at $68965, and Etobicoke-Lakeshore (Ward 3) at $65575. The wards with the lowest household income are: Humber River-Black Creek (Ward 7) at $65,458, York South-Weston (Ward 5) at $67,964, and Scarborough Centre (Ward 21) at $70,624.

2.3 Variables of Interest

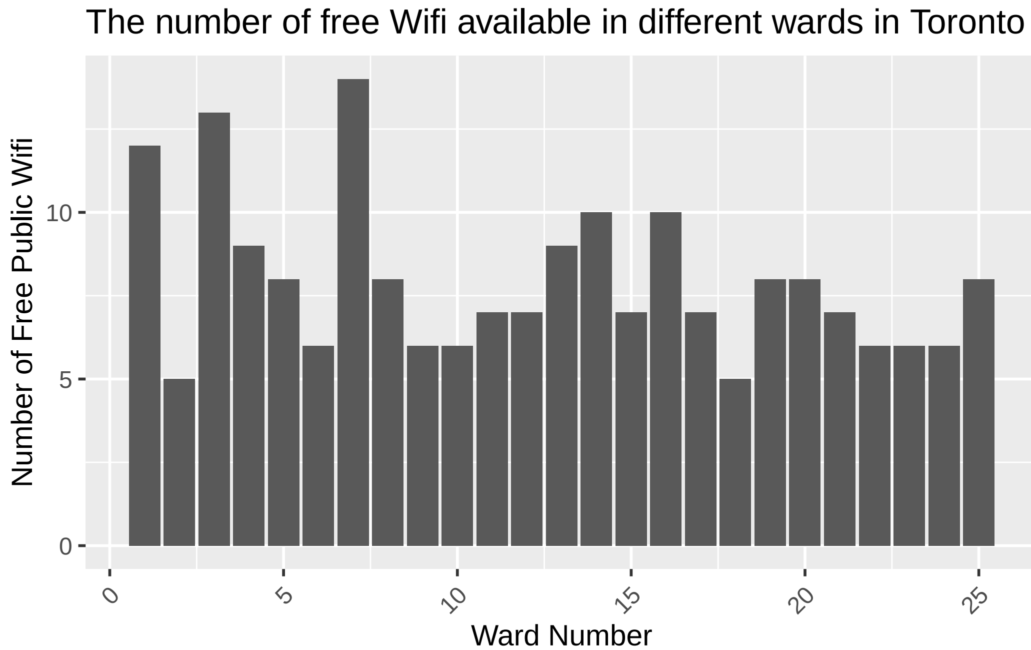

Figure 1: The number of free Wifi available in different wards in Toronto

3 Model

The goal of my modelling strategy is twofold. Firstly, I want to analyze to what effect power play opportunities, power play effectiveness, save percentage, goals against average and shooting percentages all have on average goals scored per game. Secondly, I want to use these results to predict the average goals scored per game for the next season.

In the section below, the Bayesian analysis model used to investigate the multiple linear regression model of average goals scored per game is detailed.

3.1 Model set-up

Define y_i as the leaguewide average goals scored per game. Then β_1 is the leaguewide average power plays per game, γ_1 is leaguewide powerplay percentage, θ_1 is leaguewide save percentage, ϕ_1 is the leaguewide goals against average, and κ_1 is the leaguewide average shooting percentage.

$$
\begin{aligned}
y_i|\mu_i, \sigma &\sim \text{Normal}(\mu_i, \sigma) && (1)\\
\mu_i &= \alpha + \theta_i + \phi_i + \kappa_i + \beta_i * \gamma_i && (2)\\
\alpha &\sim \text{Normal}(0, 2.5) && (3)\\
\beta &\sim \text{Normal}(0, 2.5) && (4)\\
\gamma &\sim \text{Normal}(0, 2.5) && (5)\\
\theta &\sim \text{Normal}(0, 2.5) && (6)\\
\phi &\sim \text{Normal}(0, 2.5) && (7)\\
\kappa &\sim \text{Normal}(0, 2.5) && (8)\\
\sigma &\sim \text{Exponential}(1) && (9)
\end{aligned}
$$

We run the model in `R` (R Core Team 2022) using the `rstanarm` package of (**citestan?**). We use the default priors from `rstanarm`.

3.1.1 Model justification

We expect a positive relationship between average goals scored per game and power play opportunities, power play percentage, goals against average, and shooting percentage. The higher those four variables are, the more goals there should be. In particular, there should also be a negative relationship between goals scored and save percentage. With a lower save percentage, there are less saves that are occuring which means there should be more goals. Additionally, the two power play variables are interacted with eachother, since they are directly related to one another. There cannot be a power play percentage without a power play opportunity.

4 Results

4.1 Building Type

Societal need for public Wi-Fi differs according to building types

While I talked about the increase of the amount of productive forwards and defensemen, here I will discuss the increase in the amount of good forwards and compare them to the amount of elite forwards. To be classified as an elite forward, usually they would need to finish the season at around a 1.4 PPG pace. Because of how hard of a feat it is to achieve a sustained 1.4 PPG pace, there are very few elite forwards in the NHL. Figure 2 shows the amount of forwards that finish in multiple PPG ranges.

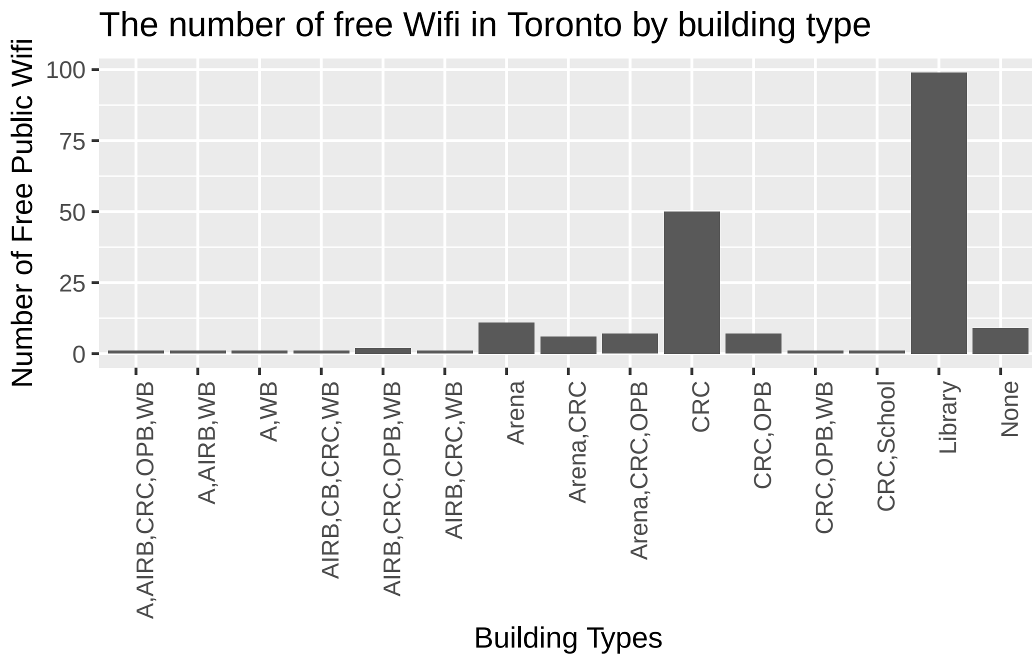

Figure 2: The number of free Wifi in Toronto by building type

As evidenced, the amount of elite players have remained consistent over the seasons, although the big spike in the 2021-22 season may be a sign that times are changing. The bigger story here though, is the amount of players that finish in the 1.2 and 1.4 range from 2017-18 beyond. There is a dramatic spike in these productive players from before 2017-18 to that season and beyond. The graphs here show that there while the ceiling of player talent has remained the same, the floor is steadily increasing.

The type of building can often reflect the different needs of modern people for WiFi, and having more public WiFi coverage proves that it has a stronger degree of Internet digitization needs.

For example, libraries have embraced technology, expanding their offerings beyond books to include a rich array of digital resources. Public WiFi is now a vital tool for students, researchers, and casual readers, facilitating access to online databases, ebooks, and collaborative group projects. Moreover, Community Recreation Centre have transformed into dynamic digital hubs, serving as venues for social gatherings and work. Here, individuals can check emails, work remotely, and stay informed about current events, all while enjoying a cup of coffee.

4.2 Population

Higher population density correlates with increased distribution of free public WiFi

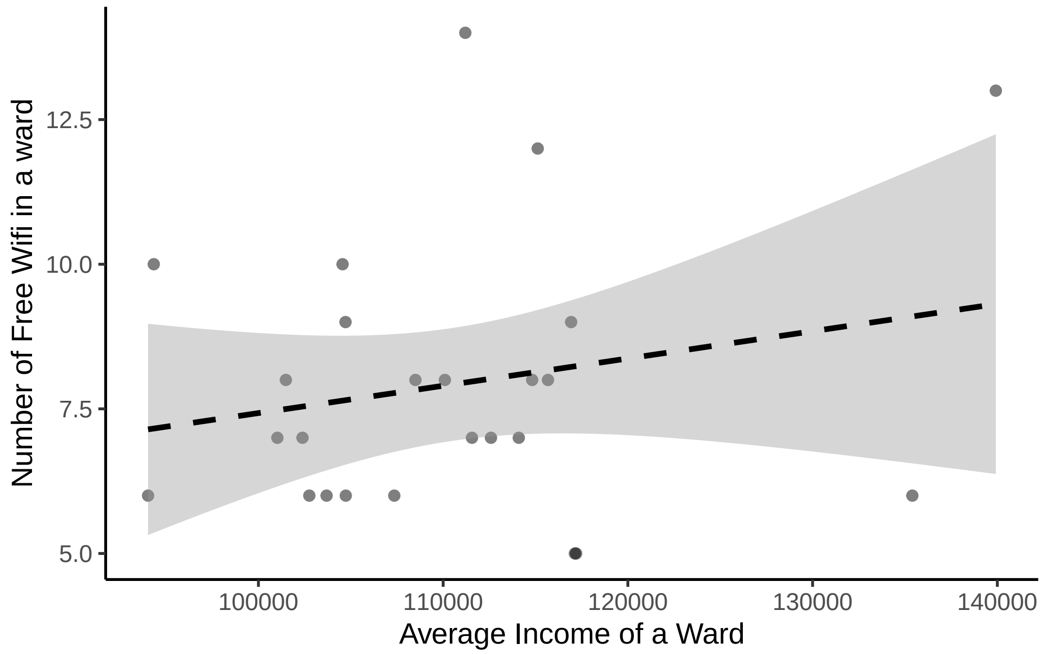

Figure 3: Linear regression model of the number of produced ASL words by the range of children's ages during their early developmental years.

Model 1, as illustrated in Figure 3, displays the correlation between a child's age in months and the number of ASL words they can produce at a given age. The scatterplot depicts the general trend of vocabulary growth as a child grows in age, further emphasized by the regression line. The model indicates that as the age of a child increases, the number of vocabulary items that that child produces increases as well. The regression line allows for the prediction of future outcomes based on the known data available from the dataset. By utilizing this model, we can estimate when a child will be able to produce a certain number of ASL vocabulary words or phrases at a certain age.

From Figure 3, we can clearly see that Etobicoke-Lakeshore (Ward 3) has the greatest population, and Spadina-Fort York (Ward 10) has the second greatest population.

In fact, this is similar to the distribution of free public WiFi in Toronto, but it does not exactly match. Ward 3, as the most populous area, has 13 public WiFi, which is a relatively large number in all Wards, and Ward 10 has 5, which is an insignificant number. But overall, for different Wards, a higher population slightly results in a higher amount of public WiFi.

4.3 Income

Income levels have limited influence on availability of free public Wi-Fi

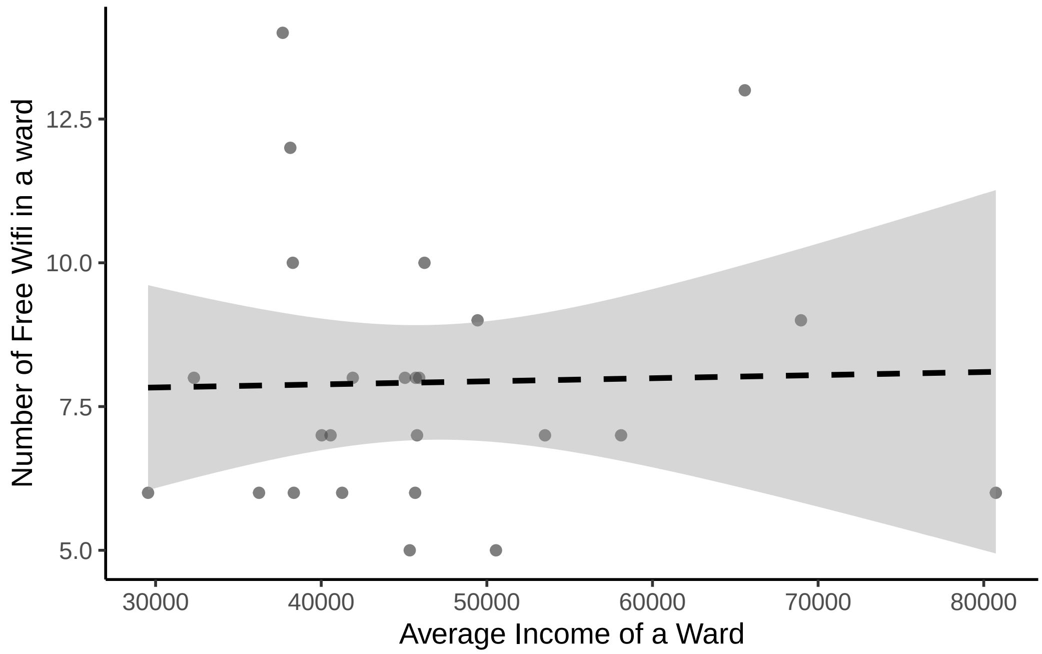

Figure 4: Linear regression model of the number of produced ASL words by the range of children's ages during their early developmental years.

From Figure 4, we can clearly see that Spadina-Fort York (Ward 10) has the greatest average income, Toronto Centre (Ward 13) has the second greatest average income, and Etobicoke-Lakeshore (Ward 3) has the third greatest average income.

We can conclude that there is no observable correlation between the number of Toronto public WiFi and the average household income in a ward.

5 Discussion

All in all, a significant number of people are increasingly relying on public Wi-Fi when they're out and about, underscoring their need for instant, hassle-free connectivity. Whether for work, social interaction or navigation, the modern lifestyle requires a seamless Internet experience, and the increasing number of academic and recreational projects joining the ranks of the application of public free WiFi is undoubtedly a strong support for the development of public WiFi in Toronto.

Furthermore, our data analysis indicates that while population size does exert a modest impact on the dissemination of free WiFi, the average income of a region lacks sufficient influence to be regarded as a determining factor in the allocation of public WiFi.

6 Appendix

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