Hierarchy of Urban Diversity

The relationship between the public transport network and the urban diversity of Amsterdam

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Abstract
The paper examines the relationship between the public transport network and urban diversity in Amsterdam using urban mapping and data analysis. The paper presents a hierarchical analysis of the urban diversity outcome, which is based on the computation of the average diversity scores for each geographical area. The Simpson index is used to measure urban diversity combined with the Urban Network Analysis Toolbox to isolate geographical areas. The diversity is ranked using the number of amenities per function, with the index ranging from zero to one, where higher values indicate greater diversity. The areas exhibiting the highest degree of urban diversity are those located within two-hundred meters of the Noord-Zuidlijn, followed by those situated within a similar distance from metro line 51. The third category is comprised of areas located within a two-hundred-meter radius of the tram stops, while the least diverse areas are the ones lying between the metro and tram network. The study concludes that the causal relationship between the tram and metro network and urban diversity cannot be definitively established based on the findings of this research. Nonetheless, the present study confirms the existence of a correlation between the two.

Key concepts/words
urban diversity, public transport, Amsterdam, walking distance, urban mapping

1. Introduction

Walkability is a term most used in urban planning. The walkable city is a book written by Jeff Speck about urban design and how to create walkable cities. The important improvements of a walkable city over a car-dependent city are mostly wealth, health, and sustainability. To improve a city's walkability, public transport is proven to be a useful tool. A well-connected public transportation system and walkable infrastructure in a city enable greater mobility and access to different neighborhoods and amenities. When public transport is efficient and dependable, it can encourage more people to use it and reduce their reliance on cars. For example, a good public transportation system can enable people from various parts of the city to travel to areas that they may not otherwise have access to, such as job opportunities, cultural events, or educational institutions. A walkable city also encourages people to spend more time outside, which can increase opportunities for social interaction and community building. [1]

There is increasing evidence that cities with high population density and easily accessible amenities can create wealth simply due to their proximity to one another. The availability of numerous amenities, such as businesses,

[1] Speck, J. (2012). *Walkable City: How Downtown Can Save America, One Step at a Time*. Farrar, Straus, and Giroux.

restaurants, and other services in proximity, enables easy accessibility and potentially leads to greater economic activity. As a result, the city may experience increased property values and overall wealth. [2] Another benefit of a well-connected city is described in the book *Urban Sprawl and Public Health* by Howard Frumkin, Lawrence Frank, and Richard J. Jackson. The book Urban Sprawl and Public Health states that individuals who use public transportation are over three times more likely to meet their recommended daily physical activity of thirty minutes compared to those who drive. It is becoming increasingly evident that well-designed urban environments can have a positive impact on healthcare. [3] Finally, it should be noted that the primary justification for a well-connected city is its sustainability. While people tend to be fixated on sustainable products such as bamboo flooring, solar panels, low-flow showerheads, and energy-efficient light bulbs, these items have a minimal impact on our carbon footprint compared to our location. Our location plays a significant role in our carbon footprint, with the most significant impact coming from our reliance on driving. [4] In summary, the key benefits of a walkable city, in contrast to a car-centric one, are related to wealth, health, and sustainability.

This sparked my interest, could the improvements of a walkable city be observed? Is it possible that a better well-connected city changes its urban plan? Do amenities centralize around certain areas where more people tend to pass by? To measure the variety and heterogeneity of an urban environment we use the term urban diversity. In other words, the range and distribution of several types of amenities, services, and spaces within a city. Urban diversity can significantly impact the quality of life for urban residents, visitors, and workers. A diverse range of facilities can enhance a city's livability, attractiveness, and competitiveness by providing residents with access to amenities and services that meet their needs and preferences. [5]

Urban diverse areas are significant in shaping the economic and social dynamics of cities. John M. Quigley dedicated a research paper to the relationship between urban diversity and economic growth. The research concludes that urban diversity is positively correlated with economic growth. A diverse area is proven to be more innovative and creative, leading to the development of innovative ideas, products, and services. This can stimulate entrepreneurship and business development, resulting in job creation and economic growth. [6]

This paper aims to examine urban diversity and its relation to the public transport network. Urban mapping was used as a method combined with data analysis. This method is based on the paper *Mapping Diversity: from ecology and human geography to Urbanism and Culture* where technology and data were used as powerful tools for mapping and understanding diversity. [7] Following this method, data on the urban environment, urban network analysis, and the Simpson diversity index were used to conclude the research question: What is the influence of the tram and metro network on the urban diversity of Amsterdam?

In Chapter 2, the research will be presented, which is divided into three sections. The first part outlines the principles on which the research is based and describes how the urban network analysis was conducted. It details the use of the Urban Network Analysis Toolbox (UNA) to examine the reach of Amsterdam's tram and metro network and how the Simpson index was integrated into the analysis. The second part of the chapter elaborates on the findings of the study on urban diversity within a two-hundred-meter distance of both metro and tram stations. In the third part, the study analyzes the urban diversity of areas lying between the tram and metro network, to identify any differences between these areas and those around the public transportation network. Chapter 3 contains the conclusion of the research and answers the research question. Chapter 5 reflects the research findings, which include a discussion of the advantages and limitations of the study. Additionally, recommendations for further research will be presented.

[2] Glaeser, E. L., & Gottlieb, J. D. (2009). The Wealth of Cities: Agglomeration Economies and Spatial Equilibrium in the United States. In *Journal of Economic Literature* (DOI: 10.1257/jel.47.4.983).
[3] Frumkin, H., Frank, L., Frank, L. D., & Jackson, R. J. (2004). *Urban Sprawl and Public Health: Designing, Planning, and Building for Healthy Communities*. Island Press.
[4] Speck, J. (2012). *Walkable City: How Downtown Can Save America, One Step at a Time*. Farrar, Straus, and Giroux.
[5] Sheikh, W. T., & Van Ameijde, J. (2022). *Promoting livability through urban planning: A comprehensive framework based on the theory of human needs* (https://doi.org/10.1016/j.cities.2022.103972). Cities.
[6] Quigley, J. M. (1998). *Urban Diversity and Economic Growth* (DOI: 10.1257/jep.12.2.127). Journal of Economic Perspectives.
[7] Baciu, D. C., & Della Pietra, D. D. (2021). *Mapping diversity: From ecology and human geography to urbanism and culture* (DOI: 10.31219/osf.io/sdvaz). OSF preprints.

2. Research

This chapter is divided into three parts, the first part is about the urban analysis, the second is about the urban diversity per tram and metro stop and the third part is about the urban diversity outside of the tram and metro network. The research was conducted using QGIS, Excel, Rhino7, and the plugin: Urban Network Analysis (UNA).

2.1 Urban analysis

The urban analysis is based on open-source data provided by the municipality of Amsterdam. The analysis is made by combining two datasets. The first dataset comprises data points for each building, including information about its function. The second dataset contains a data point for each metro and tram station. These inputs were run through the urban network analysis, with the metro and tram stops as origins and the buildings as destinations, to isolate the buildings within two hundred meters. The buildings in the dataset are categorized into eight functions: commercial, education, healthcare, industry, office, sport, residential, and other. These categories are used to calculate the urban diversity of the areas surrounding each metro and tram stop, using the Simpson index. The data is transferred to Excel to perform these calculations, resulting in a ranked list of the areas around the stops from most to least diverse.

Urban network analysis

The reach of each metro and tram stop is calculated using the Urban Network Analysis Toolbox (UNA), which is a plugin that works with the computer software Rhino7. The UNA toolbox is a powerful tool for understanding the structure and function of urban street networks. Five network centrality measures including reach, gravity index, betweenness, closeness, and straightness can be computed on spatial networks using the toolbox. [8] For this research only the reach of single points is calculated. The reach option in the toolbox traces an accessibility buffer from the point of interest in all directions on the street network until the limiting radius is reached. To conduct the network analysis, three components are required: a network, origins, and destinations. The network is represented by pavement centerlines and road crossings, which mimic pedestrian walking patterns, and a maximum distance of two-hundred meters is set to reach a destination. The origins are the metro and tram stops, and the destinations are buildings. The nearest centerline is used to link the destination points. After the reach calculation is complete, the building points are isolated, and the facilities for each tram or metro stop are exported to an Excel sheet. The Simpson index is then used to rank the tram and metro stops in order of their diversity, with the most diverse stops listed first.

Simpson index

The Simpson index was first discovered in 1949 by Edward H. Simpson in his research paper *Measurement of Diversity*. [9] The index is a measure of the diversity within a community. The index ranges from zero to one, with higher values indicating greater diversity. The Simpson diversity Index is represented as one minus the result of the sum of squares of each species' proportion divided by the square of the total proportion of all species in the area. The index was originally developed to calculate population diversity. However, according to a recent paper titled *Mapping Diversity: from ecology and human geography to Urbanism and Culture*, it can also be utilized to rank the urban diversity of a specific area. [10]

$$Simpson\ index = 1 - (\Sigma {x_i}^2/(\Sigma x_i)^2)$$

In this analysis, the number of amenities per function was used as the variable and could therefore be ranked by higher or lower urban diversity.

In previous research, urban diversity is calculated in square meters. Combining the Simpson index with a network analysis allows for urban diversity to be calculated in a free form. The advantage of this method is that the relation between certain points and the direct impact on urban diversity can be analyzed.

[8] Sevtsuk, A., & Mekonnen, M. (2012). *Urban network analysis: A new toolbox for ArcGIS* (DOI: 10.3166/RIG.22.287-305). Revue internationale de géomatique.

[9] Simpson, E. (1949). Measurement of Diversity. *Nature* (https://doi.org/10.1038/163688a0).

[10] Baciu, D. C., Mi, D., Birchall, C., Della Pietra, D., Van Loevezijn, L., & Nazou, A. (2022). *Mapping diversity: from ecology and human geography to urbanism and culture* (https://doi.org/10.1007/s43545-022-00399-4). SN Social Sciences.

2.2 Urban diversity per metro and tram stop

The graphic shown in Figure 1 is the result of calculating the urban diversity of the area surrounding metro and tram stops. The circles in the graphic represent the metro and tram stops and are color-coded to indicate the level of urban diversity, with higher diversity shown in darker shades of blue and lower diversity shown in lighter shades. The larger circles represent areas with higher diversity, while the smaller circles represent areas with lower diversity. Metro Line 52 is represented by the darkest line, while the medium blue line represents Metro Line 51. The tram lines are indicated in light blue. The Excel sheet used to form this graphic can be found in the appendix on page 11.

Figure 1. Urban diversity surrounding metro and tram stops in Amsterdam [11]

Leidsestraat

Figure 1 illustrates that the areas with the highest urban diversity are concentrated around the city center and appear to gradually decrease towards the outer regions. Notably, the darker areas extend towards the southwest through the Leidsestraat. The Leidsestraat once served as a pilgrim path from 1345 until 1658, subsequently becoming one of the busiest traffic routes in Amsterdam. However, after cars were banned from driving through, in 1971, it transformed into one of the most expensive streets in the city. [12] Today, it is widely known for its numerous shops and boutiques and is located near several popular attractions such as the Rijksmuseum, the Van Gogh Museum, and the Vondelpark, making it a popular destination for tourists and locals alike.

The high urban diversity surrounding the Leidsestraat is likely due to the significant amount of foot traffic in the area, making it economically interesting to have multiple businesses in proximity. It is worth noting that urban diversity plays a crucial role in enhancing a city's livability, attractiveness, and competitiveness. Providing residents with access to amenities and services that meet their needs and preferences, significantly impacts the quality of life for urban residents, visitors, and workers. As such, the high urban diversity surrounding the Leidsestraat is a significant contributing factor to its popularity among both tourists and locals.

[11] Zuidmeer, J. M. (2023h). *Urban diversity surrounding metro and tram stops in Amsterdam.*
[12] *De Leidsestraat: Van pelgrimspad tot topwinkelstraat*. (2020, 21 september). Gemeente Amsterdam. https://www.amsterdam.nl/nieuws/achtergrond/leidsestraat

Newmarket

Another remarkable sight is the low urban diversity score of the Newmarket whilst located in the historic center of the city. The Newmarket is known to be a vibrant and multicultural square, surrounded by many cafes, bars, restaurants, and shops. But it is also a residential area. There are several apartment buildings and houses located around the square, and many people live in the surrounding neighborhood. The residential character of the area can be seen in the narrow streets and alleys that surround the square, which is lined with traditional Dutch houses and buildings. [13] Despite being a busy and popular tourist destination, Newmarket has managed to maintain a strong sense of community, and many residents are actively involved in local organizations and events. The metro station is also located to the east of Newmarket Square where most of the residential houses are found. The higher number of residential places makes for a lower urban diversity score.

Squares

The city of Amsterdam has several notable public spaces such as Museumplein, Koningsplein, Muntplein, Leidseplein, and Rembrandtplein. These locations are also among the top ten tram and metro stations with the highest urban diversity scores. The historical and cultural significance of these squares is reflected in their high diversity scores. Over the centuries, these squares have played a significant role in Amsterdam's development and growth. Additionally, they host various cultural attractions, including museums, theaters, and music venues. For example, Museumplein is home to multiple world-renowned museums, including the Rijksmuseum and the Van Gogh Museum. Their historical and cultural value makes them popular destinations for locals and tourists alike, offering a wide range of shops, restaurants, cafes, and other amenities. [14] Resulting in higher urban diversity scores.

Metro line

Upon further analysis of the data, a hierarchy in urban diversity has been identified. The analysis indicates that the level of urban diversity is noticeably higher around the stops of metro line 52. Metro line 52 is known as the Noord-Zuidlijn and runs from the north of Amsterdam to the south. This is the most recent addition to the metro network. The project was approved in 1996, and construction work began in 2003. However, the project was plagued by delays, setbacks, and technical issues, which led to the final opening of the line in July 2018, several years later than originally planned. [15]

To clarify, it was found that the hierarchy of urban diversity is not limited to metro line 52 having a higher ranking, but also extends to the overall comparison of metro stops and tram stops. Specifically, it was found that metro stops generally had higher urban diversity scores than tram stops. Among the metro lines, the stops on line 52 had the highest average urban diversity score of 0.586, while line 51 had the second-highest score of 0.435. On the other hand, the tram stops had a significantly lower average urban diversity score of 0.314. In summary, the results indicate that the urban diversity is higher around metro stops than tram stops, and the urban diversity around the stops of metro line 52 is higher than the urban diversity around the stops of line 51.

[13] *Newmarket Amsterdam*. (z.d.). https://amsterdamNewmarket.nl/

[14] Witman, B., & De Haan, H. (2010). *Amsterdamse pleinen*. Valiz.

[15] NOS. (2018, July 21). Noord/Zuidlijn geopend: “Er is veel gevraagd van Amsterdammers.” *NOS*. https://nos.nl/artikel/2242534-noord-zuidlijn-geopend-er-is-veel-gevraagd-van-amsterdammers

2.3 Urban diversity outside of the metro and tram network

The graphic shown in Figure 2 is the result of calculating the urban diversity of the areas between the metro and tram networks. The tramlines were used as a boundary to create enclosed areas to analyze. These surfaces were set back by one hundred meters to ensure no data was overlapping. The areas were given a number and the points in these areas were exported to Excel to be given an urban diversity number using the Simpson index. The areas are color-coded to indicate the level of urban diversity, with higher diversity shown in darker shades of blue and lower diversity shown in lighter shades.

The graphic shown in Figure 3 is the result of the urban diversity of the area compared to the adjacent metro and tram stations. The bright green color suggests that the area has a lower diversity index than all the surrounding tram stops. The bright red suggests that all the surrounding tram and metro stops have a lower urban diversity index. And for example, the light green where three out of four (75%) surrounding tram and metro stops have a higher diversity number than the area. The Excel sheets can be found in the appendix on pages 12 and 13.

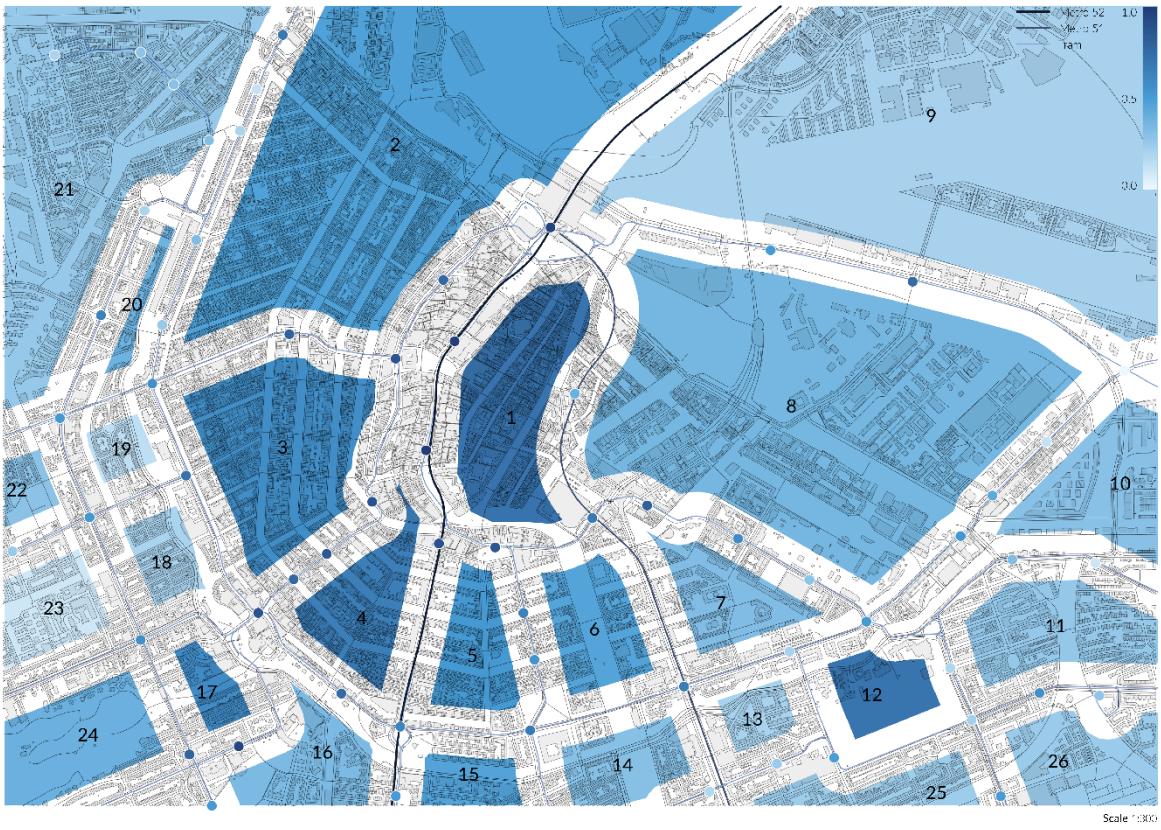


Figure 2. Urban diversity between the metro and tram network in Amsterdam [16]

Center

The map indicates that the central area of Amsterdam has the highest level of urban diversity. The pattern of urban diversity is similar to the calculation per metro and tram stop, with the most diverse areas being concentrated around the city center and gradually decreasing towards the outer regions. This is likely due to the number of amenities and tourist attractions in the region, as well as the availability of various metro and tram stops nearby. It is not surprising that the urban diversity index is highest in this area, which is a popular tourist destination. In addition, the western part of the canal district, comprising areas two through seven, also scored high compared to regions outside this ring, suggesting the presence of diverse amenities and services. The findings indicate that the diversity index is influenced by various factors, including the presence of tourist attractions, transportation networks, and urban planning.

[16] Zuidmeer, J. M. (2023f). *Urban diversity between the metro and tram network in Amsterdam.*

Park

Area twelve, located on the southeast side of the center, is a notable area due to its high urban diversity. The area is centered around the Oosterpark and is surrounded by a variety of public buildings, sports facilities, hotels, shops, and restaurants. Despite having a large surface area, this area has the fewest number of amenities compared to the other areas. However, the combination of the limited yet diverse range of amenities contributes to the high urban diversity score of this area.

Areas seventeen and twenty-four, located within the Vondelpark in the Oud-Zuid neighborhood, also have high urban diversity scores. The Vondelpark is a large and well-known public park in Amsterdam, which attracts a significant number of tourists and locals. The park is surrounded by a variety of amenities, contributing to its high urban diversity score. In summary, the parks in the city have high urban diversity scores, likely due to the challenge of collecting data within these spaces and the diverse functions that surround them.

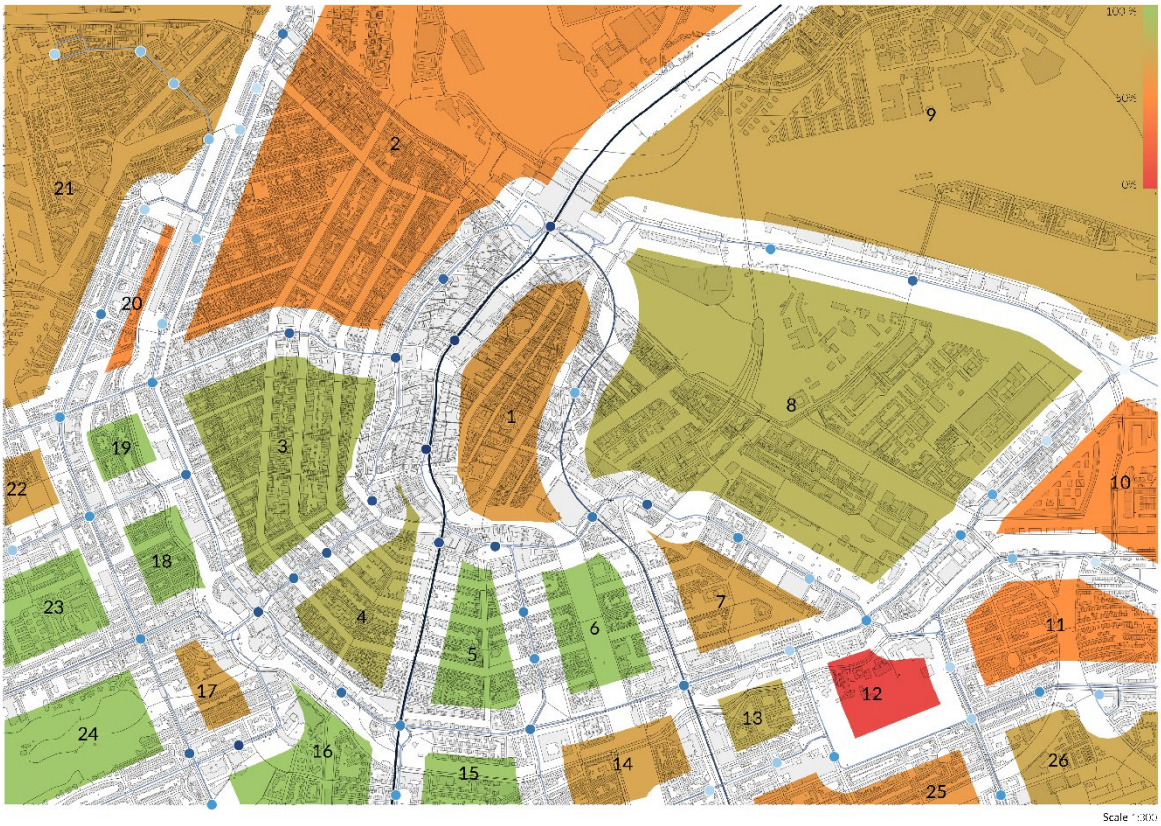


Figure 3. Urban diversity between the metro and tram network compared to adjacent tram and metro stops [17]

Lower diversity between metro and tram network

The graphic in Figure 3 shows that most areas range from bright green to orange, this indicates that the urban diversity of most areas is lower than the urban diversity surrounding adjacent metro stations. On average the score of the areas in between the metro and tram network is lower than 75% of the surrounding metro or tram stations.

Area twelve stands out as having a higher urban diversity score than the surrounding tram stops since the tram stops in this residential area have a lower diversity score. This is because the Oosterpark, located in area twelve, has a diverse range of amenities in its surroundings, as described in the previous text.

To investigate the urban diversity hierarchy further, it is important to consider that the average diversity score in areas situated between the metro and tram lines is 0.214. This value is lower than the average diversity scores of the stations on metro lines 52, 51, and the tram.

[17] Zuidmeer, J. M. (2023e). *Urban diversity between the metro and tram network compared to adjacent tram and metro stops.*

3. Conclusion

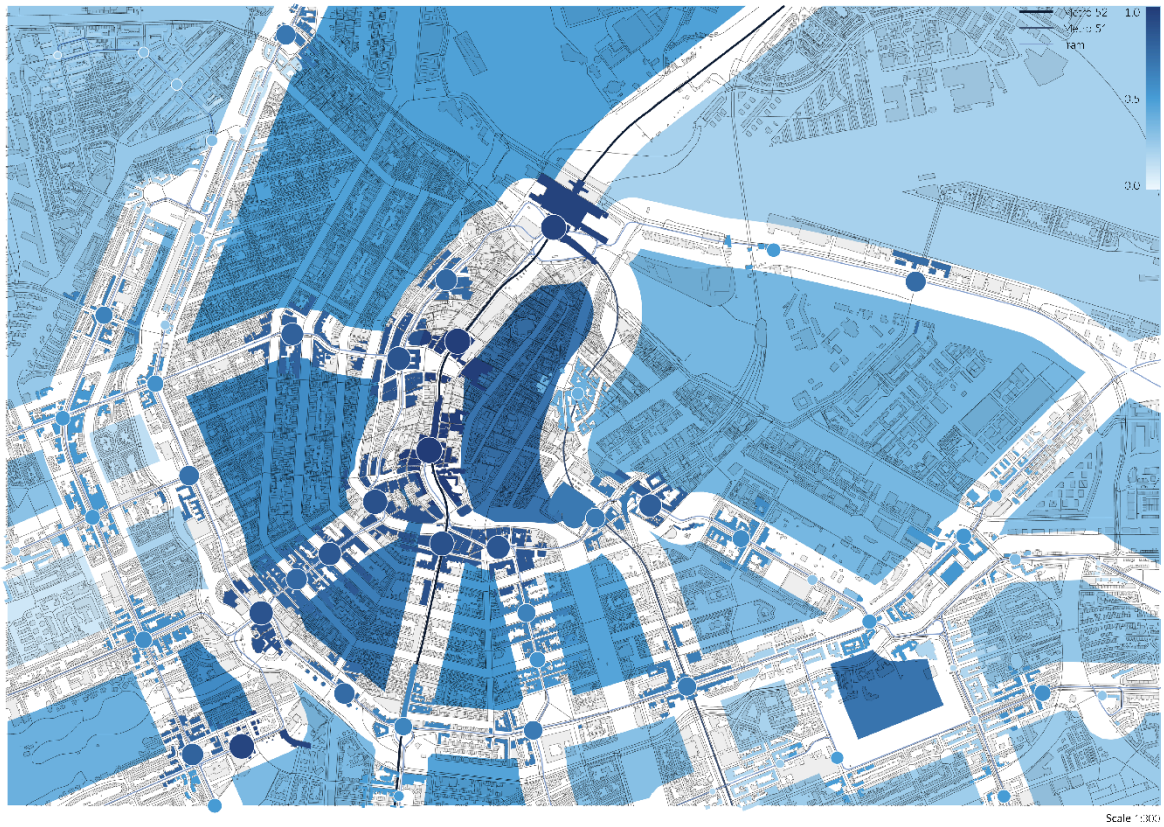


Figure 4. Urban diversity surrounding the metro and tram stop and in between the metro and tram network in Amsterdam [18]

This paper aimed to analyze the urban diversity around metro and tram stops in Amsterdam, using open-source data provided by the municipality. The urban analysis was based on a combination of two datasets; the first dataset comprises data points for each building, including information about its function. The second dataset contained a data point for each metro and tram station. The level of diversity was calculated using the Simpson index, and data points were isolated within a range of two-hundred meters around each metro and tram station using the urban network analysis toolbox. These data points were compared to those in the areas between the stations to determine the urban diversity. The resulting data was then used to generate a visual representation of urban diversity, with distinct colors used to indicate higher and lower diversity areas.

The analysis showed that the Leidsestraat is one of the most urban diverse areas in Amsterdam, which is related to the high number of people passing by the street, making it economically interesting to have multiple businesses in this area. The Newmarket, on the other hand, had a low urban diversity score, which can be attributed to the higher number of residential buildings in the area. The squares in Amsterdam, including Museumplein, Koningsplein, Muntplein, Leidseplein, and Rembrandtplein, were found to have high urban diversity scores, due to their historical and cultural values. The results also demonstrated that the center of the city is the most diverse, probably because of its historical value and therefore and its ability to draw in tourists. Remarkable is how these areas have a lower urban diversity score than the tram and metro stops in the bordering area.

The paper presents a hierarchical analysis of the urban diversity outcome, which is based on the computation of the average diversity scores for each geographical area. The areas exhibiting the highest degree of urban diversity are those located within two-hundred meters of the Noord-Zuidlijn, followed by those situated within a similar distance from metro line 51. The third category is comprised of areas located within a two-hundred-meter radius of the tram stops, while the least diverse areas are the ones lying between the metro and tram network.

[18] Zuidmeer, J. M. (2023g). *Urban diversity surrounding the metro and tram stop and in between the metro and tram network in Amsterdam*.

In conclusion, this study aims to address the research question: "What is the impact of the tram and metro network on the urban diversity of Amsterdam?" The causal relationship between the tram and metro network and urban diversity cannot be definitively established based on the findings of this research. Nonetheless, the present study confirms the existence of a correlation between the two. The observed higher levels of urban diversity in certain areas can be attributed, in part, to the concentration of individuals in those areas. On the other hand, likely such areas would not have gained such popularity without easy accessibility via the metro and tram network.

The results of this analysis can have practical implications for urban planning and development in Amsterdam. By identifying areas with higher urban diversity, policymakers can better understand the needs and preferences of different communities and plan more effective and inclusive urban development strategies. Furthermore, by identifying areas with lower urban diversity, policymakers can work to increase the availability of amenities and services in those areas, promoting social equity and inclusion.

4. Outlook and perspectives

This study does have some limitations that should be acknowledged when interpreting its results. One limitation is that the data used in the analysis are open source, which may not be as accurate or complete as official data. Consequently, some function categories were not considered in the analysis, resulting in a more limited scope. Another limitation is that the analysis is limited to the metro and tram stops in the center of Amsterdam, which may not be fully representative of the entire city.

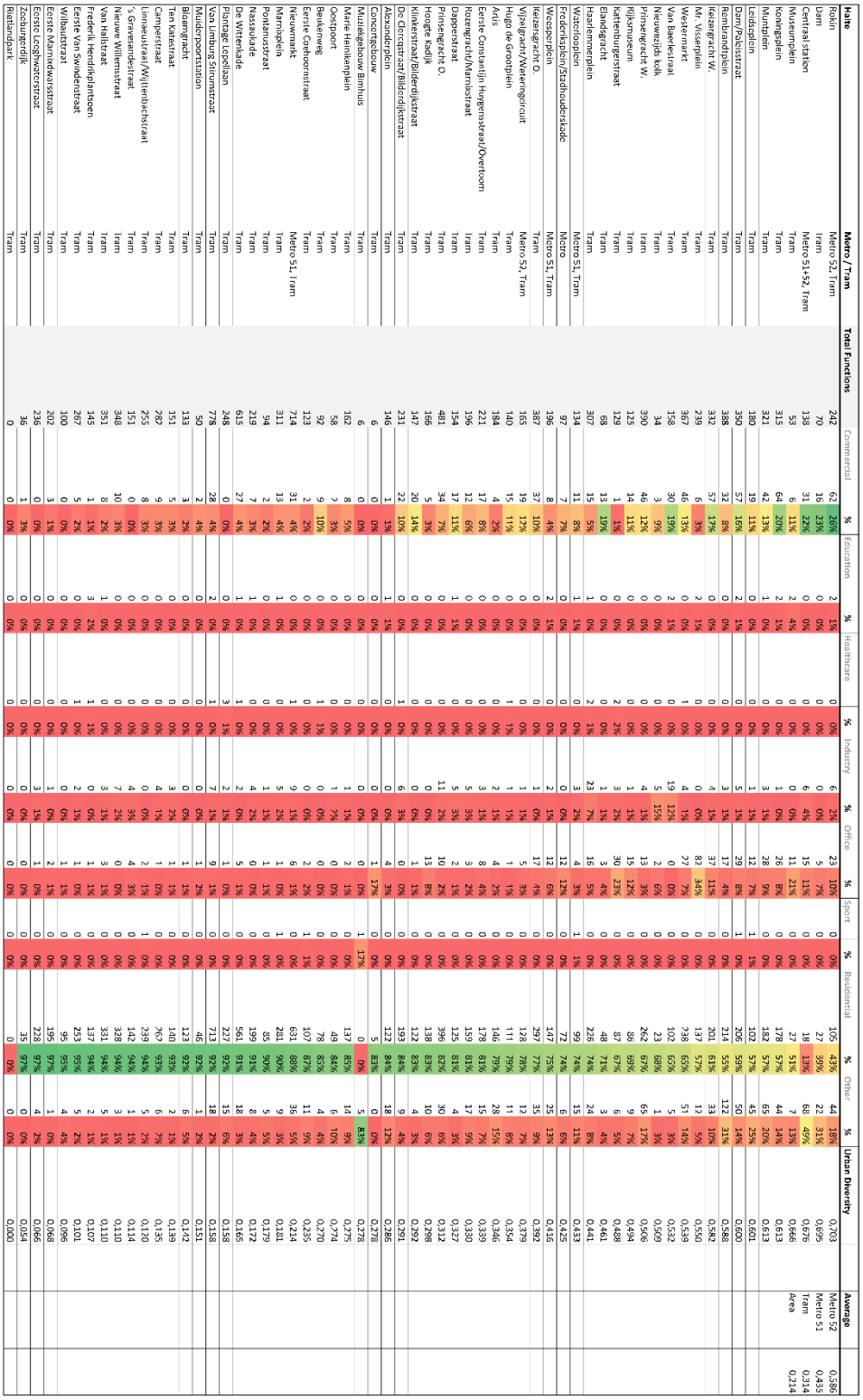
Furthermore, the analysis only focuses on the number of amenities per function as variables and does not account for other factors that may influence urban diversity, such as cultural and social factors. Future research should aim to address these limitations by using more comprehensive and accurate data sources and considering a broader range of factors that can affect urban diversity. It could also incorporate the causality between the historic urban planning before and after the construction of the public transport network.

To gain a deeper understanding of the implications of urban diversity, future research could explore the relationship between urban diversity and other urban outcomes, such as social cohesion and economic development. By doing so, we can gain a better understanding of how urban diversity affects various aspects of urban life and use this knowledge to inform urban planning and development strategies.

Despite these limitations, the study offers valuable insights into the urban diversity around metro and tram stops in Amsterdam, using a combination of open-source data and analytical tools. The findings can be used to guide urban planning and development strategies that prioritize social equity and inclusion in the city.

In conclusion, while this study provides important insights into the urban diversity around metro and tram stops in Amsterdam, it is important to acknowledge its limitations. Future research should aim to address these limitations and explore the relationship between urban diversity and other urban outcomes to better inform urban planning and development strategies that promote social equity and inclusion.

5. Appendix



Halte	Metro / Tram	Total Functions	Commercial	%	Education	%	Healthcare	%	Industry	%	Office	%	Sport	%	Residential	%	Other	%	Urban Diversity	Average
Rokin	Metro 52,Tram	242	62	26%	6	2%	0	0%	6	2%	23	10%	0	0%	105	43%	44	18%	0,703	0,586
Dam	Tram	70	16	23%	0	0%	0	0%	0	0%	5	7%	0	0%	27	39%	22	31%	0,695	Metro 52
Centraal station	Metro 51+52, Tram	138	31	22%	0	0%	0	0%	6	4%	15	11%	0	0%	18	13%	68	49%	0,676	Metro 51
Museumplein	Tram	53	6	11%	2	4%	0	0%	0	0%	11	21%	0	0%	27	51%	7	13%	0,666	Tram
Koningsplein	Tram	315	64	20%	2	1%	0	0%	1	0%	26	8%	0	0%	178	57%	44	14%	0,613	Area
Muntplein	Tram	321	42	13%	1	0%	0	0%	3	1%	28	9%	0	0%	182	57%	65	20%	0,601	
Leidseplein	Tram	180	19	11%	0	0%	0	0%	1	1%	12	7%	1	1%	102	57%	45	25%	0,601	
Dam/Paleisstraat	Tram	390	57	16%	2	1%	0	0%	5	1%	29	8%	0	0%	206	59%	50	14%	0,600	
Rembrandtplein	Tram	388	32	8%	0	0%	0	0%	3	1%	17	4%	0	0%	214	55%	122	31%	0,588	
Keizersgracht W.	Tram	332	57	17%	0	0%	0	0%	1	1%	37	11%	0	0%	201	61%	33	10%	0,582	
Mr. Visserplein	Tram	239	6	3%	2	1%	0	0%	0	0%	82	34%	0	0%	137	57%	12	5%	0,550	
Westermarkt	Tram	367	46	13%	0	0%	1	0%	4	1%	27	7%	0	0%	238	65%	51	14%	0,539	
Van Baerlestraat	Tram	158	30	19%	2	1%	0	0%	19	12%	0	0%	0	0%	102	65%	5	3%	0,532	
Nieuwezijds kolk	Tram	34	3	9%	0	0%	0	0%	5	15%	2	6%	0	0%	23	68%	1	3%	0,509	
Prinsengracht W.	Tram	390	46	12%	0	0%	0	0%	4	1%	13	3%	0	0%	262	67%	65	17%	0,506	
Rijksmuseum	Tram	125	14	11%	0	0%	0	0%	1	1%	15	12%	0	0%	85	68%	9	7%	0,494	
Kattenburgerstraat	Tram	129	1	1%	0	0%	2	2%	3	2%	30	23%	0	0%	87	67%	6	5%	0,488	
Elandsgracht	Tram	68	13	19%	0	0%	0	0%	1	1%	3	4%	0	0%	48	71%	3	4%	0,461	
Haarlemmerplein	Metro 51, Tram	307	15	5%	1	0%	2	1%	23	7%	16	5%	0	0%	226	74%	24	8%	0,441	
Waterlooplein	Metro 51, Tram	134	11	8%	1	1%	0	0%	3	2%	4	3%	1	1%	99	74%	15	11%	0,433	
Frederiksplein/Stadhouderskade	Metro	97	7	7%	0	0%	0	0%	2	2%	12	12%	0	0%	72	74%	6	6%	0,425	
Waterlooplein	Metro 51, Tram	196	8	4%	2	1%	0	0%	2	1%	12	6%	0	0%	147	75%	25	13%	0,416	
Keizersgracht O.	Tram	387	37	10%	0	0%	0	0%	1	0%	17	4%	0	0%	297	77%	35	9%	0,392	
Vijzelgracht/Weteringcircuit	Metro 52, Tram	165	19	12%	0	0%	0	0%	1	1%	5	3%	0	0%	128	78%	12	7%	0,379	
Hugo de Grootplein	Tram	140	15	11%	0	0%	1	1%	1	1%	1	1%	0	0%	111	79%	11	8%	0,354	
Artis	Tram	184	4	2%	0	0%	0	0%	2	1%	4	2%	0	0%	146	79%	28	15%	0,346	
Eerste Constantijn Huygenstraat/Overtoom	Tram	221	17	8%	0	0%	0	0%	3	1%	4	2%	0	0%	178	81%	15	7%	0,339	
Rozengracht/Marnixstraat	Tram	196	12	6%	0	0%	0	0%	5	3%	3	2%	0	0%	159	81%	17	9%	0,330	
Dapperstraat	Tram	154	17	11%	1	1%	0	0%	5	3%	2	1%	0	0%	125	81%	4	3%	0,327	
Prinsengracht O.	Tram	481	34	7%	0	0%	0	0%	11	2%	10	2%	0	0%	396	82%	30	6%	0,312	
Hoogte Kadijk	Tram	166	5	3%	0	0%	0	0%	0	0%	13	8%	0	0%	138	83%	10	6%	0,298	
Klaverstraat/Bilderdijkstraat	Tram	147	20	14%	0	0%	0	0%	0	0%	1	1%	0	0%	122	83%	4	3%	0,292	
De Clercqstraat/Bilderdijkstraat	Tram	231	22	10%	0	0%	1	0%	6	3%	0	0%	0	0%	193	84%	9	4%	0,291	
Alexanderplein	Tram	146	1	1%	1	1%	0	0%	0	0%	4	3%	0	0%	122	84%	18	12%	0,286	
Concertgebouw	Tram	6	0	0%	0	0%	0	0%	0	0%	1	17%	0	0%	5	83%	0	0%	0,278	
Muziekgebouw Binnhuis	Tram	6	0	0%	0	0%	0	0%	0	0%	0	0%	1	17%	5	83%	0	0%	0,278	
Marie Heinkenplein	Tram	8	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	7	88%	1	13%	0,278	
Oosdoort	Tram	162	8	5%	0	0%	0	0%	1	1%	2	1%	0	0%	137	85%	14	9%	0,275	
Beukenweg	Tram	58	2	3%	0	0%	1	1%	1	2%	0	0%	0	0%	49	84%	6	10%	0,774	
Eerste Coehoornstraat	Tram	92	9	10%	0	0%	1	1%	0	0%	2	2%	0	0%	78	85%	4	4%	0,270	
Nieuwmarkt	Metro 51, Tram	123	2	2%	0	0%	0	0%	0	0%	6	5%	1	1%	107	87%	11	9%	0,235	
Marnixplein	Tram	714	31	4%	0	0%	1	0%	9	1%	6	1%	0	0%	631	88%	36	5%	0,214	
Pontanusstraat	Tram	311	13	4%	1	0%	0	0%	5	2%	1	0%	1	0%	281	90%	9	3%	0,181	
Nassaukade	Tram	94	2	2%	0	0%	0	0%	1	1%	1	1%	0	0%	85	90%	5	5%	0,179	
De Wittenkade	Tram	219	7	3%	1	0%	0	0%	2	1%	0	0%	0	0%	199	91%	8	4%	0,172	
Plantage Lepellaan	Tram	615	27	4%	1	0%	1	0%	2	0%	5	1%	0	0%	561	91%	18	3%	0,165	
Van Limburg Stirumstraat	Tram	248	0	0%	2	1%	3	1%	7	3%	9	4%	0	0%	227	92%	15	6%	0,158	
Muiderpoortstation	Tram	778	28	4%	2	0%	1	0%	7	1%	9	1%	0	0%	713	92%	18	2%	0,158	
Bloemgracht	Tram	50	2	4%	0	0%	0	0%	0	0%	1	2%	0	0%	46	92%	1	2%	0,151	
Ten Katestraat	Tram	133	3	2%	0	0%	0	0%	0	0%	1	1%	0	0%	123	92%	6	5%	0,142	
Camperstraat	Tram	151	5	3%	0	0%	0	0%	3	2%	1	1%	0	0%	140	93%	2	1%	0,139	
Linnaeustraat/Wijttenbachstraat	Tram	282	9	3%	0	0%	0	0%	4	1%	1	0%	0	0%	247	93%	6	2%	0,135	
's Gravesandestraat	Tram	255	8	3%	0	0%	0	0%	0	0%	2	1%	0	0%	239	94%	5	2%	0,120	
Nieuwe Willemstraat	Tram	151	0	0%	0	0%	0	0%	4	3%	0	0%	0	0%	142	94%	1	1%	0,114	
Van Hallstraat	Tram	348	10	3%	0	0%	0	0%	7	2%	0	0%	0	0%	328	94%	3	1%	0,110	
Frederik Hendrikplantsoen	Tram	351	8	2%	1	0%	0	0%	3	1%	3	1%	0	0%	331	94%	5	1%	0,110	
Eerste Van Swindenstraat	Tram	267	5	2%	0	0%	1	0%	2	1%	1	0%	0	0%	253	95%	5	2%	0,101	
Wilbautstraat	Tram	100	0	0%	0	0%	0	0%	0	0%	1	1%	0	0%	95	95%	4	4%	0,096	
Eerste Marnixdwarsstraat	Tram	202	3	1%	0	0%	0	0%	1	0%	2	1%	0	0%	195	97%	1	0%	0,068	
Eerste Leeghwatersstraat	Tram	236	0	0%	0	0%	0	0%	3	1%	1	0%	0	0%	228	97%	4	2%	0,066	
Zoutbrugerdijk	Tram	36	1	3%	0	0%	0	0%	0	0%	0	0%	0	0%	35	97%	0	0%	0,054	
Riatlandpark	Tram	0	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0,000	

Figure 5. Excel: Urban diversity surrounding metro and tram stops in Amsterdam [19]

[19] Zuidmeer, J. M. (2023d). *Excel: Urban diversity surrounding metro and tram stops in Amsterdam.*

Area	Total Functions	Commercial	%	Education	%	Healthcare	%	Industry	%	Office	%	Sport	%	Residential	%	Other	%	Urban Diversity
1	2.717	243	9%	10	0%	4	0%	91	3%	91	3%	0	0%	1954	72%	324	12%	0,458
12	40	1	3%	1	3%	0	0%	1	3%	4	10%	0	0%	29	73%	4	10%	0,453
4	1.057	92	9%	0	0%	0	0%	16	2%	54	5%	1	0%	801	76%	93	9%	0,408
17	124	11	9%	1	1%	0	0%	0	0%	5	4%	0	0%	99	80%	8	6%	0,349
3	2.561	165	6%	9	0%	1	0%	85	3%	111	4%	3	0%	2061	80%	126	5%	0,343
5	720	4	1%	2	0%	1	0%	25	3%	37	5%	1	0%	603	84%	47	7%	0,290
2	8.504	329	4%	10	0%	3	0%	234	3%	250	3%	5	0%	7290	86%	383	5%	0,260
15	606	37	6%	0	0%	1	0%	17	3%	9	1%	0	0%	522	86%	20	3%	0,252
6	664	10	2%	1	0%	0	0%	16	2%	27	4%	0	0%	573	86%	37	6%	0,250
24	51	0	0%	0	0%	0	0%	0	0%	4	8%	0	0%	45	88%	2	4%	0,214
20	106	5	5%	0	0%	0	0%	0	0%	1	1%	0	0%	94	89%	6	6%	0,208
8	5.641	60	1%	5	0%	8	0%	89	2%	156	3%	7	0%	5051	90%	265	5%	0,195
16	415	12	3%	3	1%	0	0%	7	2%	8	2%	0	0%	374	90%	11	3%	0,186
7	612	6	1%	9	1%	2	0%	10	2%	6	1%	1	0%	554	91%	24	4%	0,178
14	304	2	1%	0	0%	0	0%	5	2%	11	4%	0	0%	277	91%	9	3%	0,167
10	45	0	0%	0	0%	0	0%	0	0%	1	2%	0	0%	41	91%	3	7%	0,165
22	354	4	1%	1	0%	0	0%	9	2%	5	1%	0	0%	333	91%	12	3%	0,161
11	1.048	35	3%	3	0%	1	0%	17	2%	4	0%	0	0%	967	92%	21	2%	0,147
21	4.686	95	2%	9	0%	4	0%	84	2%	48	1%	3	0%	4334	92%	109	2%	0,143
26	410	5	1%	4	1%	0	0%	6	1%	9	2%	0	0%	381	93%	5	1%	0,135
25	588	25	4%	2	0%	0	0%	5	1%	3	1%	0	0%	548	93%	5	1%	0,129
9	2.061	20	1%	5	0%	3	0%	35	2%	27	1%	4	0%	1937	94%	30	1%	0,116
13	390	0	0%	3	1%	0	0%	4	1%	8	2%	0	0%	367	94%	8	2%	0,113
18	313	6	2%	1	0%	0	0%	1	0%	3	1%	0	0%	295	94%	7	2%	0,111
19	125	1	1%	1	1%	0	0%	1	1%	0	0%	0	0%	120	96%	2	2%	0,078
23	188	1	1%	0	0%	0	0%	1	1%	1	1%	0	0%	183	97%	2	1%	0,052

Figure 6. Excel: Urban diversity in between the metro and tram network in Amsterdam [20]

[20] Zuidmeer, J. M. (2023a). *Excel: Urban diversity in between the metro and tram network in Amsterdam.*

Area	Score	UD	Surrounding Stations												
1	0,67	0,458	Centraal statio Hi	Dam Hi	Rokin Hi	Rembrandtple Hi	Waterlooplein Lo	Nieuwmarkt Lower							
2	0,56	0,260	Haarlemmerpl Hi	Eerste Marnix Lo	Nieuwe Willen Lo	Marnixplein Lo	Bloemgracht Lo	Rozengracht/N Hi	Westermarkt Hi	Dam/Paleisstr Hi	Nieuwezijds kc Higher				
3	0,88	0,343	Westermarkt Hi	Rozengracht/N Lo	Elandsgracht Hi	Leidseplein Hi	Prinsengracht Hi	Keizergracht V Hi	Koningsplein Hi	Dam/Paleisstr Higher					
4	0,86	0,408	Koningsplein Hi	Keizergracht V Hi	Prinsengracht Hi	Leidseplein Hi	Rijksmuseum Hi	Vijzelgracht/W Lo	Muntplein Higher						
5	1,00	0,290	Muntplein Hi	Vijzelgracht/W Hi	Frederiksplein, Hi	Prinsengracht Hi	Keizersgracht (Hi	Rembrandtple Higher							
6	1,00	0,250	Rembrandtple Hi	Keizersgracht (Hi	Prinsengracht Hi	Weesperplein Hi	Waterlooplein Higher								
7	0,71	0,178	Waterlooplein Hi	Weesperplein Hi	's Gravesande Lo	Alexanderplein Hi	Plantage Lepel Lo	Artis Hi	Mr. Visserplein Higher						
8	0,85	0,195	Centraal statio Hi	Nieuwmarkt Hi	Waterlooplein Hi	Mr. Visserplein Hi	Artis Hi	Plantage Lepel Hi	Alexanderplein Hi	Hoogte Kadijk Hi	Eerste Coehoo Hi	Eerste Leeghw Lo	Rietlandpark Lo	Kattenburgers Hi	Muziekgebouw Higher
9	0,75	0,116	Centraal statio Hi	Muziekgebouw Hi	Kattenburgers Hi	Rietlandpark Lower									
10	0,50	0,165	Rietlandpark Lo	Eerste Leeghw Lo	Eerste Coehoo Hi	Hoogte Kadijk Hi	Pontanusstraa Hi	Zeeburgerdijk Lower							
11	0,50	0,147	Pontanusstraa Hi	Zeeburgerdijk Lo	Eerste Van Sw Lo	Linnaeustraat/ Lo	Dapperstraat Hi	Muiderpoortst Higher							
12	0	0,453	Alexanderplein Lo	's Gravesande Lo	Beukenweg Lo	Linnaeustraat/ Lo	Eerste Van Swi Lower								
13	0,80	0,113	Weesperplein Hi	's Gravesande Hi	Wilbautstraat Lo	Camperstraat Hi	Beukenweg Higher								
14	0,67	0,167	Frederiksplein, Hi	Weesperplein Hi	Wilbautstraat Lower										
15	1,00	0,252	Vijzelgracht/W Hi	Frederiksplein, Hi	Marie Heinike Higher										
16	1,00	0,186	Museumplein Hi	Concertgebou Hi	Rijksmuseum Hi	Vijzelgracht/W Hi	Marie Heinike Higher								
17	0,67	0,349	Eerste Constar Lo	Van Baerlestra Hi	Museumplein Higher										
18	1,00	0,111	Elandsgracht Hi	Klinkerstraat/E Hi	Eerste Constar Hi	Leidseplein Higher									
19	1,00	0,078	De Clercqstraa Hi	Klinkerstraat/E Hi	Elandsgracht Hi	Rozengracht/N Higher									
20	0,50	0,208	Frederik Hend Lo	Hugo de Groot Hi	De Clercqstraa Hi	Rozengracht/N Hi	Bloemgracht Lo	Marnixplein Lower							
21	0,70	0,143	Haarlemmerpl Hi	Eerste Marnix Lo	Nieuwe Willen Lo	Frederiksplein, Hi	Hugo de Groot Hi	De Clercqstraa Hi	Nassaukade Hi	De Wittenkade Hi	Van Limburg S Hi	Van Hallstraat Lower			
22	0,67	0,161	De Clercqstraa Hi	Klinkerstraat/E Hi	Ten Katestraat Lower										
23	1,00	0,052	Ten Katestraat Hi	Klinkerstraat/E Hi	Eerste Constar Higher										
24	1,00	0,214	Eerste Constar Hi	Van Baerlestra Higher											
25	0,60	0,129	Wilbautstraat Lo	Camperstraat Hi	Beukenweg Hi	Linnaeustraat/ Lo	Oostpoort Higher								
26	0,75	0,135	Oostpoort Hi	Linnaeustraat/ Lo	Dapperstraat Hi	Muiderpoortst Higher									

Figure 7. Excel: Urban diversity per area compared to surrounding metro and tram stops [21]

[21] Zuidmeer, J. M. (2023b). *Excel: Urban diversity per area compared to surrounding metro and tram stops.*

Halte	Urban Diversity
Rokin	0,7033
Dam	0,6951
Centraal station	0,6760
Museumplein	0,6657
Koningsplein	0,6130
Muntplein	0,6127
Leidseplein	0,6007
Dam/Paleisstraat	0,5995
Rembrandtplein	0,5881
Keizergracht W.	0,5815
Mr. Visserplein	0,5505
Westermarkt	0,5389
Van Baerlestraat	0,5316
Nieuwezijds kolk	0,5087
Prinsengracht W.	0,5058
Rijksmuseum	0,4945
Kattenburgerstraat	0,4881
Elandsgracht	0,4611
Area 1	0,4583
Area 12	0,4525
Haarlemmerplein	0,4412
Waterlooplein	0,4334
Frederiksplein/Stadhouderskade	0,4247
Weesperplein	0,4156
Area 4	0,4076
Keizersgracht O.	0,3918
Vijzelgracht/Weteringcircuit	0,3787
Hugo de Grootplein	0,3536
Area 17	0,3489
Artis	0,3462
Area 3	0,3428
Eerste Constantijn Huygensstraat/Overtoom	0,3393
Rozengracht/Marnixstraat	0,3298
Dapperstraat	0,3270
Prinsengracht O.	0,3124
Hoogte Kadijk	0,2982
Klinkerstraat/Bilderdijkstraat	0,2919
De Clercqstraat/Bilderdijkstraat	0,2907
Area 5	0,2904
Alexanderplein	0,2857
Concertgebouw	0,2778
Muziekgebouw Bimhuis	0,2778
Marie Heinikenplein	0,2747
Oostpoort	0,2741
Beukenweg	0,2696
Area 2	0,2600
Area 15	0,2522
Area 6	0,2497
Eerste Coehoornstraat	0,2346
Nieuwmarkt	0,2143
Area 24	0,2138
Area 20	0,2081
Area 8	0,1949
Area 16	0,1856
Marnixplein	0,1807
Pontanusstraat	0,1788
Area 7	0,1783
Nassaukade	0,1716
Area 14	0,1672
De Wittenkade	0,1650
Area 10	0,1649
Area 22	0,1611
Plantage Lepellaan	0,1583
Van Limburg Stirumstraat	0,1581
Muiderpoortstation	0,1512
Area 11	0,1468
Area 21	0,1432
Bloemgracht	0,1421
Ten Katestraat	0,1387
Area 26	0,1354
Camperstraat	0,1351
Area 25	0,1294
Linnaeustraat/Wijttenbachstraat	0,1201
Area 9	0,1159
's Gravesandestraat	0,1142
Area 13	0,1135
Area 18	0,1107
Nieuwe Willemsstraat	0,1103
Van Hallstraat	0,1098
Frederik Hendrikplantsoen	0,1065
Eerste Van Swindenstraat	0,1013
Wilbautstraat	0,0958
Area 19	0,0780
Eerste Marnixdwarsstraat	0,0677
Eerste Leeghwaterstraat	0,0662
Zeeburgerdijk	0,0540
Area 23	0,0523
Rietlandpark	0,0000

Figure 8. Excel: Urban diversity surrounding metro and tram stops and in between the network in Amsterdam [22]

[22] Zuidmeer, J. M. (2023c). *Excel: Urban diversity surrounding metro and tram stops and in between the network in Amsterdam.*

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