An introduction of diversity on isochrones, a look at the effect of the Tel Aviv light rail.

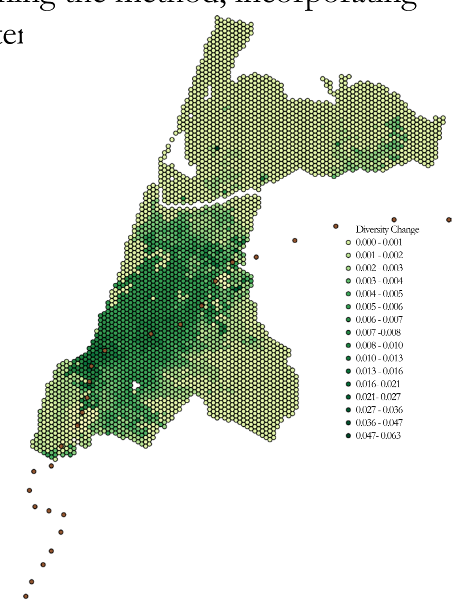
AR2A011 Architectural History Thesis

Author: Coby Bianco
Supervisor: Dan C.Baciu

Delft University of Technology

Abstract

The construction of a light rail system in Tel Aviv has the potential to impact commuting patterns and accessibility of amenities. This study develops a method to assess the impact of the light rail system on urban diversity, using isochrones generated from public transportation and walking networks. Diversity maps were created for the existing and future situations, measuring the diversity of amenities within isochrones. Preliminary results show a slight increase in diversity along the light rail route, but further improvements to the classification system and validation are needed. The findings have implications for urban planning and transportation policy. Future research can focus on refining the method, incorporating additio syste



With special thanks to Walter Kahn for the many hours of help setting up ArcGIS

Introduction

Tel Aviv has been wanting a light rail system for over half a century. An initial attempt was made in the 60's but it progressed no further having a station built. It was unsuccessful due to lack of funding and a reduced priority. Ever since then discussions for the system were revisited a few times and at last these plans are becoming a reality. Tel Aviv is currently constructing both a light rail system and a metro system. Three light rail lines will be introduced in the upcoming years with the first opening this year (2023). The metro on the other hand is planned for the years after 2040. The implementation of a mass transit system, like LRT or metro, has a great impact on the inhabitants and the development of a city. (Pagliara & Papa, 2011, Nilsson & Delmelle, 2018). They are systems that reduce car dependency and improve the accessibility and spatial equality of an area, or at least that is often one of the goals. They also encourage growth and increase investment around the stations or rail corridors. Tel Aviv wants to keep up with its growth and strengthen its transportation system and connectivity with surrounding cities as the center of its metropolitan as well as move in a more sustainable direction. The light rail and metro will provide users with a better density of stations than the central bus stations and train stations with greater reliability and frequency. There is no available study about the effects of this light rail or the metro besides an isochrone map created by a transportation hobbyist by the name of Elad Alfassa, Alfassa wanted to understand how much of the city will be influenced by the LRT and metro once completed. The map created shows the service areas of the LRT and Metro in 5, 10, and 15-minute time spans (Alfassa, n.d.). In this study we want to further explore the spatial influence of the LRT, particularly the change in accessibility and urban diversity of the city. Accessibility measures the ability of one to reach a certain destination type, and diversity, as we will define it, measures the variation in amenities one can access. Accessibility and diversity are factors that influence urban health. We ask; what areas in the city will receive higher or lower accessibility and diversity as a result of the LRT? To do this we develop a method using isochrones and amenity data to model the current situation, we test the model, and then use the same method to model the changed scenario and compare the two.
Accessibility and diversity:
Accessibility measures the ability of people to reach certain goods. This is used both in the measure of a public transportation network (Ceccato et al., 2020, Liu et al., 2018) and in the context of spatial equity. The majority of studies on the topic look at opportunity accessibility like employment, healthcare, education, and culture or at the equality between public transportation and private car spatial equity (Shi, 2021, Rofé et al., 2015, Li et al., 2020). Accessibility in the context of this study is looking at accessibility to urban amenities for the purpose of measuring the diversity of those amenities. Urban diversity can be understood in a broad way and can cover both the demographic diversity of an urban environment and it can also refer to the services and shops of an urban area. The more diverse an area is in what it offers, the larger diversity of people it serves and the more different activities occur throughout the day making for a more lively and economically resilient area. The diversity we are measuring in this study is looking not at the diversity of an area, but the diversity it has access to within a certain time frame.

Method

The method we use is developed alongside our proposed study question. There are multiple studies that have used isochrones to measure accessibility in an urban environment, for example, in the context of a 15-minute city, but the topic of urban diversity is less widespread and the use of isochrones has not yet been introduced into the topic. This method we develop integrates the ideas of urban diversity and accessibility together. Instead of dividing the region by uniform grids, we generate isochrones regularly throughout the region and measure the diversity on the isochrones. In this manner, we identify first what amenities someone in the region has access to within a timeframe, and then we measure the diversity of those amenities. In our case we want to answer a question regarding a change in accessibility, and thus will be creating a diversity map for the existing situation and a diversity map for a changed situation. To develop the model we use a GIS program ArgGIS Pro and open data that is freely available. The data comes from a mixture of sources; Tel Aviv municipality provided amenity open data, the ministry of Transportation provided GTFS data and future light rail stations and stops, and OpenStreetMaps provided the streets of Israel and another version of the amenities in Tel Aviv. This data is then combined using ESRI tools and templates

Tel Aviv History and Public Transportation

Tel Aviv is the center of urbanism in modern Israel and always has been. What started as an idea for the expansion of Yafo (Jaffa) in 1906 became the center for economic growth of the region. The city was founded in 1909 during the rule of the Ottoman Empire. Yafo is a much older city being one of the oldest cities in the region. At the time, it was a densely populated Arab-Jewish city. Determined to have better living conditions a group of Jewish families bought 66 plots of land outside the city. This apart neighbourhood was recognized as an apart town in 1910 and was given the name Tel Aviv. With the Zion movement in full effect, the land of Israel was attracting many European Jewish people and they were settling in Tel Aviv rapidly increasing the population. This European influence also brought forwards European architecture and urbanism ideals. The city is still known by the name 'the white city' as a result of Bauhaus influence. Later in 1921, when the British Mandate began it had received a title of township from them. By this time the city had grown significantly. The invention of the bus was only just appearing at the start of the 20th century and by 1922 a bus company had already started within Tel Aviv and public transportation regulations were set up (Helman, 2006). The focus of the British Mandate in the Middle East was on road infrastructure more than rail infrastructure because of the excitement over cars and road transportation. This perhaps is what pushed the dominance of the bus system in Tel Aviv. However, eventually in the 60's with large-scale urbanization of the city happening, discussion towards a rail system were made. Their plans were unsuccessful leaving behind only a single subway station and no other infrastructure. As a consequence Tel Aviv has relied on a bus system until now, a bus system that has provided residents of the city and residents of surrounding cities with a quasi-reliable means of getting around and getting to and out of the city. The reliability of frequency of the bus system is not good because of the lack of dedicated bus priority infrastructure and because of high congestion, a problem that existed quite early on in the development of the city. While there have been additions to the bus priority infrastructure, it is not enough. Tel Aviv is growing and attracting more residents and soon the bus will not be able to keep up with the demand. Many large residential towers are being built all around and in the last 5 years, there has been an increase of 2000 housing units per year (Tel Aviv Yafo Municipality, n.d.). Without a good alternative to a car-dependent city, it is expected that more than 2000 cars will be added to the city streets every year moving forwards. Apart from the fact that the busses are not able to meet the demand, there is also a limitation of a bus system on such a scale: although the bus has a high station density, it takes a long time to travel far on the local busses, especially if one wants to travel to or from a nearby city where the bus crosses several cities. An alternative is to use the 2 main bus stations and the 4 train stations, but the disadvantage is that this limits commuters' access to the city and is only practical for selected areas in the city. These 2 reasons are why Tel Aviv is investing in the mass transit system.

Diversity on isochrones - today

To measure diversity we use the 6 steps of diversity provided by Baciu and Birchall (2021);
(1) defining urban diversity,
(2) collecting data,
(3) performing the analysis,
(4) synthesizing the results,
(5) validation, and
(6) employing the empirical results.
Following step 1 and 2 are straight forwards, the step of performing the analysis and the validation deviate the most from previous work, and employing the empirical results is where we implement the method to measure the change in Tel Aviv.

Step 1: Defining urban diversity.
The diversity that we are looking at in this study is the variety in availability of different amenities to an individual from anywhere within the city. Amenities in this case are services and shops provided within the city that one would reasonably use and reach with public transportation.

Step 2: Collecting data.
To carry out the analysis of the accessibility and the diversity of amenities and services a complete inventory is necessary of said amenities and services. Once the data is collected it needs to be checked for completeness and accuracy. For diversity, a rich description of the amenities will benefit the effectiveness of the analysis. However, the collection of this information is perhaps the trickiest, as there are often many sources and reliability is questionable. The information isn't necessarily grouped in one data source. OpenStreetMap (OSM) data contains points of interest as wide-ranged between graveyards, town halls and memorials (Geofabrik Download Server, n.d.). But it is by far not the most exhaustive list of amenities. The registered businesses

list in Tel Aviv has 39570 businesses (Tel Aviv Yafo Municipality, n.d.) and the municipality GIS data (Tel Aviv Yafo Municipality, n.d.-a) has 7618 businesses on the streets, 162% more than OSM. The benefit of OSM, is that the data is already tagged in categories. The benefit of the Tel Aviv municipal data is that it is richer in detail but more difficult to divide into categories. Both data sets were sorted and only the relevant data was kept. Things classified outside the scope of this study include car mechanics, industrial factories, graveyards, water towers, etc.; we only kept amenities that would contribute to our definition of diversity, a spatial distribution of the amenities is shown in Figure 1.

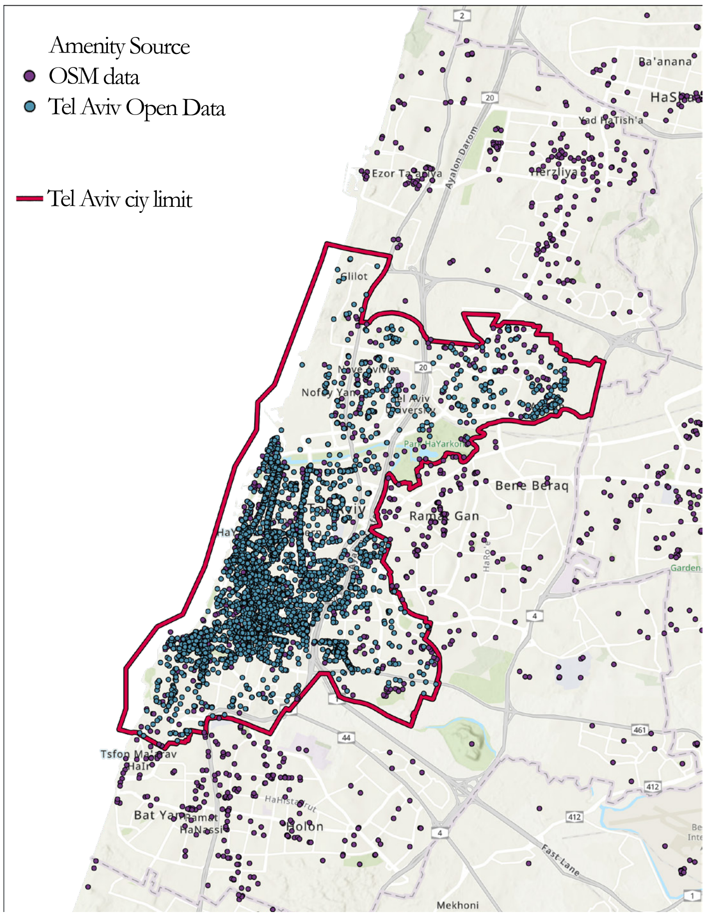


Fig 1: The amenities collected and selected to be used in the diversity mapping. The OSM data and Tel Aviv Open Data do not match together.

Step 3: Performing the analysis.

In Baciu and Birchall (2021), this step is divided into 3 sub-steps; classification system, granularity, and diversity index and scale. Because we will use the Simpson's diversity index in the 3rd sub-step we don't need to worry about scale.

Step 3.1: Classification system.

The classification system determines how the amenities provided by the data are classified, for example, kiosks and minimarkets might get classified together or apart. There are two ends of a string to consider with the classification system. On one end, there is not enough difference between amenities for a useful diversity mapping to be made, on the other end, there is too much distinction made between amenities such that each one is considered unique and the result resembles a density map or even an accessibility map. The 'correct' classification system is the point on the string where the result provides the most accurate representation of what we are trying to model. In previous work that accuracy is checked in the validation step and then corrected if needed creating a cycle until the result is satisfactory. We will use a default classification system from our intuition and leave it as is. This decision will be explained in the validation step.

Step 3.2: Granularity.

Measuring diversity on isochrones leads to an interesting granularity. Instead of dividing the studied region by a uniform grid, we use generated isochrones as our sub-divisions. Because we are looking into the effect of a public transportation change, the isochrones need to be large enough to show the impact of the public transportation change. We have chosen to analyze the city with isochrones of 15 minutes, allowing enough time for the impact of public transportation to be noticeable. Due to the large size of 15-minute isochrones, there is an incredible amount of overlap between the isochrones and their shape varies dramatically and unpredictably.

To generate isochrones on public transportation and walking routes, we use ArcGIS Pro and the public transport analyst tools. The ArcGIS Pro environment uses a walking network and a public transportation network that are connected via the public transportation stations. The street data used was provided by OpenStreetMaps downloaded from Geofabrik at https://download.geofabrik.de/asia/israel-and-palestine.html (Geofabrik Download Server, n.d.) and the public transportation data was provided by the Ministry of Transport and Road Safety as GTFS data and extracted from https://transitfeeds.com (OpenMobilityData, n.d.). The GTFS data included the street routing information but that wasn't utilized in this analysis, we care only for the schedules between stops. The geographic boundary of both datasets is for the whole country of Israel, allowing the network to incorporate intercity public transportation lines in the analysis. A network template provided by Esri, was used to form both the walking network and the public transportation network from the data collected. The street network and the public transportation data was checked for completeness and accuracy and the template was checked to ensure it was compatible with the goal. The street check makes sure all streets are present and that they connect well with the template, this can be done with a quick scan and with spot junction sampling. The GTFS data is reviewed and ensured that it contains all providers, dates, and if possible, all the route ids of the area. It is important to note that OSM street data is not guaranteed to be accurate and the scale of this project prevents us from ensuring that all streets are input correctly and that all pedestrian pathways are usable. See figure 2 for networks.

As starting points for our isochrones, we have rasterized the city; A grid of points was created with a resolution of 125 meters maximum distance between points, this allows us to measure the diversity regularly over the city. A hexagonal grid was used for a more uniform distance between points in all directions, but that is only a minor decision (figure 3). As previously mentioned, the size of the isochrones causes them to overlap, and this becomes more apparent the smaller the origin grid resolution becomes.

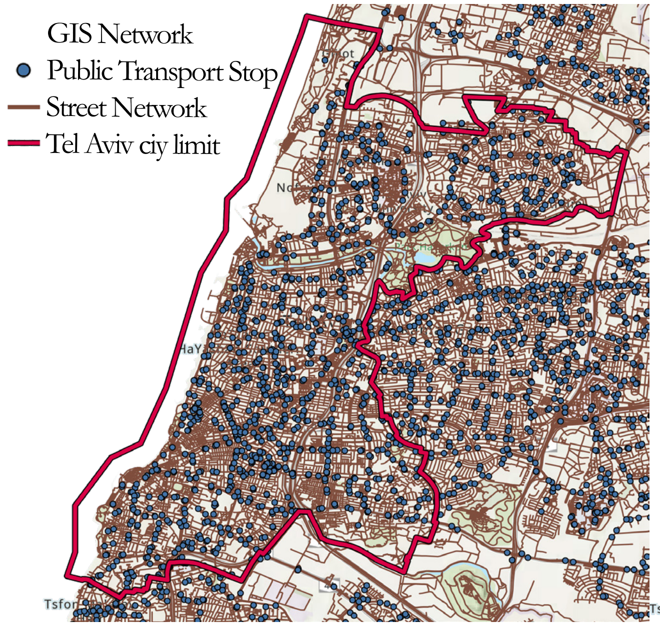


Fig 2: Complete network including street network from OSM and public transport stops and their schedules as GTFS data from the Israel Ministry of Transportation.

Fig 3: 4056 origin grid points spaced 126 meters apart. The points are the centroid of a hexagon for slightly more even distribution.

With the network and the origin points set up, isochrones can be generated using the Service Area analysis tool from Arcgis Pro and the network analyst toolset. To remain consistent we chose to set the date to 'Weekday Thursday 12:00' and the time threshold was set to 15 minutes. The results of the isochrones show that 24 points do not have a valid isochrone or do not fully extend out to the 15-minute threshold. This is likely because the origin grid points were located in places isolating them from the network, for example, between 2 lanes of a highway that the network can't cross. Below, in figure 4, is the summary of all isochrones. In figure 5, a sample of 6 isochrones are shown.

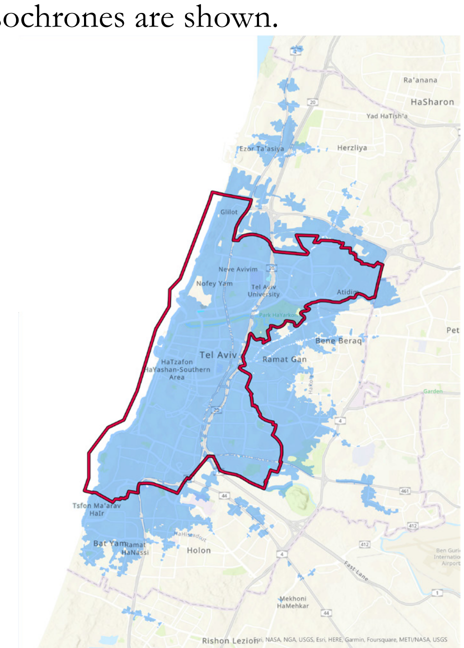


Fig 4: Results from generating 15-minute isochrones. The isochrones extend beyond the city limit because the network was built with data from the whole country.

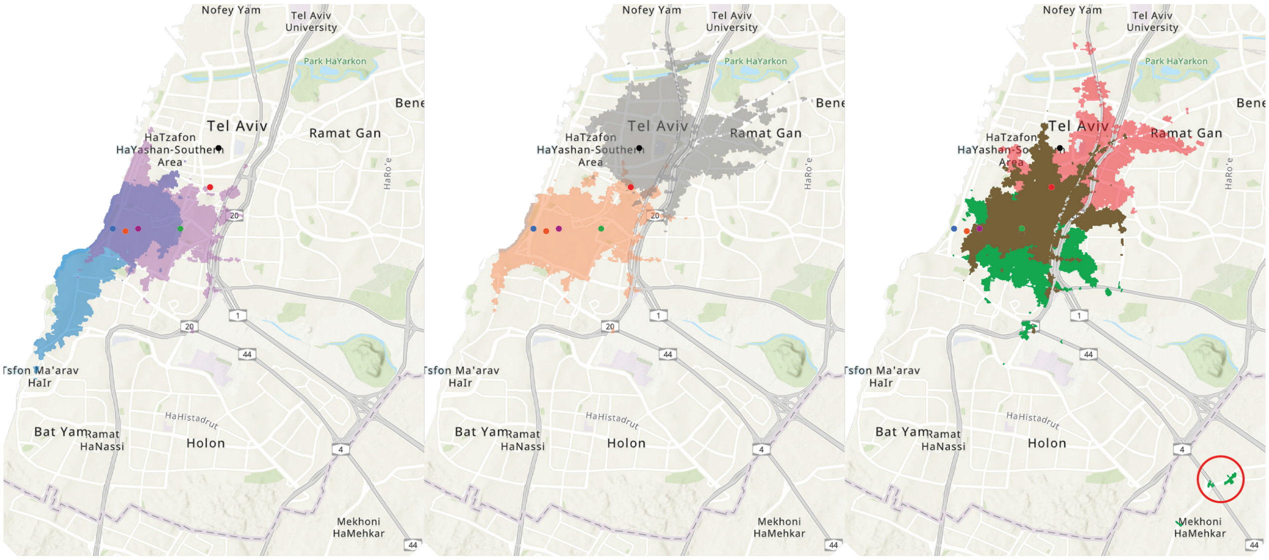


Fig 5: 6 isochrones from different origin points and their corresponding origin point (The brown is a result of green and red overlapping). This is only a small sample from a selection of 4056. The shapes of the isochrones are unpredictable, their city coverage is large, and they overlap with each other. The polygons of the isochrones are also clearly seen to be disjointed as a result of the public transportation network having only discrete stop coverage. The effect that a small origin point displacement can lead to is a drastic isochrone shape change.

Step 3.3: Diversity index.

Multiple diversity indexes can be found to measure the diversity of systems, commonly seen in species biodiversity. We use Simpson's diversity index, this method allows us to calculate diversity and compare results from different scales. The isochrone generation provides us with 1 polygon per origin grid point. We count diversity as the number of amenity classes present, as prescribed by the classification system, within each isochrone polygon. Simpson's diversity index is then calculated for each polygon. This returns a value from 0 to 1.00 that can then be attributed to the origin grid point for synthesizing the result. Figure 6, below, shows an example isochrone and the amenities within.

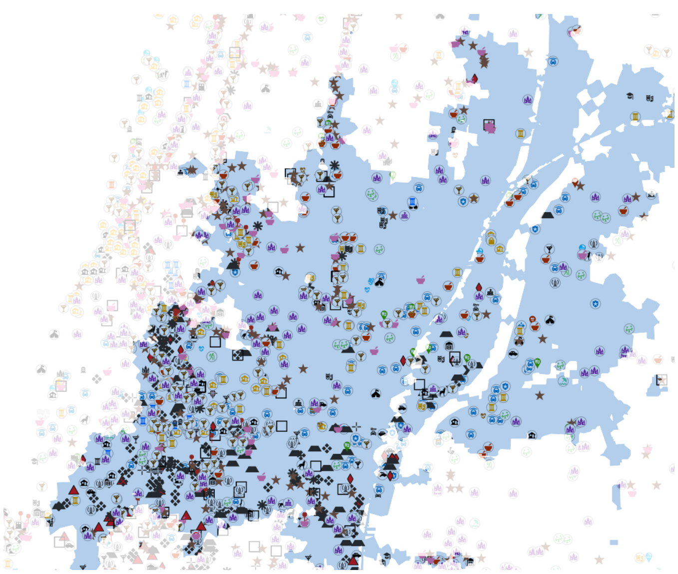


Fig 6: Shows a sample isochrone polygon with the amenities that are included in the diversity index calculation.

Step 4: Synthesizing the results.
presenting the results as a colored point on the city. Each point represents the starting point of an isochrone and the color represents the diversity index of that isochrone. The results are presented in figure 7.

Step 5: Validation.
Validation is important to ensure the result matches the reality of the situation. Critically examining the results and checking if they match any of our expectations (see figure 8) can help us identify mistakes in our classification system or approach in any of the other steps taken. The scale of our project makes validating our results and updating the classification system difficult, both in the scale of the city, and the size of the isochrones. For this we suggest validating the classification system separately from the final diversity map.

Step 6: Employing the empirical results.
The goal of measuring the diversity in this study is to show one impact the light rail will have on the city of Tel Aviv; accessibility and diversity change. The next chapter will discuss the implementation of this method with the changed scenario.

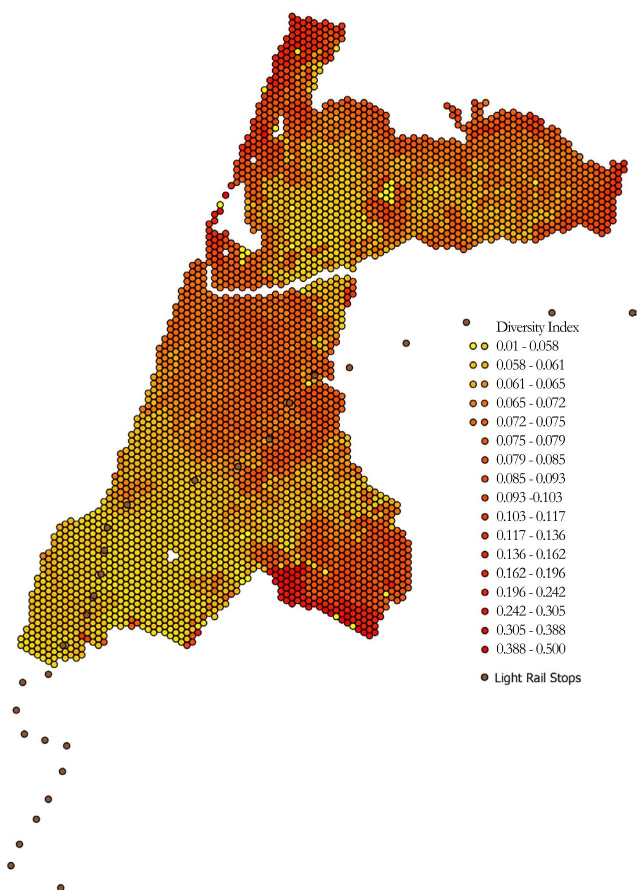


Fig 7: Results of the Simpson's diversity index calculation. The light rail stops are included in the figure but have no effect on the results.

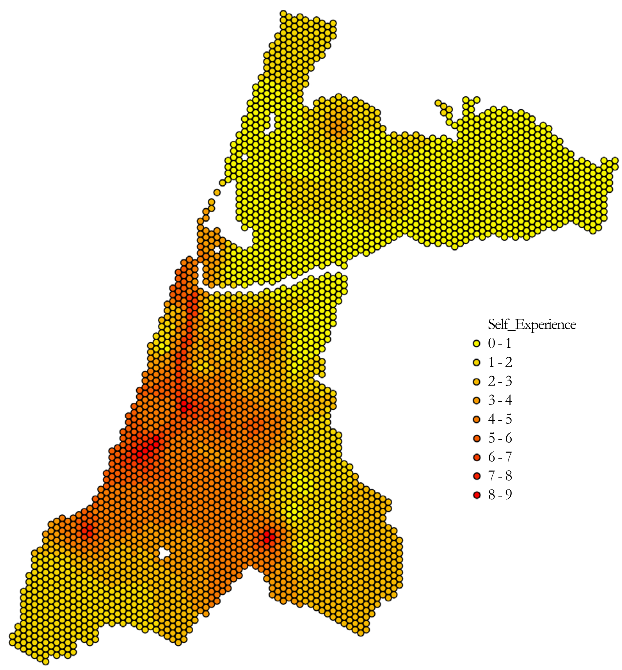


Fig 8: Results of the self-experience based 'liveliness' map. The data was interpolated to match the resolution of the diversity maps from isochrones.

Diversity on isochrones - changed scenario

The first of three light rail routes is to be opened sometime in 2023, this will influence the accessibility patterns of the city, and that in turn affects diversity as we have defined it, to show this change in accessibility and diversity, we will calculate via the same method and data as before, the changed scenario. The only exception is that we add the light rail infrastructure into our ArcGIS environment

The light rail information is not yet available in the form of GTFS. We used addtransit.com (AddTransit, n.d.) to create our own GTFS data. To form our own GTFS schedule we took the station locations of the light rail as provided by the Ministry of Transport and Road Safety (Ministry of Transport and Road Safety, n.d.), and used the 3.5-minute departure frequency advertised by the light rail company NTA ((The Red Line, n.d.). The light rail in Jerusalem was used to estimate the travel time between stops as a function of distance. New isochrones were generated using the light rail integrated network. A sanity check was carried out to ensure that the network was responding correctly.

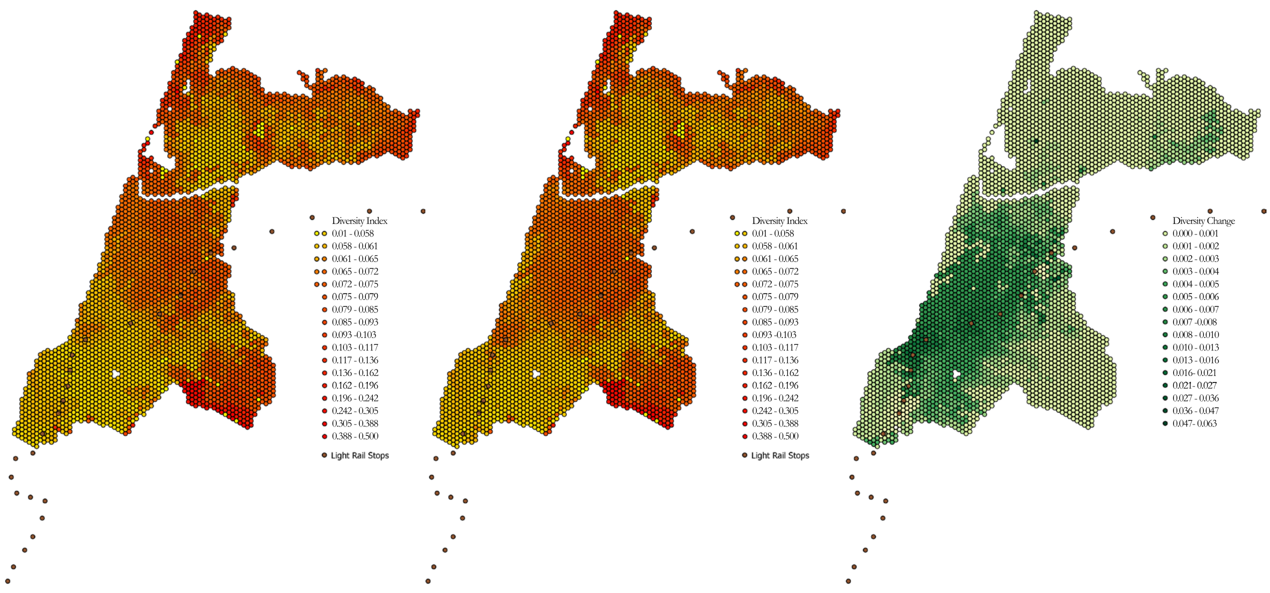


Fig 9: Left: Results of the Simpson's diversity index calculation from the existing situation.
Center: Results of the Simpson's diversity index calculation with the light rail included.
Right: The change in diversity index between existing and changed.

Discussion

Looking at figure 9, the results of both diversity maps are very similar. There is a slight visible change in diversity after the introduction of the light rail. This is exceptionally clear when looking at the diversity change map. By recording the difference in diversity change it is clear that, though the increase in calculation is very slight, the change follows with a broad stroke the path of the light rail. The reliability of these maps is not yet known, the classification system used to produce these maps is not yet optimized to produce the best result. The results as they stand now don't match expectations derived from the 'liveliness' map. In the Southeast and Northwest there is a higher index of diversity that is yet unclear and the neighborhoods of the city where diversity is expected to be high, there is only a medium diversity. The majority of the city is indexed with low diversity score which is another indication that the classification system is not optimized. A revised version is being planned with a better classification system.

Validating the classification system

To validate the classification system, a comparison is required between the results of a diversity map using the classification system and another map that is known to accurately reflect reality. The first can be made with a more traditional diversity map without the complexity of isochrones and the latter can be made by taking samples of the region and creating a map from self-experience. The first map can be created similar to the case study done by Baciu and Birchall (2021) but that is beyond the scope of this study but the latter has been presented in the 5th step. To properly match the classification step to the experienced-based map, an AI model is being developed to test classification system configurations and provide us with the 'best fit' to our experience. This classification system can then be used in further investigations into the diversity of Tel Aviv. Other improvements that can be made on this topic are those of data reliability and richness. The better the data used matches the city, the more accurate the model can be. And with the development of the AI model to match the data to our experience, this process can be more easily repeatable.

Conclusion

With the near future opening of the light rail in Tel Aviv, the pattern of commuting through Tel aviv will be affected. This change can influence the amenities in one's close reachable vicinity. We asked what areas of Tel Aviv will have a change in accessibility diversity as a result of the light rail. To determine this we measured the urban diversity on isochrones generated from the public transportation and walking networks. To develop this method and to show the change between the existing situation and the future situation, diversity maps for the existing situation and for the changed situation were created. The results showed that the influence of the light rail can be seen but only slightly; a broad stroke of diversity increase is seen following the route of the light rail. The diversity map measuring existing diversity can be used to determine the validity of this study. To determine the validity of the diversity map, a 'liveliness' map was created from self-experience. The two maps were compared. The results of the diversity map are unclear. Future work is required to develop a better classification system. An AI model to optimize the data for the purpose of creating diversity maps that better reflect reality is being developed alongside this study and will be implemented in the next step of this study. Further improvements that can be strived for are better street and amenity data. The light rail from these results will have a very slight but positive impact on the city in terms of diversity.

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