Exploring the impact of increasing accessibility by proximity on leisure social diversity: An Agent-based model approach to 15-minute cities.

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Short summary

One proposal to increase accessibility is the 15-minute city; the goal of this concept is to create a city where all daily necessities are covered in a 15 minute walk or bike ride from home. This design could lead to a reduction in the importance of city centers, which are an essential place of interaction for people of different social groups. Using an Agent-Based model and Zurich as a case study, we analyze what effects an increase in accessibility, as proposed by the 15-minute city, would have on the social diversity of leisure activities. Two conclusions can be drawn. First, the reorganization of venues has a minor effect on distance traveled; second, due to the low impact on transport behavior, we found that this approach would only have a limited effect on diversity of origins, and no effect on age or income diversity in leisure activities.
Keywords: Transport Equity and Justice, Social Diversity, 15-minute city, Accessibility, Agent-based modeling.

1 Introduction

In the literature on transport justice, one of the main focuses is on generating sufficient levels of accessibility to essential services, such as work, education, and leisure, so that all members of society can pursue their life goals and participate in the social life of their community (Martens, 2017). To achieve this goal, spatial, urban and transport policies should focus their efforts on minimizing the inequality of access to opportunities in the city by prioritizing public transport, walking, and cycling over private cars, while guaranteeing that all basic needs essential to a decent life are within reachable distance for all individuals (Pereira et al., 2017).
During the last years, the 15 minute city concept, proposed by Moreno et al. (2021), has gained popularity; the main idea behind this concept is to build more humane urban fabrics, in which all daily necessities (such as work, green areas and leisure) are in 15 minutes walking or biking radii from any point of the city. Although the main objective of this concept is to reduce car dependency and improve individuals' health by incentivizing active modes, its proposal on increasing accessibility has direct implications on transport justice and equity. The 15-minute city approach to accessibility focuses on six essential urban functions that are necessary to maintain a decent urban life: living, working, commerce, healthcare, education, and entertainment; guided by four components: proximity, ubiquity, density, and diversity.
The objective of this paper is to analyze two potentially conflicting components of the 15 minute city: proximity and diversity, with a focus on leisure activities. As explained by Moreno et al. (2021), *proximity* aims to reduce the environmental and economic externalities of transportation, especially those generated by the use of cars. Therefore, it is critical to reduce travel times by promoting a proximity-based reorganization of the city, which will allow local residents to maximize the use of their local infrastructure and generate community within their neighbors. The second component is *diversity*, this concept includes promoting a city environment that is capable of accommodating different cultures and people, promoting social cohesion, and providing an attractive landscape for tourism and its businesses, which promote economic vibrancy and an increase in employment opportunities.
The potential conflict between these two components may arise from increased proximity to leisure facilities. Increasing accessibility through greater proximity could reduce the importance of city centers and central business districts (CBD) as leisure areas. These areas are the main places where diverse social groups tend to intermingle (Toomet et al., 2015; Wu et al., 2023); therefore, this policy could decrease the levels of social diversity seen in leisure activities.

In addition, individuals tend to associate and bond with others who are similar to themselves in their personal characteristics, generating clusters in social space (McPherson et al., 2001). This tendency is known as *Homophily*, which has been observed in the preference for a social environment in restaurants and nightlife venues in the destination choice behavior (Gramsch-Calvo & Axhausen, 2024), and could aggravate the loss of social diversity.

2 Methodology

To analyze the effect of increasing the proximity to leisure venues on social diversity, using data from the Zurich Urban Region, we have designed an agent-based model adapting the Schelling model of segregation (Schelling, 1971) to leisure activities, in which the agents choose different venues to perform leisure depending on personal preferences, and these decisions generate a social environment in each venue. Later, we generated a synthetic version of Zurich in which all Points of Interest (POIs) are fairly distributed through the municipalities and compared the changes in the diversity of the social environment between these two scenarios, our analysis focus on three socio-demographic characteristics that affect leisure destination choice: age, income, and origin.

Modeled entities

In the model, there are two entities, the venues and the individuals who make the decision to participate in leisure activities. The entities are described as follows:

1. Venues: The venues are the places where the agents can choose to perform a leisure activity and have a location, a price, a rating, and a social environment. We have included 129 bars and 506 restaurants, with data collected from OpenStreetMap contributors (2017) and Google Maps. The social environment is estimated through the interaction of individuals during the simulation.
2. Agents: Each agent is characterized by home location, age, income, cultural origin, and homophily preferences, which will resemble the distribution of these characteristics of Zurich city. We used the synthetic population used in Zurich's MATSim model (Hörl & Balac, 2021) with 65,000 agents. We have separated the income groups from very low to very high. To simplify the model, we used the three most common origins in Zurich, Swiss without immigration background, Western European, and Eastern European. The distribution of socioeconomic characteristics is shown in Table 1.

Table 1: Sociodemographic characteristics of the agents

Age	Percentage	Income	Percentage	Origin	Percentage
30 or less	18.2%	Very low	13.5%	Swiss	61.8%
Between 31 and 40	22.2%	Low	39.3%	Western European	29.1%
Between 41 and 50	20.2%	Average	26.7%	Eastern European	9%
Between 51 and 60	15.9%	High	11.4%		
More than 60	23.3%	Very high	9.1%		

Process overview and scheduling

The model has two time scales: day d and intervals i. Each day has been divided into three intervals. At the beginning of each day, the agents choose which interval or consecutive intervals they go out. Figure 1 shows the model's sequence.
The probability of going out was estimated with a Logit model using the MOBIS GPS tracking dataset collected in Zurich (Molloy et al., 2022), in which we estimated the probability of seeing an individual doing a leisure activity outside of home during the day. The utility function of going out is:

$$\begin{aligned} U_{i\,=1} = &-1.72 - 0.01 \cdot Age + 0.03 \cdot (Income_2) + 0.11 \cdot (Income_3) \\ &+ 0.16 \cdot (Income_4) + 0.18 \cdot (Income_5) + 0.22 \cdot (origin_{Swiss}) \end{aligned} \tag{1}$$

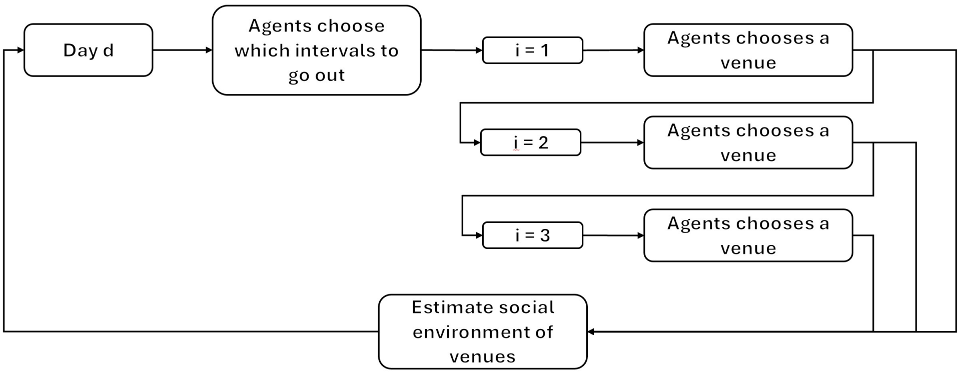

Figure 1: Overview of the decision process for the ABM

$$U_{i=2} = -2.02 - 0.03 \cdot Age + 0.03 \cdot (Income_2) + 0.02 \cdot (Income_3) + 0.02 \cdot (Income_4) + 0.05 \cdot (Income_5) + 0.23 \cdot (origin_{Swiss}) \quad (2)$$

$$U_{i=3} = -2.88 - 0.04 \cdot Age + 0.04 \cdot (Income_2) + 0.02 \cdot (Income_3) + 0.07 \cdot (Income_4) + 0.11 \cdot (Income_5) + 0.45 \cdot (origin_{Swiss}) \quad (3)$$

As shown in equations 1, 2, and 3, the probability of going out depends on the socioeconomic characteristics of the agents and the interval of the day. Younger, higher income, and Swiss individuals are more likely to go out. In addition, agents are more likely to go out during earlier intervals. After estimating the probability of going out, the agent decide if they visit a restaurant, with probability 72% or a bar with probability 28%[1]. Finally, agents choose which venue they visit using the following utility function:

$$\begin{aligned} U_{restaurant} = & -0.57 \cdot Price_2 - 1.47 \cdot Price_3 - 1.04 \cdot ln(Distance) \cdot k_r + 0.25 \cdot Rating \\ & + 0.09 \cdot ln(Attractiveness) + 0.02 \cdot Age \cdot Price_2 + 0.03 \cdot Age \cdot Price_3 \\ & + 0.12 \cdot Income_{>3} \cdot Price_2 + 0.54 \cdot Income_{>3} \cdot Price_3 - 0.35 \cdot \mu_{age} \\ & - \sigma_{age} - 1.69 \cdot \mu_{income} - 1.91 \cdot \sigma_{income} - 1.38 \cdot \mu_{origin} - 1.49 \cdot \sigma_{origin} \end{aligned} \quad (4)$$

$$\begin{aligned} U_{bar} = & -1.37 \cdot Price_2 - 3.25 \cdot Price_3 - 0.94 \cdot ln(Distance) \cdot k_b + 0.43 \cdot Rating + 0.20 \cdot ln(Attractiveness) \\ & + 0.05 \cdot Age \cdot Price_2 + 0.08 \cdot Age \cdot Price_3 - 0.04 \cdot Income_{>3} \cdot Price_2 + 0.26 \cdot Income_{>3} \cdot Price_3 \\ & - 0.03 \cdot \mu_{age} - 0.93 \cdot \sigma_{age} - 6.40 \cdot \mu_{income} - 4.65 \cdot \sigma_{income} - 0.24 \cdot \mu_{origin} - 1.30 \cdot \sigma_{origin} \end{aligned} \quad (5)$$

Equations 4 and 5 show the preference for restaurants and bars. Price is the price category of the venue (from 1 to 3), distance is the distance to the venue, rating is a measure of quality for the restaurant, attractiveness is how attractive is the area where the venue is located (measured as the number of other leisure venues in a 2 km radius). k is a calibration factor to ensure that the average distance traveled by the agents is equal to the observed leisure travel distance (≈ 3.5 km). The utility functions also include sociodemographic characteristics; as older and wealthier individuals tend to prefer more expensive venues, this effect is more important in restaurants than bars. Finally, the preference for homophily in age, income and origin is heterogeneous and log-normally distributed with mean μ and sd σ, the median values for the preferences are shown in table 2. For a more detailed explanation of how this utility function was estimated, please refer to Gramsch-Calvo & Axhausen (2024). Finally, the social environments of the venues are calculated as the percentage of individuals with each sociodemographic characteristic who visit each venue.
To analyze the impact of a 15-minute city on the levels of diversity in leisure venues, we compare two versions of the previously explained agent-based model; the first version uses the Zurich venue distribution, the second version is a simulated version of Zurich using the POI relocation algorithm

[1] The MOBIS dataset does not differentiate in the type of leisure activity that has been selected by the individuals, therefore we used the proportion of restaurants and bars in the dataset as the probabilities.

Table 2: Median preference for homophily

	Restaurant	Bar
Age	3.9	0.97
Income	0.19	0.00
Origin	0.25	0.79

proposed by Bruno et al. (2024), with the aim of improving the proximity of peripherial areas to POIs, by making even the number of POIs per capita in each municipality. The algorithm consists of calculating the POI per capita of the city to analyze the under-served and over-served municipalities of the city, by category. Later, one randomly selected venue from an over-served area is relocated to an under-served area, until there is an equal distribution of POIs per capita in each municipality. This algorithm does not represent an organic growth of the city, but it approaches an optimal 15-minute city design. Figure 5 shows the original distribution of POIs in Zurich (Plot A) and the 15 minute design (Plot B); the latter plot shows that the most benefited areas are located in the north-east and north-west parts of the city, as well as around the lake.

3 Results

After running the two models, we compare the results in terms of transport behavior and the diversity observed in the venues. The first variable to compare is the total distance traveled, Figure 3 shows the distribution of the distance traveled between the two models. There is little difference in the shape of the distributions, with the 15-minute city having a slightly higher number of shorter trips. This can also be observed in the median distance traveled, while the original model has a median distance of 3.54 km; in the 15-minute city the agents travel a median of 3.17 km.
To measure diversity in each venue, we use the Simpson Diversity Index (Simpson, 1949), normally used to analyze diversity in ecological studies and it is defined as:

$$S_v = 1 - \frac{\sum n_{gv}(n_{gv} - 1)}{N_v(N_v - 1)} \tag{6}$$

Where n_v is the number of individuals belonging to the social group g at the venue v and N_v is the total number of individuals in the venue. This index goes from 0 to 1, where 0 means no diversity (only one group of agents is observed in the venue) and 1 means full diversity (equal distribution of agents in the venue). Table 5 presents the results of the diversity estimation per day of the simulation. The X-axis shows the day, and the Y-axis shows the Simpson index. The first thing to notice is that venues tend to be more diverse in age, followed by income, and finally by origin, although this is related to the initial level of diversity of the city. In addition, bars tend to be more diverse in age than restaurants, while the opposite happens in origin diversity, in which restaurants tend to be more diverse. Finally, there is no noticeable difference between the average diversity indices of the original model and the 15-minute city model.
After analyzing the average differences of the diversity indices, we analyzed whether there were some spatial differences in these changes. Figure 5 shows the map of Zurich with the percentual change of indices between both models, the red colors show a decrease in diversity while the green show increasing diversity. The age and income maps do not show any significant change (with values between -10% and 10%), but the origin has a more heterogeneous effect, one thing that can be noticed is that the city center experiments a reduction in diversity, while peripheral areas tend to have increased diversity. To test if there is any impact of being a previously under-served area on this change of diversity, we have run a simple linear model following the equation $Y = \alpha + x \cdot \beta + \epsilon$. The results show a positive correlation between both variables with a value of β of 0.12, which means that for each POI that a municipality *receives* through the relocation process, the diversity of origin increases by 1%.

4 Conclusions and discussion

One method to deal with transportation justice issues is to increase accessibility to urban goods, the 15-minutes city proposes reorganizing cities to generate accessibility by proximity. This idea would reduce the importance of city centers, as individuals would not have the need to visit them

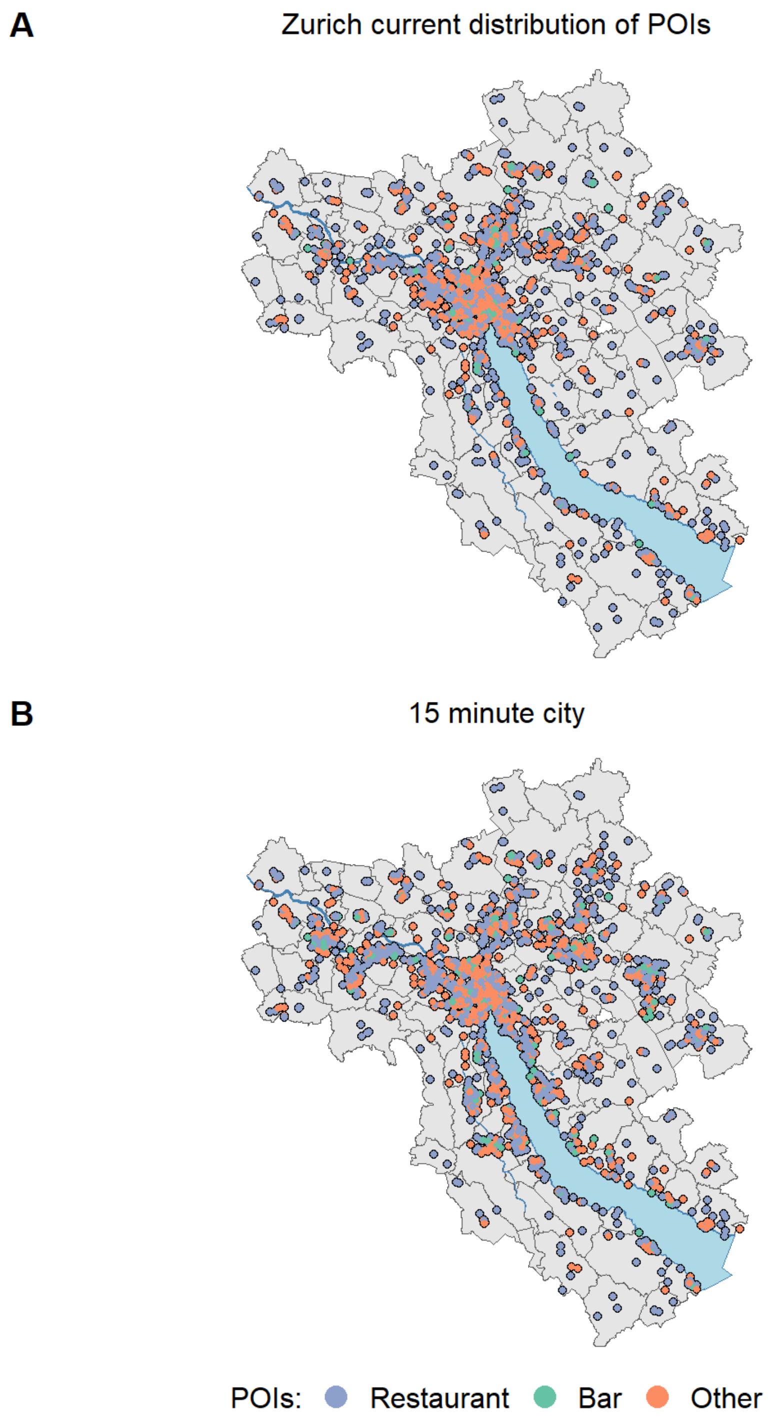

Figure 2: Overview of the decision process for the ABM

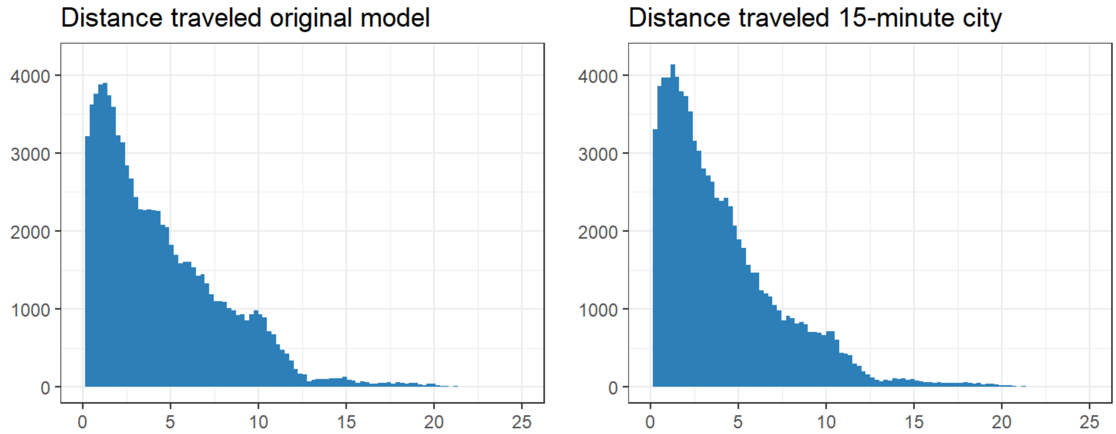

Figure 3: Diversity level by type of venue and model

to sustain their necessities, but city centers and CBDs are a source of social diversity, leading to a conflict between two essential components of the 15-minute city, proximity and diversity. With our model, we tested the impact that a reorganization of POIs would have on the social diversity of leisure venues. Contrary to our main hypothesis, we have observed that the relocation of POIs would have a small positive effect on origin diversity on previously under-served municipalities, the generation of new areas with a concentration of POIs could attract individuals from different origin groups, generating a positive effect on diversity, but this effect would be at the expense of a reduction of the diversity of previously over-served areas. Furthermore, in terms of age or income, there would be no significant change in diversity levels in the city. Finally, the results show that this reorganization would have a minor effect on the distance traveled for leisure activities (average reduction of 360 meters or less than 5 minutes walking), which is one of the motivations for building 15-minute cities.

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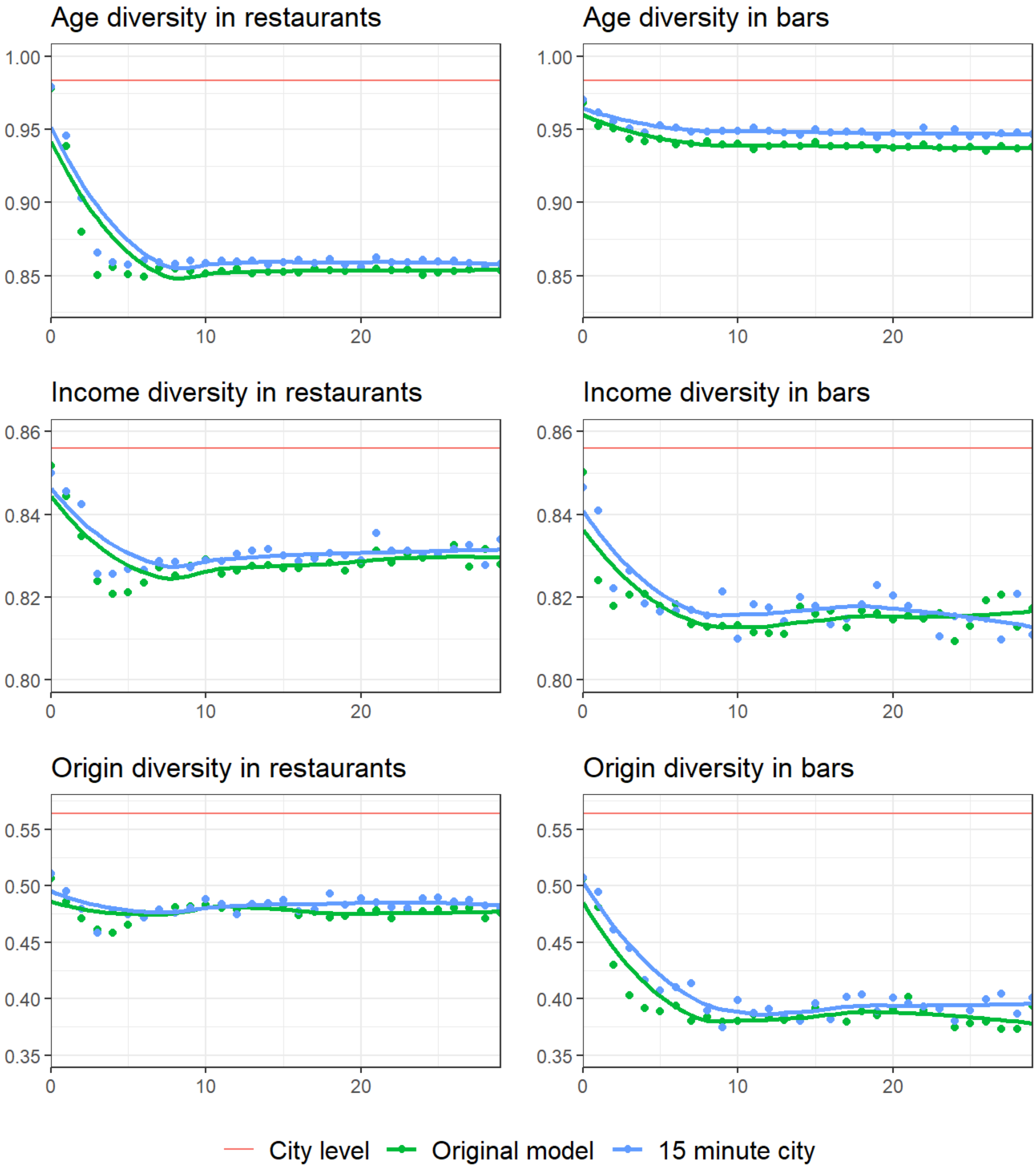

Figure 4: Diversity level by type of venue and model

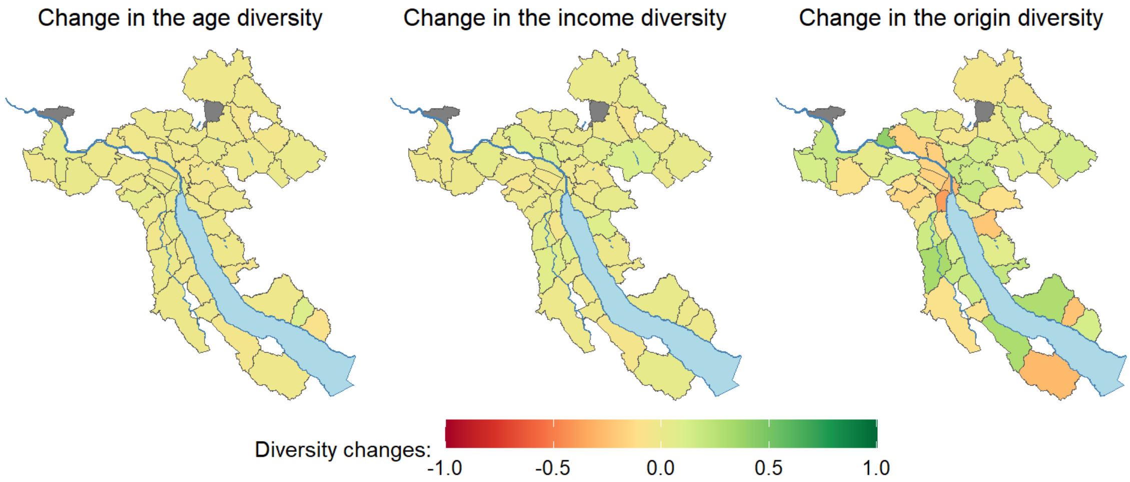

Figure 5: Changes in diversity levels by municipality

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