Spat. Inf. Res.
https://doi.org/10.1007/s41324-022-00484-z

Spatial justice in relation to the urban amenities distribution in Austin, Texas

Fatema Hussaini[1] · Ebrahim Farhadi[2,3] · Ahmad Pourahmad[2] · Simona Tondelli[3]

Received: 6 June 2022 / Revised: 30 August 2022 / Accepted: 2 September 2022

Abstract In addition to enhancing our theoretical grasp of justice, thinking spatially about it can also reveal important new insights that broaden our practical understanding in order to advance justice and democracy. On the other hand, these opportunities won't be as obvious if the spatial equities aren't made apparent and strong. Austin city has experienced a fast-urban growing in the past decades. As urban areas grow, the public facilities should increase. The purpose of this paper investigates Facilities in terms of public facilities. Even though we said that the concept of justice is very complex, it is possible to get an understanding of it by using a quantitative method. This paper explores the condition of urban justice and opportunities for accessibility to public facilities for all residents in Austin by using GIS data and the Fuzzy logic model. The facilities and services maps were made in GIS and after the Euclidean Distance and Reclassify function in Arc Map, the Fuzzy Logic model was used to analyze spatial justice. The result shows the facilities are distributed properly. Spatial justice is in the context of Austin and residents enjoy spatial justice.

Keywords Spatial justice · Urban amenities · Spatial analysis · Distribution · Austin

1 Introduction

In today's cities, public decision-making is rife with conflict, and the resolution of disagreements is rarely explicitly based on the ideals of justice [1]. In this setting, public space has drawn more focus in urban research, policy, and public discourse as a facilitator of urban justice, both as a theoretical concept and a practical concern of urban design [2]. Space, which is the geographical or physical component, and social justice, are connected in a way called spatial justice. Therefore, in order to comprehend social inequities and the regulation policies to lessen or eradicate them, it is vital to evaluate the interplay between space and society. As a result, it can be viewed as both a process and an output. The development of the idea of social justice centers on this [3, 4]. Spatial justice entails the fair and equal distribution of space and chances to use them in socially important areas [4]. Philippopoulos–Mihalopoulos defined spatial justice as the warfare among our bodies that are moved by way of a preference to occupy the same area at an identical time. This is an embodied desire that manifests itself ontologically; it is neither only distributive justice nor regional democracy. Fundamental to the development of spatial injustice and the establishment of long-lasting spatial structures of privilege and advantage is locational discrimination, which is brought about by the prejudices placed on particular populations due to their geographic location [4]. The decision-makers in the development sector gain an understanding of the crucial issue of how to control urbanization while preserving growth and advancing equity. Institutional solutions to Providing

✉ Ebrahim Farhadi
e.farhadi71@ut.ac.ir; Ebrahim.farhadi@studio.unibo.it

Fatema Hussaini
fhussaini@murraystate.edu

Ahmad Pourahmad
Apoura@ut.ac.ir

Simona Tondelli
simona.tondelli@unibo.it

[1] Department of Earth and Environment Science, Murray State University, Murray, KY, USA

[2] Department of Geography, University of Tehran, Tehran, Iran

[3] Department of Architecture, Bologna University, Bologna, Italy

Published online: 19 September 2022

fundamental human needs of public facilities are referred to as such.

The quality of life in the community is improved through public facilities for both individuals and groups. They offer quick and effective services, a sense of identity, and they establish the city's aesthetic. All levels of government, as well as additional public and quasi-public entities, provide public amenities and services [5]. Unnatural urban growth widens disparities in the usage of city Welfares. So, it made metropolitan regions' life quality worse. As a result, poor distribution of urban services can have an adverse impact on population balance as well as create cities that are unjust in both the social and economic spheres [6]. Spatial justice refers to the planning for the efficient use of places, the equal distribution of city services, and economic resources [7]. The demand for social justice in public services and the discussion of spatial inequality in cities have emerged as two of the most pressing concerns for urban planners and managers, as well as two of the most crucial considerations for the implementation of social justice [8]. Obtaining social and spatial fairness requires, infrastructure and services must be distributed properly to benefit all societal segments [9]. Due to this, we need to take a deep look at spatial justice to assist recognize justice as a geographic composition at distinct scales, now not just as an absolute or typical scale. [10]. Therefore, the deliberate management of urban planners in appropriate availability of space and social Advantages should be to decrease geographical disparity and better environmental standards and lead to increasing urban livability and achieving urban sustainability so that citizens can live a lasting life with happiness, economic well-being, environmental well-being, and The economy of human settlements should be realized along with justice and spatial equality [11]. There is ongoing dispute on the idea of the Just City as the ultimate goal of planning, not just one goal among others and of all planning, not just many plans, both in the United States and elsewhere [12]. Various quantitative and qualitative methodologies from management science and urban planning are mostly used to tackle facility location problems. Various target functions might be taken into account depending on the type of facility being located. The most common ones are limiting travel distance, maximizing service level, cutting waiting times, increasing coverage, cutting transportation expenses, or avoiding placement adjacent to dangerous facilities [13].

Adequate access to urban facilities increases the satisfaction from availing basic needs and, thus, improves the quality of living and enhances community stability [14]. The University of Groningen developed a list of 22 disparate indicators representing Quality of Life, which include adequate access to health care, educational, and recreational facilities [15]. In this context, adequate access to urban facilities can be regarded as an essential indicator of improved QoL and social sustainability, which is one of the cornerstones of urban planning policies [16].

Income inequality is growing in the United States and is a cause for concern. Wealth concentration was high in the beginning of the twentieth century, but in 1980 has continuously increased then [17]. For example, the share of national income among the poorest half of the US population steadily declined from more than 20% in 1980 to 13% in 2016, and the income share among the top 1 percent doubled from around 10% in 1980 to 20% in 2016 [18].

In addition to the political, economic, and social concerns related to rising economic inequality, there is also a growing literature linking income inequality to Urban Amenities Distribution inequality. This point shows the necessity of conducting this research to know whether all people in different areas of Austin city have proper access to urban facilities.

The authors of this work want to achieve two things: We start by using the spatial autocorrelation and closest neighbor indicator to analyze the dispensation of conveniences with geographic statistics. Second, we plotted the spatial inequality of the various Austin regions using a variety of metrics. The integrated study of spatial access serves as an Instrument for planning and controlling city development strategies or policies as well as a resource for more accurately identifying mid-level inequality.

2 Literature review

2.1 Justice and distribution of urban services

The degree of disparity, the distribution of inequality, and the socioeconomic strata that are most disadvantaged should all be assessed by urban planners and managers [19].

To study social welfare issues, studies on the distribution as the foundation of justice have been produced. One of the most crucial objectives of urban planners and managers is to comprehend spatial fairness in the deployment of urban infrastructure in order to share social resources fairly and utilize local talent. The theories of justice, which are founded on every perspective of traditional justice, demonstrate that the concept of justice extends beyond the dissemination of services [20]. Although Justice in society encompasses many ideas, the two basic axes of these studies always focus on livability and How may opportunities be distributed, and who has physical, virtual, and societal structures [21]. However, one of the key concerns when it comes to urban planning and spatial justice is the primary role of city public facilities and balanced access of city people to these services. According to Miller dispersion in conventional ideas of spatial and social justice refers to equitable distribution as well as the way that resources are allocated among individuals. All of a city's components and machinery are referred to as facilities.

It improves city dwellers' quality of life. Such definitions of urban facilities, which include urban facilities and services, are quite prevalent. Numerous necessary service tasks for city planning, management, and citizen affairs facilities can be included in the broad definition of urban facilities. However, it should be highlighted that the evaluation and categorization of urban service activities depend on urban management since figuring out the realistic extent of urban facilities and services necessitates figuring out the level of urban planners and creating connections between departments. As long as individuals are allowed to participate in urban development plans, cities can grow and exist. Consumers flock to these privileged areas as a result of the concentration of facility centers in one area of the city, which creates opposite and bipolar areas in the cities and increases environmental pressure, disturbances, traffic, and various pollutions, encompassing sound, odors and air pollution. In other words, this renders sustainable urban development impossible [22]. The "emphatic turn towards neoliberalism in political-economic practices" is another element contributing to the rise in socio-spatial inequality. It is depicted as a post-industrialization of services approach that quickly advances toward increased market liberalization. Neoliberal practices also compel those who are unemployed or having left school to take on menial, small- paying jobs. Last but not least, the decline in housing market privatization and social housing give the wealthy the chance to migrate to more places, which encourages segregation [23].

The goal of social justice and spatial equality is to promote fundamental efforts to reduce the level of inequality between citizens and people through a set of adjustment principles for Improving management and planning in cities, but these concepts are frequently presented as moral principles in programs and policies [24]. For urban planners and managers, fair spatial distribution of urban services and equal opportunity are crucial challenges. When describing equitable opportunities and spatial distribution in a location, proper consideration should be given to the sort of intended activities, the population of the examined areas, and the physical characteristics of the locations. Therefore, some academics describe spatial justice as the equitable use of public resources. and services, and they gauge it based on how far citizens are from services [6].

2.2 Public services, equality and spatial inequality

Generally speaking, public services are described as commercial ventures launched by governmental organizations that serve the public interest. Public institutions are in charge of establishing and launching them. However, the private sector is also responsible for the upkeep and support of public services for investment [25].

Richardson thinks that since philosophical and ethical attempts to explain equality have come to a halt, it is a difficult and perplexing idea that cannot be fully described. Three facets of equality are mentioned by Hudson: financial equality, reward for work equality, and equality in the delivery of public services. The first is an equal society's objective and goal. The second factor justifies a market economy by emphasizing equality of opportunity rather than income equality. The third factor is similarly significant, but it has a concealed effect on equality in mixed economies [26]. Simply put, spatial justice combines social justice with physical justice. Human society organizes space, and when we look at this organized space, fairness and injustice may be found in the material and conceptual structure, as Henri Lefebvre points out. Since people have distinct economic, social, and political foundations, and because of this, the allocation of services, facilities, income, jobs, and even residential areas is dependent on these inequalities, achieving full equality is not practical. Spatial justice places more emphasis on preventing gaps in the city and avoiding extreme inequities than it does on achieving complete equality [27]. According to Randall Collins, issues like inequality may not have clear-cut solutions because it is one of life's most well-known facts and is evident to even the most casual observer. Despite this inequity, it is a problem that is difficult to resolve or comprehend [28]. Individual and institutional inequities are a result of uneven spatial development, which also sustains these injustices [29]. But when it comes to the debate over whether societal disparity is desirable or harmful, unplanned or deliberate, long-lasting or transient [28].

Recently, social justice has emerged as one of humankind's greatest triumphs and as one of the most prevalent social phenomena of our day. In essence, spatial justice is a paradigm that emphasizes the sociospatial arrangement of advantages and restrictions on human cultures as sustainable urban growth increases demand on urban infrastructure [30]. Harvey stresses the significance of providing people's basic requirements, distributing income equitably across the country, and promoting public wellbeing. Also highlighted are the modern capitalist system's intrinsic propensity for social inequality to extend spatially and the ongoing rivalry over the expansion of territories and new regions [31].

Spatial justice refers to the separation or closeness of urban facilities and services to citizens in terms of public facility planning [32]. According to John Rawls's "Principal Elements of Justice for Urban Service Use". (1) The first step ought to be to ensure equal opportunity; (2) a minimal standard for any service; (3) Prior to knowing the distribution outcomes, the allocation rule must be agreed upon [33].

3 Materials and methods

3.1 Case study area

As the state capital of Texas, Austin is an inland city bordering the Hill Country region (Fig. 1). Austin is the top large city in America to grow in 2019. It is located at 30.2672° N and 97.7431° W. As the fastest-growing mid-size city in the United States, Austin is going through rapid racial change, gentrification, and population increase.

3.2 Fuzzy logic

Following Lotfi Zadeh's modification of fuzzy set theory, fuzzy logic initially arose in the new field of computation. Fuzzy refers to something that is wrong, imprecise, and vague. Only a few of people understood fuzzy logic, thus it didn't exit the university setting for more than 20 years after 1965. Japanese craftsmen started using fuzzy logic in the middle of the 1980s after realizing the science's potential for industry. Following a burst of scientific discussion about fuzzy logic, Europeans only really started using this science in the middle of the 1990s. It is possible to define the applicability of this subject to software science in the following manner:

Because the space between zero and one is unlimited, Fuzzy logic goes beyond the values of traditional software's logic that are "zero and one" and It offers a fresh entry into the field of computing and software research [34].

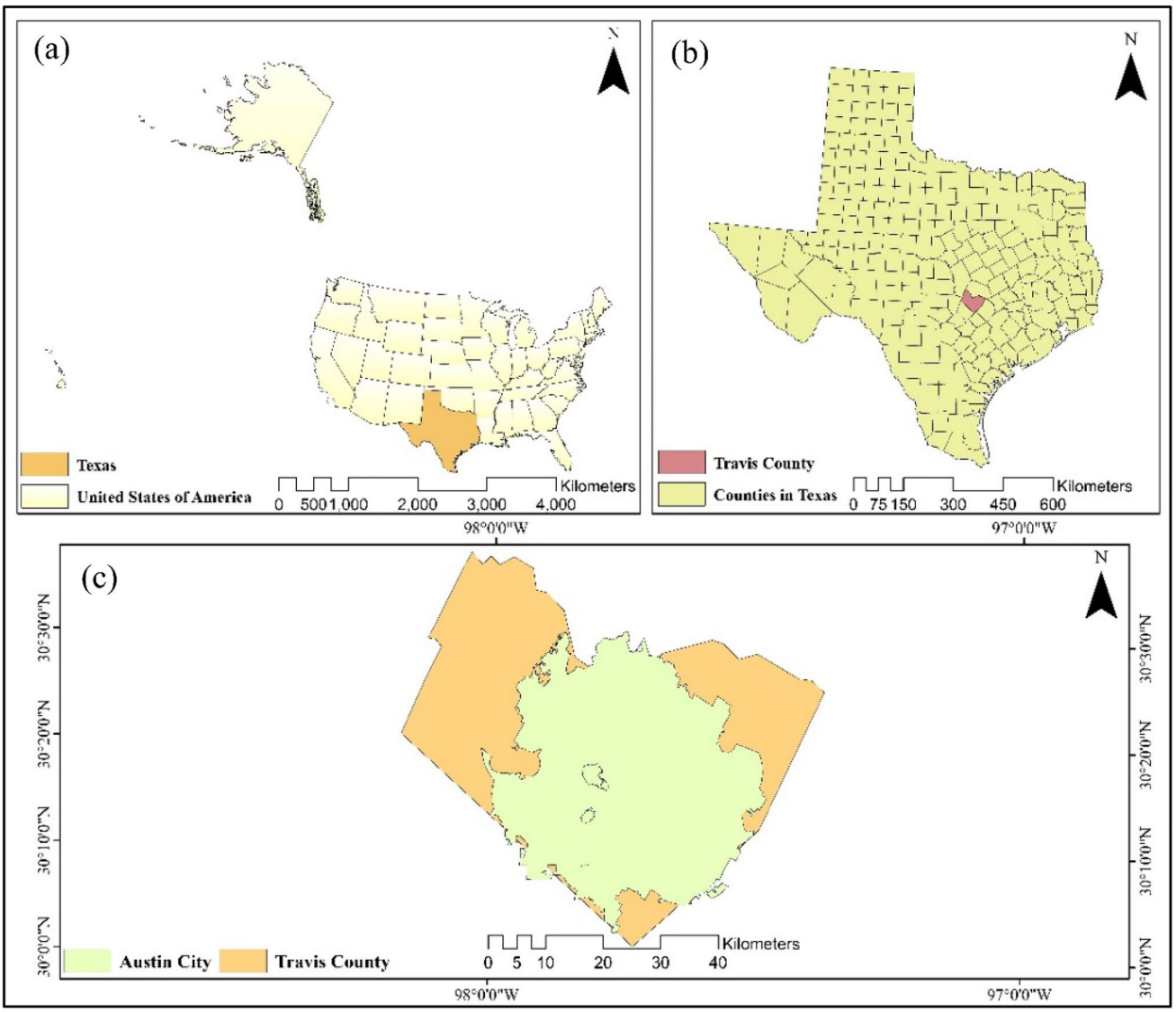


Fig. 1 The study area's geolocation map. **a** The location of Texas in the United States of America, **b** Location of Travis County in Texas, **c** Location of the city of Austin in Travis County

Regular sets were first introduced as crisp sets in classical set theory. It is one of the most original and important ideas in fuzzy logic since the addition of a defined adjective actually distinguishes between two things. The "membership function" is a simple name for this idea. A function in mathematics is defined as Eq. 1 the collection of all function outputs; in crisp sets, there are only two values in the range of the membership function, which are the same two potential values.

$$\mu A(x)\{1 \text{ if } X \in A,\ 0 \text{ if } X \notin A \tag{1}$$

For the element x in the crisp setA, the membership function is shown above as μA(x).

For fuzzy sets, the range of the membership function, which is 0–1, is changed to closed intervals {0, 1}. As opposed to numbers, human or machine languages in words and sentences., linguistic factors include characterized as factors that have acceptable values. In fuzzy logic, Language-related factors (verbal or otherwise) are employed in the same way that numerical variables are calculated in mathematics. Linguistic variables are expressed based on linguistic values discovered in the expression set (words and expressions). The aspects of linguistic variables are linguistic terms. The degree of membership of μA(x) indicates how much of element x is a part of the fuzzy set. An element is completely outside of the set if its level of membership is zero, and If it equals one, it is completely within the set. As increasing intervals, the number represents the degree of membership if the degree of participation is between zero and one. No matter what methods employed for investigation, management, and designing, the trait of uncertainty manifests itself in many ways across all phenomena and fields. A new technology called fuzzy logic uses linguistic values and specialized expertise to create and model systems instead of relying on complex and advanced mathematics.

3.3 Average nearest neighbor index (ANNI)

ANNI is calculated by determining how far each use or service is from its closest neighbor within a given geographic area. The convergence and divergence at points between various sorts of usage are calculated using the index. It's doable to comprehend the pattern of dissemination by this study. This indicator estimates the average of the NN by first calculating the interval between the centers of each object and its nearest neighbor. Considering the dispersion of the researched phenomena is grouped if the calculated average interval is less as if average of the fictitious arbitrary distributed. The impacts are said to be evenly dispersed if the computed The mean interval is higher than the assumed random distribution's mean. To make sure the nearest neighbor index test is accurate, Test statistics using the Z-score may be used. The results of this test show how a typical interval to the nearest actual neighbor varies statistically. The general rule is that the accuracy of the NNI test result increases with increasing negative Z-score.

According to statistical calculations, the neighborhood's typical nearest neighbor is determined by Eq. 2 below:

$$\text{ANN} = \frac{\underline{D}_O}{\underline{E}_O}. \tag{2}$$

Equation 3 will be evaluated, where $\underline{D}_O$ is the average distance measured between the phenomena and its closest neighbors as follows:

$$\underline{D}_O = \frac{\sum_{i=1}^{n} d_i}{n}. \tag{3}$$

If the distribution of phenomena is random, then $\underline{E}_O$ in this equation represents average separation between event and its closest neighbors. It is written as Eq. 4:

$$\underline{E}_O = \frac{0.5}{\sqrt{\frac{n}{A}}}. \tag{4}$$

In the equation above, The total number of features is n, and the overall area of the study region is A, and d_i is the separation in between event under investigation and its nearest neighbor. Z_{ANN} score can alternatively be obtained using Eq. 5:

$$Z_{ANN} = \frac{\underline{D}_O - \underline{E}_O}{SE}. \tag{5}$$

SE also equals Eq. 6:

$$SE = \frac{0.26136}{\sqrt{\frac{n^2}{A}}}. \tag{6}$$

The *p* value for a particular distribution will be roughly represented by the area under the curve, which is bound by a statistical test.

4 Research design and data

Urban facilities data for 2018 was collected from the USGS website. The data was opened in GIS software and the area of study was selected; Austin urban facilities was targeted for this survey. Each facility type was selected. Each facility was clipped in GIS software. After adding legend, scale bar, and north arrow to each map, they were exported. The maps were analyzed to observe the distribution of public facilities. The Euclidean Distance and reclassify function were applied in Arc Map software. Fuzzy analysis of each of the indices

was performed by the Fuzzy Logic model. Nearest Neighbor Index model was used to detect the distribution of urban facilities. All of facilities GIS shape files, which are: Nursing Home, Airports, Cemetery, College, Concert Hall, Convention Centre, Entertainment, Health Centre, Athletics, Historical Site, Hospitals, Library, Marina, Pools, Post Office, Public Garden, Restrooms, Schools, Parks, and Recreation Centre (Table 1), with all indices that were used in Fuzzy Overlay were used to detect the spatial justice in Austin.

4.1 The efficiency of the model in spatial justice

We use the articles that have been used to test spatial fairness with this method to demonstrate the efficacy of this model for doing so:

Marcus Thériault employed fuzzy logic to define the location of city facilities with relation to the city center, as well as to expose the variations in between residences and other types of activity, access to urban facilities. Fuzzy logic, it can model complex nonlinear functions, is conceptually simple to understand. Fuzzy logic can be coupled with traditional control methods and based upon the expertise of specialists [45].

Fuzzy logic was employed by Duncan and colleague to comprehend how sociodemographic inequality affected the spatial distribution of an ecological study. To quantify spatial socio-economic disparity in South Africa, McLennan and colleague used spatial statistics, a standard methodology used by academics to interpret data for reliable results. Clustering, which they utilized to demonstrate spatial inequality, is one of the areas of spatial statistics that this method uses to identify inequality in citizens' lives. Brooks It claims that these fuzzy models provide exceptional results and allow for more precise identification of spatial patterns.

According to Bulti and colleague, closest neighbor analysis can provide spatial distributions a precise grouping pattern. According to Mullick and colleague, fuzzy logic applied to GIS can offer a more accurate depiction of spatial variety. GIS-based research has grown further in scope in order to address issues that were previously challenging. In order to establish a novel method for assessing the quality of urban services, Bostanc and Erdem employed a fuzzy model to look at how satisfied individuals were with urban services. They presented a technique using examples from the area, and they used an analysis of residents' happiness with the municipality to show results [6]. The Niranjan study, which employs a branch of spatial statistics called spatial autocorrelation, demonstrates that expanding access to and use of services at the spatial micro-level reduces spatial inequality and supports human development. In a similar vein [46] (Fig. 2).

5 Results

5.1 Distribution of the urban amenities

To show the spatial justice in the city of Austin, in the following maps we discuss the distribution and access to facilities and show the distribution of each of these facilities using diagrams (Fig. 3).

The results of the Nearest Neighbor Index show libraries'distribution pattern. The Nearest Neighbor ratio is 1.37 is favorable, in the z-score 3.33 is bigger than + 1.56, and *p*-amount is 0.00. The amounts show the distribution pattern of libraries is dispersed in Austin (a). The results of the Nearest Neighbor Index show hospitals' distribution pattern. The Nearest Neighbor ratio is 0.66, is favorable, in the z-score − 4.37, is lesser that − 1.56, and the *p*-amount is 0.00. These amounts show that the distribution pattern of hospitals is clustered in Austin (b).

The results of the Nearest Neighbor Index show nursing homes' distribution pattern. The Nearest Neighbor ratio is 0.87, is favorable, in the z-score − 1.43, is between − 1.56 to + 1.56′ and the *p*-amount is 0.15. The amounts show the distribution pattern of nursing homes is random in Austin. The results of the Nearest Neighbor Index show the airport's distribution pattern. The Nearest Neighbor ratio is 0.12, is favorable, in the z-score − 2.37, is lesser than − 1.56, and the *p*-amount is 0.01. The amounts show that the distribution pattern of the airport is clustered in Austin.

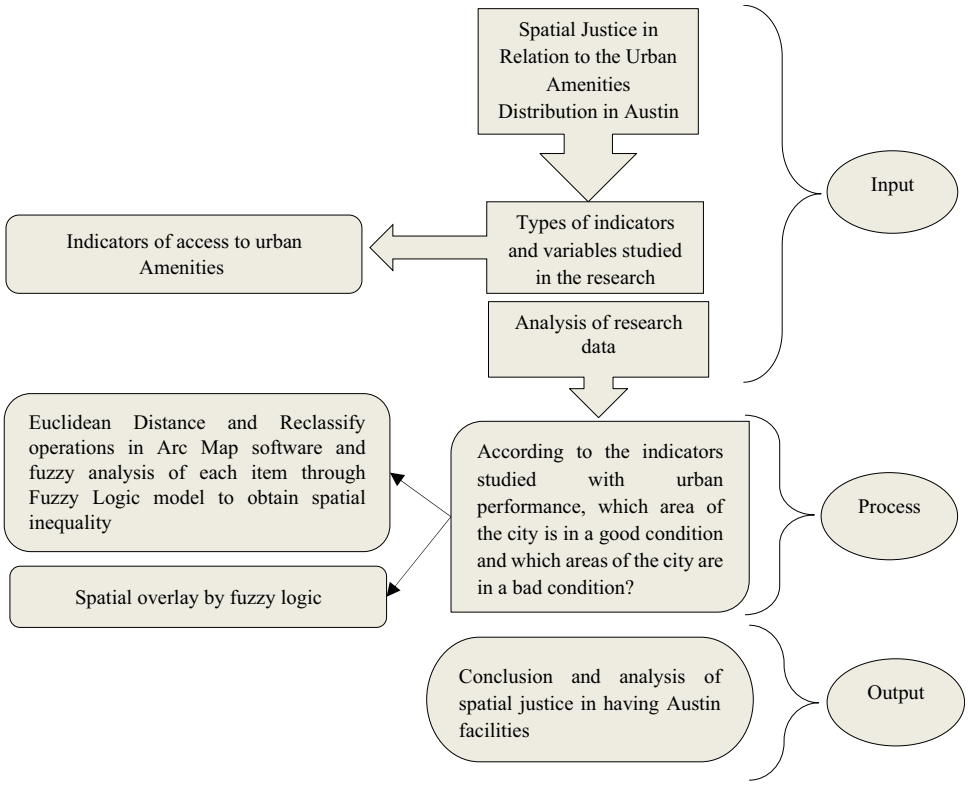
The results of Nearest Neighbor Index show the cemeteries' distribution pattern. The Nearest Neighbor ratio is 0.12, is favorable, in the z-score 2.60, is bigger than the + 1.56, and the *p*-amount is 0.00. These amounts show that the distribution pattern of cemeteries dispersed in Austin.

The results of the Nearest Neighbor Index show colleges' distribution pattern. The Nearest Neighbor ratio is 1.20, is favorable, in the z-score 1.71, is bigger than + 1.56, and the

Table 1 Indices used in analysis and investigation of spatial justice

N	20
Indices	Nursing Home, Airports, Cemetery, College, Concert Hall, Convention Centre, Entertainment, Health Centre, Athletics, Historical Site, Hospitals, Library, Marina, Pools, Post Office, Public Garden, Restrooms, Schools
References	[3, 4, 6, 10, 19, 31, 35–44]

Fig. 2 Research process



p-amount is 0.00. These amounts show that the distribution pattern of colleges is dispersed in Austin.

The results of the Nearest Neighbor Index show concert halls' distribution pattern. The Nearest Neighbor ratio is 1.75, is favorable, in the z-score 3.82, is bigger than + 1.56, and the *p*-amount is 0.00. These amounts show that the distribution pattern of concert halls in Austin.

The results of the Nearest Neighbor Index show convention centers' distribution pattern. The Nearest Neighbor ratio is 0.12, is favorable, in the z-score − 2.37, is lesser that − 1.56, and the *p*-amount is 0.00. These amounts show the distribution pattern of convention centers index is clustered in Austin (Fig. 4).

The results of the Nearest Neighbor Index show- athletics sites' distribution pattern. The Nearest Neighbor ratio is 1.60, is favorable, in the z-score 3.29, is bigger than + 1.56, and the *p*-amount is 0.00. These amounts show the distribution pattern of athletics is dispersed in Austin (a). The results of the Nearest Neighbor Index show recreation centers' distribution pattern. The Nearest Neighbor ratio is 1.96 is favorable, z-score is 2.02 is bigger than + 1.56, and *p*-amount is 0.04. The amounts show the distribution pattern of recreation centers is dispersed in Austin (b).

The results of the Nearest Neighbor Index show marinas' distribution pattern. The Nearest Neighbor ratio is 0.63 is favorable, z-score is − 3.05 is lesser that − 1.56, and *p*-amount is 0.00. The amounts show the distribution pattern of marinas—is clustered in Austin. The results of the Nearest Neighbor Index show pools' distribution pattern are random. The Nearest Neighbor ratio is 1.10 is favorable, z-score is 1.45 is between − 1.56 to + 1.56, and *p*-amount is 0.14. The amounts show the distribution pattern of pools is random in Austin. The results of the Nearest Neighbor Index show post offices' distribution pattern. The Nearest Neighbor ratio is 1.17 is favorable, z-score is 1.5 is between − 1.56 to + 1.56, and *p*-amount is 0.11. The amounts show the distribution pattern of post offices is random in Austin. The results of the Nearest Neighbor Index show public gardens' distribution pattern. The Nearest Neighbor ratio is 231.73 is favorable, z-score is 624.24 is bigger than + 1.56, and *p*-amount is 0.00. The amounts show the distribution pattern of public gardens is dispersed in Austin. The results of the Nearest Neighbor Index show restrooms' distribution pattern. The Nearest Neighbor ratio is 0.52 is favorable, z-score is − 10.16 is lesser that − 1.56, and *p*-amount is 0.00. The amounts show the distribution pattern of restrooms is dispersed in Austin. The results of the Nearest Neighbor Index show schools' distribution pattern. The Nearest Neighbor ratio is 0.85 is favorable, z-score is − 4.01 is lesser that − 1.56, and *p*-amount is 0.00. The amounts show the distribution pattern of schools is clustered in Austin.

The results of the Nearest Neighbor Index show parks' distribution pattern. The Nearest Neighbor ratio is 0.78 is favorable, z-score is − 6.45 is lesser that − 1.56, and *p*-amount is 0.00. The amounts show the distribution pattern of parks is clustered in Austin. The results of the Nearest

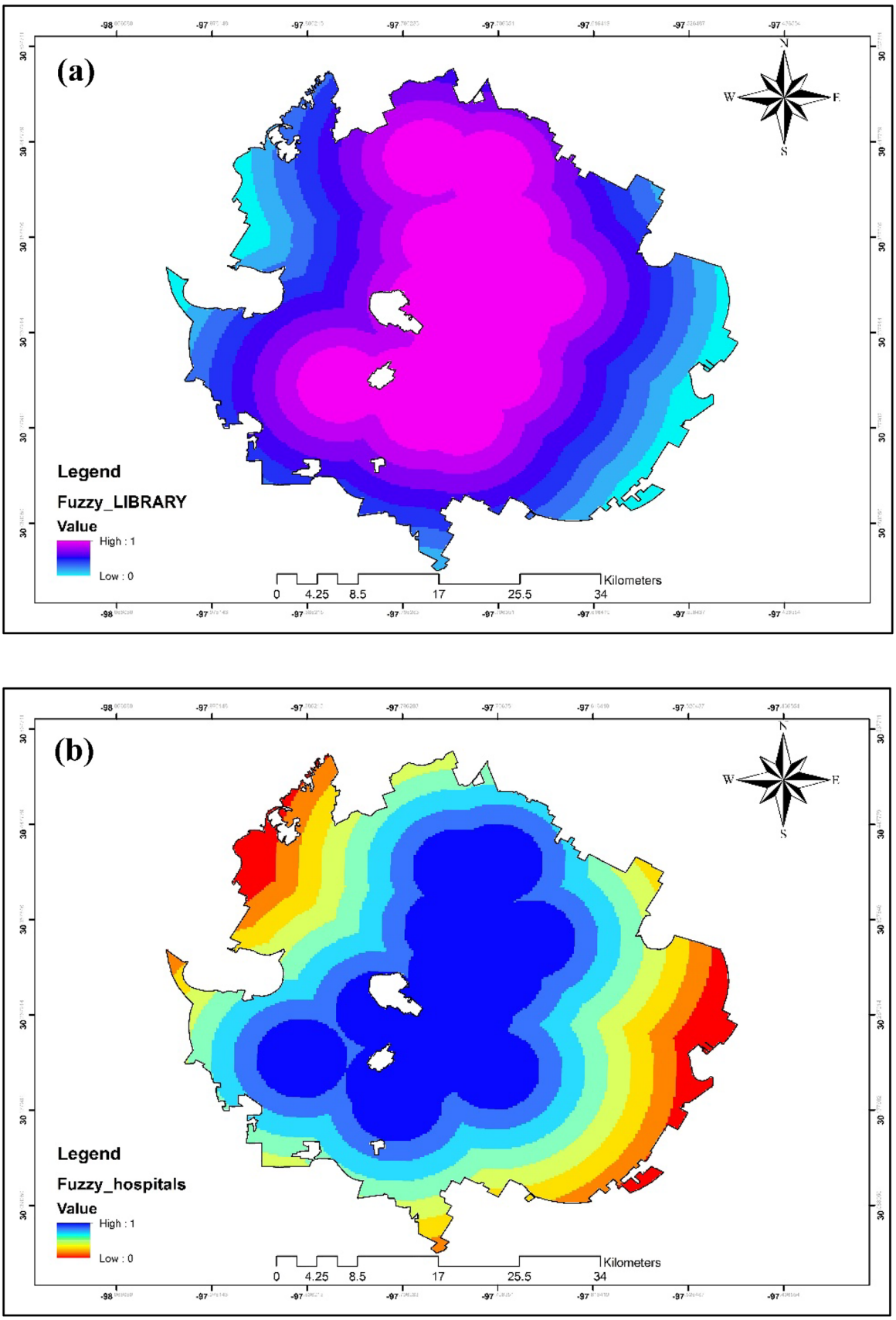


Fig. 3 Spatial analysis maps (fuzzy logic) access to Urban Facilities. **a** LIBRARY, **b** Hospitals

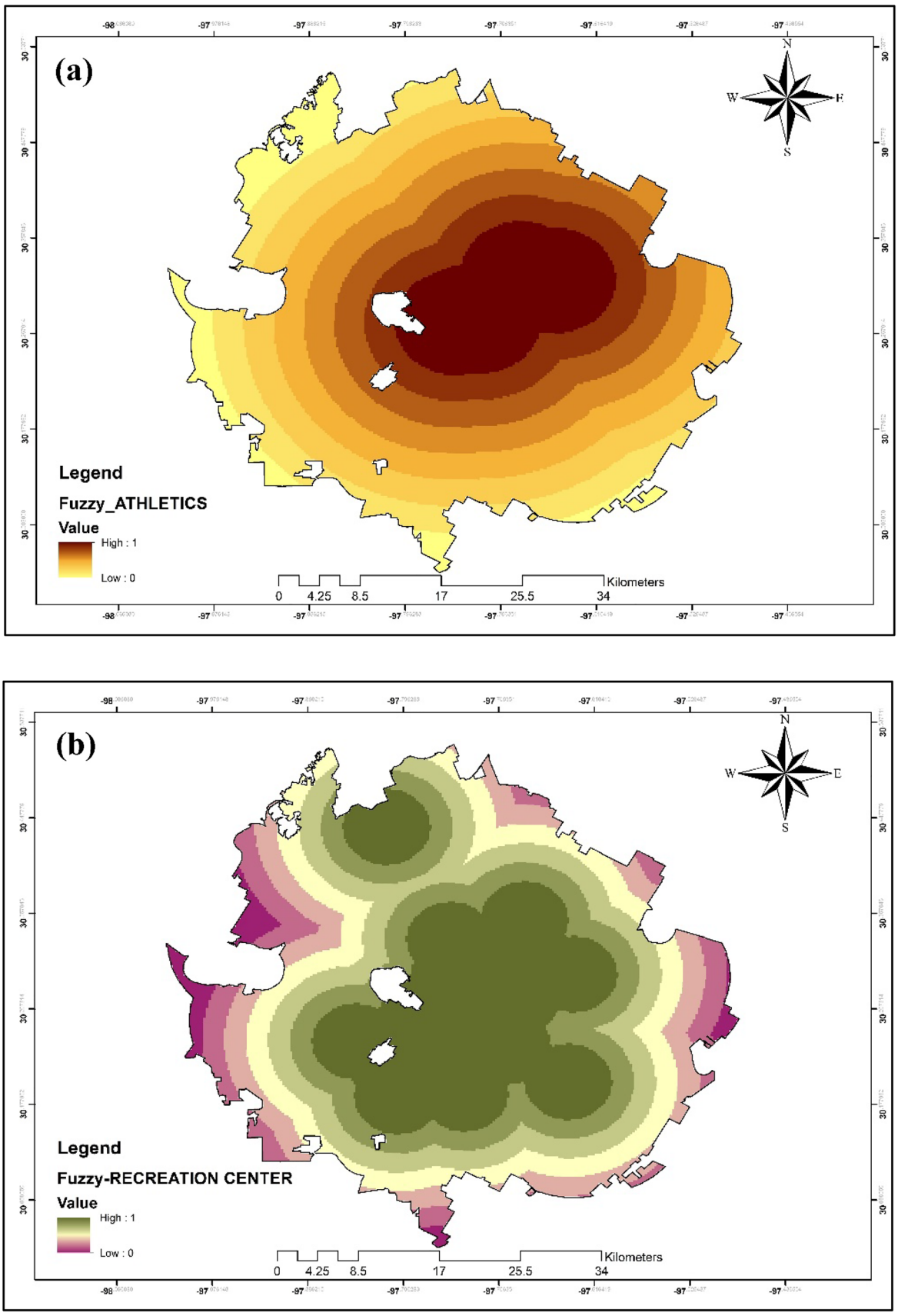


Fig. 4 Spatial analysis maps (fuzzy logic) access to Urban Facilities. **a** Athletics, **b** RECREATION CENTER

Neighbor Index show entertainment centers' distribution pattern. The Nearest Neighbor ratio is 1.95, is favorable, in the z-score 4.48, is bigger than + 1.56, and the *p*-amount is 0.00. These amounts show the distribution pattern of entertainments is dispersed in Austin. The results of the Nearest Neighbor Index show health centers' distribution pattern. The Nearest Neighbor ratio is 0.89, is favorable, in the z-score − 0.99, is between − 1.56 to + 1.56, and the *p*-amount is 0.31. These amounts show the distribution pattern of health centers is random in Austin. The results of Nearest Neighbor Index show historical sites' distribution pattern. The Nearest Neighbor ratio is 3.21, is favorable, in the z-score 8.47, is bigger than + 1.56, and the *p*-amount is 0.00. These amounts show that the distribution pattern of historical sites is dispersed in Austin.

5.2 Integrating layers with fuzzy overlay

Given the extensive Arc GIS software's skills in fuzzy mapping challenge, fuzzy amenities were employed to execute integration of ambiguous data and inter-urban operations for spatial inequality analysis. The constraint map and criteria map are now combined using the fuzzy overlay option the relevant weights are used as standard weights. Final map is what emerges from this integration. Finally, Fig. 5 showed the monitoring of urban spatial inequities from the amenities.

6 Conclusion

To foster more equal and just societies and to advance the full realization of human potential, spatial justice is essential. We must work for sustainable governance, equitable resource redistribution, and the equitable distribution of and access to spatial benefits and opportunities in order to accomplish spatial justice. A fair distribution of resources and facilities in space among various city regions, as well as their accessibility, are key components of the geographic perspective on social justice in cities. This is due of the disparate distribution inevitably causes societal crises and difficult spatial problems. Therefore, analytical knowledge of the current situation is necessary for deliberate urban management intervention in the spatial distribution of social interest to lessen spatial inequality and enhance quality of life, and by enhancing quality of life and achieving urban sustainability. The results show Spatial Justice and Urban Welfare are in good condition in Austin. Most public facilities are distributed properly. Residents have convenient access to most facilities in the city. Nursing homes, health centers, pools,

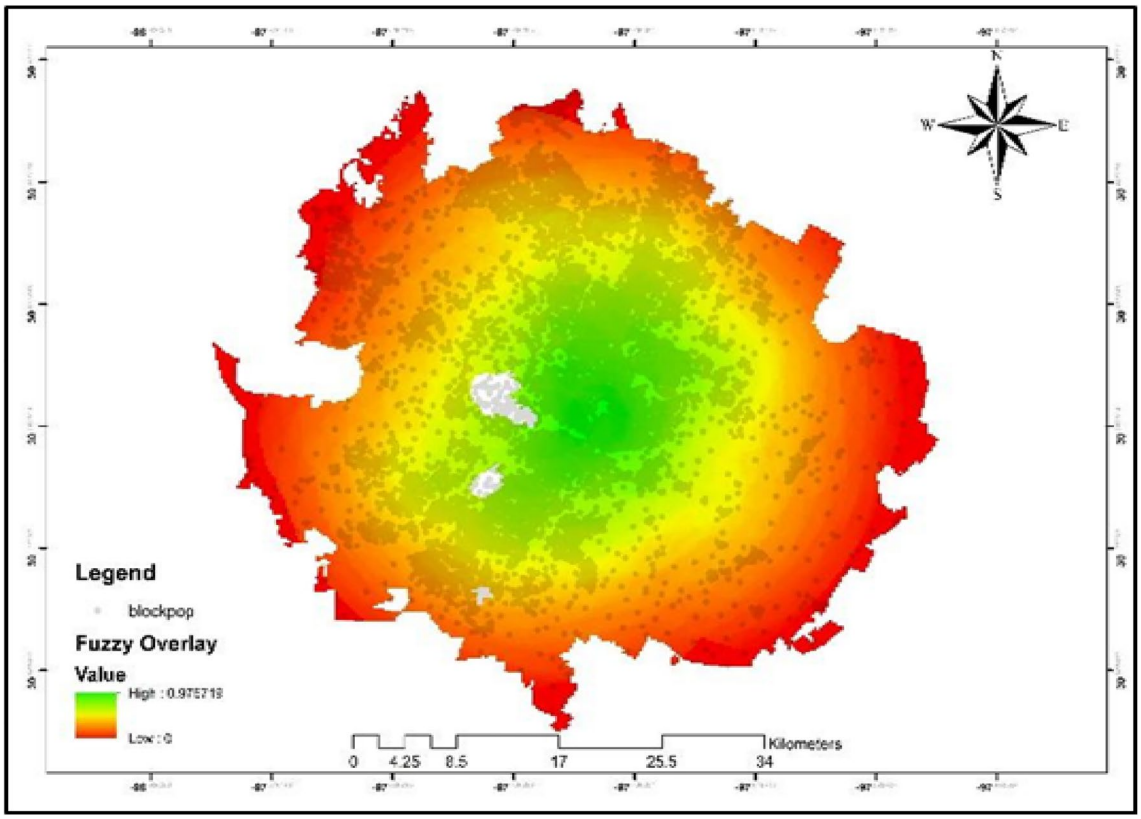


Fig. 5 Fuzzy spatial mapping for all facilities and population

and post offices distribution patterns are random. They are distributed according to population density. The airports, recreation centers, hospital, parks, schools, and marinas, distribution patterns are clustered. These facilities are provided according to the citizens' needs. The airport is located at the center of the city. The population is denser at the center of the city. Therefore, it seems the airport is located in the right place. Colleges, concert halls, cemeteries, entertainment centers, athletics centers, historical sites centers, libraries centers, public gardens centers, and restrooms centers, distribution patterns are dispersed. These facilities are created according to the population's needs. Where the population is denser, there are more of these facilities. The result shows that the facilities are distributed properly. Spatial justice is in effect in Austin and the residents enjoy its benefits.

Author contributions FH made contributions to the gathering of data, its analysis, and its writing. EF helped with data analysis and producing the manuscript. The model's analysis and application were guided by the AP and ST, who also oversaw the piece.

Funding The authors declare that they have no funding source.

Data availability The data will be available on request to the corresponding author.

Software availability Software program (ArcGIS software) to draw the map and Euclid distance model and fuzzy logistics are used to analyze the amount of spatial distribution.

Declarations

Conflict of interest Each author attests that they are not associated with or actively involved in any group or entity that has a financial or non-financial stake in the topics or resources discussed in this article.

References

1. Marcuse, P., Connolly, J., Novy, J., Olivo, I., Potter, C., & Steil, J. (2009). *Searching for the just city: Debates in urban theory and practice*. Routledge.
2. Nikšič, M., & Sezer, C. (2017). Public space and urban justice. *Built Environment, 43*(2), 165–172.
3. Dufaux, F., Gervais-Lambony, P., Lehman-Frisch, S., & Moreau, S. (2009). Birth announcement. *Justice Spatial/Spatial Justice, 1*, 1–2.
4. Soja, E. W. (2009). The city and spatial justice. *Justice Spatiale/Spatial Justice, 1*(1), 1–5.
5. Meyer, N., & Auriacombe, C. (2019). Good urban governance and city resilience: An afrocentric approach to sustainable development. *Sustainability, 11*(19), 5514. https://doi.org/10.3390/su11195514
6. Hosseini, A., Farhadi, E., Hussaini, F., Pourahmad, A., & Seraj, N. (2022). Analysis of spatial (in)equality of urban facilities in Tehran: An integration of spatial accessibility. *Environment, Development and Sustainability, 24*(5), 6527–6555. https://doi.org/10.1007/s10668-021-01715-3
7. Dikeç, M. (2001). Justice and the spatial imagination. *Environment and Planning A, 33*(10), 1785–1805. https://doi.org/10.1068/a3467
8. Soja, E. W. (2013). *Seeking spatial justice* (Vol. 16). University of Minnesota Press.
9. Philippopoulos-Mihalopoulos, A. (2014). *Spatial justice: Body, lawscape, atmosphere*. Routledge.
10. Harvey, D., Merry, A. H., Royle, L., Campbell, M. P., & Rudd, P. M. (1996). *Justice, nature & the geography of difference*. Wiley-Blackwell.
11. Hosseini, A., Pourahmad, A., & Pajoohan, M. (2015). Assessment of institutions in sustainable urban-management effects on sustainable development of Tehran: Learning from a developing country. *Journal of Urban Planning and Development, 142*(2), 05015009.
12. Marcuse, P. (2009). Spatial justice: Derivative but causal of social injustice. *Spatial Justice, 1*(4), 1–6.
13. Farahani, R. Z., Fallah, S., Ruiz, R., Hosseini, S., & Asgari, N. (2019). OR models in urban service facility location: A critical review of applications and future developments. *European Journal of Operational Research, 276*(1), 1–27.
14. Altschuler, A., Somkin, C. P., & Adler, N. E. (2004). Local services and amenities, neighborhood social capital, and health. *Social science & medicine, 59*(6), 1219–1229.
15. Steg, L., & Gifford, R. (2005). Sustainable transportation and quality of life. *Journal of Transport Geography, 13*(1), 59–69.
16. Rahman, M. H., Ashik, F. R., & Mouli, M. J. (2022). Investigating spatial accessibility to urban facility outcome of transit-oriented development in Dhaka. *Transportation Research Interdisciplinary Perspectives, 14*, 100607.
17. Saez, E., & Zucman, G. (2016). Wealth inequality in the United States since 1913: Evidence from capitalized income tax data. *The Quarterly Journal of Economics, 131*(2), 519–578.
18. Alvaredo, F. (2018). World inequality report 2018. In *World Inequality Report 2018*. Harvard University Press.
19. Hewko, J., Smoyer-Tomic, K. E., & Hodgson, M. J. (2002). Measuring neighbourhood spatial accessibility to urban amenities: Does aggregation error matter? *Environment and Planning A, 34*(7), 1185–1206. https://doi.org/10.1068/a34171
20. Mattila, H. (2002). Aesthetic justice and urban planning: Who ought to have the right to design cities? *GeoJournal, 58*(2–3), 131–138. https://doi.org/10.1023/B:GEJO.0000010832.88129.cc
21. Martínez, J. (2009). The use of GIS and indicators to monitor intra-urban inequalities. A case study in Rosario, Argentina. *Habitat International, 33*(4), 387–396. https://doi.org/10.1016/j.habitatint.2008.12.003
22. Méndez, M. L., & Otero, G. (2018). Neighbourhood conflicts, socio-spatial inequalities, and residential stigmatisation in Santiago, Chile. *Cities, 74*, 75–82. https://doi.org/10.1016/j.cities.2017.11.005
23. Shi, Q., & Dorling, D. (2020). Growing socio-spatial inequality in neo-liberal times? Comparing Beijing and London. *Applied Geography, 115*, 102139. https://doi.org/10.1016/j.apgeog.2019.102139
24. González, R. C. L. (2019). Urban justice. In A. M. Orum (Ed.), *The Wiley Blackwell encyclopedia of urban and regional studies.* Wiley-Blackwell. https://doi.org/10.1002/9781118568446.eurs0373
25. Cho, C. M. (2003). Study on effects of resident-perceived neighborhood boundaries on public services accessibility & its relation to utilization: using Geographic Information System, focusing on the case of public parks in Austin, Texas. Doctoral dissertation, Texas A&M University.

26. Richardson, H. W. (1979). Aggregate efficiency and interregional equity. In H. Folmer & J. Oosterhaven (Eds.), *Spatial inequalities and regional development*. Springer. https://doi.org/10.1007/978-94-017-3046-4_7
27. Dupont, V. (2017). Do geographical agglomeration, growth and equity conflict? *Papers Regional Science, 86*(2), 193–213. https://doi.org/10.1111/j.1435-5957.2007.00118.x
28. Grabb, G. (1997). *Theories of social inequality—Classical and contemporary perspectives* (3rd ed.). Harcourt Canada.
29. Susan, S., & F. (2014). The just city. *International Journal of Urban Sciences, 18*(1), 1–18. https://doi.org/10.1080/12265934.2013.834643
30. Nygren, A. (2018). Inequality and interconnectivity: Urban spaces of justice in Mexico. *Geoforum, 89*, 145–154. https://doi.org/10.1016/j.geoforum.2017.06.015
31. Harvey, D. (2010). *Social justice and the city* (Vol. 1). University of Georgia Press.
32. Tsou, K. W., Hung, Y. T., & Chang, Y. L. (2005). An accessibility-based integrated measure of relative spatial equity in urban public facilities. *Cities, 22*(6), 424–435. https://doi.org/10.1016/j.cities.2005.07.004
33. James, A. (2017). *Constructing justice for existing practice: Rawls and the status quo John Rawls* (pp. 69–104). Routledge.
34. Van Pelt, M. (2008). *Fuzzy logic applied to daily life*. Seattle.
35. Safdari Molan A., & Farhadi, E. (2019). Spatial analysis of the proximity effects of land use planning on housing prices (case study: Tehran, Iran). In *International conference on computational science and its applications* (pp. 642–659). https://doi.org/10.1007/978-3-030-24302-9_46
36. dos Santos, R. S., Şahin Bülbül, M., & Isadora, L. L. (2019). School inequalities and urban welfare: Going beyond socioeconomic status with data science. *Acta Scientiae, Canoas, 21*(6), 2–27. https://doi.org/10.17648/acta.scientiae.5494
37. Conti, A., Moura, A. C. M., Martinez, G. A. T., Tondelli, S., & Patata, S. (2021). Applying geodesign in the City of Bologna (Italy): The case study of the Navile Region. In *International conference on innovation in urban and regional planning* (pp. 265–270). Springer.
38. Safdari Molan, A., Farhadi, E., Saganeiti, L., & Murgante, B. (2021). Border tourism development strategies in Kaleybar compared to regional rivals. *Sustainability, 13*(20), 11400. https://doi.org/10.3390/su132011400
39. Zanganeh Shahraki, S., Hosseini, A., Sauri, D., & Hussaini, F. (2020). Fringe more than context: Perceived quality of life in informal settlements in a developing country: The case of Kabul, Afghanistan. *Sustainable Cities and Society journal, 63*(12), 102494. https://doi.org/10.1016/j.scs.2020.102494
40. Greer, J. R. (2002). Equity in the spatial distribution of municipal services: How to operationalize the concepts and institutionalize a program, Doctoral dissertation, University of Texas at Dallas, USA.
41. Iveson, K. (2011). Social or spatial justice? Marcuse and Soja on the right to the city. *City, 15*(2), 250–259. https://doi.org/10.1080/13604813.2011.568723
42. Zanganeh Shahraki, S., Ahmadifard, N., Farhadikhah, H., Fotouhi Mehrabani, B., Haydari, A., Abdali, Y., Abbasi Fallah, V., Farhadi, E., Cividino, S., Vinci, S., & Salvati, L. (2020). Spatial planning, urban governance and the economic context: The case of 'Mehr' housing plan Iran. *Land, 9*(5), 1–13. https://doi.org/10.3390/land9050169
43. Aqbelaghi, S. A., Ghorbani, M., Farhadi, E., & Shafiee, H. (2018). Environmental approach in modelling of urban growth: Tehran City, Iran. *Asian Journal of Water, Environment and Pollution, 15*(2), 47–56. https://doi.org/10.3233/AJW-180017
44. Vignoli, F., de Luca, C., & Tondelli, S. (2021). A spatial ecosystem services assessment to support decision and policy making: The case of the city of Bologna. *Sustainability, 13*(5), 2787.
45. Piroozfar, R. (2012). Fuzzy logic: A rule-based approach, in search of a justified decision-making process in urban planning. Doctoral Thesis, Technische Universität Berlin.
46. Wu, B., Yip, T. L., Xie, L., & Wang, Y. (2018). A fuzzy-MADM based approach for site selection of offshore wind farm in busy waterways in China. *Ocean Engineering, 168*, 121–132.