Capability Index: Applying a Fuzzy-Based Decision-Making Method to Evaluate Social Inclusion in Urban Areas Using the Capability Approach

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Abstract
There is rising interest in re-evaluating transport policy, moving away from analysing concrete economic indicators and towards examining the number of persons participating in activities as ‘social justice.’ So, using the Capacity Approach, this study presents an aggregated model to calculate the level of capability in two neighbourhoods in Tehran, Iran, involving variables from the ‘Individuals’ and ‘Environment’ dimensions. The computed factors were then weighted by the Fuzzy AHP technique based on the opinion of Iranian and international experts and combined to produce the final Capability Index (CI). CI results show that residents of the central business district, with an average of 0.628, had a 20% higher CI than residents of the city’s outskirts, with 0.483. Furthermore, CI values corroborate prior research results that individuals with higher income, education level, and work position, in addition to higher individual capacity, benefit from a better neighbourhood environment. Also, calculations show that the neighbourhoods are not environmentally accessible for people with disabilities, and this group is suffering from low external capability. Additionally, the model estimates different levels of CI to evaluate the current status and prioritize future urban projects, so the model can be helpful for policy-makers to investigate the capability dimensions separately and decide about future plans.

Keywords Capability approach · Social equity · Fuzzy logic · Urban transport policy · Tehran
1 Introduction

Fair allocation of resources and level of participation in valuable opportunities is a fundamental requirement in social inclusion for all population groups and moving toward a just city (Adli & Chowdhury, 2021; Kamruzzaman et al., 2016; Shortall, 2008; Vecchio & Martens, 2021). Hence, the increasing attention to this issue and the studies concerning the application of justice in transport planning as an enabler for reaching opportunities is promising. Although social equity is a multifaceted and context-sensitive concept, the transport planning literature has mostly considered accessibility as the key term for the evaluation of justice. Accessibility is defined and understood for reaching spatially distributed opportunities and encompasses the interactions of the transport system, land use system, and individuals’ characteristics (Azmoodeh et al., 2021; Cao & Hickman, 2019a; Hananel & Berechman, 2016; Martens, 2016; Nahmias-Biran et al., 2017; Oviedo & Guzman, 2020; Pereira et al., 2017; Ryan et al., 2015; Vecchio, 2020). Yet there are traditional objective approaches in transport-related social exclusion literature that evaluate justice/accessibility in terms of transport and land use system interactions and overlook individuals’ characteristics, experiences, and aspirations for taking part in activities (Vecchio & Martens, 2021). Thereby, although accessibility is mostly used to evaluate social equity, yet planning frameworks are somewhat incapable of involving the indicators such as income, age, sex, etc., that significantly affect freedom of choice (Mella Lira, 2019; Motieyan & Mesgari Mohammad, 2018), since ‘similar accessibility means different things to different people because the capability of people to utilize accessibility is different’ (Adli & Chowdhury, 2021). So, though it is clear that more attention is needed for the administration of social justice, there are ambiguities regarding its ethical principles, the basic factors, the desired level between groups, and its impact on transport planning and policy (Lucas et al., 2016; Pereira et al., 2017).

Based on the Rawls theory and criticism toward utilitarian approaches and the welfare economy that consider the distribution of welfare as the key to reaching justice, the Capability Approach (CA) was proposed by Amartya Sen and developed by Martha Nussbaum. The CA highlights the freedom of choice for people to achieve the opportunities they value to have a decent life, and it does not measure justice based on specific outcomes and achievements of individuals but on the extent to which people are able to participate in activities (freedom of choice) is the basis of justice (Nussbaum, 2003; Parey, 2020; Robeyns, 2005a, 2005b; Sen, 1999). It argues that although individuals may not use their current capabilities, the freedom of choice and ability of each individual to participate in activities is valuable (Nahmias-Biran et al., 2017). Therefore, due to the fundamental arguments of CA for reaching wellbeing among people, a growing body of literature has been focused on translating key terms of CA in transport planning or employing it as the theoretical basis for evaluating social inclusion via different operational applications. This paper, also, builds its interpretation on adopting CA key terms in transport planning to propose a framework that serves as a measure to evaluate the capability among different areas and groups.

The paper is structured as follows. Section 2 reviews the literature of transport-related CA studies, focusing on the methodology of empirical studies in the field. Section 3 briefly defines the key terms of CA to clarify objectives and contributions that are addressed in Sect. 4. Section 5 provides the methodology framework, case study, and data collection. Section 6 provides results, and the discussion according to environmental or individuals’
differences has been mentioned in Sect. 7. Finally, the paper is ended with a conclusion section (Sect. 8).

2 Literature Review

Exploring transport-related social justice shows literature has been extensively focused on understanding ethical principles to apply in planning (Azmoodeh et al., 2022; Banister, 2018; Cao & Hickman, 2019a, 2019b; Di Ciommo & Shiftan, 2017; Litman, 2019; Lucas et al., 2019; Martens, 2016; Pereira et al., 2017), among them, there have been recent attempts to translate and employ CA in transport policy-making. Though it may still be problematic to utilize CA in different societies/contexts (Cao & Hickman, 2019a; Sen, 1999), studies have opened the way to build a planning framework on CA implications to understand how the transport system would grant individuals the equity and freedom to choose between alternatives based on their expectations.

As (Cao & Hickman, 2019b) have also mentioned, studies could be divided into theoretical and empirical categories. Theoretical literature has been focused on the definition of justice in transport and brought out the CA as an ingenious approach in transport planning through comparison with other justice theories and ethical principles (Beyazit, 2011; Pereira et al., 2017). Besides, regarding the conceptualization of ‘capability’ in the context of mobility and movement, capability literature can be mainly classified into mobility-as-capability and accessibility-as-capability strands (Vecchio & Martens, 2021). The former translates capability as a person’s physical, financial and social ability to be mobile and interact with society, which makes mobility a prerequisite for other capabilities (Beyazit, 2011; Vecchio & Martens, 2021). However, this interpretation is criticized as it overlooks the extent that just being mobile may not be sufficient for individuals to meet their needs. The latter, which also is the focus of this paper, considers the capability as accessibility since accessibility focuses on both person’s abilities to move through space and participate in opportunities distributed around her (Vecchio, 2020).

Further, capability-as-accessibility literature can be categorized into (1) top-down and (2) bottom-up (Vecchio & Martens, 2021); which former refers to an accessibility-measure analysis of the extent that transport and land use systems make people able to reach valued activities, and the latter indicates assessments of a person’s perceived accessibility to opportunities and examine how mobility options may enhance or impede one’s participation in activities, especially for disadvantaged groups. For example, (Martens, 2016) provides an accessibility measure that is able to evaluate the overall level of access to opportunities via regions’ public and private transportation systems, conducted in Rotterdam-The Hague, within given thresholds. (Nahmias-Biran et al., 2017) have proposed a CA-based measure that considers accessibility disadvantage as injustice in participation in activities for individuals, and also evaluates transport projects against cost–benefit approaches. In 2019, they also used activity-based models to estimate destination and mode choices in different transport development scenarios and designed a model called ‘Value of Capability Gains’ that considered both efficiency and justice implications in a cost–benefit analysis (Nahmias-Biran & Shiftan, 2019). The answer of these types of studies for the sufficient level of capability, as one of the main challenges in the capability literature (Pereira et al., 2017), is the minimum threshold of accessibility.

Besides, (Ryan et al., 2015) assess the impact of public transportation as a means of traveling among the young community of Stockholm. (Hickman et al., 2017) studied 11 low
and high-income neighbourhoods in Manila, Philippines, to find out about people’s ability to achieve what they need and how they actually travel. Also, By considering Capability and Functioning as individuals’ opportunities for activity participation and actual daily participation in outdoor activities, (Cao & Hickman, 2019b) have conducted survey-based research in London to reveal noticeable Capability and Functioning differences in socio-demographic groups and geographical areas. (Cao & Hickman, 2019a) has also investigated the differences in Capabilities and Functioning in Beijing using Martha Nussbaum’s Basic Capabilities notion as the research framework. So, these studies have generally focused on the effect of transport system on the experience and perception of accessibility by people.

In conclusion, top-down approaches offer more aggregate, environment-dependent results regarding measuring accessibility, while the bottom-up method gives more complete interpretations of an individual’s preferences of valued activities or the way external conditions encourage or impede her to participate in opportunities. Also, approaches are different in required data, as bottom-up studies are survey-based studies and require the data for individuals’ achieved access as functioning. So, since the current paper claims to offer a framework that belongs to the first approach, before drawing up the scheme of this study and providing its contribution to the current literature, it is necessary to briefly review the key concepts of CA and their translation in transport planning. Therefore, Sect. 3 completes the connection between the current approaches in the literature review with CA concepts, besides defining the prerequisite concepts for the current study’s framework.

### 3 Capability Approach: Key Concepts

The CA generally emphasizes human dignity, equal respect for all, and guaranteeing a bare minimum level of needs in society. It takes notions like Resources, Conversion Factor, Capability, Choices, and Functioning into consideration as its key terms for addressing one’s freedom of choice (Fig. 1) (Beyazit, 2011; Pereira et al., 2017; Robeyns, 2005a, 2005b):

- **Resources**: Resources are market and non-market productions and services available to a person, which this availability is related to the individual’s contextual and social

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**Fig. 1** Person’s capability set in her social and personal context (Robeyns, 2005a, 2005b)
features and shapes her possibility of access to opportunities. Some scholars limit resources as environmental features such as transport and land use system (Vecchio & Martens, 2021), while others think of income, wealth, etc. as resources, too (Beyazit, 2011; Robeyns, 2017).

- **Conversion factor**: Conversion factors are individuals’ characteristics and contextual structure (social and environmental) that determine the degree to which people are able to transform resources into capabilities (De Rosa, 2018). For instance, in the case of using mobility resources: level of income, physical ability, skills, knowledge of transport options, etc., can be understood as conversion factors. Furthermore, some overlaps can be seen in describing resources and conversion factors, and ‘there is no a priori distinction’ between them (Vecchio & Martens, 2021). For example, income could be considered as both resource, that gives a person the possibility to achieve her goals and a conversion factor that enables people to make use of objective resources, such as paying for different transport modes or parking lots. In addition, some measurable external conditions may affect internal capabilities or conversion factors; for example, feeling safe (conversion factor) to move from one place to another is meaningfully correlated with transport system (e.g., safety of the vehicle), and living environment factors (e.g., level of crime or crashes in the neighbourhood), so the whole set would influence on the experience of residents and thus gradually reduce/increase the willingness for walking, cycling or using transport system, either private or public mode (Fakhrahmad et al., 2022).

- **Capabilities**: Except for some differences in conceptions of CA provided by Sen and Nussbaum (Lessmann, 2007), they generally concur that capability is a set of freedoms and opportunities available to an individual that can choose or act upon, which ‘… is a combination of personal abilities and political, social and economic environment’ (Nussbaum, 2011; Sen, 1979). This interaction between internal capabilities and the external environment is what Nussbaum refers to as ‘combined capabilities’ (Nussbaum, 2011). The capability is the freedom to do or to be what a person values doing or being, and is shaped by translating resources through conversion factors. So, ‘accessibility as a capability is the degree to which persons have the possibility to move and access the available opportunities that they have reason to value’ (Vecchio & Martens, 2021). In synthesis, understanding accessibility as a combined capability would bring three main challenges (Pereira et al., 2017). First, individuals and environment interactions, which include a person’s characteristics (e.g., physical and mental fitness, affordability to use transport technologies, etc.) and the environment’s social and physical factors that provide her freedom. Second, physical environment interaction, namely transport and land use system, indicates the extent to which the transport system performance and land use distribution pattern enhance the person’s ability to achieve her desired opportunities. Finally, determining a basic threshold accessibility/capability that accounts for a level of freedom that gives people access to a set of essential opportunities to live decently.

- **Choices**: Choices are decisions made by people that are composed of personal history and psychology that prefer a doing or being over another (Robeyns, 2005a, 2005b).

- **Functioning**: CA considers the concept of Functioning to what a person ends up doing or being in order to survive. So, in comparison with capabilities that show ‘beings’ or ‘doings’ available to a person, functionings are actual ‘being’ or ‘doings’, or achieved goals.
4 Objectives and Contribution

This paper will make its contribution to the literature by addressing two principal research purposes. First of all, this paper explicitly focuses on analysing capabilities by proposing a top-down approach that measures the level of capability. The conceptual framework assumes that since there are some similar factors between resources and conversion factors (see Sect. 3), despite top-down literature that makes a distinction between resources and conversion factors, these parameters could be analysed aggregately. Therefore the proposed model makes no clear distinction between resources and conversion factors, and the variables have been classified into two general ‘Individual’ and ‘Environment’ dimensions. The framework has also gone beyond evaluating hypothetical scenarios and measures the level of capability, Capability Index (CI), in two neighbourhoods of Tehran, Iran using a Fuzzy AHP method to weight individual and environmental characteristics based on experts’ opinions. A Fuzzy logic-based method, which has not been previously employed in the capability approach literature related to urban transport planning, is applied to capture the imprecisions in experts’ judgments in applying CA and investigating the context-sensitivity in social-related urban decisions, as well.

In addition, the CA is primarily concerned with reaching a basic level of capability to opportunities for people to guarantee a level of freedom to do valued things. So, by calculating CI in the case studies, the model defines different thresholds of capability (CI) and outlines the capability range of each neighbourhood/population, which could be useful for evaluating transport-land use system conditions.

In synthesis, although the measure cannot be considered as a bottom-up approach, in addition to analysing each individual’s accessibility regarding the distribution of transport facilities and opportunities (resources/external conditions), the measure somewhat considers the internal characteristics of individuals (conversion factors/internal capabilities).

5 Methodology

As mentioned before, it is difficult to clearly separate resources and conversion factors to some extent (see Sect. 3, Conversion factors). Therefore, by focusing on combining affective factors in shaping capability set, this study intends to aggregate a person’s internal and external available features and provide her CI. Thus, the weights of variables have been captured through conducting a pairwise comparison among experts, separately for each major criterion. Finally, by employing a linear weighting combination method, the values of criteria would be aggregated to calculate the CI of neighbourhoods and individuals. The results are then provided according to individual and environmental differences across study areas and determine the strengths of the model in addressing the capability threshold.

5.1 Case Study and Data

Tehran, the capital of Iran, with an area of 751 square kilometers, owns a population of 8.7 million (2016); that is the most populated city in Iran and 13th among the most populated capitals in the world. Studies have shown that over the last four decades, Tehran has undergone the highest level of urbanization in Iran (91.34%), such that this rapid, unsustainable growth has led to an imbalance and inequality, especially in peripheral areas. As a result of
rapid population growth and the flow of migrants from rural areas to cities searching for jobs, one-third of the urban population resides in marginal areas and struggles with poor accessibility to opportunities (Pilehvar, 2021). Moreover, raising a mostly unemployed community without affluent income and higher education, which is experiencing poverty in accessibility to valued activities, exacerbates the social equity and quality of life status through marginal residents.

In order to address the capabilities of different geographical areas and individuals’ characteristics, this study focuses on two neighbourhoods, one in the central district of the city (Neighbourhood (1)) and the other in the urban fringe area (Neighbourhood (2)). This choice primarily concerns the condition of persons’ living area based on transport and land use system; besides, it considers the variations in people’s socio-economic characteristics since there are notable differences in income and employment status between the two contexts. Figure 2 shows the 1-km radius catchment area (equal to 15-min walk distance) around the centre of each neighbourhood as a geographical anchor for people living in the neighbourhood. Although the results of surveys show a higher willingness to walk among citizens (approximately 20 min), a 1 km radius is defined as an accepted standard.

Primary and secondary data were collected for this study. Primary data were collected through two-phase surveys among experts and residents. The survey among experts conducted in three steps consists of reciprocal comparisons of variables, sub-variables, and variable ranges using AHP Fuzzy (see Sect. 5.3.2). Also, the data of 276 persons living in mentioned neighbourhoods were selected from a face-to-face and then online survey (due to the start of the COVID-19 pandemic), conducted with 2136 residents across all
neighbourhoods of Tehran to capture their demographic and socio-economic status. Each survey lasted approximately 10 min and was rated as ‘understandable’ on average.

Secondary Data comprises Geographic Information System shapefiles showing the distribution of land uses, transport system features through space, and urban living environment attributes, such as pollution and crash rate in the neighbourhood.

### 5.2 Variables

(Lucas et al., 2019) mention mobility/accessibility, traffic-related pollution; traffic safety; and health as the key dimensions for assessing equity in transport and defining focal variables, possible measures, operationalization, and disaggregation for each variable. In this study, the variables are divided into two ‘Individual’ and ‘Environment’ dimensions to address the capability level of a person who lives in a certain area.

- **Dim. 1—Individual**: that provides individuals’ characteristics for internal features, and
- **Dim. 2—Environment**: consists of
  
  a) **Living Environment**: that comprises land use system, exposure to pollution, and traffic safety variables, and
  
  b) **Transport & Mobility**: that includes variables of mobility/accessibility such as public transport quality, road network coverage and access, along with walkability and bikeability in the living environment.

Table 1 shows dimensions, variables’ categorization, and the definition of the framework’s indicators either in neighbourhood scale or 1-km network service area.

Some variables that are proposed by this study will be calculated, as follows:

- **Public Transport Coverage (E_PT):**

  \[
  E_{\text{PT}} = \sum_{i=1}^{3} \left( \frac{w_i \times SA_i}{SA} \right)
  \]

  where:

  - \(i = \text{Public transport mode for travel (metro, bus, BRT)}\)
  - \(SA = \text{1-km service area (km}^2\))
  - \(SA_j = \text{service area of mode } i \text{ (km}^2\)).
  - \(w_i = \text{weight of mode } i \text{ (see Table 2).}\)

- **Catchment Area Population Density (E_CA):**

  \[
  E_{\text{CA}} = \left[ \sum_{i,j} \left( \frac{w_i \times a_{i,j}}{SA_i} \right) \right]
  \]

  where:

  - \(a_{i,j} = \text{shared area of mode } i \text{ with mode } j \text{ (km}^2\); } i, j = \text{metro, bus, BRT.}\)
  - \(SA_i = \text{service area of all mode } i \text{ stations (km}^2\)).
  - \(w_i = \text{weight of mode } i \text{ (Table 2).}\)
### Table 1 Description of variables

| Dim        | Category                          | Variable             | Indicator | Definition                                                                 |
|------------|-----------------------------------|----------------------|-----------|-----------------------------------------------------------------------------|
| Individual | Individual’s characteristics      | Age                  | I_AG      | Age                                                                           |
|            |                                   | Gender               | I_G       | Gender                                                                       |
|            |                                   | Income               | I_IN      | Income                                                                       |
|            |                                   | Car ownership        | I_CO      | Car ownership                                                                |
|            |                                   | Employment           | I_EM      | Employment                                                                   |
|            |                                   | Education            | I_ED      | Education                                                                    |
|            |                                   | Disability           | I_D       | Person’s mobility impairments                                               |
| Environment| Living environment                | Land use diversity   | E_LD      | Land use type mixed-use                                                     |
|            |                                   |                      |           | Land use type land use type lt Variety of ENLs*                             |
|            |                                   |                      |           | Land use type mixed-use mu Ratio of non-residential land uses to all land uses|
|            |                                   | Spatial DISTRIBUTION | E_SD      | LU DISTANCE                                                                  |
|            |                                   |                      |           | LU DISTANCE                                                                  |
|            |                                   |                      |           | LU DISTANCE                                                                  |
|            |                                   | Attractiveness       | E_A       | Attractiveness                                                               |
|            |                                   | Pollution            | E_P       | Pollution                                                                    |
|            |                                   |                      |           | Pollution                                                                    |
|            |                                   |                      |           | Pollution                                                                    |
|            |                                   | Crash rate           | E_CR      | Crash rate                                                                  |
|            | Public transport coverage**       | Transport and mobility| E_PT      | Public transport coverage                                                   |
|            |                                   |                      |           | Travel time reliability                                                     |
|            |                                   |                      |           | Ratio of Peak/off-peak travel time                                          |
|            |                                   |                      |           | Average price of using PT mode per kilometre                                |
|            |                                   |                      |           | Safety                                                                       |
|            |                                   |                      |           | Safety of mode based on average crash rate                                  |
|            |                                   |                      |           | Frequency                                                                    |
|            |                                   |                      |           | Average frequency of the PT mode                                            |
|            |                                   |                      |           | Average speed of the PT mode                                                |
|            |                                   |                      |           | Average capacity of the PT mode                                             |
| Dim                          | Category | Variable | Indicator | Definition                                                                                                                                 |
|-----------------------------|----------|----------|-----------|-------------------------------------------------------------------------------------------------------------------------------------------|
| Road Network                | E_RN     | Average circuitry | ac | Ratio of the shortest path network distance to the Euclidean distance between an origin and destination (OD) pair (Huang & Levinson, 2015) |
| Completeness                | c        |          |           | Level of completeness in the network using a link-node approach (Parthasarathi, 2014)                                                       |
| Catchment Area population density | E_CA     |          |           | Average level of congestion for stations of mode i                                                                                            |
| Integration                 | E_I      | To other modes | im | Number of modes that are linked to mode i                                                                                            |
|                             |          | To land uses | il | Variety of ENLs within mode i catchment area                                                                                                |
| Usability for disabled      | E_UD     | Slope    | ws        | If mode i is usable for people with mobility impairments                                                                                        |
| Walkability                 | E_W      | Slope    | ws        | Ratio of sidewalks slope percentage                                                                                                        |
|                             |          | Length   | wl        | Ratio of the length of all sidewalks to all of the network                                                                                   |
|                             |          | Alpha index | wa | Evaluates the number of cycles in comparison with the maximum number of cycles (Daniel et al., 2020)                                         |
| Bikeability                 | E_B      | Slope    | bs        | Ratio of bicycle lanes slope percentage                                                                                                    |
|                             |          | Maximum motorized speed | bm | Ratio of bicycle lanes with low maximum speed of motorized (Hartanto, 2017)                                                                 |
|                             |          | Alpha index | ba | Evaluates the number of cycles in comparison with the maximum number of cycles (Daniel et al., 2020)                                         |

*Essential Non-residential Land uses (ENL): Administrative, Educational, Commercial, Public Services, Healthcare, Green Space, Sports Facilities, and Cultural (Motieyan & Azmoodeh, 2021)

**Public Transport Coverage’ indicators have been used to weight Metro, BRT, and Bus as the city’s main active public transport modes
| Variable Name                              | Indicator Name | Weight | Variable/Indicator Range                      | Description | Range | Weighting |
|-------------------------------------------|----------------|--------|-----------------------------------------------|--------------|-------|-----------|
| **Individuals’ characteristics**         |                |        |                                               |              |       |           |
| Age                                       | –              | –      | 18–45                                        | H            | w     |           |
|                                           |                |        | 45–65                                        | M            | 1/2w  |           |
|                                           |                |        | > 65                                         | L            | 1/5w  |           |
| Gender                                    | –              | –      | Man                                          | H            | w     |           |
|                                           |                |        | Woman                                        | M            | 2/3w  |           |
| Income                                    | –              | –      | Deciles 9 & 10                               | H            | w     |           |
|                                           |                |        | Deciles 5–8                                  | M            | 1/3w  |           |
|                                           |                |        | Deciles 1–4                                  | L            | 1/7w  |           |
| Car ownership                              | –              | –      | Yes                                          | H            | w     |           |
|                                           |                |        | No                                           | L            | 1/5w  |           |
| Employment                                 | –              | –      | Full time                                    | H            | w     |           |
|                                           |                |        | Part-time                                    | M            | 1/2w  |           |
|                                           |                |        | Unemployed                                    | L            | 1/5w  |           |
| Education                                 | –              | –      | MSc or higher                                | H            | w     |           |
|                                           |                |        | Bachelor or equivalent                        | M            | 1/2w  |           |
|                                           |                |        | Undergraduate or lower                        | L            | 1/3w  |           |
| Disability                                 | –              | –      | No                                           | H            | w     |           |
|                                           |                |        | Yes                                          | L            | 1/9w  |           |
| Living environment                         |                |        |                                               |              |       |           |
| Land use diversity                         | Land use type  | 0.500  | 7/8–8/8                                       | H            | w     |           |
|                                           |                |        | 4/8–6/8                                       | M            | 1/2w  |           |
|                                           |                |        | 0/8–3/8                                       | L            | 1/3w  |           |
|                                           | Mixed-use      | 0.500  | 40–60%                                       | H            | w     |           |
|                                           |                |        | 30–40 or 60–70%                              | M            | 1/2w  |           |
|                                           |                |        | 0–30 or 70–100%                              | L            | 1/3w  |           |
| Land use spatial distribution              | LU distance    | 0.500  | 0–350 m                                      | H            | w     |           |
|                                           |                |        | 350–750 m                                    | M            | 1/2w  |           |
|                                           |                |        | 750–1000 m                                   | L            | 1/3w  |           |
|                                           | LU chain       | 0.500  | 0–350 m                                      | H            | w     |           |
|                                           | distance       |        | 350–750 m                                    | M            | 1/2w  |           |
|                                           |                |        | 750–1000 m                                   | L            | 1/3w  |           |
| Attractiveness                             | –              |        | > 3.9                                        | H            | w     |           |
|                                           |                |        | 2.3–3.9                                      | M            | 1/2w  |           |
|                                           |                |        | 1–2.3                                        | L            | 1/3w  |           |
| Pollution                                 | Air Pollution  | 0.500  | < 50                                         | H            | w     |           |
|                                           |                |        | 50–100                                       | M            | 1/2w  |           |
|                                           |                |        | > 100                                        | L            | 1/3w  |           |
| Noise pollution                            |                | 0.500  | < 50                                         | H            | w     |           |
|                                           |                |        | 50–55                                        | M            | 1/2w  |           |
|                                           |                |        | > 55                                         | L            | 1/3w  |           |
| Crash rate                                |                |        | 0–5                                          | H            | w     |           |
|                                           |                |        | 5–10                                         | M            | 1/2w  |           |
|                                           |                |        | > 10                                         | L            | 1/3w  |           |
### Table 2 (continued)

| Variable name             | Indicator Name          | Weight | Variable/indicator range                       | Description | Range | Weighting |
|---------------------------|-------------------------|--------|-----------------------------------------------|-------------|-------|-----------|
| Transport and mobility    | PT transport coverage   |        | Metro – 0.568w                                |             |       |           |
|                           |                         |        | BRT – 0.310w                                 |             |       |           |
|                           |                         |        | Bus – 0.122w                                 |             |       |           |
| Road network              | Average circuity        | 0.500  | 0.67–1 H                                      |             |       |           |
|                           |                         |        | 0.34–0.67 M                                  |             |       |           |
|                           |                         |        | 0–0.34 L                                     |             |       |           |
|                           | Completeness            | 0.500  | 0.67–1 H                                      |             |       |           |
|                           |                         |        | 0.34–0.67 M                                  |             |       |           |
|                           |                         |        | 0–0.34 L                                     |             |       |           |
| Catchment area population |                       |        | 0.67–1 H                                      |             |       |           |
|                           |                         |        | 0.34–0.67 M                                  |             |       |           |
|                           |                         |        | 0–0.34 L                                     |             |       |           |
| PT integration            | To PT modes             | 0.500  | 3 H                                           |             |       |           |
|                           |                         |        | 2 M                                           |             |       |           |
|                           |                         |        | 1 L                                           |             |       |           |
|                           | To other land uses      | 0.500  | 7/8–8/8 H                                     |             |       |           |
|                           |                         |        | 4/8–6/8 M                                     |             |       |           |
|                           |                         |        | 0/8–3/8 L                                     |             |       |           |
| Usability for disabled    |                         |        | 0.67–1 H                                      |             |       |           |
|                           |                         |        | 0.34–0.67 M                                  |             |       |           |
|                           |                         |        | 0–0.34 L                                     |             |       |           |
| Walkability               | Sidewalk running Slope  | 0.333  | 0–2% H                                        |             |       |           |
|                           |                         |        | 2–5% M                                        |             |       |           |
|                           |                         |        | > 5% L                                        |             |       |           |
|                           | Sidewalk length         | 0.333  | 0.67–1 H                                      |             |       |           |
|                           |                         |        | 0.34–0.67 M                                  |             |       |           |
|                           |                         |        | 0–0.34 L                                     |             |       |           |
|                           | Alpha INDEX             | 0.333  | 0.67–1 H                                      |             |       |           |
|                           |                         |        | 0.34–0.67 M                                  |             |       |           |
|                           |                         |        | 0–0.34 L                                     |             |       |           |
| Bikeability               | Slope                   | 0.333  | 0–2% H                                        |             |       |           |
|                           |                         |        | 2–6% M                                        |             |       |           |
|                           |                         |        | > 6% L                                        |             |       |           |
|                           | Maximum motorized Speed | 0.333  | 0.67–1 H                                      |             |       |           |
|                           |                         |        | 0.34–0.67 M                                  |             |       |           |
|                           |                         |        | 0–0.34 L                                     |             |       |           |
|                           | Alpha index             | 0.333  | 0.67–1 H                                      |             |       |           |
|                           |                         |        | 0.34–0.67 M                                  |             |       |           |
|                           |                         |        | 0–0.34 L                                     |             |       |           |
• Usability for Disabled (E_UD):

\[ E_{UD} = \frac{\sum w_i \times N_i \times f_i}{\sum w_i \times N_i} \]  

(3)

where:
- \( w_i \) = weight of mode i (Table 2).
- \( N_i \) = mode i number of usable stations for people with disabilities.
- \( f_i \) = mode i percent of usable fleet for people with disabilities.
- \( N_i \) = mode i number all stations.

5.3 Calculating Capability Index (CI)

5.3.1 Analysing Variables

To address the strengths of each variable/dimension, which are actually benefits and burdens to reach desired capability threshold, according to Table 1, a four-level weighting process is designed to weight 1) Major Criteria (Category), 2) Criteria (Variables), 3) Subcriteria (indicators), and 4) ranges for each variable/indicator that is either High, Medium or Low (Fig. 3). To mitigate the imprecisions arising in decision-making, especially in social studies, besides employing CA in transport planning that is somewhat new, a fuzzy AHP pairwise comparison questionnaire was conducted with 48 experts in transport-related equity planning from Iran, as the study context, and other countries worldwide to weight major criteria and criteria of the framework. Also, to complete the weighting process, to
Table 3 FAHP scale

| Linguistic terms | FAHP scale |
|------------------|------------|
| Equally          | (1, 1, 1)  |
| Very Lower       | (1, 2, 3)  |
| Lower            | (2, 3, 4)  |
| Medium           | (3, 4, 5)  |
| Higher           | (4, 5, 6)  |
| Very Higher      | (5, 6, 7)  |
| Excellent        | (7, 8, 9)  |

avoid complexity in weighting the subcriteria’s indicators are weighted equally and ranges are weighted by the authors’ team via a simple weighting approach (Table 2).

5.3.2 Weighting Variables: Fuzzy AHP

Although conventional Analytical Hierarchical Process (AHP) has the advantage of simplicity and ease of use, it has some shortcomings, mainly because of neglecting the imprecision associated with specifying experts’ judgments to a number that leads to an unbalanced scale of pairwise comparisons and makes the results and rankings rather unreliable. Therefore, based on the fuzzy theory proposed by (Zadeh, 1965), Fuzzy AHP (FAHP) was employed to improve the nine-point scaling scheme into comparisons that take the vagueness of assessments into account (Chiu et al., 2014; Mahtani & Garg, 2018; Tripathi et al., 2021). Accordingly, this study aims to employ FAHP because social considerations, context sensitivity, and subjective assessment are intertwined with the strength of benefits and burdens in equity planning, making a considerable imprecision in judgments.

In FAHP, comparisons are made by triangular fuzzy numbers (TFNs) (Table 3) that are used to compare each pair of elements and construct the fuzzy pairwise comparison matrix.

There are several methods to produce output as a set of fuzzy weights from the FAHP comparison matrix, such as the Geometric mean method, fuzzy logarithmic least-squares, and linear goal programming or crisp weights like extent analysis and fuzzy preference programming based nonlinear method (Tripathi et al., 2021); which in this study we used the extent analysis approach proposed by (Chang, 1996). So there are four steps to determine the weights of variables using FAHP in Chang’s extent analysis approach, as follows:

Step 1. Producing fuzzy pairwise comparison matrix.

\[
\tilde{C} = (\tilde{C}_{ij})_{n \times n} = \begin{bmatrix}
(1, 1, 1) & (l_{12}, m_{12}, u_{12}) & \cdots & (l_{1n}, m_{1n}, u_{1n}) \\
(l_{21}, m_{21}, u_{21}) & (1, 1, 1) & \cdots & (l_{2n}, m_{2n}, u_{2n}) \\
\vdots & \vdots & \ddots & \vdots \\
(l_{n1}, m_{n1}, u_{n1}) & (l_{n2}, m_{n2}, u_{n2}) & \cdots & (1, 1, 1)
\end{bmatrix}
\]

where l, m, u represent the lower (pessimistic), medium (most likely), and upper (optimistic) bounds of TFNs.

\[
\tilde{C}_{ij} = (l_{ij}, m_{ij}, u_{ij}) \text{ and } \tilde{C}_{ij}^{-1} = (1/u_{ij}, 1/m_{ij}, 1/l_{ij}); i, j = 1, 2, \ldots, n \text{ and } i \neq j
\]
Step 2. Generating fuzzy weight matrix.

The fuzzy extent value of the $i$th criterion is calculated as (Tripathi et al., 2021):

$$
\tilde{S}_i = \sum_{j=1}^{n} a_{ij} \otimes \left[ \sum_{k=1}^{n} \sum_{j=1}^{n} \tilde{a}_{kj} \right]^{-1} = \left( \frac{\sum_{j=1}^{n} l_{ij}}{\sum_{k=1}^{n} \sum_{j=1}^{n} u_{kj}}, \frac{\sum_{j=1}^{n} m_{ij}}{\sum_{k=1}^{n} \sum_{j=1}^{n} m_{kj}}, \frac{\sum_{j=1}^{n} u_{ij}}{\sum_{k=1}^{n} \sum_{j=1}^{n} l_{kj}} \right) ; i = 1, \ldots, n
$$

(6)

where $j$ and $k$ are rows and columns of the corresponding matrix.

Step 3. Generation of crisp weight.

In this step, fuzzy priorities would be approximated based on calculating the degree of possibility between two fuzzy extent values; so:

$$
V \left( \tilde{S}_i \geq \tilde{S}_j \right) = \begin{cases} 1 & m_i \geq m_j \\
\frac{(u_i-l_i)}{(u_i-m_i)+(m_j-l_j)} & l_j \geq u_i \\
0 & \text{otherwise}
\end{cases}
$$

(7)

where $\tilde{S}_i = (l_i, m_i, u_i), \tilde{S}_j = (l_j, m_j, u_j)$

Step 4

Finally, the estimation of priority vector is calculated by Eq. (8), then normalized weights for each criteria is calculated by dividing each weight by the sum of weights:

$$
\frac{V \left( \tilde{S}_i \geq \tilde{S}_j | j = 1, \ldots, n; j \neq i \right)}{\sum_{k=1}^{n} V \left( \tilde{S}_k \geq \tilde{S}_j | j = 1, \ldots, n; j \neq k \right)}
$$

(8)

5.3.3 Calculating Capability Index (ci)

Besides Individual characteristic variables obtained from the conducted survey in the study area, Environment variables were calculated using various spatial and network analysis in GIS. So, collected or calculated values put a variable in a range (High, Medium, or Low) that indicates the level of capability provided by that variable. Then, each range is converted to a number via assigned weight ($W_{\text{range}}^i$). In synthesis, the Capability Index for an individual with specific characteristics living in a certain geographical area of the city will be calculated as:

$$
\text{CI} = \sum_{i=1}^{n} W_{\text{range}}^i \times W_{\text{subcriteria}}^i \times W_{\text{criteria}}^i \times W_{\text{majorcriteria}}^i
$$

(9)

where $n$ is the number of criteria. It should be noted that some criteria (e.g., age, gender) do not have subcriteria and $W_{\text{subcriteria}}^i$ will be assumed as 1 in Eq. (9). Therefore, according to Table 2 Eq. (10):

$$
\sum_{i=1}^{n} W_{L}^i \times W_{\text{subcriteria}}^i \times W_{\text{criteria}}^i \times W_{\text{majorcriteria}}^i \leq \text{CI} \leq \sum_{i=1}^{n} W_{H}^i \times W_{\text{subcriteria}}^i \times W_{\text{criteria}}^i \times W_{\text{majorcriteria}}^i
$$

(10)
6 Results

6.1 FAHP Results: Experts’ Opinions

As mentioned before, to implement the weighting approach, the FAHP survey was conducted among 48 experts with an equity-related area of expertise worldwide. Figure 4 shows the criteria’s ranking divided by experts’ location and general area of expertise participated in the survey. Then, overall weights of major criteria and criteria involving both Iranian and International experts’ judgments were achieved by aggregating all comparisons presented in Table 4.

Figure 4 shows that in the case of the Individuals’ Characteristics criteria, both Iranian and International experts have primarily focused on individuals’ affordability indicators such as Income, Employment, and the ability to use resources (conversion factor), specifically Disability.

Besides, weights of the Living Environment indicate great attention to Spatial Distribution and attraction of activities in the living area. Also, a noticeable difference in the importance of safety in the living neighbourhood is observable between the opinions of the two groups, which again underscores the relationship between resources and conversion factors.

Finally, regarding Transport & Mobility variables, though weights are close, there is still considerable concern about public and private transport resources available to individuals compared to Walkability and Bikeability of the neighbourhood, such that PT Coverage and Road Network performance have been ranked first in overall aggregation. Also, it can be investigated through the lens of gender equality issues, since the majority of Iranian women perceive participation in outdoor physical activities as a non-acceptable social behaviour (Soltani & Hoseini, 2014).
Table 4 Aggregated FAHP weights

| Rank | Criteria          | Weight | Name                | Weight | Name                  | Weight |
|------|-------------------|--------|---------------------|--------|-----------------------|--------|
| 1    | Individuals’ characteristics | 0.205  | Income I_IN         | 0.328  | Spatial distribution E_SD | 0.340  |
| 2    | Disability        | 0.257  | Disability I_D      | 0.269  | Attractiveness E_A     | 0.264  |
| 3    | Employment        | 0.538  | Employment I_EM     | 0.138  | Land use diversity E_LD | 0.229  |
| 4    | Car ownership     |        | Car ownership I_CO  | 0.123  | Pollution E_P          | 0.095  |
| 5    | Age               |        | Age I_AG            | 0.070  | Crash rate E_CR        | 0.072  |
| 6    | Education         |        | Education I_ED      | 0.045  |                       |        |
| 7    | Gender            |        | Gender I_G          | 0.027  |                       |        |

*Consistency Index (CI) for Major Criteria matrix; CI=0.016, Individual’s Characteristics matrix; CI=0.080, Living Environment matrix; CI=0.024, and Transport & Mobility matrix; CI=0.016
6.2 Differences by Environment

The living environment should provide such a condition that gives habitants the possibility to translate resources into capabilities. So, based on Fig. 2 features, Table 5 shows the results of the Environment dimension’s calculation for two chosen neighbourhoods and provides the comparison between the final values.

For example, according to Eq. (9), because in Neighborhood (2) LU Distance = 564.8, and LU Trip Chain Distance = 644.1 are in Medium (= 1/2w) and Low (= 1/3w) range, with 0.500 for sub-criteria weight, and 0.340 for the weight of criteria obtained from FAHP, Spatial Distribution is 0.142. Also, to calculate the value of the major criteria, Living Environment, all the criteria of this dimension should be calculated as Eq. (9), and the sum of weights should be multiplied by 0.257 as the weight of major criteria achieved from FAHP.

\[
0.142 = 0.340 \times \left[ \left( \frac{1}{2} \times 0.5 \right) + \left( \frac{1}{2} \times 0.5 \right) \right]
\]

6.3 Differences by Individual’s Characteristics

The second dimension to consider for measuring the Capability Index is the characteristics of a person that makes her able to use the Environment’s features. For example, someone without a car, or affordability to use public transport costs is not capable of using the transport system even though she lives in an area with accessible transport resources. In the same way, lack of serviceability for PT stations or fleets makes it difficult for people with Disabilities to access outdoor activities.

Table 6 summarizes socio-demo graphic characteristics and the ability in Individual dimension belonging to groups of people living in each neighbourhood, aggregated based on each characteristic of a group: age, gender, etc. So, by using Eq. (9), Fig. 5 represents the Capability Index (CI) of different groups calculated via multiplying individual column values in Table 6 by \( W_{FAHP} \) of individual dimension (= 0.205), summing up with the value of Environment capability for each neighbourhood (Table 5), sorted in decreasing order. The CI values are also divided into three equal intervals: Low, Medium and High; such that \( CI_{min} = 0.284 \) implies minimum individual and environmental circumstances (all variables are in Low range), and \( CI_{max} = 1.000 \) is the ideal value of CI.

7 Discussion

As the essence of the framework has merged resources with conversion factors, findings would be better interpreted by considering the results of both terms together. The differences between experts’ judgment in internal and external conditions can lead to investigating the current capability of individuals and proposing future policies for transport-related equity planning.

In order to investigate the Environment dimension (Table 6), weights of the Living Environment hold a significant point; as Spatial Distribution, Attractiveness, and Land use Diversity that widely focus on urban mixed-use, Transit-Oriented Development (TOD), and sustainable growth are ranked above Pollution and Safety and indicates a strong consensus about the improvement of integrated walkable neighbourhoods. An appropriate mixture of activities that are easily accessible to residents would lead to a decrease in car trips and traffic-related
### Table 5  Environment's capability for two neighbourhoods

| Major criteria       | Criteria                  | Sub-criteria | Neighbourhood (1) | Neighbourhood (2) |
|----------------------|---------------------------|--------------|-------------------|-------------------|
|                      | Name                      | $W_{FAHP}$   | Value             | Class       | $W_{cal}$ | $W_{Criteria}$ | $W_{Major Criteria}$ | Value             | Class       | $W_{cal}$ | $W_{Criteria}$ | $W_{Major Criteria}$ |
|                      |                           | $W_{FAHP}$   | $W_{cal}$ | $W_{Criteria}$ | $W_{Major Criteria}$ | $W_{cal}$ | $W_{Criteria}$ | $W_{Major Criteria}$ | $W_{cal}$ | $W_{Criteria}$ | $W_{Major Criteria}$ | $W_{cal}$ | $W_{Criteria}$ | $W_{Major Criteria}$ |
| Living environment   | Spatial distribution      | 0.340        | 0.500 | 0.250 | 0.170 | 0.684 | 513.8 | M | 0.250 | 0.170 | 0.684 | 564.8 | M | 0.250 | 0.142 | 0.492 |
|                      |                           | 485.3        | M | 0.250 | 644.1 | L | 0.167 |
|                      | Attractiveness            | 0.264        | 4.1 | H | 0.264 | 0.264 | 3.7 | M | 0.132 | 0.132 |
|                      |                           | 1.00 | H | 0.500 | 0.171 | 1 | H | 0.500 | 0.153 |
|                      | Land use diversity        | 0.229        | 0.500 | 37 | M | 0.250 | 10.3 | L | 0.167 |
|                      |                           | 66.5 | M | 0.325 | 0.042 | 87 | M | 0.325 | 0.042 |
|                      | Pollution                 | 0.095        | 0.65 | 0.132 | 0.132 |
|                      |                           | 61.51 | L | 0.117 | 67 | L | 0.117 |
|                      | Crash rate                | 0.072        | 5.3 | M | 0.036 | 0.036 | 10.1 | L | 0.024 | 0.024 |
| Transport and mobility| PT Transport coverage     | 0.281        | 0.500 | 1.296 | M | 0.250 | 0.08 | 0.573 | 0.067 | L | 0.094 | 0.094 | 0.423 |
|                      |                           | 0.719 | M | 0.141 | 0.141 | 1.452 | L | 0.167 | 0.064 |
|                      | Road network              | 0.192        | 0.500 | 0.014 | L | 0.167 | 0.011 | L | 0.167 |
|                      |                           | 0.529 | M | 0.070 | 0.070 | 0.943 | L | 0.047 | 0.047 |
|                      | Catchment Andndrea        | 0.140        | 0.500 | 1.00 | H | 0.500 | 0.135 | M | 0.250 | 0.101 |
|                      |                           | 0.314 | L | 0.040 | 0.040 | 0.051 | L | 0.040 | 0.040 |
|                      | PT Integrandndntion       | 0.135        | 0.330 | 2 | H | 0.330 | 0.058 | 0.5 | H | 0.330 | 0.046 |
|                      |                           | 0.330 | 0.95 | H | 0.330 | 0.672 | M | 0.165 |
|                      | Usability for Dis-andndnddmbled | 0.120 | 0.330 | 0.663 | M | 0.165 | 0.531 | M | 0.165 |
|                      | Bikeability               | 0.062        | 0.330 | 2 | H | 0.330 | 0.051 | 0.5 | M | 0.330 | 0.031 |
|                      |                           | 0.330 | 0.843 | H | 0.330 | 0.736 | M | 0.165 |
|                      |                           | 0.330 | 0.663 | M | 0.165 | 0.531 | M | 0.165 |
|                      | Environment Capandnddmbility = |           | 0.485 |           | 0.356 |
Table 6  Descriptive statistics

|                          | Neighb. (1) \((n = 162)\) | Neighb. (2) \((n = 114)\) |
|--------------------------|----------------------------|----------------------------|
|                          | Frequency | Percentage | Individual | Frequency | Percentage | Individual |
| Gender                   | Male       | 68  | 41.98 | 0.720 | 68  | 59.65 | 0.670 |
|                          | Female     | 94  | 58.02 | 0.686 | 46  | 40.35 | 0.549 |
| Age                      | 18–44      | 140 | 86.42 | 0.708 | 70  | 61.4  | 0.615 |
|                          | 45–64      | 17  | 10.49 | 0.613 | 38  | 33.33 | 0.610 |
|                          | > 65       | 5   | 3.09  | 0.605 | 6   | 5.26  | 0.594 |
| Education                | Undergraduate (UG) | 22  | 13.58 | 0.593 | 23  | 20.18 | 0.541 |
|                          | Bachelor’s degree or equivalent (BSc) | 52  | 32.1 | 0.667 | 57  | 50  | 0.589 |
|                          | Master’s degree or higher (≥ MSc) | 88  | 54.32 | 0.747 | 34  | 29.82 | 0.729 |
| Employment               | Unemployed | 50  | 30.86 | 0.595 | 42  | 36.84 | 0.526 |
|                          | Full-time  | 92  | 56.79 | 0.766 | 50  | 43.86 | 0.717 |
|                          | Part-time  | 20  | 12.35 | 0.658 | 22  | 19.30 | 0.715 |
| Car Ownership            | No \((C_N)\) | 40  | 24.69 | 0.631 | 11  | 9.65 | 0.584 |
|                          | Yes \((C_Y)\) | 122 | 75.3 | 0.723 | 103 | 90.35 | 0.631 |
| Income                   | Deciles 1 – 4 | 14  | 8.64 | 0.635 | 43  | 37.71 | 0.595 |
|                          | Deciles 5 – 8 | 60  | 37.03 | 0.707 | 68  | 59.64 | 0.683 |
|                          | Deciles 9 & 10 | 88  | 54.32 | 0.901 | 3  | 2.63 | 0.768 |
| Disability               | No \((D_N)\) | 160 | 98.77 | 0.701 | 111 | 97.37 | 0.651 |
|                          | Yes \((D_Y)\) | 2  | 1.23 | 0.640 | 3  | 2.63 | 0.352 |
| Average                  |             |     |       | 0.700 |     |       | 0.621 |
externalities such as pollution and crash rates. These factors highly affect the experiments of people to interact with land use system and make their future conversion factors and choices.

Results presented in Fig. 6 also prove how external capabilities spatially differ between neighbourhoods, particularly between neighbourhoods in central business districts (CBD) and peripheral areas of the city. Land uses with higher attractiveness and better mixedness in the neighbourhood (1) make opportunities more accessible and desirable for residents to participate compared with the neighbourhood (2). Also, closeness in the distribution of opportunities that would increase the tendency and freedom to achieve more activities in lower commute times enhance the accessibility/capability in this neighbourhood. On the other hand, both cases considerably suffer from externalities like pollution and crash rate, such that region 19, where neighbourhood (2) is located, is one of the most dangerous regions in Tehran in fatal accidents (Yearbook, 2018). Therefore, it would dynamically affect the residents’ willingness to attend outdoor activities, especially vulnerable groups like elderly groups or people who have to or prefer to walk or ride a bike.

Besides, though the weights of Transport & Mobility variables are close, there is still considerable concern about public and private transport resources available to individuals compared to Walkability and Bikeability of the neighbourhood (Table 4). Rankings show specialists firstly prefer a city with a widespread public transport system that is comfortably available to residents, integrated with all land use types, and usable for disabled groups beside accessible road network. Moreover, neighbourhoods must benefit from active transportation facilities to improve public health, reduce gas emissions and transportation costs.

Accordingly, Neighbourhood (1) benefits from better Transport & Mobility conditions in almost all variables (Fig. 6). Diversity and coverage of public transport system, along with a better performance of road network, especially in case of average circuity and alpha index (Table 5), make individuals able to commute via different modes easily. The network
structure and lower number of streets with maximum motorized speed (bmm) improve active transportation in this region.

However, the lack of public transport usability for people with disabilities, as an important group to consider for planning, in both neighbourhoods is undesirable. Ranking Disability as the second important criterion determines that experts are well aware of difficulties for groups with physical impairments and the limitation of these groups to transform resources. For example, urban development plans still neglect groups with disabilities in Iranian cities, especially regarding the design of sidewalks, PT stations, and fleets to remove physical barriers that cause discomfort in mobility. Also, most of the people in this group are still unable to live independently and participate in activities on a par with other citizens. Figure 6b determines inaccessible design of public transport stations and fleets have led to a huge impact on people with impairments, especially in Neighb. (2), as D_Y group is experiencing the least CI. So, as the elderly can partly be considered in the disability group, the transport system, sidewalks, and road network should be properly designed in order to decrease the limitations and extra travel costs imposed on this group.

In conclusion, irrespective of the socio-demographic characteristics of residents in these areas, Neighbourhood (1) benefits from an integrated transport-land use system where its density and diversity in the distribution of land uses are supported by transport system, which reduces the disparity in opportunities. The circumstances are considerably worse in Neighbourhood (2), located in Tehran’s suburbs as the living area of more economically vulnerable people (Fig. 6c).

Moreover, there are some noticeable issues to point out regarding Individual dimension. Primarily, Income and income-related variables (Employment) are ranked firsts from both domestic and international experts’ judgments. Apart from Disability, judgments
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principally concern individuals’ level of affordability or the activity that brings welfare, such as Employment status. Moreover, according to Table 6 and Fig. 5, observing the profiles of individuals residing in intra-neighborhood comparisons assert the advantage of better-off groups in CI, such that employing in a full-time job and higher education directly leads to a higher income brings more capability in both neighborhoods. This is similar to the findings of (Cao & Hickman, 2019a; Lucas et al., 2019), who asserted the significant differences in capability and functioning regarding annual income. Inter-neighborhood comparisons also reveal that the general trend has been repeated in Neighb. (2), with the difference that people with better job status and income level have higher capabilities, such that people with part-time jobs or monthly incomes in deciles 5–8 are ranked among top five groups.

Car ownership, which is strongly correlated with income status, is also significant merit and extends the capability and is ranked among income-related variables and affordable groups, especially in the context of Neighb. (1). It leads to higher trip frequency and trip distance as the key terms of accessibility and mobility. On the other hand, locating in peripheral and far from opportunities, in addition to the lack of public transport alternatives in Neighb. (2) (Fig. 2) have forced most of the people to use a private car (\(C_Y = 90.35\%\)) despite their lower-income level and employment status. This mutual relationship exacerbates the capability in Neighb. (2), as the costs for vehicle ownership and making long-distance trips along with poor PT Coverage lead to restricting the spatial span of participating in essential activities in a matter of time.

Besides, the effect of Gender, which is broadly focused in the capability literature, is somewhat overlooked in the FAHP judgments, which may be because of the generality of questions in pairwise comparisons or experts think affordability can largely compensate for sexual inequalities. Nevertheless, despite the slight difference in FAHP weight (0.027 for men and 0.013 for women), CI results show that men are more likely to have higher levels of capability in both neighborhoods (Fig. 5). It may be a consequence of being more active in the labor market to occupy more higher-status jobs (Robeyns, 2003), higher payments, and sometimes a higher chance for men to be hired for full-time jobs.

In general, considering all capability dimensions, the poverty in transport and land use system in Neighb. (2) makes residents suffer from lower capabilities (Fig. 7). In addition to lower environmental features, that is mainly due to a weak interaction between transport and land use system, because of significant differences in job status, education, and income level, Neighb. (2) individuals’ capability (or conversion factors) is low, too. Also, Fig. 7 shows that both cases primarily suffer from transport poverty that is not able to efficiently integrate with land use distribution and provide accessibility to activities. So, the living environment condition is not highly suitable as the somewhat high distance between land uses along with pollution issues force people to avoid attending opportunities. Therefore, however, both neighborhoods have higher average individual values than environmental, it seems that the major cause for restriction of capability set is that people do not have enough available resources.

Besides, calculating average CI based on average individuals’ characteristics (Table 6), and calculating CI for two hypothetical persons with maximum (= 1) and minimum (= 0.2) individual characteristics maintain Environment does not provide enough resources for inhabitants. Therefore, even a person with the highest internal features is not able to reach the ‘High’ capability level, mainly in Neighb. (2), where all groups fall in the Low CI condition (Fig. 8).

Finally, major criteria’s weighting denotes a general tendency for planning an environment that provides resources fairly and makes all groups able to achieve opportunities via
different transport means. The weight of 0.205 for Individual’s Characteristics, which is close to Living Environment, declares a paradigm shift from planning for equality to equity planning and human-centered policy-making that respects residents’ abilities to overcome burdens, participate in activities and live a decent life. Since an inclusive environment both enhance the external condition and the internal features of residents (such as Neighbourhood (1)), equity planning should primarily focus on a fair distribution of resources regarding individuals’ internal abilities and turn attention to deprived neighbourhoods (such as Neighbourhood (2)). So, improvement in this mutual relationship (resources and conversion factors) would increase the capability and fair distribution of accessibility among people.
8 Summary and Conclusion

In line with growing interest in the concept of equity and focusing on ethical principles in transport planning, the Capability Approach got special attention in recent years because CA emphasizes humans’ freedom of choice and the ability to use distributed resources, called capability. Therefore, beyond fairness in the distribution of resources, CA also concerns individuals’ conversion factors to participate in activities (Capabilities) regarding their socio-demographic characteristics, especially for vulnerable groups.

Based on the CA key concept, especially the relationship between resources, conversion factors, and capabilities, this paper has proposed an aggregate framework to calculate the capability level. The reasoning and method of aggregation can be added to current literature, especially top-down approaches, that mostly make a distinction between resources and conversion factors. So, by conceptualizing capability as accessibility and involving experts’ opinions and inhabitants’ characteristics the model determines the differences between capabilities regarding environment and individuals’ characteristics in two neighbourhoods of Tehran, Iran. Then, by focusing on 1) Environment features: such as land use distribution, living environment externalities, transport system performance, and mobility potentials in the neighbourhoods, and 2) Individuals’ socio-demographic characteristics like age, gender, income level, the model has measured an index, Capability Index (CI), that helps policy-makers to evaluate the current capabilities between different geographical areas and population groups. CI is the level of capability for each person/group and is calculated by measuring criteria/sub-criteria for each population group and neighbourhood, weighted by FAHP survey conducted among experts worldwide. Also, the framework addresses the concerns about determining the minimum threshold of capability/accessibility by calculating and classifying the variables and determining CI for each population group.

The results of the FAHP show experts are primarily concerned about the fair allocation of resources, so Transport & Mobility and Environment are weighted above Individual’s Characteristics. Also, regarding criteria weighting, Public transport coverage, road network design, land use distribution, income, and disability got higher weights among all. Moreover, external and internal features and final CI support previous literature findings achieved via surveys conducted with residents to investigate their capabilities. So, FAHP findings, which is conducted among experts from miscellaneous contexts, would give an opportunity for further studies to compare planners’ opinions with residents’ preferences and combine them to make urban policies.

The findings of this study assert the correlation between the living area and internal capability (Cao & Hickman, 2019a), such that the individual capability of all population groups in Neighbourhood (1) located in CBD area is higher than Neighbourhood (2) in the peripheral area of the city. Also, disregarding the weights for criteria and the external condition, a person with a higher education level, better job status, and higher income level shows higher individual capabilities, as (Cao & Hickman, 2019a; Hickman et al., 2017) have also claimed. So, in aggregation with better environmental conditions, people living in Neighbourhood (1) benefits from better capabilities (CI) compared with their counterparts in Neighbourhood (2). The results also support the findings on gender inequality by previous studies (Hickman et al., 2017; Mella Lira, 2019), as in both case studies, men have ranked above females, and this gap got wider in Neighbourhood (2) as a more deprived area. Differences in (dis)ability of people are significant in both cases, as well.

The second major finding of this study is to determine a minimum CI threshold that can be proposed as a basic level to consider for policy-making. So, identifying worse-off
populations/neighbourhoods would help prioritize the allocation of resources and empower
the population since measuring the capability would help determine the gap between the
real available opportunities to people and their ability for actual participation. Also, the
effect of future urban projects on residents’ life can be estimated beyond measuring the
physical accessibility, as it often does not consider different groups or barriers to partici-
pating in activities. The proposed method by the current paper can add a new framework
to struggle with this critical challenge that has been previously addressed by many scholars
such as (Martens, 2016; Nahmias-Biran & Shiftan, 2019; Pereira et al., 2017).

This method of analysis has some limitations. First, although involving more variables
may result in model complexity, it can improve the method’s accuracy. Also, however,
Iranian experts have participated in the survey, but participating local experts of chosen
neighbourhoods would better determine the residents’ actual needs and provide the specific
weights. Besides, the lack of data, particularly for Transport & Mobility variables has led
to some limitations in the accuracy of measuring these criteria, and causes shortcomings in
evolving top-down into the designed framework.

As the capability approach and its application is an underdeveloped framework, future
studies on the current topic are therefore recommended. However, provided FAHP is
employed to consider imprecisions about variables, the method does not consider interac-
tions and dependencies between criteria. The mentioned limitation can be resolved using
other techniques such as fuzzy DEMATEL, which analyses the mutual influences among
factors. Also, the aggregation method can be improved by using a fuzzy aggregation
method, instead of the weighted aggregation technique that is used in the current study.
Besides, as each variable encompasses a large body of literature, measuring each (sub)
criterion can be improved regarding its calculation method, assigned ranges, and the con-
text the model used to employ. In addition, the framework can be further modified with the
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Declarations

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