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THE CITY CHALLENGES AND EXTERNAL AGENTS. METHODS, TOOLS AND BEST PRACTICES

Vol.15 n.2 August 2022

print ISSN 1970-9889 e-ISSN 1970-9870
University of Naples Federico II

TeMA Journal of
Land Use, Mobility and Environment

THE CITY CHALLENGES AND EXTERNAL AGENTS. METHODS, TOOLS AND BEST PRACTICES

2 (2022)

Published by
Laboratory of Land Use Mobility and Environment
DICEA - Department of Civil, Architectural and Environmental Engineering
University of Naples "Federico II"

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Editor-in-chief: Rocco Papa
print ISSN 1970-9889 | on line ISSN 1970-9870
Licence: Cancelleria del Tribunale di Napoli, n° 6 of 29/01/2008

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The cover image shows a sea glacier ice that melts away.

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TeMA Journal of Land Use, Mobility and Environment

THE CITY CHALLENGES AND EXTERNAL AGENTS. METHODS, TOOLS AND BEST PRACTICES

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TeMA Journal of Land Use, Mobility and Environment

TeMA 2 (2022) 227-248
print ISSN 1970-9889, e-ISSN 1970-9870
DOI: 10.6092/1970-9870/8906
Received 12th January 2022, Accepted 20th May 2022, Available online 31th August 2022

www.tema.unina.it

Combining resources and conversion factors

Evaluation of capabilities and social inequities in urban areas by proposing a conceptual framework based on capability approach

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Abstract
A growing body of recent studies involves the social effects of distributive justice in the field of transportation, which mostly can be traced back to the studies of spatial mismatches, income, or gender inequality. So, this paper seeks to address challenges related to the conceptualization of capability and proposes a new aggregated framework to draw the connection between Resources, Conversion Factors, and Capabilities as the key terms of the Capability Approach. Consequently, by classifying the resources and conversion factors to "individual characteristics," "transportation options," and "urban living environment" dimensions, the model would provide an index that expresses the level of capabilities called the Capability Index (CI). The results of scenarios evaluated in this paper demonstrate that the significant difference in the capabilities is mainly affected by car ownership and income variables with 2.214 and 0.223 Cohen's d effect size, respectively. Also, disability in the young age group causes a more significant reduction in their capability index than their old counterparts. The model demonstrates the need to highlight the capability notion and the need for improving new methods to underscore human characteristics as the focal point in urban policy-making.

Keywords
Social equity; Distributive justice; Capability approach; Transport policy; Urban planning.

How to cite item in APA format
Azmoodeh, M., Haghighi, F. & Motieyan, H. (2022). Combining resources and conversion factors. *Tema. Journal of Land Use, Mobility and Environment*, *15* (2), 227-248. http://dx.doi.org/10.6092/1970-9870/8906

1. Introduction

There has been a considerable body of literature on the social effects of distributive justice in urban and transport planning in recent decades, which represents significant inequalities in distribution (Pereira et al., 2017). These findings can be traced back to the studies of spatial mismatches, gender inequality, and, more recently, transportation and social exclusion (Cao & Hickman, 2019b; Di Ciommo & Shiftan, 2017; Hananel & Berechman, 2016; Mella Lira, 2019a). Taken together, all of these investigations show the impact of the inadequate ability of individuals to participate in economic and social activities. To this end, scholars have designed their evaluations based on different philosophical theories of social justice using different approaches and indicators.

Although there is no single thorough definition for justice, as a primary definition based on various theories' principles, justice can be perceived as a broad moral and political ideal (Fraser, 1995; Kymlicka, 2002; Young, 2011), which is concerned with three basic questions: (1) how to distribute benefits and burdens in society (distributive justice), (2) the fairness of the decision-making procedures, and (3) the rights that must be recognized and enforced. Moreover, the concept of justice is characterized by two basic principles: respect for one's independence and moral equity, since all people are entitled to equal respect and consideration. Literature has different interpretations of moral independence and equality and offers different responses to three fundamental and, yet, interwoven questions about distributive justice: (1) what (benefits and burdens) should be distributed? (2) Distribution models should be based on which moral principles? Moreover, (3) what is the fairest distribution model? (Martens, 2016; Pereira et al., 2017)

Hence, various justice approaches have attempted to delineate appropriate ethical principles for evaluating justice especially for deprived social groups, and propose an appropriate pattern for distribution (Lucas et al., 2016; Van Wee & Roeser, 2013). Theories such as utilitarianism, libertarianism, intuitionism, Rawls' Egalitarianism, and the capability approach (CA) have offered different answers to three basic questions raised (Pereira et al., 2017); among which, the capability approach, as discussed in this article, believes that opportunities must be shared based on human dignity and equal respect, or that people should have basic capabilities above the minimum level (Martens, 2016; Nussbaum, 2011; Pereira et al., 2017). The CA is mainly based on Sen's critiques of traditional utilitarian approaches, which suggest a resource distribution pattern that maximizes aggregate welfare. CA believes the focus on the distribution of resources or primary goods (proposed by Rawls) cannot recognize the diversity of human needs and preferences because people vary fundamentally in their ability to translate resources into 'beings' and 'doings'. So, he concludes that the extent to which people can convert resources into a decent life is the core notion of freedom, not merely the distribution of resources or welfare that only relates to what people actually do (Pereira et al., 2017; Nahmias-Biran et al., 2017). Also, the capability approach emphasizes the extent of opportunities available to people, depending on their characteristics. While this approach is not explicitly about transportation, it is considered a means of partially fulfilling one's basic needs through providing equal accessibility to opportunities and services and the ability to participate in social and economic activities (Hananel & Berechman, 2016; Papa, 2013; Smith et al., 2012; Zali et al., 2016).

Besides, there is still a debate on the complexity of the practical operation of CA in transport planning. Because of the not-so-long history of the application of the capability approach in transportation planning, many studies have attempted to translate the concepts of CA into transport (Beyazit, 2011; Chiappero-Martinetti et al., 2021; Pereira et al., 2017), and there are still limited researches that have proposed a CA-based measure or framework in planning (Hananel & Berechman, 2016; Martens, 2016; Nahmias-Biran et al., 2017; Nahmias–Biran & Shiftan, 2016; Nahmias-Biran & Shiftan, 2019; Oviedo & Guzman, 2020; Smith et al., 2012).

Therefore, among others, this study aims to propose a framework for employing CA in urban mobility planning with emphasis on the interaction between resource distribution and the individuals' characteristics to make use of them. So, in order to clarify the contribution of the proposed model this paper is structured as follows.

Key concepts of CA are briefly provided in section 2 as a prerequisite for understanding the contribution of the literature and current study. Section 3 reviews the literature on employing CA in transport and classifies the studies according to their methodology. Section 4 addresses the originality and contribution of the current study. Section 5 utilizes the CA concepts and highlights the study objectives to present the designed conceptual framework and implement it by evaluating different scenarios. Finally, Results and discussion are provided in Section 6 and the paper ends up with a conclusion in section 7.

2. The Capability Approach: Definition & Key Terms

In expressing his theory, Amartya Sen developed a concept that stands between well-being and resources: Capability (Akhavan & Vecchio, 2018; Sen, 1979). Capabilities are a set of freedoms and opportunities that individuals can choose or act upon, which "... is a combination of personal abilities and political, social and economic environment" (Nussbaum, 2011). The CA emphasizes the extent of opportunities available to people, depending on their characteristics. As shown in Fig. 1, provided by (Robeyns, 2005), the capability approach is consists of five key concepts as Resources, Conversion Factors, Capabilities, Choices, and Functioning (Beyazit, 2011; Robeyns, 2005; Vecchio & Martens, 2021). *Resources* are the material and immaterial productions that give the possibility to people to make use of them. For example, for some capabilities, the input will be financial resources such as income level, or (Vecchio & Martens, 2021) have considered transport or land use systems as distributed resources among a city. *Conversion Factors* consist of personal, social, or environmental features that enable a person to use/transform resources to capabilities (Robeyns, 2005). Thus, conversion factors are a set of inherent conditions (e.g. disability), aspirations, and life experiences that translate resources to a set of freedoms to choose between available 'beings' or 'doings', namely Capabilities. There is no clear distinction between resources and conversion factors, as conversion factors can be applied to a broader understanding of resources, such as the educational degree or income level (also mentioned as resource) that someone has. Also, people decide to choose one capability over another to meet their needs. Finally, functionings are considered as the achieved capabilities, and the assessment of justice and social living conditions must distinguish the traits that the individual is capable of (capabilities) from what the person ultimately does (functioning) (Nussbaum, 2011).

Therefore, the crucial difference between studies to employ CA in the operational application is how to design the whole framework, or most importantly the focal variable, Capability. The capability approach considers not only the diversity of individuals' characteristics (e.g., preferences, values, needs, and abilities) but also the social structures and constraints affecting individuals' capacity to translate resources and opportunities into practice.

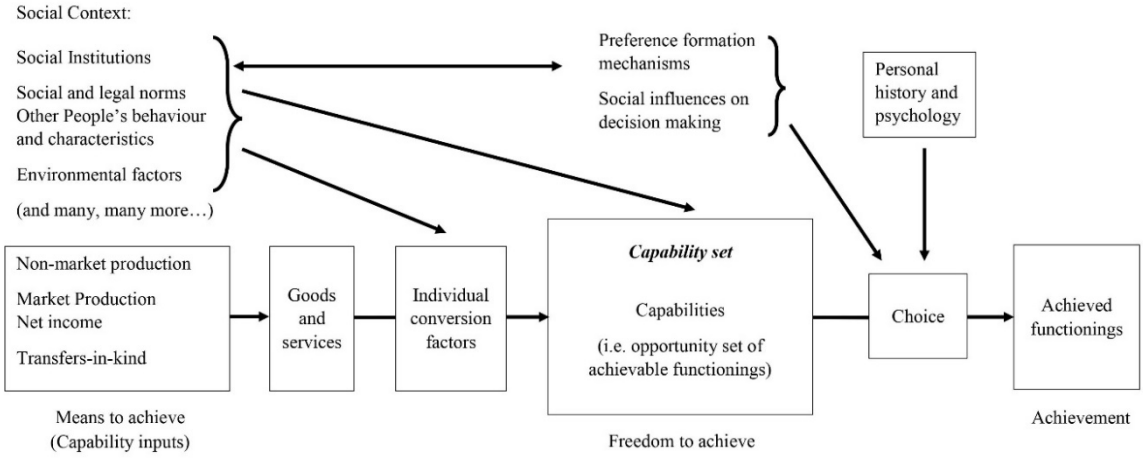

Fig.1 Person's capability set in his/her social and personal context (Robeyns, 2005)

3. Literature Review

Exploring the transport-related CA literature, the studies can be classified from two perspectives. First, considering the study contribution as it either theoretically help to shape our understanding from CA to utilize in transport policy (Beyazit, 2011; Pereira et al., 2017; Robeyns, 2005), or empirically evaluates the capabilities, functionings or the factors that make differences between them. Second, as (Vecchio & Martens, 2021) have also mentioned, is the understanding of the capability concept in practice, as some scholars have translated capability as mobility (Beyazit, 2011; Ryan et al., 2019), meanwhile, a larger group conclude that accessibility is the synonym of capability (Cao & Hickman, 2019a, 2019b; Martens, 2016; Nahmias-Biran & Shiftan, 2019; Oviedo & Guzman, 2020; Vecchio & Martens, 2021). Mobility-as-capability studies have considered mobility equals to the definition: "the ability to move freely from place to place" in Nussbaum's Central Human Capabilities, under the "bodily integrity" capability (Nussbaum, 2011). So, it seems that mobility captures the actual access to opportunities and neglects the freedom to choose or alternative means to supply basic needs, such as telecommunication. On the other hand, accessibility-as-capability literature concludes that the multi-dimensional essence of the accessibility term can cover the definition of capability as both consider the possibility of a person to participate in activities (Martens, 2016; Vecchio & Martens, 2021).

Additionally, capability-as-accessibility literature can be categorized into (1) top-down and (2) bottom-up approaches. The former pertains to accessibility-measure analyses of how transport and land use systems make it possible for people to reach valued activities, and the latter refers to assessments of a person's perceived accessibility to opportunities and how mobility options may affect participation in activities, especially for disadvantaged groups (Vecchio & Martens, 2021). The literature on the first approach, as the main focus of the current study, have been adopted different accessibility measures as activity-based (Nahmias–Biran & Shiftan, 2016; Nahmias-Biran et al., 2017), gravity-based (Oviedo & Guzman, 2020), or a combination of cumulative opportunity and gravity-based measures (Martens, 2016) to evaluate the accessibility/capability based on possible accessible opportunities via different transport modes.

So, considering the moral principle of CA that believes the main principle of distribution should be based on human characteristics, some models have utilized functions to translate all possible opportunities to those that people are able to participate (Nahmias–Biran & Shiftan, 2016; Nahmias-Biran et al., 2017). Also, (Vecchio & Martens, 2021) propose a model with transport and landuse as inputs that some conversion function (factor) should transfer them to capability (as a top-down approach), though defining such function could be somewhat intricate, and yet it is not clearly specified in the literature. In addition, (Nahmias–Biran & Shiftan, 2016), in providing their measure, only examined the scenarios for 'rich' and 'poor' groups as the conversion factor to translate available resources. Table 1 provides a summary of studies that employ CA in transport planning based on their method and understanding of capability.

Scholars	Type	Method	Capability	Key Findings
(Beyazit, 2011)	Theoretical	-	Mobility	– Translating CA terms to transport system objects – Showing strengths and weaknesses of CA – In terms of social justice, projects using CA are more compatible with transport equity implications. – CA can suggest a qualitative and quantitative evaluation method.
(Pereira et al., 2017)	Theoretical	-	Accessibility	– Compares key theories of justice in transport application. – Distributive justice in transport disadvantage and social exclusion should focus on accessibility, based on Rawls' theories and CA – Analysis of the effects of transport policymaking should consider minimum threshold for accessibility to key destinations.

Scholars	Type	Method	Capability	Key Findings
Mella Lira, 2019b	Theoretical	-	Accessibility	– Proposed and discussed the application of a CA-based framework to use in transport policymaking. – Proposed using survey/interview as data collection method. – CA might be seen as a complementary evaluation method for transport projects.
Randal et al., 2020	Theoretical	-	Accessibility	– Review of distributive justice and equity in transport literature. – Develop a conceptual framework of distributive justice to apply in transport policy, and evaluate it by a case study in New Zealand). – Transport policy is a social conversion factor that influences people's ability to translate resources and opportunities into the functionings. – Transport policy is a promoter of a wide range of capabilities.
Vecchio & Martens, 2021	Theoretical	-	Accessibility	– According to the literature review and considering key terms of CA, accessibility can better conceptualize the capability concept. – Transport and land use system are considered as resources. – A comprehensive framework consist of both top-down and bottom-top approaches that considers both traditional accessibility measures and individuals preferences to choose functionings.
Smith et al., 2012	Empirical	Modeling	Accessibility	– Framed a discussion based on CA to evaluate the minimum transport needs and costs of rural households. – Rural households should spend a larger share of their monthly income on transportation than families living in the central areas of the city. – Rural households should inevitably use cars and the increase in fuel prices or taxes in this sector will negatively affect them.
Martens, 2016	Empirical	Modeling	Accessibility	– Proposes a new decision-making framework based on CA, instead of traditional Four-step model. – The CA establishes a better relationship with the field of social justice in transportation. – Despite the relatively good public transportation system in the case study area, there are wide differences in transportation and potential accessibility between people with and without car. – Urban areas have the largest share in the poverty of accessibility. – Identifying the minimum accessibility threshold remains one of the most important challenges to social justice.
Nahmias–Biran & Shiftan, 2016	Empirical	Modeling	Accessibility	– Provides an innovative and comprehensive justice-based model for transportation projects' evaluation. – This model examines the benefits of the project from the perspective of people with accessibility, as the main advantage produced by each transportation project. – Used an activity-based accessibility measure named SVOA to estimate the overall benefit of a transport project that is subjective well-being as they claim. – Suggests that social and spatial factors be included in the social welfare assessment based on the introduction of the concept of accessibility.

Scholars	Type	Method	Capability	Key Findings
Nahmias-Biran et al., 2017	Empirical	Modeling	Accessibility	– Compared the differences between CA and the utilitarianism approach. – Compared to other theories, CA would better demonstrate the requirements of social justice in transportation appraisal. – The benefits of the "poor" individual from the public transport investment is significantly higher than the scenario to improve car-dependent projects. – Highlighted the question: How to set a sufficient minimum accessibility threshold?
Nahmias-Biran & Shiftan, 2019	Empirical	Modeling	Accessibility	– The principle of Diminishing Marginal Utility can be applied for the accessibility. – The more options available to the passenger, the lower the final benefit of adding another alternative. – They developed a new measure, "Value of Capability gains" VOC, which considers both efficiency and equity outcomes of a transportation improvement project. – Defining an accessibility threshold is very individual and can be defined as a function of personal characteristics.
Oviedo & Guzman, 2020	Empirical	Modeling	Accessibility	– To investigate the applicability of accessibility measures to discuss equity and sustainability. – Evaluating the relationship between accessibility, equity, and sustainability using non-work accessibility as the main indicator. – Using a gravity measure that is calibrated based on actual travel behavior. – Low- and middle-income groups have higher accessibility than high-income cohorts by both private and public transport.
Hananel & Berechman, 2016	Empirical	Case study evaluation	Accessibility	– Proposed CA-based framework for transport decision-making process. – Assessed the CA implications in a real world transport project. – The CA is not a utopia and can be used in the field of transportation in the real world applications. – The main challenge to adopt CA is to specify the minimum threshold for accessibility. – Political support in using CA in real life is often difficult in many urban areas.
Hickman et al., 2017	Empirical	Survey	Accessibility	– High-income neighborhoods have a higher level of capabilities and functioning than low-income neighborhoods. – Low-income groups are less likely to participate in important life activities and are more likely to experience social exclusion. – The effect of neighborhood safety i.e. not to be attacked, stolen, or harassed) on women is more than men. – Elderly people spend the most on transportation for their daily commuting, followed by middle-aged people. – Income and location have a significant impact on individual capabilities and functionings.

Scholars	Type	Method	Capability	Key Findings
Chikaraishi et al., 2017	Empirical	Survey	Accessibility	– Capability index increases with increasing income and level of education and has a high dependence on car ownership. – The average travel time increases with increasing capability. – The variance of travel time increases with the individual's capability. – People with less capability spend more time on productive activities. – People with higher incomes had more options for optional activities for entertainment or leisure, shopping, and long-distance travel.
Cao & Hickman, 2019b	Empirical	Survey	Accessibility	– The incumbent population is likely to have more benefits than newcomers. – Almost all indicators have shown statistically significant differences according to variation in income. – Females are more concerned about travel safety. – Younger adults are more likely to use public transport. – Having a car would enhance some capabilities. – Capabilities and Functionings are different according to socio-economic characteristics and geographical location of citizens in London.
Cao & Hickman, 2019a	Empirical	Survey	Accessibility	– The incumbent population is likely to have more benefits than newcomers. – Almost all indicators have shown statistically significant differences according variation in income. – Findings indicate a small change in the travel behavior of low-income groups before and after the construction of the metro station. – Public transport investment totally benefits middle- and high-income groups. – Capabilities and Functionings are different according to socio-economic characteristics and geographical location of citizens (in China).
Mella Lira, 2019a	Empirical	Survey	Accessibility	– Women in the middle- and lower-income sectors show a lower tendency, though they consider a higher level of importance for this factor. – Higher-income, level of education and dependency on car ownership leads to a higher capability. – Proximity to other users is mainly defined by the mode of transportation, while public transportation users are less desirable. – The capability approach will be effective for improving transportation assessment methods and considering new measurement tools.
Vecchio, 2020	Empirical	Survey	Accessibility	– Introduces "Microstories" of individuals' everyday mobilities as a suitable analytical tool for describing the relationship between mobilities and capabilities. – "Microstories: personal recollections of everyday mobility experiences, perceptions and aspirations, to be contrasted with aggregate accessibility analyses". – Microstories can be used as a complementary tool to evaluate transport systems, especially in local disadvantaged areas, emphasizing individuals' perspectives, needs, and desires.

Tab.1 Capability Approach in transport planning literature review

Moreover, accessibility requires to be recognized as a combination of personal abilities and the social, economic, and built environment, which is a complex and multidimensional concept (Battarra et al., 2018; Tyler, 2006). So, it is essential to formulate accessibility considering two crucial components that are analytically different but conceptually interconnected (Pereira et al., 2017):

- the individual's ability to use transportation technologies and transportation systems depends on the interaction of personal and environmental factors. Personal characteristics may include, for example, physical and mental fitness, mobility, and cognitive skills sufficient to understand and interact with the resources, which can be understood as *Conversion Factors* (see Section 2);
- another component considers the extent that the interaction between the transportation system and land use patterns (*i.e. Resources*) enhances the capabilities of individuals (*i.e. Conversion Factors*). For instance, if someone is able to use the transportation system, does it improve her ability to access the desired opportunities? Even if one is able to access and use the transportation system, one may not necessarily be able to reach the destination she wants. This is because accessibility/capability depends on the constraints of individuals and additional external factors related to land use patterns and the transportation performance versus the distribution of opportunities and activities (Banister & Hickman, 2006; Kenyon et al., 2002; Soltani et al., 2016).

In conclusion, referring to the definition of CA key terms (see Section 2), since factors such as income or car ownership can be considered both resource and conversion factors, the current study intends to resolve this ambiguity from its own perspective, aiming to facilitate the modeling of capabilities. So, the paper suggests aggregating all resources and conversion factors as weighted variables of a unit multi-dimensional framework that all variables interact mutually. The reason that the developed framework avoids using a separate function to translate resources to capabilities is that 1) there are uncertainties about some factors, such as income that would be used in resources or the conversion function, 2) some variables are correlated, as car ownership is related to the income level and can be evaluated together, and 3) the importance of different resources may not be equal in different contexts; for example, the development of new metro lines in a city may offer higher levels of accessibility/capability for residents than cycling path. Therefore, a weighting process will be finally needed.

4. Objectives and Contribution

To sum up, in addition to addressing challenges related to the conceptualization of capability as accessibility and its multidimensional essence, since some factors such as income can be considered both resource and conversion factors, in order to evaluate people's capabilities and the dynamic interaction between these two concepts, this paper proposes to employ an aggregated weighting method that considers resources and conversion factors in mutual interaction and avoids a sequential process to evaluate capabilities (Fig.1). Therefore, individual characteristics like age, gender, disability, and car ownership have been examined along with environmental factors (landuse and transport system). To this end, variables classified in three dimensions as Individuals' Characteristics, transportation options, and living environment have been collected to build the conceptual framework representing individual and environmental features that make someone's capabilities set. Then, based on the authors' opinions and a survey among residents, a simple weighting method weights the variables to highlight the importance of individual or environmental characteristics and measure an index for a person's capability as the Capability Index (CI). Finally, scenarios/CIs for 16 different persons are evaluated in a hypothetical residential block in an urban area, and results are discussed through the lens of individual differences. Therefore, it is necessary to mention that this paper aims to underscoring the new framework that considers resources and conversion factors aggregately and the hypothetical implementation is a simple representation for further studies. So, provided statistical analysis is necessarily mentioned to be used in future similar works.

5. Methodology & Implementation

5.1 Methodology

Conceptual Framework

The concept of capability, rather than being confined to individuals or the built environment, is a combined notion representing the interaction of all the components; that is, what amenities and opportunities the physical environment provides, and to what extent people can utilize their characteristics to achieve well-being. By reviewing the literature on various indicators of different aspects, three dimensions are determined to compose the study's proposed model and measure the level of capability (capability index (CI)) in the study area. Also, to interpret and measure every dimension, it is comprised of several involving variables that are gathered from equity literature. Therefore, the model dimensions and their belonging variables are (Fig. 2):

- transportation options (public and private): road network, public transport system, etc.;
- living environment: mixed-use and attractiveness of land uses, quality of the living environment (e.g. Pollution);
- individuals' characteristics: residential location, age, gender, income, disability, car ownership;

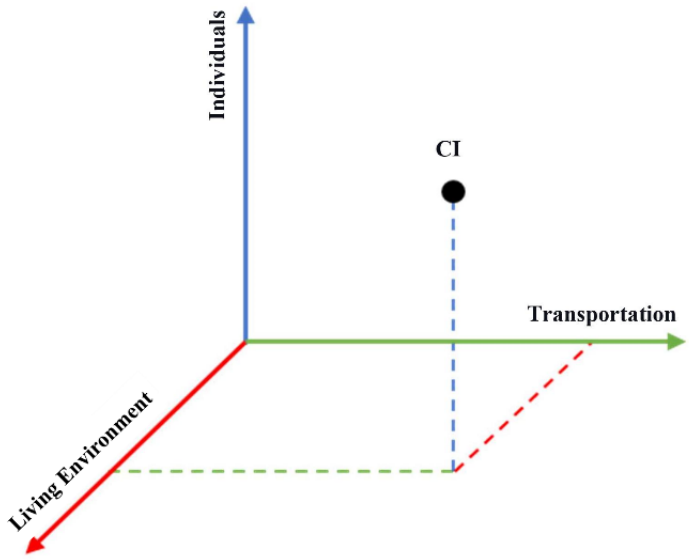

Fig.2 Three-dimensional framework for measuring Capability Index

The point shown in the 3-dimensional coordinate system represents a person's accessibility/capability level regarding the interaction of her resources and conversion factors. As a result, the CI will be evaluated, not only based on the urban infrastructure and modes of transport available to people but also on the residents' ability to translate given resources into opportunities. That means, depending on the distance to public transport stations, the ease of using a transport mode, land use attractiveness, transport integration, level of income, or car ownership, the freedom to choose to participate in activities will vary among social groups. For example, income level grants people the freedom to choose among different available modes or car ownership will extend the range of accessibility to land uses.

Variables

Accordingly, each dimension and its constituent variables should be determined and measured. The variables should record the environmental and individual characteristics concerning equity implications and data availability in the study area. Therefore, to discover the capability approach strength in capturing various

conditions for people residing in an urban area, the variables should be described and measured for each dimension by reviewing the previous literature and experts' opinions (Tab.2). It is worth noting that the variables have been defined proportionally to the designed scenarios, and the capability is a more complicated notion in practice.

	Dimension	Variable
1	Individuals' Characteristics	Age
		Gender
		Income
		Disability
		Car ownership
2	Living Environment	Land-use Type
3	Transportation Options	Modes
		Integration
		Usability for disabled

Tab.2 Describing Variables

Modelling Procedure

Based on the proposed framework, measuring the variables will frame the model's fixed dimensions (transport and living environment indicators). Hence, by examining individuals' various characteristics, the model would calculate the CI for different scenarios, including measuring every person's freedom of choice in his desirable walking or driving distance. Finally, the CI results for individuals of a block would be statistically analyzed and discussed.

The statistical analysis is needed to determine whether data has been drawn from a normally distributed population, there is any outlier data, and what is the best statistic test to interpret the samples to explore the differences each variable makes in the capability of inhabitants. Because the normal distribution will create a standard condition for all individuals, and the planning provisions can reasonably originate from a certain distribution.

Although it is foreseeable that people with disabilities or lower incomes will be less capable, yet their CI should not be an outlier, as their ability to live in their residential location will generally be reduced. Figure 3 illustrates the methodology process for the present study.

5.2 Implementation

Case Study: Scenarios for a Block Residents

As mentioned before, measuring the variables will indicate the effect of each dimension. Tab.3 shows the measurement/descriptive classification for variables introduced in Tab.2. Then, the scenarios will be tested for 16 individuals inhibit in a residential block, based on different individual characteristics, while the environment dimensions (Transport and living environment indicators) are equal among them (Tab.4).

The individuals' profiles are 16 hypothetical but not so out-of-mind persons that are specially defined to shed light on the effect of various characteristics, and to reduce the complexity, it is assumed that they live in the same physical environment in the same residential block. Thus, the model is applied to estimate capability differences between people with different abilities through measuring the CI.

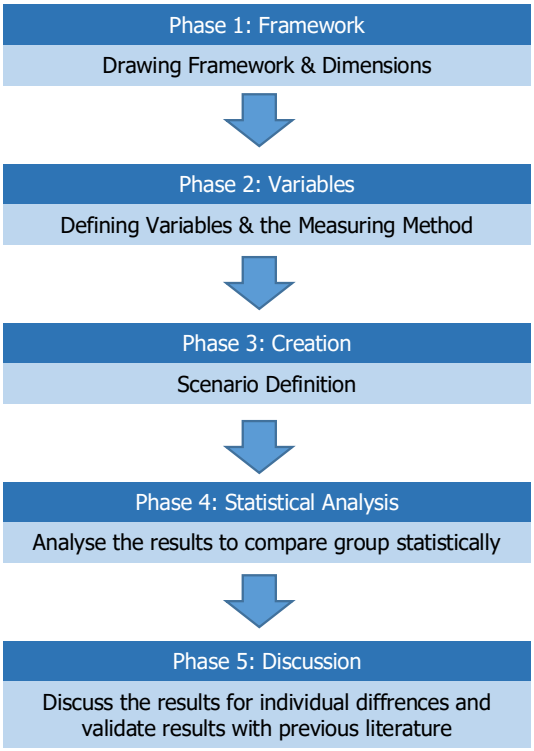

Fig.3 Methodology process

Fig.4 schematically shows the physical attributes for a census block taken from a real residential block in which the individuals live, which *d* indicates the optimal walking Euclidean distance for the elderly, *2d* for youth, and *D* shows optimum driving distance. The symbols on the left show the variety of modes available (regardless of service quality) in these spheres, and the lower marks indicate the type of land use available (regardless of number or attractiveness) in the given segment. Tab.5 presents the system integration pattern, which specifies the land uses and modes that each transport mode can connect.

	Dimension	Variable	Classification/Measurement
1	Individuals' Characteristics	Age	Old
			Young
		Income	Low
			High
		Disability	No
			Yes
		Car ownership	No
			Yes
2	Living Environment	Land-use Type	Healthcare (H)
			Park (P)
			Commercial (C)
			Educational (E)
3	Transportation Options	Modes	Metro
			Bus
			BRT
			Bicycle
		Integration	Connection to other modes or land uses
		Usability for disabled	No
			Yes

Tab.3 Measuring Variables

*Young: 18-64 years; Old: +65 years

** To highlight the effect of income level, medium-income groups are neglected. Low income: three lowest deciles of income; High: Top three deciles of income

Ind.	Age	Income	Disability	Car	Ind.	Age	Income	Disability	Car
1	Old	High	Yes	Yes	9	Young	High	Yes	Yes
2	Old	High	No	Yes	10	Young	High	No	Yes
3	Old	High	Yes	No	11	Young	High	Yes	No
4	Old	High	No	No	12	Young	High	No	No
5	Old	Low	Yes	Yes	13	Young	Low	Yes	Yes
6	Old	Low	No	Yes	14	Young	Low	No	Yes
7	Old	Low	Yes	No	15	Young	Low	Yes	No
8	Old	Low	No	No	16	Young	Low	No	No

Tab.4 Individual's Characteristics

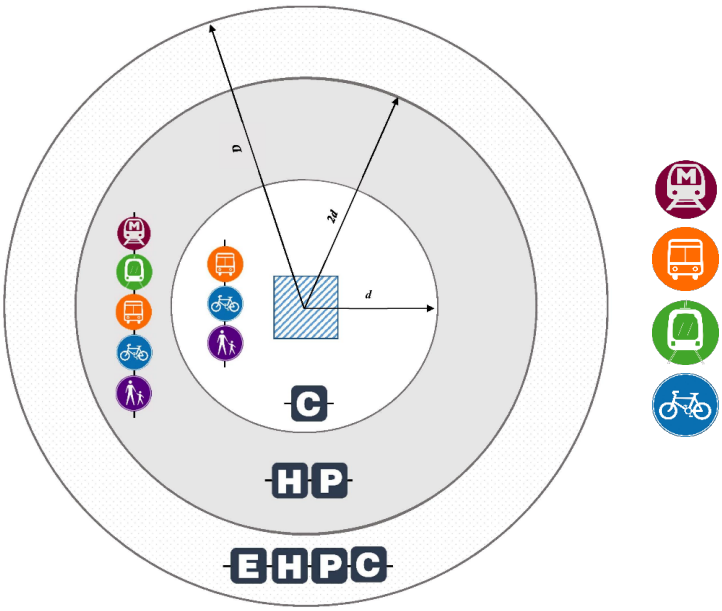

Fig.4 Model Schematic

Mode	Connection	
	Land-use	Mode
Metro	Healthcare , Park	Bus
Bus	Commercial	-
BRT	Educational	Metro
Bicycle	Park	Metro

Tab.5 Transport system integration

Model Assumptions and implications

The following assumptions have been applied to reduce the complexity of the model:

- the area is walkable for non-disabled people and wheelchair accessible for people with disabilities;
- only BRTs and buses are usable for disabled people;
- if a mode is usable for disabled people, its performance is also the same for non-disabled people;

- the desirability of each mode does not vary with the age group;
- since the destinations are approximately in one neighborhood, the effect of air pollution in this neighborhood is considered constant;
- gender differences do not affect people's mobility.
- *D*, the desirable driving distance, has been hypothetically considered a higher reachable distance by car to demonstrate the difference in walking distance.

In addition to the above assumptions, and in order to differentiate between individuals' preferences, based on a short survey conducted among 50 inhabitants around the study area to enquire land use preferences, public transport affordability, and optimum walking distance, it has been found that parks and healthcare for the elderly, and educational and commercial land uses for young people are in higher priority (Tab.6). For people with high incomes, modes of transport (in terms of travel costs) are not considerably different, but for low-income people, BRT, Metro, and bus are respectively affordable (Tab.7). Also, 500m, 1000m have been considered for *d* and *2d* as the desirable walking distance for elderly and young people. The coefficients of Tables 6 and 7 are considered as coefficients for model implementation. It is worth mentioning that the weighting method in this paper does not follow any specific method in order to draw a general scheme for weighting and aggregation; so the weights are simply assigned based on the authors' team. Accordingly, weights are relative values (preferences over each other) to highlight the differences between the importance of variables. Although the data have been collected through the survey, based on the ranked options, the weights are finally assigned by authors to bold the contrast between weights and increase the interpretability of the framework. Moreover, based on the framework's design, all indicators should be weighted in interaction with each other, surveying residents' and experts' opinions. For example, although the integration and affordability of each transport mode have been calculated in order to measure the level of accessibility for each individual to distributed opportunities (Table 8 for Metro), the transport modes are also different regarding their capacity, safety, speed, peak hour/off-peak hour speed, etc. So, each mode would be weighted based on a decision-making process between experts. In the extension of the model, besides the type of destination/land use, its attractiveness is also important. So, the weight of attractiveness in relation to land-use type will be assigned based on experts' judgments. For this purpose, Multi-Criteria Decision-Making (MCDM) methods such as Analytic Hierarchy Process (AHP) or Analytic Network Process (ANP), in either crisp or fuzzy approaches, seem to be compatible with the structure of the framework, as it is based on reciprocal comparison of variables in an aggregate model.

Age	Commercial	Educational	Healthcare	Park
Old	1	1	2	2
Young	2	2	1	1

Tab.6 Preference coefficients for different age groups

Income	Walk	Bicycle	Bus	BRT	Metro
Low	5	4	4	3	2
High	5	5	5	5	5

Tab.7 Preference coefficients of modes of transport to income

For each mode, the value of integration is measured by the desirability of the modes or land uses that the mode provides access to them. For example, for accessibility to Metro station, a person will get a 2 (low-income) or 5 (high-income) from Table 7. Additionally, because Metro connects to healthcare (old: 2, young: 1), park (old: 2, Younger: 1), and bus (low income: 4, high income: 5) (Tables 5, 6, 7), it can bring 6, 8, 7 or

9 for transport integration. To sum up, the individual will get 8 or 10 (for low income), or 12 or 14 (for high income), regarding just access to Metro station (Table 8).

Individual	Mode		Transport Integration						Sum	
	Metro		Low			High				
	Low	High	Park	Healthcare	Bus	Park	Healthcare	Bus	Low	High
Young	2	5	1	1	4	1	1	5	8	12
Old	2	5	2	2	4	2	2	5	10	14

Tab.8 Calculation Example of CI for accessibility to Metro

6. Results and Discussion

6.1 Scenario Interpretation

Similar to the term "microstories" that (Vecchio, 2020) uses to express the daily mobility experience based on each individual's characteristics and environment, four scenarios of the model are described for people listed in Table 4. These results implicitly show differences in individuals' capability (CI) living in the residential block due to different interactions between available resources and conversion factors (Table 9).

Ind.	How resources and opportunities are used
2	An *old* age person with no disability, who can choose between 4 modes of walking, cycling, bus, and personal car. If the person's priority is to meet his healthcare needs (healthcare land-use is in priority for older people (Table 5), he will have to use a personal car, as he is not within walking distance of the health centers and the bus is not connected to the health center.
7	An *old* age person with a disability will have to use public transport due to low income and no car ownership to meet his needs (e.g. healthcare, park), so he will have to choose between bus and bicycle. In this case, if the sidewalks leading to the bus stops are walkable (or able to use a wheelchair), then this mode will only provide a connection to the commercial land-uses.
16	There is a *Young* man with no disability, who prefers to use public transport because of low income. Firstly, there is no commercial or educational land uses in his desirable walking range. Also, although all modes of public transport are within walking distance, only BRT can connect him to educational opportunities.
10	A *Young* person with no disability who has the freedom to choose from all modes of transport due to his high income. Therefore, he can achieve his desired land-uses with a favorable mode. This means that he is capable of using all resources and access to all opportunities freely.

Tab. 9 Interpretation of the model scenario for the people in the block

6.2 Capability Index (CI)

According to the coefficients applied in Tab.5 and 6, 16 different states can be evaluated for all capability indices in the residential block in Figure 4 (Tab.10).

The results in Table 10 show the extent to which, in equal conditions for individuals, their socioeconomic characteristics can influence their conversion factor. For example, the disability makes 15 units' difference between individuals 7, 8, which are the same in other variables. Also, the results show that individuals' stories defined in (Table 9) have the CI of 201, 41, 161, and 223, respectively. As a result, individual 7 has the least CI, individual 10 has the highest CI, and the other two have facilities and limitations that make them relatively capable of meeting their needs. Moreover, this study shows that age, income, disability, and car ownership influence individuals' ability, as the lowest level of capability occurs for a person with an *old* age group, low income, disability, and not owning a car. It is now possible to evaluate the extent and impact of each variable on the final CI results.

Ind.	CI	Age	Income	Disability	Car	Ind.	CI	Age	Income	Disability	Car
7	41	Old	Low	Yes	No	**1**	169	Old	High	Yes	Yes
3	45	Old	High	Yes	No	**13**	180	Young	Low	Yes	Yes
15	56	Young	Low	Yes	No	**14**	181	Young	Low	No	Yes
11	60	Young	High	Yes	No	**9**	184	Young	High	Yes	Yes
8	66	Old	Low	No	No	**6**	190	Old	Low	No	Yes
4	77	Old	High	No	No	**2**	201	Old	High	No	Yes
16	161	Young	Low	No	No	**12**	203	Young	High	No	No
5	165	Old	Low	Yes	Yes	**10**	223	Young	High	No	Yes

Tab.10 Capability indices (CI)

6.3 Statistical Analysis

Normality

Before comparing the social groups, normality tests were conducted to determine if the CI is well-modeled by a normal distribution and would follow a rational pattern for evaluation and policymaking. Results show, since the significance of Kolmogorov-Smirnov and Shapiro-Wilk are 0.200 and 0.109 respectively (df=16), and are higher than 0.05 (as we investigate the normal distribution for 5% error), the null hypothesis, which assumes the dataset is normal, is failed to reject. Besides, the Skewness and Kurtosis with -0.597 and -0.973 are between (-2, 2) are proving the dataset will be modeled by a normal distribution. Also, Grubbs' test shows no outlier data, and all data values come from the same normal distribution for a 0.95 significance level.

Paired-Samples Test

By ascertaining the normality of data distribution, we now compare two population means to determine whether there is any statistical evidence that the mean difference between paired observations is significantly different from zero and evaluate this difference's size. Table 11 represents the paired-samples t-test statistics and differences results. The Null hypothesis would be the equality of two groups' means, and the alternative would prove the opposite. Besides, according to sample size (n = 8), degree of freedom (df = 7) and confidence coefficient of 95% ($\alpha = 0.05$) data, the two-tailed t-test critical value is CV = 2.365 from student's t-distribution table. It indicates any t values exceeding 2.365, two groups of individuals are statistically significantly different, regardless of which group is better.

Further, the results show, for *Disability* and *Age* variables, the confidence interval does include zero, $t(7) < 2.365$, and $p > .05$. Thus, this test would fail to reject the null hypothesis, and groups would not be considered statistically significant. On the other hand, results support the idea that owning a car or higher income would significantly differ between population groups. Positive lower and upper intervals, $t(7) > 2.365$ and $p < 0.05$ for both *Car Ownership* and *Income,* admits there is a significant difference between samples. Also, Cohen's d effect size is 2.214 and 0.223, respectively, which indicates a substantial effect of *Car Ownership* and a small effect size of Income on individuals' Capability index.

	Variable	Group	n	Mean	Confidence Interval		SD	t(7)	p	Cohen's d
					Lower	*Upper*				
1	*Disability*	Disabled	8	112.50	-3.991	104.491	66.798	2.191	.065	-
		Non-disabled	8	162.75			59.167			
2	*Age*	Old	8	119.25	-2.668	76.168	68.153	2.205	.063	-
		Young	8	156.00			63.160			
3	*Car Ownership*	Not owned	8	88.63	57.752	138.248	59.788	5.758	.001	2.214
		Owned	8	186.63			18.524			
4	*Income*	Low	8	130.00	1.213	29.287	63.673	2.569	.037	0.223
		High	8	145.25			72.239			

Tab.11 Paired-sample test results (α=0.05, df =7)

6.4 Individual characteristics

The principal purposes of this study are: first to demonstrate the capability level through the conceptualization of capability as the accessibility, and second, combine the concepts of resources and conversion factors to propose an aggregated framework to measure capabilities level (CI). So, since the distribution and performance of transport and land use system can be considered as fixed variables, by comparing the means and trends of two dependent groups of individuals (people who are the same in all variables, except one), we will discuss how each characteristic can affect the final CI.

Disability

Figure 5 shows the CI of individuals with and without disability, with other conditions remaining the same (below and upper x-axes show individual numbers in (Tab. 10), which are separated related to each group). According to the graph:

For people with disabilities, the graph witnessed a dramatic rise in car ownership (from 60 for ind. 11 to 165 for ind. 5), which will increase their ability to achieve the demanded land uses. Also, the capability gap with their non-disabled counterparts reaches its lowest level, which is approximately the same for individuals 13 and 14 at 180 and 181.

Along with disability, age groups make a significant difference in the CI of individuals. People 7 and 3 with disabilities and people 8 and 4 with no disabilities show little difference in CI, all of whom are elderly. In contrast, subjects 15 and 11 report significant variations compared to persons 16 and 12, with the highest difference in the CI for individuals 11 and 12, both of whom are young. This meaningful variation implies that reducing the mobility of young people can cause a notable decrease in their freedom of accessibility to opportunities.

Figure 6 depicts a comparison between the capability index of two age groups, young and old. The following discussion can be concluded from the results:

Except for one case, all older people have a lower CI than their younger counterparts, primarily because of their lower ability to walk longer distances and access facilities. This is also proved by many studies which denote urban accessibility changes for different age segments (Papa et al., 2018; Gargiulo et al., 2018)

In one case, between individuals 6 and 14, the CI of the younger person is lower. It seems that the environmental effect on the young person makes him less capable of pursuing nearby activities. It is also

justified in Figure 4, the number of available and desirable land uses in driving distance (D) is more significant for older people (4 vs 3).

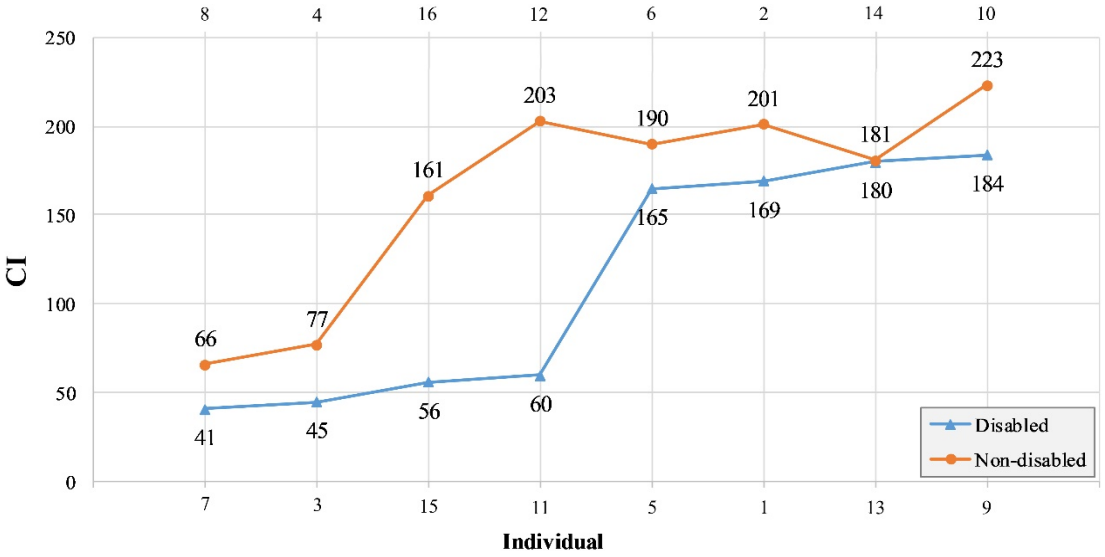

Fig.5 Comparison of capability Index between Disabled and Non-disabled groups

Age

Additionally, two notable increases occur in the graph. For older people, the jump is from the CI of ind. 4 to ind. 5, which car ownership makes this steep rise; and for young people, a 101-unit increase between two persons 11 and 16 is due to non-disability for person 16, which supports the idea that disability will have a major impact on youth.

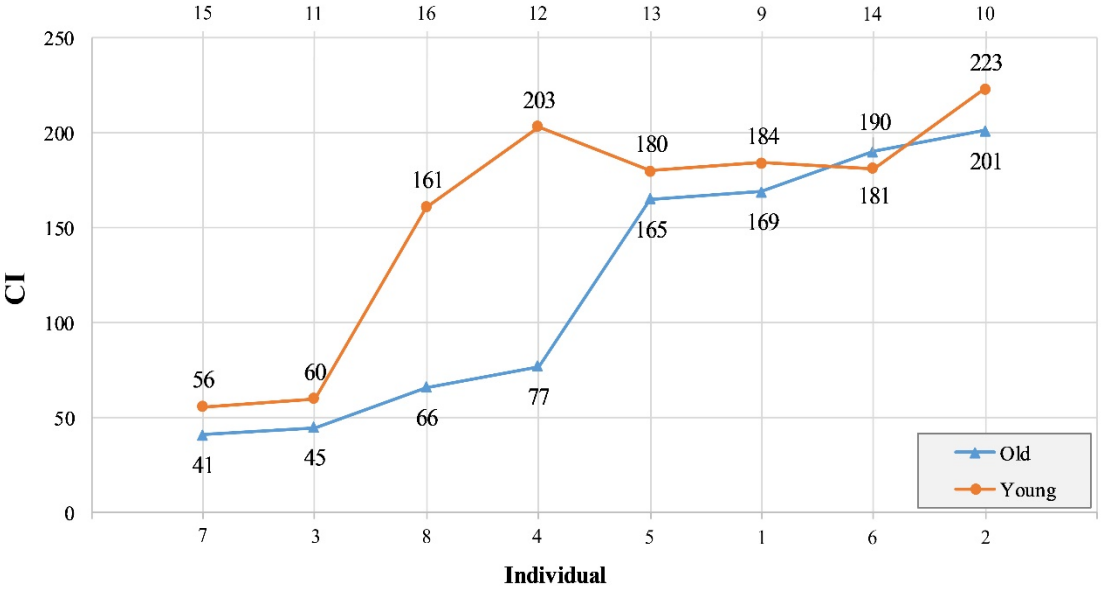

Fig.6 Comparison of Capability Index for Young and Old age groups

Car Ownership

Fig.7 shows the CI comparison of people with and without car ownership (use public transport), while other variables are constant. We can conclude:

According to Table 10, car ownership does affect the CI of individuals. As Cohen's d explains, in comparison to public transport users, owning a car makes a very significant difference in CI (effect size = 2.214> 0.8).

The most considerable difference in CI for people is because of the car ownership variable, which is that 6 out of 8 public transport users experience a lower capability than average (mean = 145.37), and supports the results of previous studies (Martens, 2016).

Only two people without a car have a relatively high CI (person 16 and 12) who are both young and non-disabled, so they have enough ability to be mobile and compensate for not having a car.

Furthermore, the CI fluctuations among people without a car are much higher than those owning a car (162 units vs 58 units), which explains due to a lack of accessibility through the optimal walking distance, owning a car would make a significant variance in the CI, as it is opposed to accessibility-based planning paradigm.

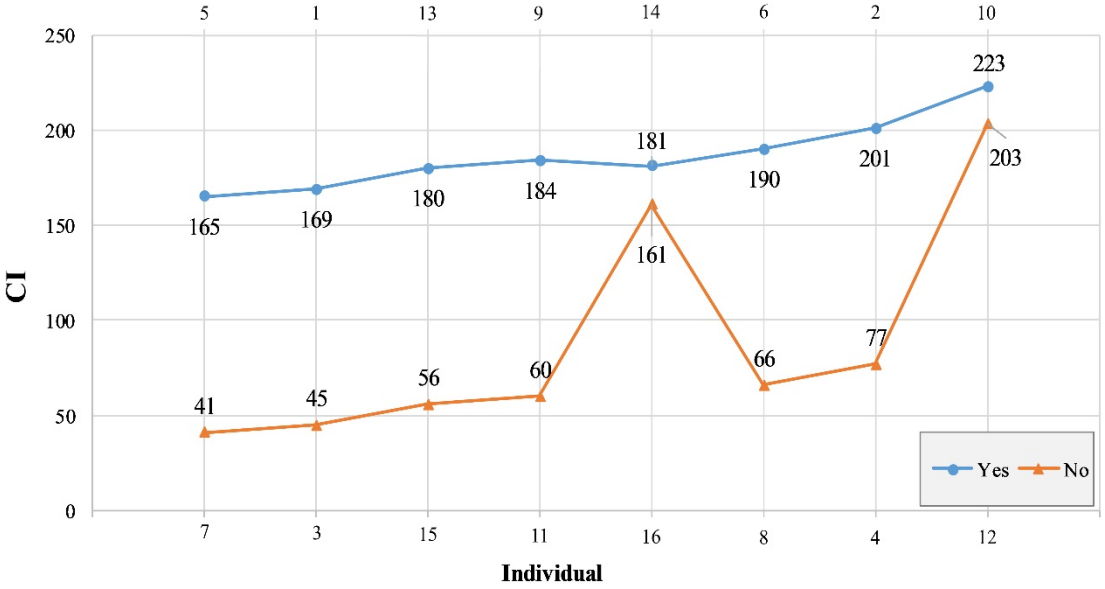

Fig.7 Comparison of Capability Index for people with and without owning a private car

Income

Fig.8 shows the comparison between the CI of high- and low-income groups, ceteris paribus. The results imply: Income makes a significant difference between individuals. As Table 10 reports, although the size of the income level effect is relatively small (0.223 ≅ 0.2), but proves the influence of affordability on the level that people can meet their needs. Variances in income level make little difference between the two groups. That is maybe due to the simplification of the model implementation, in which income level only affects the desirability of using various public transport modes (Tab.7).

The dramatic increase in the two graphs is due to differences in age groups proves that with the same income level, younger people are more capable of meeting their needs because of their higher mobility level.

7. Summary & Conclusion

Justice is an extensive notion that has long been regarded as one of the essential human aspirations, but implementing the concept into the field of urban-transport policy has just happened in recent decades. As a result, many studies have focused on interpreting the concepts of different justice theories in transportation and compared the possibilities and shortcomings of each approach. The capability approach, developed by Sen and then Nussbaum, is one of the most influential theories that has received much attention because of its emphasis on individuals' freedom of choice in interacting with the environment. So, this study seeks to propose a model to capture the capability level of individuals, which reveals the level of ease, freedom, and ability of individuals to achieve social activities and afford their basic needs.

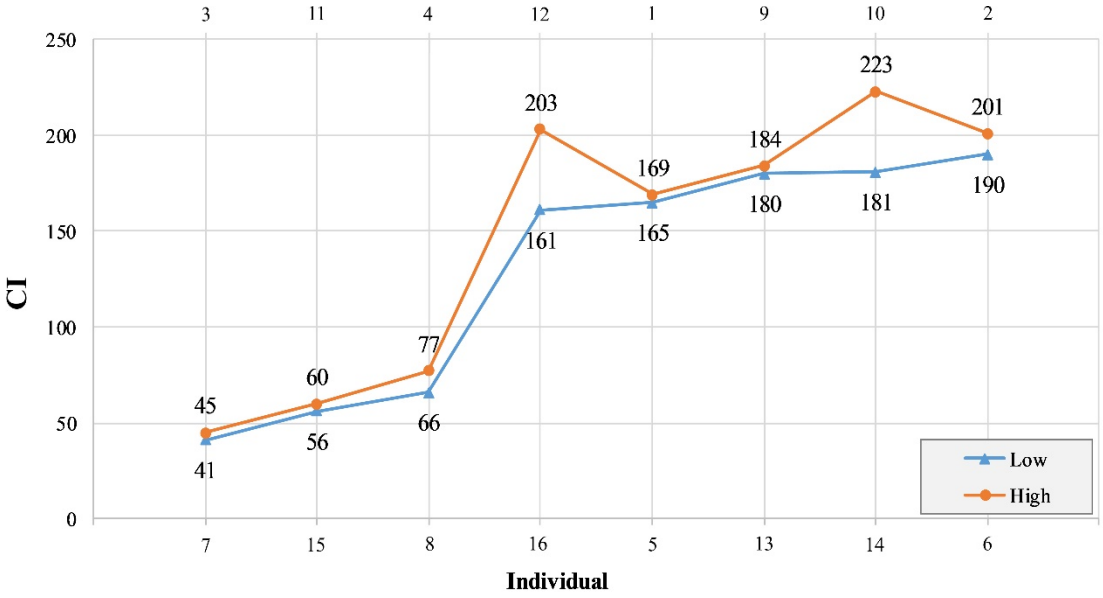

Fig.8 Comparison of Capability Index for low- and high-income level group

The not-so-distant situations that individuals struggle with and may restrict them from choosing freely among the opportunities.

Consequently, focusing on the differentiation of individuals' characteristics and their ability to interact with their environment and to simplify the implementation of capability theory in planning, the model of study provides an index called Capability Index (CI), indicating the extent to which each individual is able to meet his own basic needs. Consequently, according to the results of previous studies, a number of prominent variables are defined in the three dimensions of individuals, living environment, and transport options, and the model was established to evaluate the scenarios in which the capability of 16 individuals with different demographic, socioeconomic and environmental characteristics was compared.

The results indicate, the normal distribution of the CI dataset with no outlier data supports for use of parametric statistical tests besides providing a reasonable paradigm for decision making. Also, evidence shows the most significant difference in the capability index is made by car ownership status. This claim is supported by 2.214 Cohen's d size effect coefficient, besides 75% of people using public transport have a capability below the average of society. This meaningful difference indicates the need to plan for accessible neighborhoods by active transport modes like walking, such that it leads to achieving everyday opportunities within a sustainable urban area, considering all vulnerable groups such as the elderly. The easier individuals achieve opportunities by private car, in comparison to public transport, the more they gradually tend to use it; that will result in an increase in externalities such as pollution and crash rates. Such externalities especially take a negative effect on vulnerable groups and reduce their capabilities. So, the planning for equity of accessibility will tend to design an integrated public transport-land use system that grants accessibility to activities and will reduce the superiority of car ownership over other modes. An efficient management system for taxes and parking, especially in CBDs will also help to move toward accessibility-based planning.

Besides, although the paired sample t-test fails to prove the disability and age effect on compared groups, comparing the means reports non-disability increase the CI, and the effect of disability in the younger age group causes a more significant decline in their ability than older people. These findings hold insightful hints to be studied in further studies because researchers mostly do not consider the effect of disability on younger age groups over time. As the decline in capability is more apparent in young groups, it warns about the danger of exclusion, isolation, and future mental health consequences. Unpleasant experiences in achieving outdoor activities may lead to a decline in hopes and aspirations in a considerable proportion of society. Moreover, this exclusion would be multiplied by the inaccessible design of sidewalks, transport stations, and fleets, especially

in developing countries, which deprives a significant part of vulnerable people. So, considering variables of urban design, which have been neglected in the previous literature would be determinant in the evaluation of capabilities.

Moreover, the results for higher income and lower age groups corroborate past literature findings, as these characteristics increase the chance of ability and perceived freedom in using different modes of transport (active, public, and private), and consequently, the level of capabilities and functionings are higher for these groups (Cao & Hickman, 2019a; Hickman et al., 2017). Consequently, the model demonstrates the need to evaluate residents' capabilities based on inherent individual characteristics and enhance them through equitable urban-transport planning, fair distribution of benefits and burdens, and a paradigm shift to justice-based planning. Therefore, a mutual interaction between individuals and the environment results in higher capabilities (CI) and more social inclusion among all groups. An accessible efficient LUT system, as mentioned in sustainable development goals in urban areas, would gradually affect people's experiences and shape their aspirations to make use of available resources. Although vulnerable groups are in priority for equity planning, encouraging well-off people, that are more willing to use private mobility resources, to use public transport or active mobility means could be an effective policy toward controlling the traffic and its belonging externalities. However, evaluating the capability is context-sensitive, and observing the travel behavior in different income groups is necessary (bottom-up approach).

Generally, although the paper corroborates past literature findings, such as the effect of income level on capability, the model does not claim that is able to fully consider all individual characteristics; especially experiences and aspirations that are regarded among conversion factors. Because these features should be captured through a continuous questionnaire over time according to changes in land-use and mobility options, and some externalities like pollution or crash rate within a living neighborhood. Therefore, the model will not fully address the complex concept of capability, but it suggests the extension of such a framework would consider a reliable level of capability among individuals.

Hence, it is suggested that by reducing the assumptions of this study by utilizing big data sources, relying on more accurate weighting and calculation methods and tools (e.g., Geographic Information System), future studies would provide more accurate and reliable results. Besides, since this paper has specifically focused on material resources, combining such a framework with a bottom-up approach can enrich the evaluations and better describe the conversion factors.

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Image Sources

Fig.1: Extracted from Robeyns, I. (2005);

Fig.2: This image is designed by the Authors;

All other images are graphs that created by the Authors.

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