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Ana Maria A. C. Rocha · Eufemia Tarantino ·  
Carmelo Maria Torre · Yeliz Karaca (Eds.)

# Computational Science and Its Applications – ICCSA 2020

20th International Conference  
Cagliari, Italy, July 1–4, 2020  
Proceedings, Part VII

7  
Part VII



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# Computational Science and Its Applications – ICCSA 2020

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## Preface

These seven volumes (LNCS volumes 12249–12255) consist of the peer-reviewed papers from the International Conference on Computational Science and Its Applications (ICCSA 2020) which took place from July 1–4, 2020. Initially the conference was planned to be held in Cagliari, Italy, in collaboration with the University of Cagliari, but due to the COVID-19 pandemic it was organized as an online event.

ICCSA 2020 was a successful event in the conference series, previously held in Saint Petersburg, Russia (2019), Melbourne, Australia (2018), Trieste, Italy (2017), Beijing, China (2016), Banff, Canada (2015), Guimaraes, Portugal (2014), Ho Chi Minh City, Vietnam (2013), Salvador, Brazil (2012), Santander, Spain (2011), Fukuoka, Japan (2010), Suwon, South Korea (2009), Perugia, Italy (2008), Kuala Lumpur, Malaysia (2007), Glasgow, UK (2006), Singapore (2005), Assisi, Italy (2004), Montreal, Canada (2003), and (as ICCS) Amsterdam, The Netherlands (2002) and San Francisco, USA (2001).

Computational science is the main pillar of most of the present research, industrial and commercial applications, and plays a unique role in exploiting ICT innovative technologies. The ICCSA conference series has provided a venue for researchers and industry practitioners to discuss new ideas, to share complex problems and their solutions, and to shape new trends in computational science.

Apart from the general track, ICCSA 2020 also included 52 workshops in various areas of computational science, ranging from computational science technologies to specific areas of computational science, such as software engineering, security, machine learning and artificial intelligence, blockchain technologies, and of applications in many fields. We accepted 498 papers, distributed among 6 conference main tracks, which included 52 in workshops and 32 short papers. We would like to express our appreciation to the workshops chairs and co-chairs for their hard work and dedication.

The success of the ICCSA conference series in general, and of ICCSA 2020 in particular, vitally depends on the support from many people: authors, presenters, participants, keynote speakers, workshop chairs, session chairs, Organizing Committee members, student volunteers, Program Committee members, Advisory Committee members, international liaison chairs, reviewers, and others in various roles. We take this opportunity to wholeheartedly thank them all.

We also wish to thank our publisher, Springer, for their acceptance to publish the proceedings, for sponsoring part of the Best Papers Awards, and for their kind assistance and cooperation during the editing process.

We cordially invite you to visit the ICCSA website <http://www.iccsa.org> where you can find all the relevant information about this interesting and exciting event.

July 2020

Oswaldo Gervasi  
Beniamino Murgante  
Sanjay Misra

# Welcome to the Online Conference

The COVID-19 pandemic disrupted our plans for ICCSA 2020, as was the case for the scientific community around the world. Hence, we had to promptly regroup and rush to set in place the organization and the underlying infrastructure of the online event.

We chose to build the technological infrastructure using only open source software. In particular, we used Jitsi ([jitsi.org](https://jitsi.org)) for the videoconferencing, Riot ([riot.im](https://riot.im)) together with Matrix ([matrix.org](https://matrix.org)) for chat and asynchronous communication, and Jibri ([github.com/jitsi/jibri](https://github.com/jitsi/jibri)) for live streaming sessions on YouTube.

Six Jitsi servers were set up, one for each parallel session. The participants of the sessions were helped and assisted by eight volunteer students (from the Universities of Cagliari, Florence, Perugia, and Bari), who assured technical support and smooth running of the conference proceedings.

The implementation of the software infrastructure and the technical coordination of the volunteers was carried out by Damiano Perri and Marco Simonetti.

Our warmest thanks go to all the volunteering students, to the technical coordinators, and to the development communities of Jitsi, Jibri, Riot, and Matrix, who made their terrific platforms available as open source software.

Our heartfelt thanks go to the keynote speakers: Yaneer Bar-Yam, Cecilia Ceccarelli, and Vincenzo Piuri and to the guests of the closing keynote panel: Mike Batty, Denise Pumain, and Alexis Tsoukiàs.

A big thank you goes to all the 454 speakers, many of whom showed an enormous collaborative spirit, sometimes participating and presenting in almost prohibitive times of the day, given that the participants of this year's conference come from 52 countries scattered over many time zones of the globe.

Finally, we would like to thank Google for letting us livestream all the events via YouTube. In addition to lightening the load of our Jitsi servers, that will allow us to keep memory and to be able to review the most exciting moments of the conference.

We all hope to meet in our beautiful Cagliari next year, safe from COVID-19, and finally free to meet in person and enjoy the beauty of the ICCSA community in the enchanting Sardinia.

July 2020

Ivan Blečić  
Chiara Garau



# Organization

ICCSA 2020 was organized by the University of Cagliari (Italy), University of Perugia (Italy), University of Basilicata (Italy), Monash University (Australia), Kyushu Sangyo University (Japan), and University of Minho (Portugal).

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**Data Science for Cyber Security (DS4Cyber 2020)**

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# A Literature Review on Walkability and its Theoretical Framework. Emerging Perspectives for Research Developments

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**Abstract.** Urbanization identifies the contemporary city as the crucible of human condition. This tendency elicits the issue of the ways in which the built environment affects human behaviour. In particular, walking emerges as a central topic. Walking, in fact, is conceptualized as a vector for engaging with the world, and as a conduit to physical activity, social contact and optional practices. Consequently, a vast body of literature exists, related to the concept of walkability. The latter can be defined as the built environment potential to affect people's propensity to walk to different destinations and for different purposes. This study, through a comprehensive literature review investigates four concepts: capability; affordance; configuration and Urban ethics. These concepts embody four central dimensions of the research on walkability: arguments for investigating walkability; conceptualization of person-environment transactions; methodologies and ethical implications. The aim of this study, thus, is to individuate the theoretical framework for a precise understanding of the impact of the built environment on human behaviour and to underline perspectives for the further development of the research on walkability.

**Keywords:** Walkability · Capability · Affordance · Space syntax · Urban ethics

## 1 Introduction

Increasingly people live in an artificial environment superimposed to the natural environment. By 2050, this second nature will be constituted for almost 75% of the world population by urban areas [1]. Urbanization thus emerges as a vital force affecting human well-being in the next future and determines the primacy of the city in defining the human condition for the majority of humanity [2].

The political, social, and environmental aspects of urbanization constitute thus a central issue for research in different disciplines. The ways in which the attributes of the built environment (BE) affect human behaviour are a central issue within the disciplinary areas of urban studies and urban planning. In particular, walkability, defined as the

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potential of the BE to afford walking, emerges as a central topic. Walking, in fact, entails an embodied basis for engaging with one's material environment [3] and a multi-dimensional category of behaviour, including an utilitarian component – e.g. walking as a form of transportation – and a recreative and social component – walking as a vector to physical activity, or as a pre-condition for social interactions [4–6]. This study aims to investigate, via a literature review, the concepts of capability, affordance, configuration and urban ethics, within the context of walkability. Capability refers to the ability of a person to achieve a state or condition deemed as valuable [7]. Affordances refer to the functional, emotional, and social opportunities and constraints incorporated into a setting in relation to a specific category of individuals [8, 9]. Configuration refers to topological relations among elements within a structure and urban ethics entail the ethical and moral implications of urbanization and of urban processes [10].

These concepts are emerging as central for framing and understanding four distinct dimensions of the discourse on walkability: i) capability refers to the conceptualization of outcomes on well-being of environmental opportunities for walking for different purposes and to different destination; ii) affordances incorporate a conceptualization of person-environment transactions; iii] the notion of configuration relates to the individuation of environmental co-relates of walkability and definition of indicators and techniques for their assessment; and iv] urban ethics underlines Consequences of walkability on inter-subjective relations, identities and norms within the contemporary city. Consequently, the objective of this study is twofold: on the one hand the objective is to define a consistent theoretical framework for understanding the relations between the built environment and the outdoor practices of the urban populations. On the other hand, the focus of this paper is to underline potential perspectives for the future development of the research on walkability.

The paper is structured into six sections: after the introduction, a review of the literature on walkability is presented. The third section describes the methodological framework and the fourth section introduced the concepts of capability, affordance, configuration and urban ethics. The results obtained from the literature review are then discussed. Finally, conclusions reassume the fundamental findings of the study and outlines the objectives of its development.

## 2 State of the Art on Walkability

Walkability can be defined as a measure of the physical environment potential to enable walking, as a predictive indicator of active travel and physical activity [11], or as an indicator of the usability of the built environment to people [12] who walk to different destinations and for different purposes [4, 5, 13, 14].

Walking is conceptualized, in fact, as a multi-dimensional behavioural category that includes an utilitarian dimension - walking as a necessary activity - a leisure dimension - walking as an optional and recreational activity per se or as a conduit to physical activity - and a social dimension, thus related to walking as a vector to interactions among individuals [6, 15]. A vast consensus exists, about the beneficial effects of walking. In particular, walking is associated to improved physical and mental health, to better perceived well-being and to quality of life, to health-economic effects,

and sociability [16]. In Ferdman's words, Walking, as an embodied mobility mode, is conducive to multiple types of objective goods, including walking as knowing, walking as creativity, walking as sociability and walking as achievement [17].

As a consequence, an association between built environment, every-day practices and health outcomes is recognized particularly with respect to the areas of obesity, cardio-vascular and chronic diseases, autonomy, local economic development, independence of the elderly and social connectedness [12, 16, 17].

The existing literature correlates walkability to attributes of both the social and physical environment. Environmental correlates include contextual factors, such as access to transit, network configuration and land-use patterns and intrinsic factors, such as width and slope of pedestrian paths, condition of surfaces, street furniture, priority of pedestrian movement.

Different approaches to the relation between built environment and outdoor practices result in different definitions and categorizations of environmental correlates of walkability [4, 18]. Web-based tools focus on quantitative macroscale indicators, such as intersection density, population density, and distance from amenities; questionnaires report pedestrians' perceptions and preferences related to significant spatial and social properties of the urban space [20]. Audit tools are based on qualitative evaluation of urban design microscale aspects of route segments. Lastly, Multi-criteria analysis model conceptualizes walkability in terms of both inherent and endowed characters of the built environment. More precisely, the 3Ds layout [19], operationalizes walkability in terms of density, diversity, and design. Ewing et al. [20] propose a 5-dimension layout, adding the categories of distance to transit and destination accessibility. Alternative layouts include attractiveness, safety, comfort and accessibility [21]; use and fruition, health and wellbeing, appearance, management, environment, and safety and security [22]. Furthermore, The 5Cs layout relates walkability to connectedness, conviviality, convenience, comfort and conspicuousness [23]. Moura et al. [24] added the further dimensions of commitment and coexistence. This 7C's layout is then adapted by Garau et al. [18, 25], to structure a methodological framework for the analysis of built-environment factors conducive to children's independent outdoor activities. Despite the relevance of walkability-related methodological frameworks for supporting decision-making processes, significant limits emerge from the existing literature. Firstly, despite the fact that arguments for improving walkability refer to human well-being, a comprehensive conceptualization of the latter is rarely considered. Furthermore, the ethical issues emerging from the discourse on walkability, and related to the category of conflict, are neither recognized or exhaustively investigated. Secondly Moura et al. [24] and Battista and Manaugh [26] Underline limits in accounting for the effects of individual characteristics, including age, gender, abilities, needs and purposes and contextual socio-economic factors, on people's perceptions of the public space. Lastly, the existing measures of walkability marginally account for the effect of the topology of spatial structures on patterns of natural movement, co-presence and co-awareness. Prospects of addressing these criticalities are embodied in the concepts of capability, affordance, urban ethics and configuration, which are comprehensively analysed in the subsequent sections.

### 3 Methodology

This study investigates to what extent the existing literature on walkability recognizes the research prospects embodied in the concepts of capability, affordance, configuration and urban ethics. This study is articulated in two parts. Firstly, a theoretical framework is established by discussing the concepts of capability, affordance, configuration and urban ethics. Then a review of the literature on walkability is conducted and a set of indicators is measured to determine the centrality of each concept within the existing literature.

Indicators include number of results found (Na), number of citations (Nc), average citations per item (Ac), Number of citing articles (Nca) and h-index. The latter is expressed as an integer value, h, measuring the number of articles cited at least h times. Moreover, the distribution across disciplinary areas of articles and of citing articles is assessed, by measuring the number of items per WoS category. These indicators are relevant for measuring the general impact of topics and articles.

**Table 1.** Queries utilized for the research of Articles on walkability included into the Web of Science Database

	Query
1	TS = (“walkab*” AND (“built environment” OR “neighborhood*” OR “street*”)) AND Document type: Article; Time-span: 2011–2020
2	TS = (“walkab*” AND (“built environment” OR “neighborhood*” OR “street*”)) Refined by: WoS Categories: (Transportation OR Environmental Sciences OR Engineering Multidisciplinary OR Environmental Studies OR Urban Studies OR Geography OR Regional Urban Planning OR Transportation Science Technology OR Engineering Civil OR Green Sustainable Science Technology OR Economics OR Engineering Environmental OR Architecture) AND Document type: Article; Time-span: 2011–2020
3	TS = (“walkab*” AND (“built environment” OR “neighborhood*” OR “street*”)) Refined by: WoS Categories: (#2) AND Topic: (“capabilit*” OR “capacit*”) AND Document type: Article; Time-span: 2011–2020
4	TS = (“walkab*” AND (“built environment” OR “neighborhood*” OR “street*”)) Refined by: WoS Categories: (#2) AND Topic: (“affordanc*”) AND Document type: Article; Time-span: 2011–2020
5	TS = (“walkab*” AND (“built environment” OR “neighborhood*” OR “street*”)) Refined by: WoS Categories: (#2) AND Topic: (“space syntax”) AND Document type: Article; Time-span: 2011–2020
6	TS = (“walkab*” AND (“built environment” OR “neighborhood*” OR “street*”)) Refined by: WoS Categories: (#2) AND Topic: (“ethic*” OR “gentrif*” OR “inequalit*”) AND Document type: Article; Time-span: 2011–2020

The literature review is articulated on six stage. Primarily, a set of articles on walkability is selected within the Web of Science (WoS) database, through a query containing the terms ‘walkability’, ‘built environment’, ‘street’ and ‘neighbourhood’, and considering the interval 2011–2020 as time span. Then, the indicators Na, Nc, Ac,

Nca and h-index are measured, and the distribution of items across WoS categories is determined. The set of articles is then refined by considering documents related to the disciplines of urban planning, according to WoS categories (see Table 1). The indicators Na, Nc, Ac, Nca and h-index are calculated with respect to the refined set of articles. In stage 3 the set of documents resulting from step 2 is refined through the query “topic: ‘capacity’ OR ‘capability’” and the indicators Na, Nc, Ac, Nca and h-index are determined. The articles are then analysed to investigate two factors: definition of capability and its positioning within a theoretical model relating built environment attributes, walking behaviour and well-being.

In stage 4 the set of documents identified in stage 2 is refined through the query “topic: ‘affordance’” and the indicators of impact and frequency are measured. Then, the articles are analysed to investigate conceptualizations of affordance and of its positioning within a model of interactions among individuals and the built environment.

In stage 5, the set of documents resulting from step two is refined according to the query “topic = ‘space syntax’”. The term space syntax refers to a complex of techniques and models for investigating the relation between topological properties of a spatial structure and patterns of human behaviours. Space-syntax is herein considered as instrumental to assess the centrality of the concept of configuration within the literature. The resulting set of articles is then analysed to measure the Na, Nc, Ac, Nca and h-index indicators. Afterwards, a thorough review of the articles is conducted according to four criteria: i) conceptualization of walking; ii) representation of the spatial structure; iii) Configurational properties considered; iv) relation of the configurational independent variable(s) with walking. Lastly the refined set from stage 2 is queried to identify a sub-set of documents containing the terms “ethics”, “inequality” and “gentrification” and the Na, Nc, Ac, Nca and h-index indicators are measured. The articles are then analysed to identify ethical issues related to walkability and to identify the type and direction of the relation between walkability and the observed ethical issues. In the sub-sequent section a comprehensive definition of the concepts of capability, affordance, configuration and Urban ethics is presented.

#### **4 Theoretical Framework: Capability, Affordance, Configuration and Urban Ethics**

The relevance of walking with respect to people’s well-being can be re-conceptualised through the capability approach. In Sen’s words [7], capability can be defined as the ability of an individual to achieve a specific functioning, hence a state or condition, deemed as valuable. Sen intends the concept of capability also as the alternative combinations of functions, from which the person can choose one set. In this sense the concept of capability, while accounting for achievements, incorporates the intrinsic significance, in terms of an individual’s well-being, of freedom and of the act of choosing per se [27].

Martha Nussbaum, [28] points to the incompleteness of Sen’s framework. In particular, Nussbaum builds on the Aristotelian analysis of the human good, to underline the necessity to individuate a list of capabilities central to human good living. According to Nussbaum, the central capabilities include: life; bodily health; bodily



integrity; affiliation; practical reason; play; senses, imagination, and thought; emotions; connection to nature and other species; control over one's environment [28]. Furthermore, the concept of capability implies the availability of different opportunities, as a condition that shapes the alternative combinations of functions constituting the capability set. This opportunity dimension is the focus of the research on the assessment of the walkability of public open spaces.

In this respect the concept of affordance [8, 29] emerges as a central category. Affordances are defined as the functional, emotional and social opportunities and constraints incorporated into a setting in relation to a specific individual or to a specific category of individuals. Thus, the concept of affordance is relational, situational and dynamic [30, 31]. It is relational since it refers to a set of relations among the attributes of the environment and the corporality of the individual. Hence, the concept of affordance overcomes the subject-object dichotomy. It is situational, since the actualization of opportunities is situated in space and time. Moreover, it is dynamic, since processes of perception-action affect both the environment and individual abilities, thus determining new or reshaped patterns of affordances. Thus, affordances are instrumental to a conceptualization of opportunities for individual-environment transactions that accounts for individual characteristics and contextual factors.

Finally, the accessibility component of walkability is related to the configuration of the urban layout [12]. Configuration can be defined as the set of relationships among parts, all of which interdepend in a global structure. Distance is the fundamental relation determining the structure of a spatial layout. Within the space syntax theory, three conceptualizations of distance are utilized [32]: metric, which refers to the distance in metres between the centre of an origin segment and the centre of a destination segment; topological, which defines distance as the number of syntactic steps in a graph needed to move from a space to the other; and geometrical, which conceptualizes distance in terms of angular changes of direction along the path between an origin space and a destination space. These conceptualizations of distance are applied to two different forms of representing a spatial system: the axial map is a representation of a spatial system as the set of the fewest and longest lines that intersect all the convex spaces within the system. The segment map represents a spatial system as the set of sections of axial lines lying between two consecutive intersections. Two configurational properties capture the movement dimension of accessibility [33]. Integration is referred to as the normalised distance of an origin space to all other spaces in a system; integration hence describes the to-movement potential of a space [34]. Choice is defined as the probability that a space is comprised in the shortest routes from all spaces to all other spaces. Thus, choice measures the through movement of a space [32].

Furthermore, integration, and choice, can be measured at different radii from an origin space, to focus the analysis of configurational variables on specific forms of movement. For instance, radii ranging from 400 to 800 m are relevant for the analysis of patterns of natural pedestrian movement. Furthermore, Pedestrian movement, determines patterns of co-presence and co-awareness, which constitute an opportunity for social interaction. Co-presence, in fact, is defined as the group of people who may not know each other, that are present at the same time in a space that they share and use. Co-awareness, on the other side, identifies a group of people using a space, who are aware of each other [10]. A further relevant property is intelligibility, which refers

to the co-relation between local and global properties. Intelligibility indexes the degree to which the number of connections from a line to adjacent spaces is a reliable indicator of the importance of that line in the whole system [35].

Finally, a further research direction concerns the position of walkability, particularly from the point of view of marginalized groups of users, within urban ethics [2, 36, 37]. Ethics can be mobilized through spatial design and planning for advancing social justice, diversity, sustainability via the project of the contemporary city and of its spaces [2]. In particular the discourse on the Just city [38], underlines the need to emphasise equity as a central objective of urban planning. The idea of the ‘ethical city’ underlines the centrality of ethics for the development of attractive, competitive, resilient and sustainable cities. Moreover, Mitchell [39] and Soja [40] claim for an urban realm more responsive to the needs of the diverse urban populations, and in particular of the most disadvantaged users. Within this perspective tendencies towards Gentrification as a “process of displacement of one group of residents with another of higher social status, entailing new patterns of social segregation” emerge as a central issue [41].

These concepts constitute the premises of a theoretical model encompassed in a methodology for the assessment of the public space with respect to walkability. Within this model walkability is determined by the environmental factors that, in relation with the characteristics of the user, produce accessibility and the functional, social, emotional affordances of a setting. Walkability in turn, affects people’s well-being, by shaping their capability set. Within this perspective, walkability, as an opportunity for achieving central capabilities, acquires an ethical significance. The results from the analysis of the impact of the proposed concepts on the existing literature on walkability, and a set of hypotheses for the future development of the research on this topic are presented in the following sections.

## 5 Results

The analysis of the existing literature on walkability reveals that the concepts of capability, affordance, configuration and urban ethics are still largely unexplored. More precisely, the concept of affordance has the least impact and centrality within the existing literature on walkability, while urban ethics and configuration present higher centrality and represent increasingly studied aspects of the walkability issue (see Table 2). In particular, the research through the WoS database, reveal the existence of 1385 articles, published during the interval 2011–2020, referring to ‘walkability’, ‘built environment’, ‘street’ and ‘neighbourhood’. These articles have been cited 18122 times ( $N_c = 18122$ ), within 7638 articles, excluding self-citing articles. These values result in an average number of citations per item equal to 13.08, and in an h-index equal to 56. With respect to the distribution of items across WoS categories, 633 articles belong with the disciplinary field ‘Public environmental occupational health’(45.7%) 186 with the research area ‘transportation’ (13.4%), 145 with the research area ‘environmental science’ (10.5%), 144 with both the categories ‘environmental studies’ and ‘urban studies’ (10.4%).

**Table 2** Measures of Centrality of the concepts of capability, affordance, configuration and Urban ethics, within the literature on walkability. Indicators include Number of articles (Na), Number of citing Articles (Nca), Number of citations (Nc), Average Citations per item (Ac) h-index, most frequent category (MFC) and most frequent category for citing articles (MFCca).

	Query #1	Query #2	Query #3	Query #4	Query #5	Query #6
	Walkability (general)	Walkability (Refined)	Capability	Affordance	Configuration	Urban ethics
(Na)	1385	618	14	1	18	31
(Nca)	7638	3102	111	–	178	215
(Nc)	18122	5334	114	–	200	256
(Ac)	13,08	8,63	8,14	–	11,11	8,26
h-index	56	34	5	–	8	9
MFC	Public Occ environmental health (633)	Transportation (186)	Urban Studies (7)	Environmental studies	Urban Studies (7)	Public Occ environmental health (11)
MFCca	Public Occ envir. health (2514)	Public Occ envir. health (746)	Envir. Science (35)	–	Envir. Studies (51)	Urban Studies (71)

The refined set, determined through query #2 (see Table 1) includes 618 articles, cited 5334 times within 3102 articles, determining an average number of citations per item of 8,63 and an h-index of 34, thus inferior than the Ac and h-index measured for the set determined via the query #1.

Furthermore, 14 articles included in the sub-set including 633 results identified via the query #2, refer to capability or capacities. Items within this sub-set are cited 114 times, within 111 different articles, and are characterized by an average number of citations per item of 8.14 and an h-index equal to 5. An in-depth review of items within this sub-set reveals that only four articles refer to capacity or capability as the ability of an individual to achieve a specific state deemed as valuable (See Table 3). More precisely, capacity is conceptualized by Ferdman [17] as a potential that manifests itself in things that are intrinsically valuable and therefore objectively good, thus resembling Nussbaum’s definition of fundamental capabilities [28]. On the other hand, Gadd [42] defines capacity as a quality of an actor, thus referring either to a potential of a material element or to capabilities of individuals. Lastly, capabilities, are defined by Blečić et al. [4] and Annunziata et al. [43] as valuable states of being that a person has effective access to, thus resembling Sen’s original definition. Within this framework, walkability is conceptualized as a potential of the built environment, resulting from different morphological and social factors, that embodies an external opportunity for the individual to achieve capabilities.

As for the concept of affordance, only one article recognizes its relevance within the context of walkability [27]. The concept of affordance is herein utilized to conceptualize the emotional, social and functional opportunities embodied in the built environment that determine the usefulness of public open spaces. Usefulness, and walkability, are in turn conceptualized as a dimension of external opportunity that shapes the capability set of the individuals, thus affecting their well-being.

**Table 3.** Conceptualization of Capability in the existing literature on walkability

Title	Definition of capability	Capability-walkability relation
Blecic, Ivan, et al. [4]	Person's capabilities are valuable states of being that a person has effective access to	W. as external conditions affecting the capability set
Dovey, Kim, Pafka, Elek [14]	Capacity as a potential of the BE; Capacity as capability	W. is a set of capacities embodied in urban morphologies. W. as an external condition for achieving capabilities
Ferdman, Avigail [17]	A potential that manifests itself in things that are intrinsically valuable and objectively good	W. as an external condition for development and exercise of capabilities

Within the refined set resulting from query #2, only 18 articles refer to configurational properties measured via Space Syntax. Items within this sub-set are cited 200 times within 178 different articles, with an average number of citations per item of 11.11 and an h-index of 8. These articles, nonetheless refer to different aspects of the spatial structure of the city, and individuate different relations between configurational variables and walking. More precisely, the configurational properties analysed include Control, axial integration (within a topological radius of 3) [44], Segment integration (within a metric radius of 1000 m) [45], Intelligibility, Angular segment Integration (within a topological radius of 3) [46], Topological segment Integration (within a metric radius of 1000 m), Segment angular choice (within metric radii equal to 200 and 3000 m) [47]; The relation between configurational properties and walkability or walking behaviours is positive for measures of angular integration and angular choice, measured within radii ranging from 100 to 2000 m [48, 49], while a negative relation is observed for Control, Local axial integration ( $r = 3$ ) and Segment integration ( $r = 1000$  m), with respect to walking as optional activity [44, 45] (see Table 4).

Lastly, 31 articles contain the terms (“ethic\*” or “gentrif\*” or “inequalit\*”). These articles are cited 256 times within 215 different documents, excluding self-citing articles. The sub-set is thus characterised by an average number of citations per item equal to 8.26 and by an h-index of 9. An in-depth analysis of the sub-set of the 12 most cited articles, underlines a relevant ethical perspective within the research on walkability, focused on the issue of social inequalities engendered by urban policies. In particular, the distributive asymmetry embodied in policies of urban renewal aimed at structuring dense, walkable, transit-accessible neighbourhoods, engenders an increase in house and land values, resulting in gentrification pressures, issues of affordability, and decrease in inclusiveness and social diversity [52–54]. Moreover, walkability is positively associated with the socio-economic status of neighbourhoods, and with health outcomes by Su et al. [55]. Their research underlines that, in the city of Shenzhen, China, neighbourhoods with significant concentration of rental properties, unemployment, individuals with low level of education, and Children, are characterized by low level of walkability, resulting in a greater incidence of cardiopathy and hypertension in the population.

**Table 4.** Conceptualization of configuration in the existing literature on walkability

Title	Conceptualization of walking	Topological property	Relation to walking
Koohsari, M. Javad, et al. [44]	Walking as optional activity	Control; Local axial integration (r = 3)	(-) Control; Local axial integration (r = 3) to walking
Koohsari, M. Javad, et al. [45]	Walking as optional activity	Segment integration (R = 1000)	(-) Segment integration (R = 1000) to walking
Lamíquiz, Patxi J., and Jorge López-Domínguez [46]	Walking as transport	Connectivity; Axial integration (r = 3, 5, n); Intelligibility	(+) Axial Integration r = 5, 3, n to walking
Su, Shiliang, et al. [47]	Walking as transport; Walking as vector to PA	Segment integration (r = 5, n); Segment mean depth (r = n)	(+) IWI - Integrated Walkability Index, to walking
Dhanani, Ashley, Lusine Tarkhanyan, and Laura Vaughan [49]	Walking as active transport	Segment angular integration (200 < R < 3000); Segment angular choice (200 < R < 3000);	(+) Segment angular integration (400 < R < 2000) to pedestrian densities. (+) Segment angular choice (R = 2000) to ped densities; Segm. Ang. integration R = 2000 > Segm. Ang. choice (R = 2000)
Koohsari, Mohammad Javad, et al. [50]	Walking as physical activity	Topological segment Integration (R = 1000)	(+) Topological segment Integration (R = 1000) to walking
Bielik, Martin, et al. [48]	Walking as transport	Segment Angular Choice (100 < R < 2000)	(+) (R600) to Actual ped movement; (+) to AWA
Ozbil, Ayse, et al. [51]	total walking	Angular segment Integration (R = n);	(+) Directional reach to natural movement

Lastly, Zandieh et al. [56] observe heterogeneous associations of walkability factors to socio-economic factors measured at the neighbourhood scale and to levels of walking, conceptualized as a vector to physical activity and, thus, to healthy aging. In particular, residential density, land-use mix, street connectivity, and retail density are positively associated to levels of area deprivation and negatively associated to walking levels. On the contrary, land-use intensity, referred to green areas and recreation centres and measured by land area, is negatively associated to levels of area deprivation and positively related to walking levels. These studies emphasise that spatial inequalities in built environment correlates of walkability, exacerbated by policies of urban renewal, tend to manifest and reproduce inequalities in access to spatial, social and financial capital. This tendency results in increasing social injustice, particularly with respect to achievement and exercise of the foundational human capabilities related to life, bodily health, bodily integrity, affiliation and control over one's environment (see Table 5).

**Table 5** Urban Ethics in the existing literature on walkability and association to walkability. (+) indexes a positive association of the independent environmental variable with ethically relevant variables. (–) indexes a negative association

Title	Ethical issue considered	Relation with walkability
Quastel, Noah, Moos, Markus, Lynch, Nicholas [52]	Gentrification	(+) Densification to gentrification and affordability issues; (+) walkability, density, proximity to transit, and increasing social status
Gose, Maria, et al. [57]	Inequality	(+) SES and BE factors to Weight status among children. (–) walkability to BMI-SDS.
Talen, Emily, Menozzi, Sunny, Schaefer, Chloe [53]	Gentrification, affordability, inclusiveness, social diversity	(+) Walkability to less affordability, less social diversity, inclusiveness and to processes of gentrification
Su, Shiliang, Pi, Jianhua, Xie, Huan, Cai, Zhongliang, Weng, Min [55]	Social inequalities	(+) Walkability to SES and health outcomes. (–) walk score to No house property, unemployment, Less educated, Blue-collars, and Children
Immergluck, Dan, Balan, Tharunya [54]	Social inequalities; gentrification	(+) walkability, and density to higher land and housing costs and gentrification pressures;
Su, Shiliang, Zhou, Hao, Xu, Mengya, Ru, Hu, Wang, Wen, Weng, Min [47]	Social Inequalities	(+) Walkability to Socio-economic conditions. (+) IWI – ind. of walkability – to proportion of uneducated, of blue collar, of people with undergraduate degree and above
Zandieh, Razieh, Flacke, Johannes, Martinez, Javier, Jones, Phil, van Maarseveen, Martin [56]	Social Inequalities	(+) residential density, land-use mix, street connectivity, and retail density to levels of area deprivation; (–) to walking levels. (–) land-use intensity (green areas and recreation centres) to levels of area deprivation; (+) to walking levels
Koschinsky, Julia, Talen, Emily, Alfonzo, Mariela, Lee, Sungduck [58]	Social Inequalities	(+) Walkability factors (safety, connectivity, signs of neglect) to income

In the sub-sequent section research perspective comprehensive related to capability, affordance, configuration and urban ethics are outlined.

## 6 Conclusions

The proposed research outlines a perspective for the development of the research on walkability, building on the concepts of capability, affordance, configuration and urban ethics. These concepts are marginally considered by the existing literature on walkability, within the context of transportation, urban and regional planning. The proposed literature review emphasizes that these concepts are instrumental to overcome limits of existing approaches to the operationalization of walkability. These limits relate to four dimensions: i) conceptualization of well-being; ii) consideration of the relational and situational character of the actualization of opportunities embodied in the BE; iii) Assessment of the effects of the configuration of spatial layouts on patterns of movement; iv) ethical implications of spatial inequalities in the distribution of environmental correlates of walkability.

These findings embody relevant indications for the development of the research on walkability. Future stages of this study will focus on the definition of a methodological framework for the assessment of the built environment from the point of view of walkability. According to the findings of this literature review, the framework for walkability will take into consideration three aspects: i) the operationalization of the concept of affordance via the utilization of techniques of consensus building and Public Participatory GIS tools for the selection and weighting of indicators, according to the characteristics of different stakeholders; ii) The integration of multi-criteria analysis and Space Syntax techniques for increasing the validity and relevance of the measure of walkability [59]; iii) definition of indicators for measuring aspects of social inequalities at different stages of the planning process: firstly, for assessing the correlation between levels of walkability and levels of area deprivation; secondly for monitoring policies of urban renewal with respect to the arising of social injustice and pressures for gentrification.

As a result, the objective is the construction of a framework that supports decision-making processes within urban and territorial planning practices, in two ways: first, in the identification of criticalities embodied in the spatial, material and socio-economic structures of the city; and, secondly, by monitoring variations in patterns of spatial practices and social inequalities, engendered by interventions of urban renewal and regeneration. In this respect, the framework for walkability will be able to orient the design and planning processes towards the construction of meaningful, imageable, inclusive public spaces, respondent to the needs of different stakeholders, by doing good strategies for new smart cities paradigm [60].

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