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The distribution of walkability in an African city: Praia, Cabo Verde

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ABSTRACT

This paper analyses disparities in walking conditions in neighbourhoods with different incomes and urbanization levels in Praia, the capital of Cabo Verde islands. Walkability is measured considering factors relevant to a semi-arid, post-colonial, fast growing, middle-income African city. The estimated indicators measure the availability of destinations accessible on foot and the quality of the walking experience. The study found that high income neighbourhoods have the lowest overall provision of pedestrian space and protection from traffic (in more urbanized areas) and the lowest walking accessibility to people, shops, and leisure areas (in less urbanized areas). Low income neighbourhoods have the highest environmental risks (in more urbanized areas) and the highest slopes, lowest provision of formal pedestrian space, and lowest accessibility to jobs, facilities, and bus stops (in less urbanized areas). The results provide insights into the type of public policies needed to improve walkability in the different parts of the city.

1. Introduction

Walking is a healthy activity and has a low environmental impact, compared with motorised modes of transport (Maizlish et al., 2013; Rabl & Nazelle, 2012). The recognition of these benefits has lead policy-makers around the world to implement transport and urban policies to promote walking. The identification of the obstacles that pedestrians face in different parts of the city is an important component of those policies, because there is evidence that the propensity for walking is associated with the characteristics of the local built environment (Heath et al., 2006; Owen, Humpel, Lesli, Bauman, & Sallis, 2004; Saelens & Handy, 2008; Wang, Chau, Ng, & Leung, 2016). Over the last decade, researchers have proposed a large number of indicators of walkability, based on aspects such as accessibility to key destinations (Iacono, Krizek, & El-Geneidy, 2010; Kuzmyak, Baber, & Savory, 2006; Witten, Pearce, & Day, 2011), population and employment density (Greenwald & Boarnet, 2001; Wells & Yang, 2008), land use mix (Frank, Schmid, Sallis, Chapman, & Saelens, 2005), and street layout (Neckerman et al., 2009; Parks & Schofer, 2006; Porta & Renne, 2005).

These aspects may not be relevant to all cities. In particular, in many African cities, such as Praia, the focus of this study, walking is restricted by geographic and historical factors and by growing urban sprawl and motorisation. The constraints on walking may lead to a reduction in physical activity and in the accessibility of disadvantaged groups to key urban facilities. In this context, planning for walking becomes an important instrument for promoting public health and social equity.

The objective of the paper is to estimate indicators of walkability suited to the context of African cities such as Praia. The analysis provides novel insights into the study of walkability, given that the majority of the studies in this field have focused on North American or European cities, which face different challenges from those faced by some African cities.

The indicators are classified into two groups (availability of destinations for pedestrians and quality of the walking experience) and analysed in terms of their distribution among areas with different levels of urbanization and inhabited by different income groups. These two variables were chosen because of their role in the social and spatial organization of many contemporary African cities, which, according to authors such as Rodrigues (2009) and Kombe (2014) can be roughly subdivided into four types of areas: 1) dense central neighbourhoods built during the colonial period; 2) dense slums in central areas with geographic and environmental limitations; 3) low-density affluent areas in the suburbs (including gated communities) and 4) poor peri-urban areas at the fringes of the city.

2. Measuring walkability in an African context

Cities in Africa are growing faster than anywhere else (UN DESA, 2015; Parnell & Pieterse, 2014). This growth has been accompanied in many cases by urban sprawl and population and job decentralization

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(Cervero, 2013; Mabin, Butcher, & Bloch, 2013; Naudé, 2008; Todes, 2012). The widening of the distance between residential areas and centres of attraction reduces the opportunities for walking, especially in cities with hot and arid climates. At the same time, the growth of income is leading to higher rates of car ownership and usage, further marginalizing walking as a means of transport (Sietchiping, Permezel, & Ngomsi, 2012).

Restrictions to walking are especially relevant in African cities due to the insufficiencies of the public transport supply and to the fact that a large part of the population relies on walking as the major mode of transport (Olvera, Plat, & Pochet, 2013; Pendakur, 2005; Trans-Africa Consortium, 2010). Those restrictions have an equity dimension, as they may limit access to employment and services for women and low-income households (Olvera et al., 2013; Salon & Gulyani, 2010; Venter, Vokolkova, & Michalek, 2007) and have an impact on the quality of life of the elderly (Olawole & Aloba, 2014).

However, concepts used in developed countries in the discussion of transport disadvantages need to be adapted. For example, Lucas (2011) argues that the concept of social exclusion needs to take into account that in developing countries, transport poverty is a problem of the majority, rather than of a minority of the population. The concept of environmental justice, understood as the fair distribution of the negative effects of transport, also needs to be translated to the African context, as documented in a case study in Nairobi by Becker (2012).

The methods used to quantify issues of social exclusion or environmental justice in the field of transport may also not be fully applicable in the context of developing countries. Indicators of walkability are based in many cases on a set of destinations pedestrians need to access, such as health centres, food shops, public services, and green spaces. This set may not capture the full range of destinations usually accessed on foot in cities in developing countries. For example Oyeyemi et al. (2013) included access to open fields, wells, food canteens, and building materials shops in their study of perceived walkability in Nigeria.

Studies of walkability rarely include indicators of access to places where people meet to socialize. However, research has shown that walking has an important role in the vitality of local social networks (French et al., 2014; Zhu, Yu, Lee, Lu, & Mann, 2014). If we assume that people meet in each other's homes, then areas with lower population density are less attractive to walking trips to socialize. However, people can also meet in outdoor public spaces such as streets, squares, and gardens. The need to recognize the differences between the “link” and the “place” functions of streets has been increasingly recognised (Jones, Boujenko, & Marshall, 2007), but the measurement of walkability tends to considers streets only as links to a destination, and not as a destination itself. More generally, in cities with hot climates, and where large parts of the urban space are informal, as in many African cities, the object of analysis should go beyond walking as movement, and consider outdoor life in general. This perspective accounts not only for the relevance of social interactions in public spaces near homes and workplaces, but also for the large proportion of people in those cities who work outdoors, such as street vendors (Ikioda, 2016).

The identification of streets as the main element linking the origins and destinations of walking trips should also be questioned. Arguably, the space available to pedestrians in cities in developing countries is considerably higher than in developed countries. The whole space occupied by unpaved paths in informal areas is usually shared by pedestrians and motorised vehicles. In addition, there is often a large number of open spaces available for pedestrians to move around. The use of indicators such as the provision of pedestrian pavements (Parks & Schofer, 2006) may therefore underestimate the amount of space potentially available for walking. Indicators of street connectivity, usual in walkability studies in North America (Leslie et al., 2007; Oakes, Forsyth, & Schmitz, 2007) also have limited applicability in informal areas of African cities, where there are no formal streets, or where most of the formal streets are connected by informal links used by pedestrians.

The geographic context of African cities is also distinctive. Many cities have grown from settlements established during the colonial period, in locations that benefited the colonial political and economic structure, near natural ports or in areas rich in natural resources (Njoh, 1999, Ch.9). As cities expanded, they started to cover nearby areas, where mobility is in many cases limited by slopes and by environmental risks such as floods and landslides. In these areas, the movement of pedestrians may even be impossible during the rainy season, due to accumulation of debris, mud, and water. The areas with the most severe geographic limitations tend to be occupied informally by the poorer households (UN-Habitat, 2003, Ch. 5).

Social factors are also relevant. For example, there is ample evidence that the propensity for walking and spending time outdoors in fast-growing cities in developing countries is negatively affected by fear of crime, especially in the case of women and older pedestrians (Oyeyemi, Adegoke, Sallis, Oyeyemi, & De Bourdeauduij, 2012; Rech et al., 2012; Villaveces et al., 2012). In those cities, cars are also perceived as a status symbol and as a defence against the negative aspects of the built and social environment faced by pedestrians (Pitcher & Graham, 2006).

Increasingly, the main obstacle to non-motorised modes of transport in African cities is the transport system itself. The growth in traffic demand created by urban expansion and rising income tends to be accommodated by new road infrastructure, where priority is given to motorised modes (De Langen, 2005). Tulu, Washington, King, and Haque (2013) argued that in developing countries, pedestrian safety is influenced by specific factors such as the lack of separation between pedestrians and vehicles in busy roads, lack of crossings, presence of roadside vendors, and the combination of poor street lighting and high proportions of pedestrians walking at night. The effect of the increased encroachment of roads and cars on pedestrian space is also emphasized in the studies of Damsere-Derry, Ebel, Moch, Afukaar, and Donkor (2010) and Amoako, Cobbinah, and Niminga-Beka (2014) in Ghana. Bradbury (2014) also argues that community severance (the barrier effect of roads on pedestrian mobility) affects access to local facilities, especially for children, women, and the elderly. This impact may be explained by high traffic levels but also by factors specific to developing countries, such as emission of dust on unpaved roads (Greening, 2011).

3. Case study: Praia

Praia is located in Santiago island and is the largest city of Cabo Verde, with 130,271 inhabitants at the time of the 2010 census, representing 26.5% of the country's population. The population has increased 2.5 times since 1980 (CMP, 2013, p.51). Average income has also been growing fast, as Cabo Verde progresses into a middle-income economy. These trends have contributed to the urbanization of the plateaus and hills surrounding the historical centre, which is located in a plateau near the port (Fig. 1). Due to geographic restrictions and to the fast and haphazard growth, the urban space is fragmented and centres of attraction are no longer concentrated in the historical centre, but dispersed throughout the city. However, some neighbourhoods have virtually no jobs or local facilities (Nascimento, 2009; CMP, 2013, Ch. 5).

As a result of the rapid population growth, large parts of the city have been occupied by informal settlements, which represent 57% of the total urban area (CMP, 2013, p.211). These settlements are home to a low-income population and lack access to basic services and infrastructure such as piped water, sewerage, electricity, waste collection, and paved roads (Silveira, 2011). They also tend to be far from commercial areas and other important locations (Nascimento, 2009), and to be located in hilly areas or floodplains (Lima, 2012; Monteiro et al., 2012). Flood risk is a major concern in Praia, as annual rainfall is concentrated in a small number of days (Sabino, Querido, & Sousa, 1999).

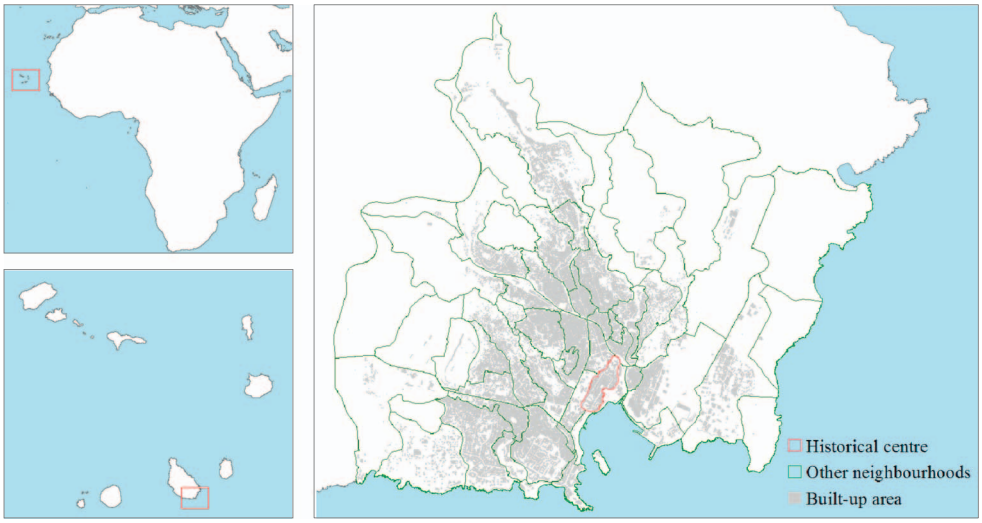


Fig. 1. Praia - geographic context, neighbourhoods, and built-up area.

Transport is a pressing issue in the city. According to the 2010 census, only 19% of the households have a private vehicle. However, the figure varies between 2% and 89%, in the least and most affluent neighbourhood respectively. The bus network is limited and does not reach many of the poorest neighbourhoods (CMP, 2013, p. 283–284). Some areas are at a distance of several kilometres to the nearest bus stop (Anciaes, Nascimento, & Pinto, 2014). The role of shared taxis for intra-urban travel is relatively small, unlike in other African cities. Walking is therefore the main means of transport for the population in some parts of the city.

Walking is also an important leisure activity, shared by all age and socio-economic groups, especially in the areas near the waterfront in the early morning and evening (Fig. 2a). A series of surveys conducted by students of the University of Cabo Verde has also confirmed that streets, open spaces, and outdoor sporting facilities are the main places for socializing in informal neighbourhoods (Andrade, 2010; Lopes, 2010; Pires, 2010; Teixeira, 2010).

However, walking is restricted by the hot, dry climate, and by the location of many neighbourhoods in hills and plateaus (Fig. 2b). There is also a lack of formal public space, as outside the historical centre, public squares and green spaces are rare (Furtado, 2008). Concerns about personal security are increasing, due to the steady growth of crime incidents over the last decade (Furtado, Pinheiro, Almeida, & Moreira, 2011; Pina, Correia, & Negreiros, 2011; Zoettl, 2016). The improvement of the road network has also contributed to the deterioration of pedestrian mobility. New arterial roads have been built to cope with the increase in road traffic and many of the existing roads have also been paved, contributing to higher vehicle speeds

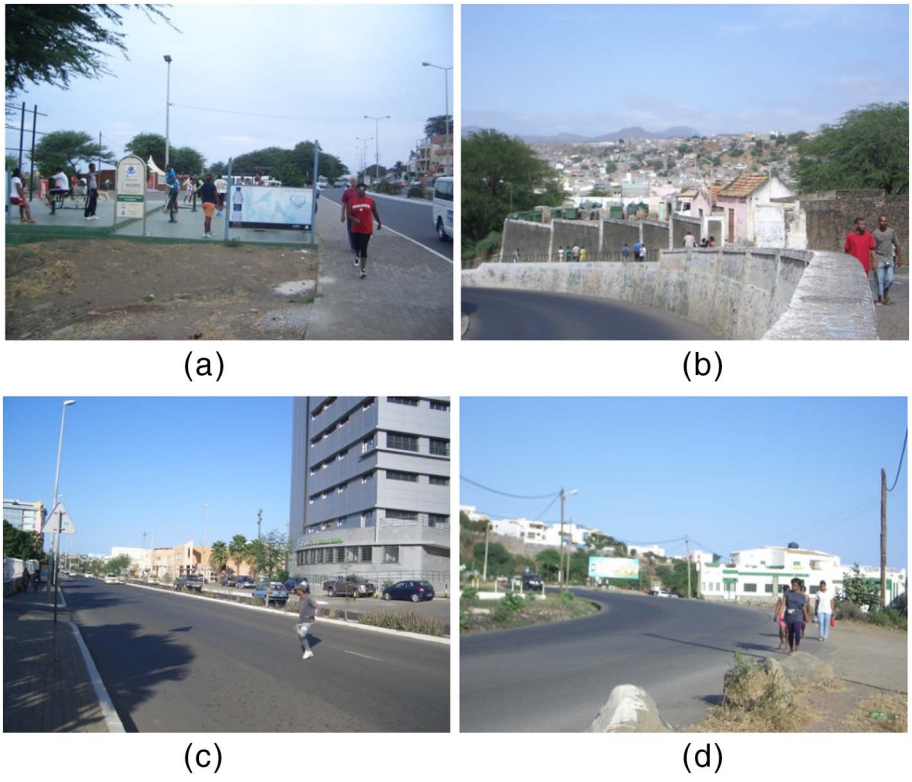


Fig. 2. Aspects of walking in Praia.

(Fig. 2c). Many roads have no pedestrian pavements (Fig. 2d). The construction of large roundabouts and the increase in on-street car parking has also created environments that are hostile and unsafe to pedestrians.

The local government has started to implement policies to improve pedestrian mobility during the last decade. Priority was first given to formal neighbourhoods, with projects to repave or pedestrianise parts of the historical centre. More recent policies have also covered informal areas, including street pavement, addition of pedestrian pavements and crossings, and provision of equipment such as outdoor sports grounds and fitness parks.

Due to the growing awareness about issues of equity and about the role of walking in well-being, there is a need to identify the areas of the city at disadvantage in terms of walking conditions. This assessment is particularly important due to the diversity of land use patterns and socio-economic characteristics of the various neighbourhoods, with differences between the more and less affluent areas and the more and less urbanized areas. The approach of this paper is therefore to analyse indicators of walkability in relation to two variables: the **average income** and the **level of urbanization** of each neighbourhood. These two variables are only weakly correlated in Praia (correlation of 0.33, significant at the 10% level), thus providing two distinct axes to measure neighbourhood walkability.

The level of income inequality in Praia is the highest in Cabo Verde, with a high incidence of absolute poverty. Around 15% of the population lives with less than 1€ per day (CMP 2013, p. 74). The map on the left side of Fig. 3 shows average neighbourhood incomes, using data from the 2010 census. The neighbourhoods with higher income are the historical centre and surrounding areas and the waterfront districts in the southwest. The neighbourhoods with the lowest income are those in the west and east fringes of the city. The income in the richest neighbourhood is 4.4 times higher than the income in the poorest neighbourhood.

The urbanization level is defined as the ratio between the urbanized area and the area considered feasible for urbanization. Fig. 4 illustrates the distinctions between those two types of areas. The unfeasible area was extracted from the map of the Praia Municipal Master Plan and includes for example areas with ecological value or with severe environmental restrictions to human land uses. The urbanized area is defined as that with human land uses. Buildings were identified in a geographic dataset containing all the buildings in the city, provided by the Praia Municipal Government. Other human land uses (public and private space) were identified in a variety of official maps and in orthophotos such as the one in Fig. 4, also provided by the municipal government.

The map on the right side of Fig. 3 shows the level of urbanization of each neighbourhood. The values are highest in the historical and geographic centres of the city and decrease as we move towards the urban fringes. The variability is explained by geographic factors that have limited the urbanization of the areas surrounding the historical centre, but also by the challenges in providing a coherent road network and a rational allocation of land uses in face of the rapid expansion of informal settlements in the last few decades (Nascimento, 2010).

4. Methods

The indicators of walkability were estimated with a Geographic Information System (GIS), using data from the National Statistics Office of Cabo Verde and the Praia Municipal Government, and from previous studies. The unit of analysis is the neighbourhood ("bairro") as classified by the National Statistics Office. The neighbourhoods of Praia are in almost all cases clearly identifiable geographic entities, as their borders are defined by features such as hills and plateaus. They also have distinct histories, as they were urbanized at different moments in time. Neighbourhoods with less than 50 residents were excluded from the analysis. The remaining set includes 42 neighbourhoods, with an average of 1835 residents.

The first group of indicators, measures availability of destinations for pedestrians, considering six types of possible destination: social networks ("access to people"), jobs, shops, facilities, leisure areas, and public transport nodes (bus stops). The second group of indicators, measures the quality of the walking experience, considering six aspects: provision of pedestrian space, proportion of formal pedestrian space, collision risk, crime, slopes, and environmental risk (from flooding and landslides).

4.1. Availability of destinations

The indicator of **access to people** is the ratio between the resident population and the urbanized area of each neighbourhood, or in other words, the population density calculated on the areas with human land uses. This formulation takes into account two characteristics of fast-growing cities in developing countries: the existence of gaps in the urban fabric created by areas that are not yet urbanized or are unfeasible for human use and the fact that social interaction may occur not only in residential areas but also in areas with other human land uses. The denominator of the indicator is therefore the area with human land uses, and not the total area of the neighbourhood or the residential area. The number of residents by neighbourhood was extracted from the 2010 census. The urbanized areas were identified as explained in Section 3.

The indicator of **access to jobs** takes into account the role of informal employment, characteristic of cities in developing countries. The indicator is defined as the ratio between the total number of formal and informal jobs and the urbanized area of the neighbourhood.

The location of formal jobs was identified from a dataset listing all the private companies in the city, provided by the National Statistics Office. The data does not include the number of people employed by

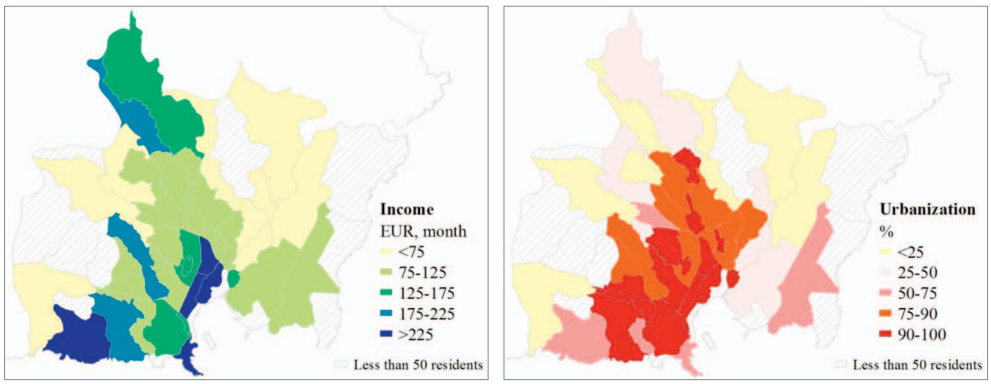


Fig. 3. Reference variables: average income and urbanization level.

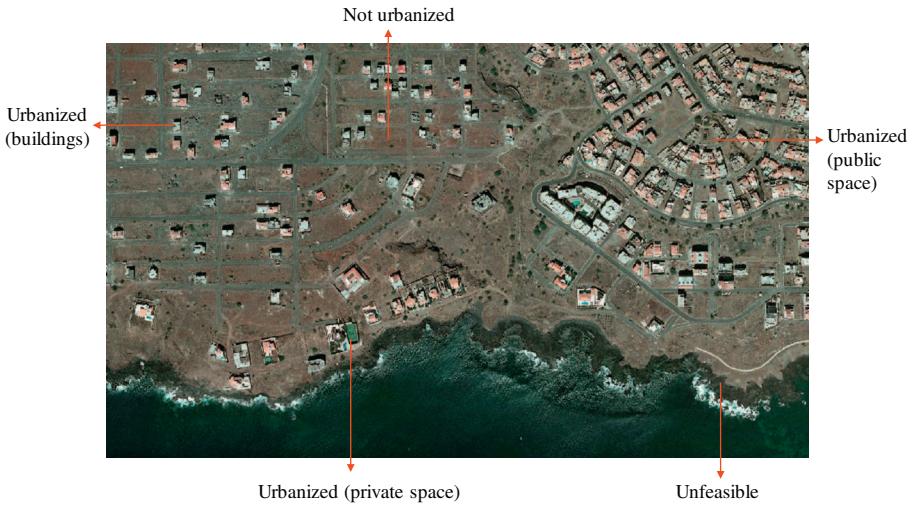


Fig. 4. Feasible space and urbanized space.

each company. A second dataset provided the total number of employees in each sector of activity. In a first stage, this number was divided equally by the number of companies in that sector. Corrections were then made to account for the existence of large companies, using information published by these companies. The location and number of employees in public sector jobs (which were not included in the companies' dataset) were identified from information in Nascimento (2009) and documents published by the national and municipal governments.

The calculation of the number of informal jobs considers street trading, as this is the major informal activity for low-income residents. The number of opportunities for street trading was identified by counting the number of sellers in a weekday in the main market in the city centre and in the surrounding areas, six smaller markets in other neighbourhoods, and in other major locations for street vending, such as squares and areas around busy roads and roundabouts.

Access to shops is the ratio between the number of places for shopping and the urbanized area of the neighbourhood. The set of places includes shops (identified in the private companies' dataset) and areas with street vendors. Weights were assigned according to the dimension of the place. The central market and branches of the largest supermarket chain in the city were assigned a factor of 3. Other markets and supermarkets were assigned a factor of 2. Small shops and areas with street vendors were assigned a factor of 1.

Access to facilities measures access to seven types of locations: public services, health centres, educational institutions, religious buildings, and culture, social, and sport facilities. The identification of these locations used information from Nascimento (2009) and from the municipal master plan. The indicator is defined as the number of all facilities divided by the urbanized area of the neighbourhood. Sub-indicators for all seven types of facility were also estimated.

Access to leisure areas is the ratio between the area of places for outdoor recreation and the urbanized area of the neighbourhood. The identification of the places was based on local knowledge and includes pedestrianized streets, squares, public gardens, green spaces, beaches, waterfront promenades, and outdoor fitness parks. Fieldwork was necessary to identify the exact area available to pedestrians, when it was not clear from the observation of orthophotos. Areas where pedestrians share the same space with motorised vehicles in formal roads or squares were excluded.

Access to bus stops is the ratio between the number of bus stops and the urbanized area of the neighbourhood. Information about the bus lines in operation were obtained from the two bus service providers. The location of the bus stops along each line was identified by fieldwork. Pairs of bus stops on opposite sides of a road were treated as one bus stop. Neighbourhoods with no bus stop were ranked according to the decreasing order of the distance to the nearest bus stop.

4.2. Quality of walking

The indicator of provision of **pedestrian space** is the ratio between the area available for pedestrians and the urbanized area of the neighbourhood. Pedestrian space is understood as public space that can be used as a link for pedestrian movement or as a place for social interaction. In formal (paved) roads and streets, this space is limited to pedestrian pavements, and excludes the carriageway area. In informal (unpaved) streets, it includes the whole area occupied by the street. The set of pedestrian space also includes formal public squares and gardens and informal open spaces (Fig. 5).

The indicator of **formal pedestrian space** is the proportion of the area occupied by pedestrian pavements and public squares in the total pedestrian space, as defined in the previous paragraph.

The indicator of vehicle-pedestrian **collision risk** is the ratio between the area occupied by carriageways of formal roads and the area with pedestrian space. The assumption is that the barrier effect of roads on the movement of pedestrians is proportional to the length and width of all roads crossing the neighbourhood. Road width is a proxy for motorised traffic levels, as it was not possible to obtain detailed traffic data. The widths of all roads in Levels 1 and 2 of the hierarchy defined by the municipal government were measured individually. The widths of roads in Level 3 were measured in a sample of roads, and the average used for all roads in this level. Only the road sections crossing urbanized space were considered, as it was assumed that pedestrians do not need to cross roads in natural areas.

The indicator of **crime** is the number of crime incidents per year divided by the area with pedestrian space. The number of incidents was taken from data published by the local government (CMP, 2013). Data was available for only 20 neighbourhoods. However, these neighbourhoods represent a suitable mix of values for the income and urbanization variables.

The indicator of **slopes** is the average slope in the pedestrian spaces of each neighbourhood. The slopes dataset was provided by the local government. The indicator of **environmental risk** is the area of all pedestrian spaces in regions considered as prone to flooding or landslides, as a proportion of total pedestrian space. Those regions were identified in maps contained in the municipal master plan (CMP, 2013, part II.4).

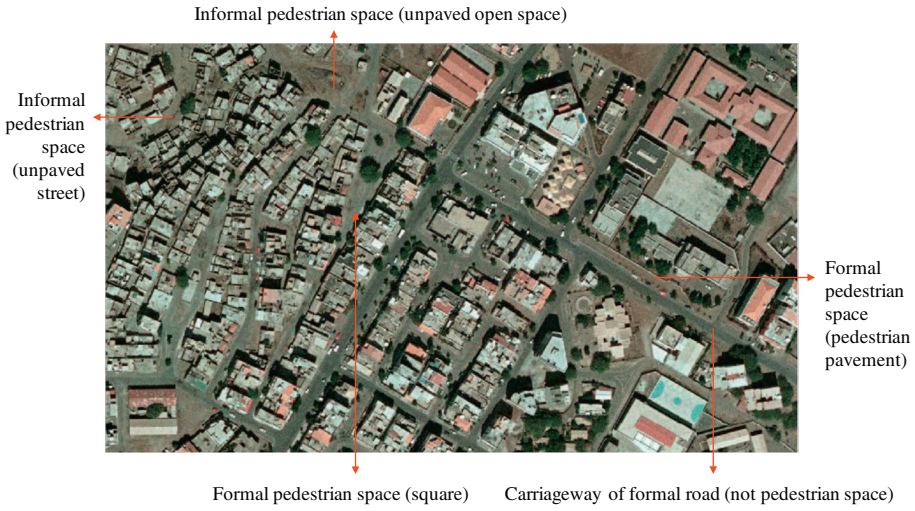


Fig. 5. Pedestrian space.

5. Results and discussion

The indicators calculated for each neighbourhood were analysed in terms of their absolute values and their rank positions, in comparison with the values and rank positions of the two reference variables (income and urbanization). The analysis of rank positions is relevant because people's perceptions about the distribution of walkability indicators may be related not only to the scale of the obstacles they face when walking in their neighbourhood, but also to whether these obstacles are higher or lower than in neighbourhoods that are already at an advantage in the distribution of other resources, such as income and access to basic infrastructure (which is related to urbanization levels).

Table 1 and Table 2 show descriptive measures for each indicator, their average values in subsets of neighbourhoods above (+) and below (−) the median of the two reference variables, and their Pearson and the Spearman (rank) correlations with those two variables. It should be noted that the indicators of availability of destinations and the first two indicators of quality of mobility measure positive aspects and the other four indicators of quality of mobility measure negative aspects. It is assumed that walking in formal pedestrian space is more amenable than walking in informal space.

The charts in Fig. 6 and Fig. 7 show the rank positions of the neighbourhoods for each of the 12 indicators. The two axes measure the position of the neighbourhoods in the ranks of the two reference variables. The further to the right a data point is, the higher the income; and the further up, the higher the urbanization level. The size of the bubbles is inversely proportional to the position of the neighbourhood in the rank of the indicator represented. Bigger bubbles mean better conditions for walking, as measured by that indicator (that is, higher values for the indicators measuring positive aspects, and lower values for the indicators measuring negative aspects). The rank positions of the indicator of access to facilities in Fig. 6 are a combination of the ranks of the sub-indicators for the seven types of facility.

5.1. Availability of destinations

The six indicators of availability of destinations for pedestrians are highly variable (Table 1). This is especially the case of access to leisure, whose median value is 0.08% and maximum value is 25.1% of the urbanized area. Income and urbanization tend to be positively related to all six types of access. The only exception is access to people, which is only significantly related to urbanization, and not with income.

The middle part of Table 1 and the charts in Fig. 6 confirm that the distribution of levels of access to people is different from the other indicators of availability of destinations for pedestrians, as the neighbourhoods with the best position are those with lower income in more urbanized areas. This finding is consistent with the patterns found in

Table 1
Descriptive measures and correlations: availability of destinations.

	Access to people People per km^2	Access to jobs Jobs per km^2	Access to shops Shops per km^2	Access to facilities Facilities per km^2	Access to leisure % of urban space	Access to bus stops Stops per km^2
Average	8313	2869	129	74	1.19	3.89
Standard deviation	6399	5793	178	147	4.48	4.91
Minimum	438	0	0	0	0	0
Median	7188	1058	66	23	0.08	2.47
Maximum	23,174	33,188	878	669	25.1	22.2
Average in subsets						
Income + urbanization +	10,460	5511	224	158	2.38	5.89
Income − urbanization +	13,234	1709	167	37	0.13	4.15
Income + urbanization −	4114	1592	52	27	0.08	3.30
Income − urbanization −	7777	662	78	17	0.67	2.48
Pearson correlation						
Income	− 0.21	0.35**	0.27*	0.41***	0.35**	0.23
Urbanization	0.53***	0.34*	0.44***	0.37**	0.21	0.41***
Spearman correlation						
Income	− 0.04	0.56***	0.40***	0.54***	0.63***	0.51***
Urbanization	0.55***	0.56***	0.59***	0.56***	0.56***	0.58***

Significance levels: ***: 1%; **: 5%; *: 10%.

Table 2
Descriptive measures and correlations: quality of walking.

	Pedestrian space % of urban space	Formal space % of ped. space	Collision risk Road area/ped. space (%)	Crime Incidents/year/km^2	Slopes Average slope (%)	Environmental risk Risk area/ped. space
Average	74.4	31.9	4.8	1311	6.2	23.4
Standard deviation	11.7	20.6	4.9	715	2.5	26.1
Minimum	42.0	0	0	352	3.0	0
Median	74.2	31.4	4.1	1132	5.6	15.8
Maximum	95.0	70.4	17.4	3155	16.7	100
Average in subsets						
Income + urbanization +	69.7	40.4	8.1	1447	4.68	13.8
Income − urbanization +	73.0	31.7	2.6	1690	5.56	29.5
Income + urbanization-	81.8	27.7	4.0	450	4.49	4.6
Income − urbanization −	79.6	23.9	1.6	1130	7.37	27.9
Pearson correlation						
Income	− 0.12	0.12	0.56***	− 0.04	− 0.34*	− 0.26*
Urbanization	− 0.30*	0.25*	0.58***	0.52***	− 0.33*	0.17
Spearman correlation						
Income	− 0.32*	0.17	0.73***	− 0.08	− 0.46***	− 0.03
Urbanization	− 0.40***	0.32*	0.71***	0.56***	− 0.31*	0.27*

Significance levels: ***: 1%; **: 5%; *: 10%.

many cities in developing countries, where population densities are high in low-income areas near the centre but not in low-income areas at the fringes of the city (Doan & Oduro, 2012). The neighbourhoods with the worst position are those with higher income in less urbanized areas. This finding reflects the low population densities in rich newly developed areas in the western limits of Praia, which include isolated gated communities (Silveira, 2011).

The distribution of other pedestrian destinations follows a consistent pattern. Access tends to be higher in areas with higher income and urbanization, and lower in areas with lower income and urbanization. The inequality between these areas is particularly high in the case of access to jobs and facilities. The distribution of access to bus stops is the most equal, as the neighbourhoods with the best position are near the centre of the chart. The areas with higher income and lower urbanization levels tend to be at disadvantage in access to shops and leisure areas and fare relatively well in terms of access to jobs, facilities, and bus stops, although a few of the neighbourhoods in these areas are near the bottom of the rank of the first two types of access. The areas with lower income and higher urbanization levels tend to be in the middle of the rank for all types of access except in the case of access to leisure areas, where some areas fare poorly.

5.2. Quality of walking

Table 2 shows the results of indicators of quality of walking. On average, around three quarters of the urbanized space of each neighbourhood are available to pedestrians. Only 32% of this space is formal space. The space occupied by roads is equivalent to only 5% of pedestrian space, but in one neighbourhood this value reaches 17%. Average slopes and environmental risks also tend to be high. As expected, the higher the urbanization level of a neighbourhood, the lower the provision of pedestrian space and the higher the proportion of formal space. More urbanized areas also tend to have more crime and a higher collision risk. Higher incomes are associated with higher collision risk but also with more formal pedestrian space, smaller slopes and less environmental risk.

The middle part of Table 2 and the charts in Fig. 7 show that there is more pedestrian space in less urbanized areas but the proportion of formal space is higher in more urbanized areas especially in those with higher income. A few of neighbourhoods with the best position in the rank of formal space are low income but almost all the neighbourhoods in the bottom of the rank are low-income.

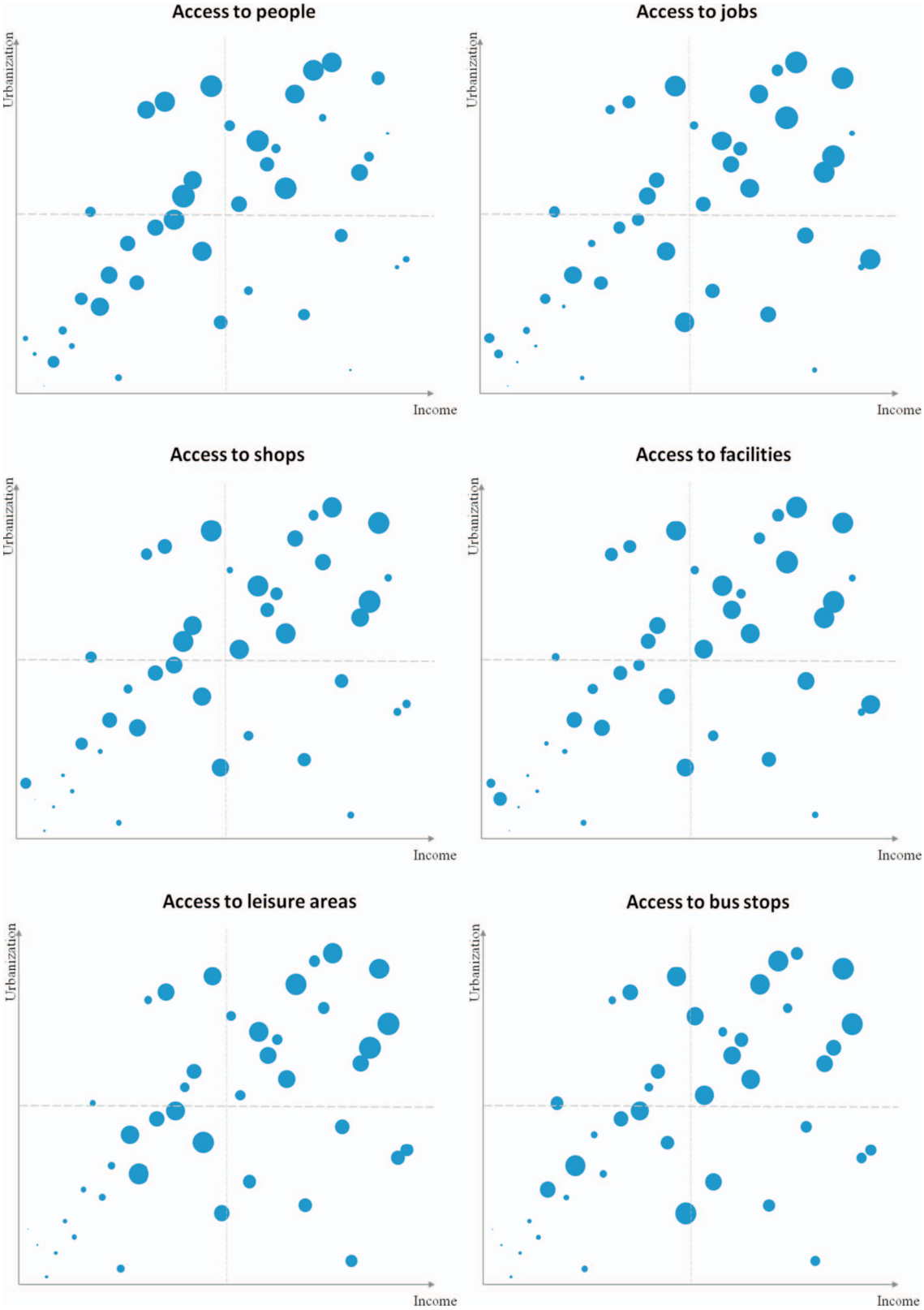
The indicator of collision risk shows the clearer pattern of all six indicators, as poorer neighbourhoods in less urbanized areas have the best positions in the rank (that is, lowest collision risk) and richer neighbourhoods in more urbanized areas have the worst positions. This pattern contradicts many of the environmental justice analyses in cities in developed countries, where a link tends to be found between the incidence of risk and nuisances from transport and other urban activities and the levels of economic deprivation of the exposed populations (Braubach & Fairburn, 2010; Deguen & Zmirou-Navier, 2010). This result is explained by the fact that most of the main roads in Praia are located in the central parts of the city or link the centre with affluent neighbourhoods on the seafront. In addition, as Praia concentrates most of the population of Santiago island, there are relatively few arterial roads linking the city with other towns and crossing the poorer suburbs.

The chart of the indicator of crime includes the 20 neighbourhoods for which crime data was available. The bubbles in Fig. 7 were drawn at the same scale as the ones for other indicators, that is, the biggest and the smallest bubble have the same size as in other charts. The chart shows that the incidence of crime is higher in neighbourhoods with higher urbanization levels (as represented by smaller bubbles). This result supports the hypothesis that crime rates are higher in areas with higher building density, because of the lack of open spaces for passive surveillance (Sampson, 1983), rather than the opposite hypothesis that crime rates are higher in areas with lower population density, because of the reduced number of residents doing that surveillance (Jacobs, 1961). However, this finding should be approached with caution due to the small sample used to analyse the distribution of the indicator of crime.

The values of the slopes and environmental risk indicators also show a divide between neighbourhoods with different income levels, as lower-income areas tend to fare considerably worse than higher-income areas (corresponding to higher average slopes and higher proportion of pedestrian areas with environmental risk in the table, and smaller bubbles in the figure). This finding is consistent with the pattern of residence location of poorer households in areas with geographic constraints in many fast-growing cities in developing countries, as mentioned in Section 2. However, the performance of low-income areas in less urbanized areas is not homogeneous, as the ones closest to the bottom of the income and urbanization ranks fare considerably well in the ranking of environmental risk.

5.3. Synthesis

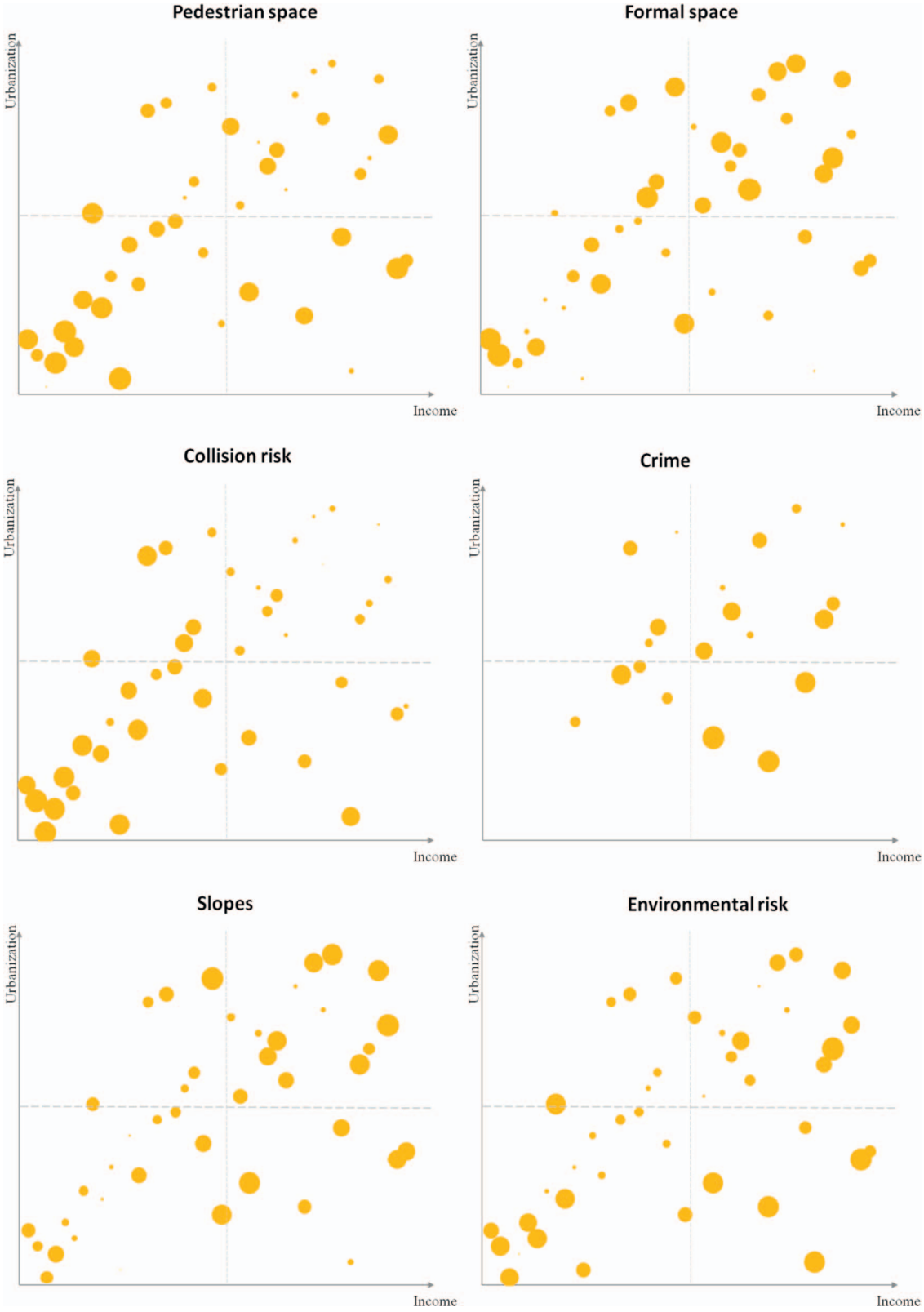
The analysis indicates that no type of neighbourhood is at disadvantage in terms of all dimensions of walkability. Richer and more urbanized neighbourhoods have the lowest provision of pedestrian space and the highest exposure to motorised traffic, but also the best



Note: Bigger bubbles represent higher rank positions, i.e. higher accessibility

Fig. 6. Neighbourhood rank positions: availability of destinations, income, and urbanization.

access to most types of destinations. Richer and less urbanized neighbourhoods have the lowest access to people, shops, and leisure areas, but the highest provision of pedestrian space and the best geographic conditions for walking in terms of terrain and safety from environmental risk. Poorer and more urbanized neighbourhoods tend to occupy areas with slopes and environmental risks and have the highest personal security issues, but have the best access to people. Poorer and less urbanized neighbourhoods also occupy areas with slopes and



Note: Bigger bubbles represent higher rank positions, i.e. better quality of walking (more pedestrian space and formal space and less collision risk, crime, slopes, and environmental risk).

Fig. 7. Neighbourhood rank positions: quality of walking, income, and urbanization.

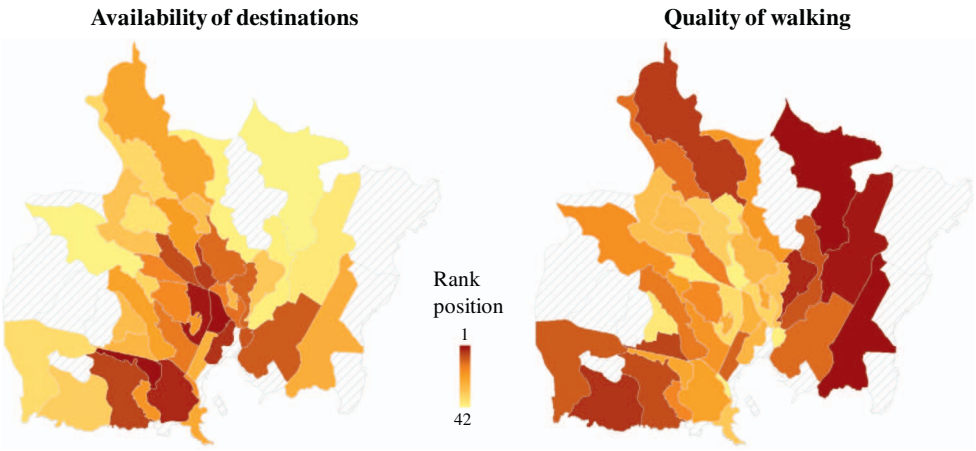


Fig. 8. Neighbourhood positions in combined rank of walkability indicators.

environmental risks, have the poorest provision of formal pedestrian space, highest personal security problems, and the lowest access to jobs, facilities, and bus stops. However, these areas are the least affected by risk posed by motorised traffic.

Fig. 8 illustrates the spatial dimension of these patterns. The maps show the position of each neighbourhood in the combined ranks of the six indicators of availability of destinations and the six indicators of quality of walking trips. The position was obtained by ranking the average values of the positions of the neighbourhoods in the ranks of the individual indicators. The availability of destinations is higher in the historical and geographic centres and in residential areas in the west. Suburban areas at the fringes tend to perform worse. In contrast, the quality of walking is better in the fringes of the city and worse in small neighbourhoods in the geographic centre.

6. Conclusions

This paper assessed the availability of destinations for pedestrians and the quality of the walking experience in an African city, using indicators that take into account its specific historical, geographic, demographic, economic, and social conditions. The distribution of the indicators was compared with income levels and levels of urbanization at the neighbourhood level. This approach can help policy-makers to identify areas with particular problems of pedestrian mobility and provides insights into how mobility problems relate with social exclusion and with land use policies.

These results also have implications for public policy in Praia. There are clear differences between the obstacles faced by pedestrians in areas with different incomes and levels of urbanization. Policy interventions to remove those obstacles apply to all the neighbourhoods which are similar in terms of those two variables. For example, in high-income neighbourhoods in more urbanization areas, the necessary measures are similar to the ones currently applied in similar neighbourhoods in many developed countries, such as the redesign of streets to increase the space available for walking and outdoor life, and traffic restriction measures to reduce the risks posed by motorised traffic. High-income neighbourhoods in less urbanization areas require measures to reduce the dispersion of the population. In low-income neighbourhoods located in more urbanization areas, transport, land use, and housing policies are needed to reduce the number of trips using routes that cross areas with environmental risk. Finally, in low-income neighbourhoods in less urbanization areas, the priority is the application of economic and land use policies to increase the number of jobs and facilities within walking distance of residential areas, and transport policies to extend the spatial coverage of bus networks.

Overall, the study found substantial variations in indicators of walkability within the same city. Given the tendencies for the growth in income inequality and in the diversification of neighbourhood types in Praia, as in other African cities, it is likely that disparities in walking conditions will widen further in the future, as housing markets start to capitalize differences in neighbourhood walkability. This may have a particularly negative impact on the levels of accessibility of poorer households to jobs and facilities, which in turn reinforces income inequality. Growing motorization may also decrease the availability of pedestrian space and increase the likelihood of collisions in areas where these problems are relatively small at the moment, such as low-income neighbourhoods in less urbanized areas. The investigation of disparities in walkability in other African cities at more advance stages of motorization and population and employment decentralization could clarify these hypotheses. More generally, the associations between income, land use, and walkability found in this study, and their possible implications in terms of reinforcing inequalities in other domains, such as employment, health, and social exclusion, support the findings obtained by studies on cities around the world that transport and land use policy cannot be dissociated from economic and social policies.

This study focussed on the interplay of spatial and economic factors in the distribution of walkability indicators at the neighbourhood level, but restrictions to walking faced by each individual are also linked to personal characteristics such as gender, age, and disability. In particular, the provision of walking mobility for older people is a pressing issue in African cities such as Praia, as their population becomes older. The study of walkability should therefore be complemented with detailed analyses of conditions faced by the elderly and other vulnerable groups within each neighbourhood.

This study provides a general assessment of the relative positions of each neighbourhood in several dimensions of walkability. This approach allows for a characterization of the disadvantages of each neighbourhood in relation to the rest of the city. However, the definition of policy priorities should also take into account the conditions of each neighbourhood in relation to what society regards as minimum standards. Variations within each neighbourhood are also relevant, as obstacles to walking may be felt only in a small part of the neighbourhood. Policy-makers must consider people's perceptions about the different dimensions of walkability in their own neighbourhood and in other neighbourhoods. A series of workshops done as a part of this research concluded that, in the case of Praia, perceptions of walkability do not influence perceptions about what constitutes one's neighbourhood, as these are clearly defined by geographic and historical factors, as mentioned in this paper. However, perceptions of walkability are not entirely consistent with the estimated indicators.

A full evaluation of neighbourhood walkability also requires the assessment of dimensions that were not considered in this paper, such as the connectivity of the street network and the quality of the pedestrian environment, including the conditions of pavements and

the existence and quality of pedestrian crossing facilities. This assessment could shed light on some of the findings of this paper. For example, the association between crime rates and urbanization levels could be related to factors such as lack of good quality public spaces or poor lighting in more urbanized areas. The assessment of walkability then requires the collection of detailed primary data, using methods such as street audits and video surveys.

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