Walkability Assessment for the Urban Environment

Lisbon Case Study

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Extended Abstract

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ABSTRACT

Whether you live in a city or a small town, and whether you drive a car, take the bus or ride a train, at some point in the day, everyone is a pedestrian. Many factors are linked to what makes an environment pedestrian friendly: built environment, weather and even crime rate, to mention a few aspects. Walking also brings many benefits such as of health problems and the reduction of pollution. Turning cities into more walkable spaces and more pedestrian orientated is of very high importance.

Walkability assessment is a way to measure if an urban environment is pedestrian friendly. Many studies are addressing this concept, although it is not recent. A large number of experts consider that it is possible to assess walkability by analyzing built environment. This dissertation follows this approach.

As part of the IAAPE project (Indicators of accessibility and attractiveness of pedestrian environments), this dissertation aims to contribute to the GIS-based framework to assess walkability, by proposing a set of indicators and value functions to quantify all the dimensions of walkability. To do so, the main objective is to collect as much information regarding indicators related to walkability as possible, normalize their values and couple them in the IAAPE framework.

The main conclusions were that different pedestrian groups (adult, children, elderly, impaired) would choose different indicators for the several dimensions of walkability analyzed according to the 7 C's (connectivity, convenience, comfort, conviviality, conspicuousness, coexistence and commitment) and that these would be different depending on the type of trip motive, i.e., leisure or utilitarian. The choice and transformation of indicators is critical in the procedure, due to different aspects: availability of databases, possibility of street auditing, and possibility to calibrate the value functions for normalization.

The model was applied to a case study in Lisbon, Portugal. The chosen area was Arroios, where urban design features are diversified. The results suggest that this methodology is transferable but further research should be done to refine the model, for instance regarding the scales using for the indicators and the value functions for normalization.

Keywords: Walkability, pedestrians, multicriteria assessment, Delphi, indicators

Introduction

As the U.S. Secretary of Transportation, Anthony Foxx, once said "*Whether you live in a city or a small town, and whether you drive a car, take the bus or ride a train, at some point in the day, everyone is a pedestrian*". Pedestrian walking quality should therefore be a top priority for governments.

Walking is also associated with a very large number of benefits not only to the active person but also to the community: it reduces pollution emissions, reduces obesity related health problems and creates more "livable communities" (Cambra, 2012; Coffee, Howard, Paquet, Hugo, & Daniel, 2013; Frank et al., 2006; Park, 2008).

Although Humans have started walking long before we started driving, there are currently more studies on how to assess motorized vehicles quality of circulation than pedestrians'. However in more recent years, a very large number of studies have been done on walkability. Walkability is simply how pedestrian friendly is the environment (Abley, Turner, & Singh, 2011). Although this concept has a relatively simple definition, measuring walkability is not short of a very complex problem. Most experts use built environment to assess and measure how pedestrian friendly the environment is.

This dissertation is part of the IAAPE project – Indicators of Accessibility and Attractiveness of the Pedestrian Environment (http://www.iaape.org). The concept behind the IAAPE project is to innovate the methodology for walkability assessment in urban environments by using an analytical framework based on GIS (Geographic Information Systems), making a further validation of the results obtained by analyzing case studies. This tool targets local authorities (Municipalities) as principal users that can analyze the impact of urban planning policies on the walkability performance of their cities. IAAPE builds upon the work by Cambra (2012).

The main objective for this work is to contribute to IAAPE's GIS-based framework to assess walkability, by proposing a set of indicators and value functions to quantify all the dimensions of walkability. Pedestrians are divided into groups of citizens (adult, children, elderly and impaired) and travel motives (utilitarian and leisure). As such, the majority of users of the network are represented for the major two types of travel motives. In order to measure walkability, built environment will be assessed.

To do so, the challenging endeavor was to collect as much information regarding indicators related to walkability, as possible, normalize their values with value functions and couple them in the IAAPE framework.

Theoretical Framework

Walkability has become one of the biggest concerns for town planners and is now the basis of a sustainable city (Ariffin & Zahari, 2013). Walkability can be defined as "the extent to which characteristics of the built environment and land use may or may not be conductive to residents in the area walking for either leisure, exercise or recreation, to access services, or to travel to work" (Leslie et al., 2007). Although in the more recent years there has been a surge in Walkability studies there is still no consensus on how to measure it. There is a dispersion of concepts and measurement methodologies, the literature is not consensual on the scale to measure walkability, authors suggest different criteria to analyze and there is a lack of validation for the methodologies (Cambra, 2012).

Some authors consider different types of walking. Leslie (2007) considers that there are two types: walking as a mean of transport and walking for recreation. The latter incorporates walking for exercise, walking for tourism and walking as a leisure activity. The goal of walking as a mean of transport is getting from an origin to a destination as quickly and as comfortably as possible. Walking as leisure is an activity in itself. The pedestrian's goal is not to reach a destination as quick as possible but to enjoy the trip.

Owen et al. (2007) differentiate walking for transport from walking for leisure and in the scientific literature some authors divide the population in sectors (S Abley & Consultants, 2010; Owen et al., 2007). The population was consequently divided into groups (adults, children, elderly and impaired) and into travel motives (utilitarian and leisure). In order to represent each group, each stakeholder was assigned a role and was to defend the interests of the group (adults, children, elderly or disabled).

Throughout the modernization of transport technology, where cars became more affordable and grew exponentially, pedestrian environment has been degraded. The built environment has been pointed out by experts such as Abley, Turner, & Singh (2011) and Leslie et al. (2007), as the main dimension to evaluate when looking to score walkability. Other authors, such as Owen et al., (2007) take into account social and demographic attributes when measuring walkability. In the literature, some authors also consider other types of indicators to measure walkability such as: weather conditions (Clark et al., 2014), Doyle & Kelly-Schwartz (2006) suggest that crime rates are very repulsive to walking. However, this paper will focus on the built environment.

There are two types of indicators to measure walkability: objective and subjective. The first is based on "immediate reality" and the second on personal perception and opinion. Whenever possible, objective criteria will be used as advised by several authors (Duncan, et al., 2013; Keast, et al., n.d.; Leslie et al., 2005; Villanueva et al., 2014)

The works from Park (2008) and Krambeck (2006) are very similar to what is expected to achieve with this dissertations. Both set out to create a way to measure walkability that could be applied to other areas. Both succeeded to a certain level. The first created a method, and succeeded to validate it but would be hard to transfer to other locations due to it characteristics. The second, created a conceptual model but never applied it. This paper aims to go beyond both these authors.

To measure walkability the present research focuses on the 7Cs of walkability proposed by Cambra (2012)

- C1: Connectivity - Is the network accessible?
- C2: Convenience - Does it suit its users? Is it functional?
- C3: Comfort - How good is the experience?
- C4: Conviviality - Is it attractive?
- C5: Clarity - Is it easy to navigate?
- C6: Coexistence - Is the presence of motorized vehicles disturbing?
- C7: Commitment – Is there a concern to do better?

Regarding the 7Cs layout, there was a general agreement, with a clear consensus on the addition of Coexistence and Commitment to the existing 5C layout (Moura, Cambra, & Gonçalves, 2014).

In order to score walkability, several methods can be found in the literature. Fruin (1971) was the first to introduce the concept of Level of Service (LOS) to pedestrians. The author scored the environment from LOS A (best) to LOS F (worst). This method is a qualitative one and has been widely used (Transportation Research Board, 2000). Abley (2006) considers a weighted average of indicators to score walkability. This methodology was used.

In order to weigh the criteria used i.e. the indicators, there a several methods that can be used, some more complex than others. The Analytical Hierarchy Process and the Analytical Network Process are very commonly used but are very complex (Mikaeil et al., 2013; Vidal et al., 2011; Wey & Chiu, 2013). The software 1000minds can also be used to weigh the criteria (www.1000minds.com). The software asks the user to choose between a series of alternatives and ranks the choices between each other, thus creating a hierarchy for the criteria. The main advantage of PAPRIKA, 1000minds' software, is its easiness of use. By choosing between two alternatives the process is therefore much simpler to the user.

Based on the previous literature review, we conclude that there has been a significant effort by the scientific community to study and develop walkability in order to foster the many advantages of a more pedestrian friendly environment. As referred before, it brings communities not only health benefits besides economical positive externalities (Litman, 2003).

Structuring

This work follows IAAPE's framework. Therefore, whenever possible methods used in the literature are applied. Otherwise some procedures are suggested based on available information. After an extensive literature review, a very large number of indicators were found. To use all of these inputs would be unfeasible as the resources used to measure all of the inputs would be considerable. Additionally, according to Baker et al.,(2002) the criteria used to measure walkability should be few in number. Therefore a structuring of the problem had to be made. In order to reduce the number of indicators, they were first grouped into the 7C's of walkability presented previously. A group of Experts from different fields, such as Academia or practitioners, were chosen to give their inputs on which indicators should be used to measure walkability. This group was purposely chosen with different backgrounds so that all the population aggregates could be represented. A series of guided Delphi sessions was conducted face to face. To each expert the Dimensions were presented as well as a series of suggested indicators used to measure walkability. The expert would also be given the chance to propose other indicators he/she would find relevant. The person chose the indicators they felt were most relevant to score each dimension. At the end of the sessions, the number of indicators was significantly reduced from a list of about 200 to 5 indicators per dimension (35 in total).

Subsequently the chosen criteria should be weighted. This is the second part of the Structuring and was divided into two parts: i) selection of indicators and ii) weighting. To assist on this, a group of stakeholders was invited. Each individual was attributed a role taking into account the stakeholder's background. This would enable each of the users group to have their interests represented.

The session took place in a room with seven posters (one for each dimension of the 7 Cs) with a description of the dimension and the indicators (i.e., shortlist from the experts). Colored stickers were given to each stakeholder according to the group they belong to.

In a first round, each participant was given 6 stickers to use on each poster. Stakeholders were asked to rank the indicators in order of importance. This could be done by putting all of the stickers in just one indicator, distribute them equally or how the participant choses. The stakeholders were asked to split into random groups and face one of the posters. The decision not to divide people into the groups they represent was meant to avoid a biased opinion or participants reaching a consensus before voting. The stakeholders had limited time and had to rotate between all posters. At the end, the votes were counted and posters changed to a second round.

In this second round stakeholders were given 28 markers to cast their votes chose without restrictions, i.e. ultimately, they could allocate all 28 stickers in one indicator or distribute them evenly along the 7 dimensions (if the stakeholder wished to do so). This round had the intention of verifying that the dimensions of walkability were not all equally important.

The results of the first round of voting by stakeholder were used for the second step of the session. One indicator per dimension was chosen, which brought some concern as sometimes indicators that have been eliminated by during the stakeholders session, were previously selected by experts as the most important to evaluate the dimension. The results of both sessions can be found the Annex.

These results clearly show that indicators have different degrees of importance for each group. It confirms the importance of weighting indicators when assessing walkability.

The results obtained on this first step allow us to take a number of observations. The first, as was pointed out previously is the confirmation that in fact different groups of users have different perceptions of what is more important to them regarding the built environment. There are some common concerns but there is not a consensual decision on what should be considered more important. By analyzing the results, it can be observed that the most agreed dimension was **comfort** and the least was **convenience**.

The second part of the Structuring, the weighing, took place after. Several methods can be found in scientific literature to determine weights of indicators in Multi Criteria Decision AnalysisXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX. After carefully analyzing the pros and cons of each other, 1000minds was chosen.

1000minds software is very user friendly and has been extensively tested. It presents the user with two scenarios and asks to choose which he/she would prefer. By asking this question, the software is able to rank the premises and weigh the criteria. But if the user puts in a high number of criteria, the questionnaire's time for completion increases significantly and users tend to get tired and lose focus after 30min. Therefore the decision was to use one indicator per dimension. The indicator chosen was the most voted by each group for each dimension on phase 1. This can lead to bias results and should, in future researches, be looked into.

The stakeholders were asked to group according to the pedestrians they were representing and answer a series of question from 1000minds. Two different sessions were held: one where the stakeholders were asked to judge their options while walking for utilitarian motives or leisure.

These two Delphi sessions produced different results as shown in the Annex. It can be observed that there is a clear difference in the weights attributed by the different groups, again confirming that in fact user groups should be separated. In addition, for each user group, the two types of journeys (utilitarian and leisure) produced different results, and should be considered separately as this dissertation proposes. When comparing results from different user groups, it can be observed that some users consider **connectivity** the most important dimension as opposed to others that consider **comfort**. In general, for utilitarian trips, **connectivity** played a bigger role than in leisure trips.

Despite believing that this was the most effective solution to assess the problem IAAPE proposes to solve, the Delphi method has some limitations. If one of the group members becomes a leader, the results of this analysis reflect his or her opinions rather than a consensus between the group. The stakeholders were chosen to represent a certain group that they are used to work with or are a part of. However, by only choosing representatives, scoring may not be representative of the group that is being tested. The validation of the model therefore plays a very important role and should be done in the future (not in the scope of this work).

17 different indicators have, to this point, been chosen by stakeholders to evaluate walkability and assess the built environment, by the 4 population segments and for utilitarian and leisure trips. As such, some indicators were selected for several combinations of trip motive vs. population group. The next challenge was to determine how to score these dimensions.

Scoring of indicators

The scoring of indicators and determination of the value function was done by using as much of the literature as possible. However, in some cases that was not possible. Indicators could be Macro or Micro, depending if they apply to an area or to a single segment, respectively. C12: Continuity of Path, C13: Condition to Take the Most Direct Path and C71: Enforcement of Legislation, are the only Macro indicators. They are measured using GIS technology.

All other indicators are measured be on-site analysis. Some arcs are considered cut-offs as they are not suitable for the use of pedestrians (e.g. an impaired user in a wheel chair requires a minum width). These segments are scored as nil. The full scope of the scoring process will not be described in this paper.

The Value-function is used to transform the scores analyzed into values that can be used in the weighted average to score walkability for the walking segment. In most of the literature consulted, author do not disclose their value functions. This is one of the greatest contributions of this paper: the proposal of value functions.

Application to the Case Study of Arroios, Lisbon

As this dissertation is integrated in the IAAPE project, the Municipality of Lisbon proposed a case study location. A safety assessment for several schools in the city of Lisbon is currently being done. In the *Arroios* area there are two schools being assessed. The study area is defined by two circumferences of 400m radius with centers in each school. This study area encompasses several different kinds of streets and neighborhoods. On the West, *Avenida Almirante Reis* is one of the most important 4-lane avenues of Lisbon. The *Anjos* neighborhood is a more traditional and residential one. Overall this case study provided enough diversity so that differences in evaluations can be observed.

The first step was to vectorize the network (design it in a GIS software). This was one of the most important steps of the process. Errors in the vectorization could potentially influence the analysis of some indicators.

Secondly, the street auditing had to be performed. In order to ensure that street auditing would not be affected by subjectivity of the evaluator, a street auditing guide was created. The 10-page document was created so that it would be as easy and objective as possible for the auditor to score the dimensions of walkability. After a brief introduction to what is being evaluated, the indicators are presented and how to evaluate them. Pictures of examples were given in order to ensure easiness of evaluation.

After the entire area was evaluated, the remaining indicators were scored using GIS analysis. This was done by using ArcGIS and the data was compiled in Excel. The results are presented in Table 1 and as a Map in Figure 1 in the Annex.

Table 1 - Measurements of Indicators in the study area

	Code	Average/result[1]	Median	25% quartile	75% quartile
Continuity of Path[1]	C12	33.21			
Condition to Take the Most Direct Path	C13	21.66	18.46	14.95	23.48
Existence of Infrastructure for Disabled Access	C14	12.78			
Land Use Mix	C21	43.04	33.33	33.33	66.67
Footway Width	C22	27.42	0.00	0.00	40.50
Everyday Use Commercial Activities' Density	C24	4.41	0.00	0.00	0.00
"Vigilance Effect": To see and be Seen	C31	51.70	50.00	25.00	75.00
Pavement Quality	C32	69.35	75.00	62.50	87.50
Existence of Public Meeting Places	C41	15.09	0.00	0.00	0.00
Existence of Attractor Destinations	C42	1.23	0.00	0.00	0.00
Land Use Mix and Service	C43	10.67	0.00	0.00	0.00
Sense of Place and Reference Elements	C51	21.08	0.00	0.00	0.00
Availability of Signals Adapted to Pedestrians	C53	41.67	50.00	50.00	50.00
Safety on Road Crossings	C61	40.58	0.00	0.00	100.00
Availability of Crossing in the Most desired Trajectory[1]	C62	36.38			
Enforcement of Legislation[1]	C71	53.49			
Standardization of Interventions and Solutions	C75	20.42	0.00	0.00	0.00

Some indicators are presented as a classification because they are assessed on a Macro scale basis (C12, C62, and C71). C14 was evaluated as a binary: either the link has the maximum score or it is awarded 0. The score therefore indicates the percentage of evaluated links that scored 1, i.e. it is possible to conclude that only 12,78% of all segments evaluated have what was considered to be an existing infrastructure for disabled access. This is a clear sign that the area that is being studied should be analyzed by competent authorities to provide access to every pedestrian.

For the indicators C12, C62 and C7 it is difficult to provide any comments as there is no benchmark and its analysis should come after other areas are evaluated.

The data for C24 and C42 is highly conditioned by the presence of an outlier. A market street on the evaluated area has 10 commercial stores and therefore all the other streets have very low scores. This is a concern and should be assessed in future analyses.

Except for **Comfort** (C3), all dimensions have low scores. This indicates that both quality of pavement and vigilance effect are good in the Arroios area of Lisbon.

[1] Due to the method used, these are Macro scale indicators and therefore, all links are awarded the same score

The dimension with the lowest scores is **Conviviality** (C4). Although these results are affected by the presence of an outlier, it was expected as it is an area with few zones that provide a physical space for citizens to interact.

When analyzing the results, it is evident that some users have a better perception of the environment than other: impaired vs. adult show great difference. There is a very large amount of cut-offs for the first group. This was expected as Lisbon is known for its narrow sidewalks. Although significant efforts are being made by the Municipality, sidewalk width remains a major concern. This can explain most of the cut-offs.

Elderly and Children groups generally scored average results (between 40 and 60). In order to compare and further provide comments on these results, other case studies should be analyzed.

It is also possible to observe that Avenida Almirante Reis is one of the avenues with the best score. This is located on the upper left corner of the study case area. This street has large sidewalks, a very large amount of appealing locations (shops, commercial activities etc...) and the crossings are all signalized. Also, the streets near Largo da Graça (southwest) have very high scores. This is a tourist attraction and has also a significant amount of commerce. On more residential blocks, scores are lower due to the lack of land use mix.

Conclusions

This dissertation had as main objective to contribute to the IAAPE evaluation procedure by defining a method to select indicators for the 7 walkability dimensions, weigh the selected indicators for different population groups and trip motives, and finally, transform these indicators into a single walkscore for each link of the pedestrian network. This was done using as much as possible the existing literature. It was achieved, but there are some points that still need work.

The model built was tested in the case study and in fact it was possible to measure walkability for the area. The results for this assessment were satisfying but a cautious optimism is needed at this point. In order to confirm these results, a validation should be done. This could potentially be achieved by measuring pedestrian traffic or by doing questionnaires to users as Park (2008).

The methodology used in this paper can be easily applied to other locations and is a marketable product for its target, the Municipalities. A walkable city brings a vast spectrum of advantages, from economic to health related and therefore the assessment of walkability in cities is of very high importance. The methodology presented is meant to be used as a tool to evaluate walkability and identify where pedestrians have the worst conditions to walk. Therefore, the municipalities, or the competent authorities, could use this product to act efficiently, in a cost efficient manner to make their cities more walkable and benefit from the numerous advantages it brings. Modern walkable cities are extremely important.

References

Abley, S. (2006). WALKABILITY TOOLS RESEARCH Variables Collection Methodology.

Abley, S., & Consultants, A. (2010). Measuring accessibility and providing transport choice. *Australian Institute of Transportation …*. Retrieved from http://www.livingstreets.org.nz/sites/livingstreets.org.nz/files/1555 Steve Abley - Accessibility - Abstract and Paper.pdf

Abley, S., Turner, S., & Singh, R. (2011). Predicting walkability. Retrieved from http://www.hardingconsultants.co.nz/ipenz2011/downloads/Abley__Steve.pdf

Ariffin, R. N. R., & Zahari, R. K. (2013). Perceptions of the Urban Walking Environments. *Procedia - Social and Behavioral Sciences*, *105*, 589–597. doi:10.1016/j.sbspro.2013.11.062

Baker, D., Bridges, D., Hunter, R., & Johnson, G. (2002). Guidebook to decision-making methods. *Department of Energy, USA*. Retrieved from https://scholar.google.pt/scholar?hl=pt-PT&q=Guidebook+to+decision-making+methods+&btnG=&lr=#0

Cambra, P. (2012). *Pedestrian Accessibility and Attractiveness Indicators for Walkability Assessment*. Retrieved from https://fenix.tecnico.ulisboa.pt/downloadFile/395144992898/Dissertacao.pdf

Clark, A., Scott, D., & Yiannakoulias, N. (2014). Examining the relationship between active travel, weather, and the built environment: a multilevel approach using a GPS-enhanced dataset. *Transportation*. Retrieved from http://link.springer.com/article/10.1007/s11116-013-9476-3

Coffee, N. T., Howard, N., Paquet, C., Hugo, G., & Daniel, M. (2013). Is walkability associated with a lower cardiometabolic risk? *Health & Place*, *21*, 163–9. doi:10.1016/j.healthplace.2013.01.009

Doyle, S., & Kelly-Schwartz, A. (2006). Active community environments and health: the relationship of walkable and safe communities to individual health. *Journal of the …*. Retrieved from http://www.tandfonline.com/doi/abs/10.1080/01944360608976721

Duncan, D., Aldstadt, J., Whalen, J., & Melly, S. (2013). Validation of Walk Scores and Transit Scores for estimating neighborhood walkability and transit availability: a small-area analysis. *GeoJournal*. Retrieved from http://link.springer.com/article/10.1007/s10708-011-9444-4

Frank, L. D., Sallis, J. F., Conway, T. L., Chapman, J. E., Saelens, B. E., & Bachman, W. (2006). Many Pathways from Land Use to Health: Associations between Neighborhood Walkability and Active Transportation, Body Mass Index, and Air Quality. *Journal of the American Planning Association*, *72*(1), 75–87. doi:10.1080/01944360608976725

Fruin, J. (1971). *Pedestrian planning and design*. Retrieved from http://trid.trb.org/view.aspx?id=114653

Keast, E. M., Carlson, N. E., Chapman, N. J., & Michael, Y. L. (n.d.). Using built environmental observation tools: comparing two methods of creating a measure of the built environment. *American Journal of Health Promotion : AJHP*, *24*(5), 354–61. doi:10.4278/ajhp.080603-QUAN-81

Krambeck, H. V. (2006). *The global walkability index*. Massachusetts Institute of Technology. Retrieved from http://dspace.mit.edu/handle/1721.1/34409

Leslie, E., Coffee, N., Frank, L., Owen, N., Bauman, A., & Hugo, G. (2007). Walkability of local communities: using geographic information systems to objectively assess relevant environmental attributes. *Health & Place*, *13*(1), 111–22. doi:10.1016/j.healthplace.2005.11.001

Leslie, E., Saelens, B., Frank, L., Owen, N., Bauman, A., Coffee, N., & Hugo, G. (2005). Residents' perceptions of walkability attributes in objectively different neighbourhoods: a pilot study. *Health & Place*, *11*(3), 227–36. doi:10.1016/j.healthplace.2004.05.005

Litman, T. A. (2003). Economic Value of Walkability - Transportation Research Record: Journal of the Transportation Research Board. *Transportation Research Record: Journal of the Transportation Research Board*, *Volume 182*(2003 Pedestrians and Bicycles 2003), 3–11. Retrieved from http://trb.metapress.com/content/m1573875u76t4223/

Mikaeil, R., Ozcelik, Y., Yousefi, R., Ataei, M., & Mehdi Hosseini, S. (2013). Ranking the sawability of ornamental stone using Fuzzy Delphi and multi-criteria decision-making techniques. *International Journal of Rock Mechanics and Mining Sciences*, *58*, 118–126. doi:10.1016/j.ijrmms.2012.09.002

Moura, F., Cambra, P., & Gonçalves, A. (2014). *IAAPE - Pedestrian accessibility and attractiveness assessment tool when planning for walkability*. *CITTA 7th Annual Conference*.

Owen, N., Cerin, E., Leslie, E., duToit, L., Coffee, N., Frank, L. D., … Sallis, J. F. (2007). Neighborhood walkability and the walking behavior of Australian adults. *American Journal of Preventive Medicine*, *33*(5), 387–95. doi:10.1016/j.amepre.2007.07.025

Park, S. (2008). *Defining, Measuring, and Evaluating Path Walkability, and Testing Its Impacts on Transit Users' Mode Choice and Walking Distance to the Station*. University of California.

Transportation Research Board. (2000). Highway Capacity Manual. *National Research Council, Washington, DC*. Retrieved from https://scholar.google.pt/scholar?q=highway+capacity+manual&btnG=&hl=pt-PT&as_sdt=0%2C5#1

Vidal, L.-A., Marle, F., & Bocquet, J.-C. (2011). Using a Delphi process and the Analytic Hierarchy Process (AHP) to evaluate the complexity of projects. *Expert Systems with Applications*, *38*(5), 5388–5405. doi:10.1016/j.eswa.2010.10.016

Villanueva, K., Knuiman, M., Nathan, A., Giles-Corti, B., Christian, H., Foster, S., & Bull, F. (2014). The impact of neighborhood walkability on walking: does it differ across adult life stage and does neighborhood buffer size matter? *Health & Place*, *25*, 43–6. doi:10.1016/j.healthplace.2013.10.005

Wey, W.-M., & Chiu, Y.-H. (2013). Assessing the walkability of pedestrian environment under the transit-oriented development. *Habitat International*, *38*, 106–118. doi:10.1016/j.habitatint.2012.05.004

Annexes

Table 2 - Results of first step of stakeholder session

		Pedestrian user group				Round 1	Round 2
Dimension	**Key-concerns**	**Adults**	**Seniors**	**Disabled**	**Children**	**aggregate**	**aggregate**
C1: Connectivity	C11: Street density (alternative routes)	0.13	0.07	0.13	0.06	0.014	0.017
	C12: Continuity of walking path/sidewalk	**0.27**	**0.37**	0.25	0.33	**0.043**	**0.084**
	C13: Path directness	0.27	0.17	0.04	**0.44**	0.031	0.036
	C14: Existence of dedicated pedestrian infrastructure, accessible to all groups	0.10	0.33	**0.50**	0.17	0.039	**0.059**
	C15: Network integration in the urban fabric	0.23	0.07	0.08	0.00	0.015	0.027
C2: Convenience	C21: Land use diversity	**0.27**	0.20	0.13	**0.28**	0.031	**0.044**
	C22: Sidewalk available width	0.23	0.07	**0.25**	0.22	0.026	0.013
	C23: Obstacles (absence of)	0.20	0.23	0.21	0.28	**0.032**	0.034
	C24: Density of daily uses	0.23	**0.33**	0.17	0.11	0.032	0.025
	C25: Facilities for accessing steep streets (escalators, elevators, ramps)	0.07	0.17	0.25	0.11	0.021	0.036
C3: Comfort	C31: "Eyes on the street" - windows and facade transparency	0.20	0.20	0.17	**0.39**	0.032	0.036
	C32: Pavement surface quality	**0.40**	**0.33**	**0.33**	0.22	**0.047**	**0.065**
	C33: Amenities (trees, benches, lighting, etc.)	0.10	0.23	0.29	0.17	0.028	0.027
	C34: Climate protection (sun, rain)	0.07	0.17	0.13	0.22	0.020	0.017
	C35: Sensory quality of urban environment	0.23	0.07	0.08	0.00	0.015	0.002

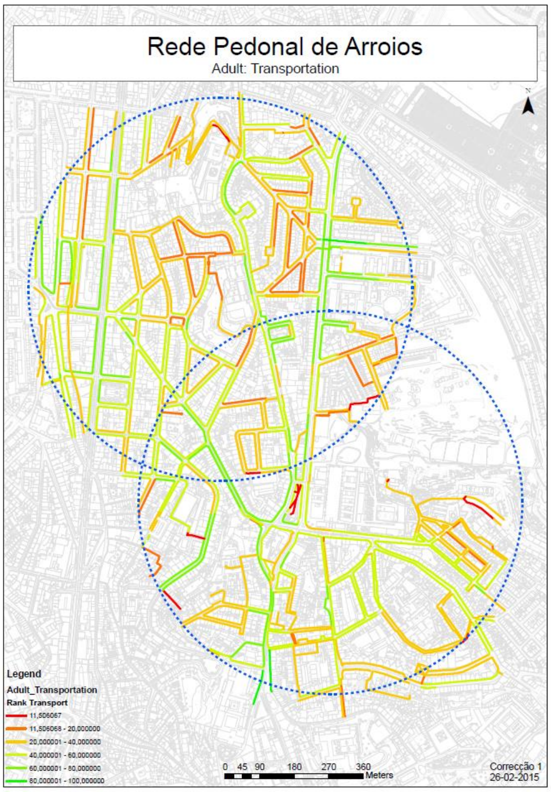
C4: Conviviality	C41: Opportunities for meeting and sojourning (benches, tables, terraces)	0.27	**0.33**	0.21	0.22	**0.038**	**0.055**
	C42: Existence of "anchor sites" - squares, open-air markets, parks, etc.	0.20	0.27	**0.29**	**0.33**	0.038	0.029
	C43: Mixed uses and mixed working hours	**0.33**	0.13	0.21	0.22	0.032	0.013
	C44: "Active edges" - absence of blank walls, empty lots, dull facades	0.03	0.17	0.17	0.22	0.020	0.023
	C45: Population density	0.17	0.10	0.13	0.00	0.015	0.015
C5: Conspicousness	C51: Landmarks	**0.43**	**0.37**	0.21	**0.50**	**0.053**	0.011
	C52: Clear sightlines	0.13	0.13	0.17	0.17	0.021	0.002
	C53: Street names, signposting, way marking	0.10	0.17	**0.46**	0.17	0.031	0.019
	C54: Architectural complexity	0.13	0.10	0.17	0.11	0.018	0.008
	C55: "Sense of place"	0.20	0.23	0.00	0.06	0.020	0.006
C6: Coexistence	C61: Traffic safety (at pedestrian crossings)	**0.37**	**0.43**	**0.33**	0.28	**0.052**	**0.076**
	C62: Pedestrian crossing location	0.17	0.07	0.33	**0.39**	0.031	0.042
	C63: Appropriate spatial segregation of transport means	0.13	0.20	0.00	0.17	0.018	0.008
	C64: Proportion of pedestrian friendly streets	0.10	0.03	0.00	0.00	0.006	0.017
	C65: Pedestrian space "invasion" - parked cars, running bicycles	0.23	0.27	0.33	0.17	0.036	**0.063**
C7: Commitment	C71: Enforcement of pedestrian regulations (as the recent disabilities act)	**0.30**	**0.33**	**0.33**	0.22	0.043	0.021
	C72: Street cleanliness	0.23	0.20	0.22	**0.39**	0.032	0.023
	C73: Means for public participation	0.17	0.03	0.07	0.00	0.011	0.019

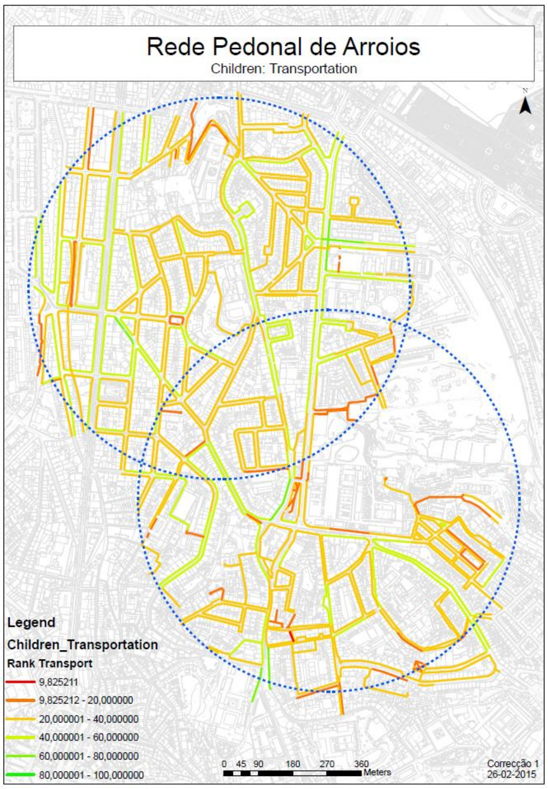
	C74: Walking initiatives (walk to school, walk to work, senior walks, etc.)	0.03	0.13	0.04	0.17	0.013	0.008
	C75: Existence of design standards and planned public space interventions	0.27	0.30	0.33	0.22	**0.047**	0.017

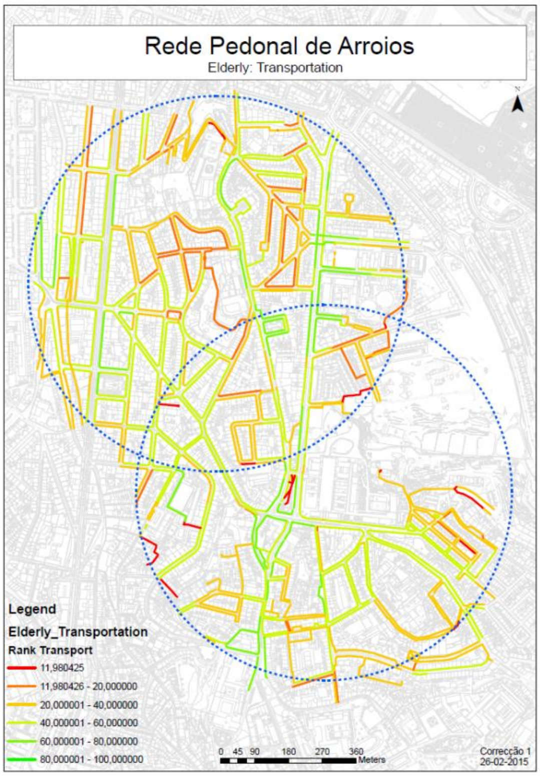
Table 3 - Results 1000minds

1000 Minds Weight results		**Utilitarian Trips**				**Leisure Trips**			
Dimension	**Key-concerns**	**Adults**	**Seniors**	**Disabled**	**Children**	**Adults**	**Seniors**	**Disabled**	**Children**
C1: Connectivity	C12: Continuity of walking path/sidewalk	0.17	0.11	---	---	0.04	0.07	---	---
	C13: Path directness	---	---	---	0.19	---	---	---	0.09
	C14: Existence of dedicated pedestrian infrastructure, accessible to all groups	---	---	0.17	---	---	---	0.17	---
C2: Convenience	C21: Land use diversity	0.06	---	---	0.15	0.19	---	---	0.23
	C22: Sidewalk available width	---	---	0.17	---	---	---	0.17	---
	C24: Density of daily uses	---	0.16	---	---	---	0.27	---	---
C3: Comfort	C31: "Eyes on the street" - windows and facade transparency	---	---	---	0.19	---	---	---	0.18
	C32: Pavement surface quality	0.17	0.21	0.17	---	0.12	0.17	0.17	---
C4: Conviviality	C41: Opportunities for meeting and sojourning (benches, tables, terraces)	---	0.11	---	---	---	0.17	---	---
	C42: Existence of "anchor sites" - squares, open-air markets, parks, etc.	---	---	0.09	0.04	---	---	0.09	0.18

	C43: Mixed uses and mixed working hours	0.17	---	---	---	0.23	---	---	---
C5: Conspicousness	C51: Landmarks	0.11	0.05	---	0.12	0.19	0.03	---	0.14
	C53: Street names, signposting, way marking	---	---	0.04	---	---	---	0.04	---
C6: Coexistence	C61: Traffic safety (at pedestrian crossings)	0.22	0.21	0.22	---	0.15	0.17	0.22	---
	C62: Pedestrian crossing location	---	---	---	0.23	---	---	---	0.14
C7: Commitment	C71: Enforcement of pedestrian regulations (as the recent disabilities act)	0.11	0.16	0.13	---	0.08	0.13	0.13	---
	C72: Street cleanliness	---	---	---	0.08	---	---	---	0.05



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Legend
Elderly_Transportation
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40,000001 - 60,000000
60,000001 - 80,000000
80,000001 - 100,000000
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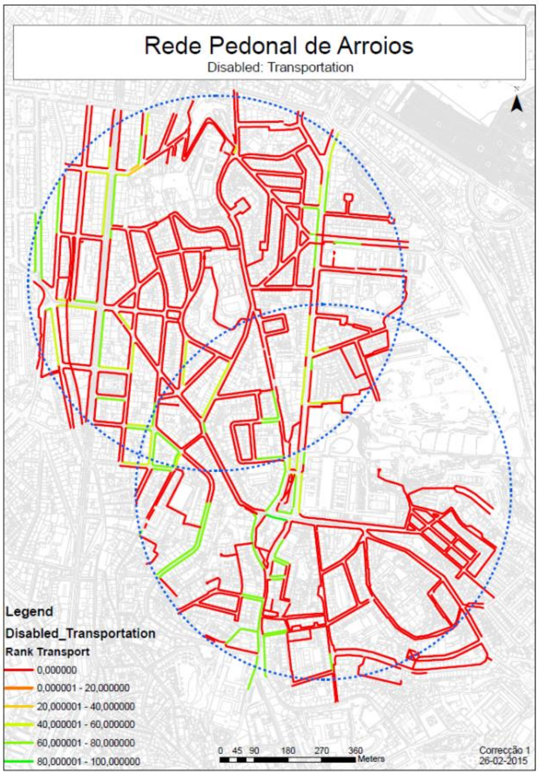
Meters
Correcção 1
26-02-2015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Disabled: Transportation
Legend
Disabled_Transportation
Rank Transport
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0,000001 - 20,000000
20,000001 - 40,000000
40,000001 - 60,000000
60,000001 - 80,000000
80,000001 - 100,000000
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Meters
Correcção 1
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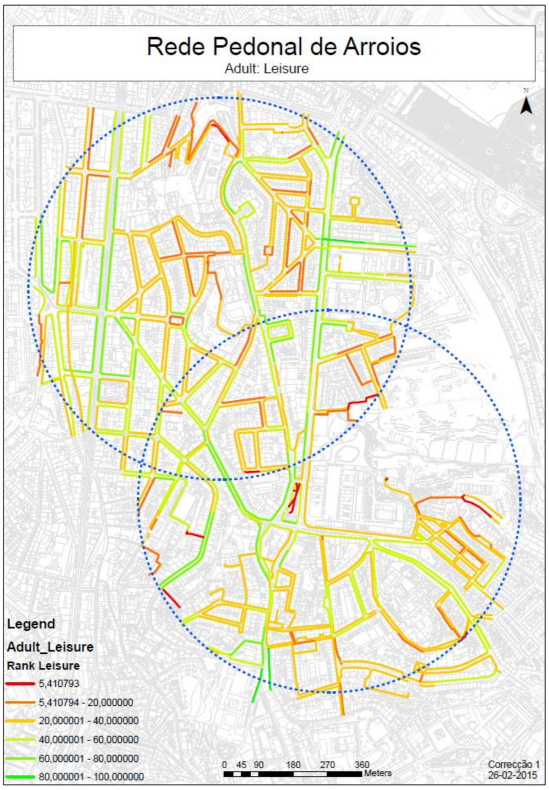
Rede Pedonal de Arroios
Adult: Leisure
Legend
Adult_Leisure
Rank Leisure
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Meters
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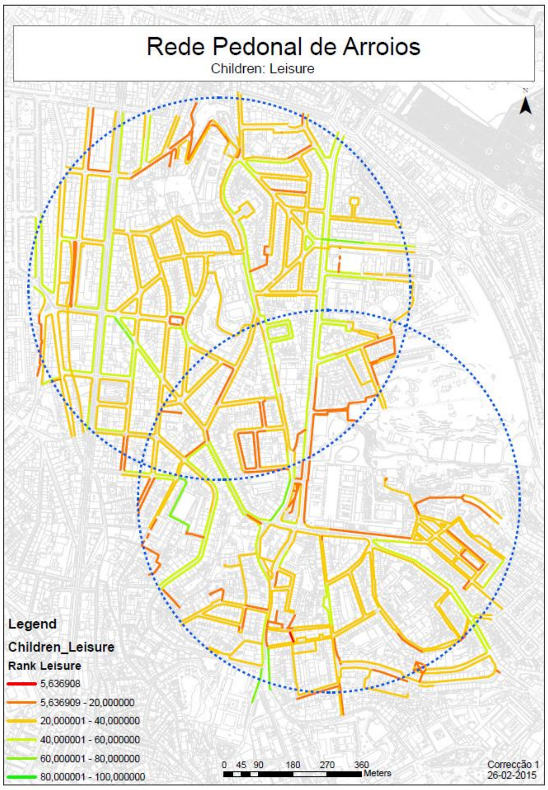
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Children: Leisure
Legend
Children_Leisure
Rank Leisure
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80,000001 - 100,000000
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Meters
Correcção 1
26-02-2015

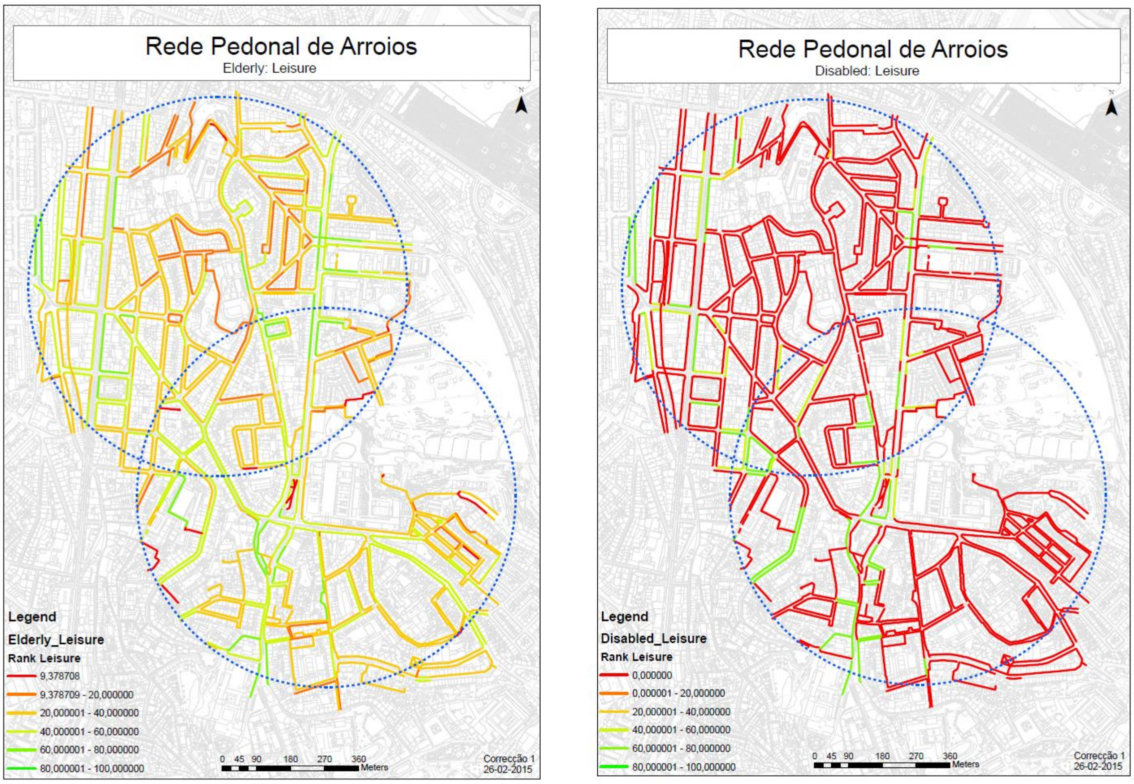

Figure 1 - Walkability evaluation for Utilitarian and Leisure trips and each population group